Synthesis Report Appendix: Urgency scoring tables

Contents

Introduction

This appendix to the CCRA2 Synthesis Report provides tables of urgency scores for each of the risks and opportunities considered in the report. The CCRA2 National Summaries provide additional detail for England, Northern Ireland, Scotland and Wales.

The purpose of this appendix is to provide a transparent audit trail of how the evidence from each of the technical chapters has been used. The reader can use this appendix to understand the Adaptation Sub-Committee's reasoning for each of the scores, and form their own judgement as required.

Full details and references for the evidence described here are available in the Evidence Report chapters. Each summary table below lists the relevant section references.

The approach to urgency scoring is explained in an annex in Chapter 2 of the CCRA2 Evidence Report. This includes definitions for magnitude and confidence.

Chapter 3: Natural environment and natural assets

Urgency scores for natural environment and natural assets					
Risk descriptor	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
Ne1. Risks to species and habitats due to inability to respond to changing climatic conditions (3.2)	UK				More action needed to reduce existing pressures, improve size and condition of habitats, restore degraded ecosystems, and deliver coherent ecological networks. More action needed to factor climate change into conservation planning and site management.
Ne2. Opportunities from new species colonisations (3.2)	UK				More action needed to deliver coherent ecological networks. More action needed to factor climate change into conservation planning and site management.
Ne3. Risks and opportunities from changes in agricultural and forestry productivity and land suitability (3.3)		UK			More research needed into developing integrated land use planning based upon changing suitability. More research needed on the nature and scale of changing land suitability and its impacts. More research needed into crop varieties, tree species and agricultural systems that are resilient to future climate change.
Ne4. Risks to soils from increased seasonal aridity and wetness (3.3)	UK				More action needed to reduce existing pressures on soils, increase uptake of soil conservation measures and restore degraded soils.

Ne5. Risks to natural carbon stores and carbon sequestration (3.3, 3.7)	UK				More action needed to restore degraded carbon stores, particularly peatlands. More research needed to account for climate change impacts on carbon stores in the UK GHG projections.
Ne6. Risks to agriculture and wildlife from water scarcity and flooding (3.4)	UK				More action needed to reduce pollution and over-abstraction and improve the ecological condition of water bodies Ensure decisions on use of water allow for necessary environmental flows and take account of climate change.
Ne7. Risks to freshwater species from higher water temperatures (3.4)		UK			More research needed on scale of risk and effectiveness of adaptation measures.
Ne8. Risks of land management practices exacerbating flood risk (3.3, 3.4)	UK				Deliver wider uptake of natural flood management in high-risk catchments especially where there are likely to be carbon storage, water quality and biodiversity benefits. Implement catchment-scale planning for flood risk management. Review potential for adverse flood risk outcomes from land management subsidies.
Ne9. Risks to agriculture, forestry, landscapes and wildlife from pests, pathogens and invasive species (3.7)			UK		Continue to implement surveillance and bio-security measures. Continue current research efforts into the impact of climate change on emerging and long-term risks. Develop cross-sectoral initiatives for risk assessment and contingency planning.

Ne10. Risks to agriculture, forestry, wildlife and heritage from change in frequency and/or magnitude of extreme weather and wildfire events (3.3)			UK		Continue to build resilience of ecosystems to drought, flood and fire. Continue current efforts to manage and respond to wildfires. Monitor heat stress impacts on livestock. Continue current efforts to manage impacts of high winds on forestry.
Ne11. Risks to aquifers, agricultural land and freshwater habitats from salt water intrusion (3.5)			England, Wales	Northern Ireland, Scotland	Continue actions to manage salinity risks to freshwater habitats. Monitor impacts on aquifers to assess whether risks are increasing.
Ne12. Risks to habitats and heritage in the coastal zone from sea-level rise; and loss of natural flood protection (3.5)	UK				More action needed to deliver managed realignment of coastlines and create compensatory habitat.
Ne13. Risks to, and opportunities for, marine species, fisheries and marine heritage from ocean acidification and higher water temperatures (3.6)		UK			More research needed to better understand magnitude of risk to marine ecosystems and heritage.

Ne14. Risks and opportunities from changes in landscape character (3.7)				UK	Monitor impacts and ensure climate change is accounted for in future landscape character assessments.

Ne1: Risks to species and habitats due to inability to respond to changing climatic conditions and Ne2: Opportunities from new species' colonisation

Step 1: What is the current and future level of risk or opportunity?

Current

There is very clear evidence of terrestrial species shifting distributions to higher latitudes and altitudes within the UK. A study of 1,573 animal species showed that most had moved northwards over the past four decades. The evidence also suggests that many species groups are shifting northwards at a lesser rate than would be expected based upon the change in temperature alone. This is likely to be explained by natural or land-use constraints on their dispersal ability.

Increases in average temperatures, shifting precipitation patterns and changes in the timing of seasonal events can have direct impacts on population trends of species at the national level. A study of 500 terrestrial species found that long-term trends in weather variables had a significant impact on 64% of species. The observed increase in average temperatures has had generally positive effects upon terrestrial invertebrates during spring and summer. However, warmer and wetter winters have also had negative effects on moth and butterfly populations.

There is evidence that in southern England drier summers have affected species composition of semi-natural lowland grasslands, woodlands and, to a lesser degree, heathlands. Increases in average temperature are thought to be causing changes in the composition of montane vegetation in the parts of the Scottish Highlands, with some arctic-alpine species declining. However, land management practices and nitrogen deposition are probably the primary drivers of change in the ecological composition of most habitat types over recent decades.

Changes in climate are having implications for the timing of seasonal events. There is evidence that many spring and summer events are occurring earlier in the year across the UK, which could be disrupting critical food chains and affecting breeding success for some species.

There is good evidence that migratory bird species are responding to changing climatic conditions. Around 40% of wintering wildfowl and wader species have declined significantly in their abundance in the UK since the 1970s, particularly in west coast estuaries, as they migrate shorter distances in the non-breeding season and many have shifted north-eastwards to new feeding grounds. This could have significant implications for internationally important wildlife sites that are protected for migratory species.

(Medium magnitude/medium confidence)

Future

Shifts in the spatial range of species and changes in phenology will have implications for the ecological composition of communities and habitats, with both winners and losers. Some areas will experience

Step 1: What is the current and future level of risk or opportunity?
local species extinctions (i.e. species that are lost from a particular cell but may remain present in other cells across the UK). Species at their southern range margin are at significant risk of being lost from current parts of their range. The scale of change will be heavily dependent on the ability of species to physically disperse and adapt to changes in average temperatures, rainfall patterns and seasonality. Species will only be able to autonomously adapt to changing climatic conditions if there is a coherent network of habitats available to them that are in a good ecological condition. Changes in species populations and community composition are also likely within distributional limits including as a result of the changing balance of competition between species, the impact of changing phenologies on foodwebs and the effects of extreme events, such as droughts and wildfire. The nature of these impacts will differ across the country according to soil type, local climate and microclimates, site management and landscape scale factors, such as the degree of fragmentation of habitats. These changes will make meeting existing conservation objectives increasingly challenging and potentially have implications for the provision of ecosystem services in the long-term, such as carbon storage, clean water provision and pollination. (High magnitude/medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	The national adaptation programmes and strategies of all four UK nations recognise that conserving biodiversity in the face of climate change requires building ecological resilience as well as preparing for, and accommodating, inevitable change. Ecological resilience can be built up in a variety of ways. The independent Lawton Review in 2010 recommended that “establishing a coherent and resilient ecological network will help wildlife to cope with climate change”. This approach is based on increasing the size, number, condition and connectivity of wildlife sites and there is growing evidence that this has a variety of benefits for climate change adaptation. For example, larger sites support populations better able to withstand the shock of an extreme drought, whereas greater connectivity across a landscape may allow some species to track suitable climatic conditions as they progressively move northwards and to higher altitudes. Beyond this ecological network approach, resilience to climate change may be enhanced by a variety of interventions to safeguard or restore ecological processes, for example maintaining wetland sites requires appropriate catchment management,

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	such as controlling or blocking drainage. Change will also increasingly be needed with approaches to conservation management at the site level. As distributions change, it will become increasingly difficult to maintain some species at their southern range margins and it will be necessary to recognise new sites where species may spread or be introduced. In some cases direct intervention may be required to reduce the risk to a species, for example controlling competitor species or manipulating microclimate through managing vegetation height. It will also be important to recognise places which may remain locally suitable for species and habitats even where the wider geographic zone remains unsuitable ('refugia') and to ensure that these places are in a good ecological condition. Ambitious policy aspirations have been set across all four UK nations to halt long-term declines in biodiversity and improve the condition and coherence of ecological networks. Meeting these targets would do much to improve the resilience of habitats and species to current and future climate change, and to safeguard the provision of vital ecosystem goods and services. However, additional effort in the next five years is very likely to be needed to achieve these targets. The primary delivery mechanism for biodiversity conservation measures on the ground are agri-environment schemes funded under Pillar II of the EU Common Agricultural Policy. There are some, relatively localised, examples of incorporating climate change into conservation planning and site management. However, reviewing site scale management for all designated sites to take account of climate change impacts and adaptation measures is a substantial undertaking and needs to proceed at a faster rate. There are currently no strategies in any of the four UK nations for identifying and safeguarding coherent ecological networks at the landscape-scale, (the need for which was highlighted by Lawton). However, a variety of local initiatives are implementing landscape-scale initiatives and a number of these are explicitly taking account of climate change. While the EU Nature Directives do not explicitly account for changing species distribution and migratory patterns driven by climate change, Article 4 of the Birds Directive obliges Member States to keep their network of Special Protection Areas under review to ensure they are the 'most suitable territories' in number and size. The current UK review of the SPA network (terrestrial and coastal) will take such species distribution changes into account. The European Commission has also provided Member States with guidance on climate change and the Natura 2000 sites. In conclusion, current policy and conservation practice to date in the UK is unlikely to be sufficient to build resilience and accommodate change so as to maintain biodiversity and ecosystem services.
Confidence	High

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**More action needed** Further action is needed now and into the future to increase current efforts to reduce existing pressures, 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 there are long lead-in times for adaptation action. There is a need to take more flexible and integrated approaches to managing natural capital, including further realignment of the coast, catchment-scale management strategies, and landscape- scale initiatives to increase habitat extent and improve habitat condition and connectivity. Climate and environmental change should also 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 and securing refugia. Site level conservation objectives and plans will need to be reviewed to assess whether management is appropriate for new or potential colonists. It is important that planning begins in time for action to be effective.
Confidence	High

Ne3: Risks and opportunities from changes in agricultural and forestry productivity and land suitability

Step 1: What is the current and future level of risk or opportunity?
Current There is good evidence that the biophysical capability of the land to support agricultural production has changed over recent decades. The average length of the growing season has increased by around 60 days over the 87-year period between 1914 and 2000 for England and Wales, with a substantial increase in the last decade of the 20th century. There is evidence of a shift to a drier regime in some locations since the 1960s, notably in eastern districts. In Scotland, an expansion in the area defined as prime agricultural land has occurred in the east since the 1960s due to a shift in average conditions

Step 1: What is the current and future level of risk or opportunity?

towards warmer, drier summers, with only a very small area presently constrained due to droughtiness. In some locations in the UK, longer growing seasons and milder winters have provided opportunities for a shift to autumn-sown crops.

The overall area of land in the UK severely constrained by wetness has slightly reduced since the 1960s. However, some locations, e.g. south-west Scotland, have experienced an increase in wetness constraints due to wetter winters. In England and Wales, a general improvement in land quality due to warmer conditions has been countered, at least to some extent, by an increase in drought risk.

It is difficult to attribute actual land-use changes to climate-related changes in land capability because of the multiple factors involved in land-use decisions. In addition, monitoring land-use change through time has been complicated by changes in UK land-use and land-cover classification systems. There is, however, evidence of the regional distribution of some crops changing, which could be at least in part due to changing climatic conditions. Forage maize is, for example, being grown much further north than was the case a decade ago.

Increases in temperature and radiation at key times of the year can have benefits for yield of some crops and varieties, as well as for grass and tree growth. However, if conditions are too hot and dry there can be negative implications for productivity. Climate conditions also indirectly affect yields through the prevalence of pests, pathogens and weeds.

Observed trends in crop yield cannot be directly attributed to recent climate change. This is because of the adoption of new varieties as well as uptake of new technology and modified management practices. In recent years, the yields of many (but by no means all) crops have reached a plateau. Where increases in yield have slowed or ceased, climate change has been suggested as a possible contributing cause.

Similarly, it is difficult to detect any trends in forest productivity in the UK that might be related to climate change. However, increasing forest productivity observed across Europe has been attributed to a combination of temperature increases, atmospheric nitrogen deposition and increasing atmospheric CO2 concentrations.

(Medium magnitude/low confidence)

Future

Crop trials and modelling suggest a wide range of possible future responses with notable geographical variability. A projected trend towards warmer drier summers is inferred to increase the risk of heat stress in sensitive crops (e.g. winter wheat) and to cause problems for those crops with high water demands (e.g. potatoes). At the same time, warmer drier summers and increased mean winter temperatures may be beneficial for some crops (e.g. maize which is sensitive to frost). There may also be increased potential for energy crops (e.g. miscanthus) which are currently limited by temperature. Increased atmospheric CO_2 concentrations may increase growth rates, however the effect on plant growth is non-linear, and dependent on other environmental factors particular light, temperature, water and plant nutrient availability and is highly species-specific.

The area of Best and Most Versatile (BMV) agricultural land[1] in England and Wales is projected to be downgraded from 37% currently to 7% in the 2080s (high emissions scenario) due to increased aridity and droughtiness. Over the same time period, the area of low grade (Grade 4) land is projected to increase from 2% to nearly 66%. Higher drought risk is likely to have increasingly adverse implications for the viability of cereal and potato production in many parts of southern and eastern England.

In Wales, northern England and Scotland the warming climate is more likely to allow for a potential

[1] Defined as Agricultural Land Classification Grades 1, 2 and 3a.

Step 1: What is the current and future level of risk or opportunity?
expansion of land used for agriculture. Grassland productivity in more marginal upland areas where temperature is currently the key limiting factor can be expected to benefit on average from increased temperatures, particularly as rainfall is not usually a limiting factor on summer growth in these areas. In general grassland productivity is most likely to decline in drier areas in the east. There are likely to be increases in tree growth rate in the future, particularly in cooler and wetter areas, because of a lengthened and warmer growing season. Faster growth rates (either per tree or at stand scale) are not necessarily beneficial as this may reduce timber quality unless different species (or different genotypes) are used, and there may also be nutrient imbalances. However, increased tree growth rates and productivity may result in larger vegetation carbon stocks and higher sequestration of CO_2 in the future. Climate change is predicted to drive tree species change across Europe, with potentially severe economic impacts on forestry. Many of the present-day dominant species used in commercial forestry will be less suitable in warmer and drier conditions, particularly in southern and eastern areas of the UK. Any increase in the frequency and duration of prolonged drought periods will reduce tree growth. Woodlands in the south and east of the UK and those on lighter and shallower soils will be at highest risk. Substantial reductions in yield class in the 2050s and 2080s for three major tree species are projected (Sitka spruce, Scots pine, and pedunculate oak) due to drought impacts, with reductions larger in lowland than upland sites. (High magnitude/medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	Farmers and foresters will be likely to take advantage of new opportunities autonomously, but this is likely to happen reactively and not through strategic planning. Land use planning decisions are mainly based upon a stationary climate and maintaining land resources in the same location (e.g. the use of BMV and prime land). There is minimal strategic planning or consideration of future land-use and the implications of changing suitability of land for agricultural production. Autonomous adaptation is likely to occur with the selection of crop and grass varieties and tree species that are well-adapted to future environments through genetics and adaptive crop breeding. It will be necessary to ensure ready access to genetic variation through the continuing maintenance of germplasm collections. However, investment in genetics and crop breeding has a long lead time between research and large-scale field implementation.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Research priority** There is a need for a realistic assessment of the suitability of current agricultural systems in the future given the projected changes in doughtiness and aridity. This could include reviewing the potential costs and benefits from more widespread production of 'novel' crops (e.g. grain maize, field-grown tomatoes, sunflowers, apricots, etc.). Such an assessment will provide the early steps to inform better decisions in the near future and reduce the risk of lock-in to unsustainable future pathways. Further research to assess how changes in agricultural suitability can be better factored into land use planning decisions is also needed, so that future option values on the land are fully considered.
Confidence	Medium

Ne4: Risks to soils from increased seasonal aridity and wetness

Step 1: What is the current and future level of risk or opportunity?
Current There has been a trend towards reductions in soil moisture due to warmer drier summers, particularly in the eastern half of the UK. This change in soil moisture, in addition to elevated temperatures and CO_2 levels, has implications for rates of physical, biological and chemical processes, and hence ecosystem functions and the goods and services provided by soils. Land management, however, has to date been a more significant driver of risk to soil health than climate change. Land use is the dominant factor explaining trends in Soil Organic Carbon (SOC) losses, particularly intensive arable cultivation on fenland peat soils in eastern England. Use of waterlogged soils by heavy machinery or high livestock numbers can cause long-term damage to soil structure and crop yields. These constraints have been alleviated in many areas for agricultural land use through surface and subsurface drainage schemes, but such schemes have a design limit and require ongoing maintenance. Soil erosion has implications for water quality, as sedimentation reduces levels of dissolved oxygen adversely affecting freshwater species. Around 5% of the 5,500 water bodies in England do not currently meet good ecological status due to sedimentation. (Medium magnitude/medium confidence) Future Increases in the frequency and intensity of heavy rainfall events will in turn increase the risk of water-based soil erosion. This risk could be further exacerbated by changes in cropping types and cultivation practices, for example the expansion of high-risk crops such as maize and increased cropping on marginal land, particularly on slopes. Based upon soil properties it is likely that areas that have drainage difficulties will continue to be vulnerable to waterlogging and compaction in the future with wetter winters. Changes in climate are expected to affect the abundance and activity of soil microflora (e.g. bacteria, fungi and protozoans), with implications for decomposition of organic matter and hence carbon storage, nutrient cycling and fertility-related ecosystem services. Warmer and drier conditions could have adverse implications for the viability of already stressed peatland habitats and their species, particularly bryophytes (mosses and liverworts). Peatlands on the eastern side of the UK are at higher risk, particularly where they are vulnerable due to drainage and adverse management practices. (High magnitude/medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	There are a number of policy interventions that provide farmers with some incentives to conserve soils. These are primarily based on the Common Agricultural Policy (CAP), as, farmers must provide minimum soil cover, take measures to prevent erosion, and maintain soil organic matter levels in order to qualify for the full single farm payment. However, in practice the low levels of inspection make it difficult for these requirements to be enforced. Voluntary agri-environment schemes funded under Pillar II of the CAP are also important mechanisms for encouraging soil conservation, although soil health is not a priority objective. There have also been efforts to incentivise soil conservation in order to improve water quality, such as the Catchment Sensitive Farming initiative in England. Autonomous responses to the changing climate (e.g. cultivation of steeper slopes; expansion of maize cropping) may increase erosion risks further in the future. Overall, current policy interventions do not appear to be sufficient to manage this risk.
Confidence	High

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**More action needed** Further action is needed to improve the condition of degraded soils, better protect soils from damaging practices and encourage the wider uptake of soil conservation. Long-term monitoring of soil health, in terms of SOC levels, erosion rates and soil biota is also needed, particularly of carbon-rich soils, to address knowledge gaps of the magnitude of this risk and its geographical variations. This will have a range of co-benefits for managing a wide range of climate and non-climate related risks and avoid lock-in to a pathway where the UK's most fertile and carbon-rich soils are lost at some point in the future. Many soil conservation actions are also cost-effective to implement now especially when accounting for non-market values, such as carbon and water quality.
Confidence	High

Ne5: Risks to natural carbon stores and carbon sequestration

Step 1: What is the current and future level of risk or opportunity?
Current Carbon is naturally stored in soils and vegetation. Vegetation growth acts to sequester CO_2 from the atmosphere into plant tissues which can then be transferred to soil carbon through litter and humus. Soils can also be a source of carbon emissions through decomposition and respiration, which may be accompanied by losses of methane (mainly from wetlands) and nitrous oxide (mainly from artificial fertilisers), both powerful greenhouse gases. The largest terrestrial carbon stocks occur in soils, particularly organic (carbon-rich) soils. Deep peat covers 10% of the total UK land area (23,000 km^2) and stores over 3 billion tonnes of carbon. When in a pristine condition, peatlands are usually waterlogged and actively sequester carbon due to retarded decomposition rates and colonisation by peat-forming species, notably Sphagnum. Across large parts of the UK, these conditions have been lost through human activities such as drainage for agriculture and forestry, intensive grazing, managed burning and peat extraction. Exposure of formerly waterlogged peats to the air as a result of drainage leads to peat oxidisation, converting carbon stored for millennia into CO_2, which is emitted to the atmosphere, a process directly analogous to the burning of fossil fuels. However, GHG emissions from degraded peatlands are not all currently accounted for in the UK's GHG Inventory. Peatlands are particularly sensitive to changes in soil moisture regime. There is some evidence that increasing temperatures are indirectly stimulating soil organic carbon loss in peat habitats through changes in vegetation and litter quality as grass species increase at the expense of shrubs and mosses.

Step 1: What is the current and future level of risk or opportunity?
The vulnerability of peatland habitats to changing climatic conditions is exacerbated by their present-day condition. A combination of widespread historical drainage, continued damaging management practices and air pollution has resulted in some 70% of peat soils in England, 75% of peatlands in Wales and 35% of Scottish peats being physically degraded. The largest vegetation carbon stocks and overall sequestration rates occur in woodlands. The 2.7 million ha of forests and woodlands in GB store an estimated 213 million tonnes of carbon, which is approximately equally split between conifers and broadleaves. Around 15 million tonnes of CO_2 was sequestered by UK forests in 2014, which is more than the 11 million tonnes of CO_2 sequestered in 1990. Carbon is also stored in coastal and marine habitats (known as 'blue carbon'), with rates of carbon sequestration particularly high in salt marsh and sand dunes. Data concerning the role of offshore habitats as sinks of blue carbon is comparatively scarce. Blue carbon stocks and flows are currently not accounted for in the UK GHG Inventory and so do not contribute to meeting the UK's statutory emissions reduction target. Climate interacts directly with the carbon cycle on land through its influence on the rate of plant and soil processes. In addition it is an important indirect factor by influencing land use choices and therefore the type of plants and soils available to store or sequester carbon. There is some evidence of enhanced tree biomass growth in recent decades across Europe but this may also be attributable to non-climate factors (enhanced nitrogen deposition; recovery from sulphur deposition; forest management changes). Evidence for the influence of climate on soil carbon remains contested but the consensus is that land use change is currently the dominant factor. Nevertheless, in some upland locations climate may be contributing to losses of carbon through erosion and losses to atmosphere and water, especially on areas of unvegetated peat Future Enhanced storage of carbon due to a longer growing season and CO_2 fertilisation is likely to be countered by loss of carbon from enhanced soil respiration due to higher temperatures. At present it is difficult to evaluate which will be the dominant process and it may also depend on changes in soil water regimes. In currently vulnerable areas (e.g. drained and intensively managed peatlands), higher temperatures and the likelihood of drier summers, particularly in the east of the UK, is likely to substantially increase the loss of carbon stocks. As well as increasing CO_2 emissions, any significant loss of carbon will also have adverse impacts on water quality. There may also be risks to forest carbon storage through effects of climate on soils, as soil carbon is the largest component of forest carbon in many soil types, particularly peat soils. Any significant expansion of agricultural production from the south and east to the north and west due to changes in land suitability would be likely to have negative implications for soil and forest carbon stocks. The UK National Ecosystem Assessment in 2011 developed a series of socio-economic scenarios to assess possible land-use changes up to the 2060s. Under one scenario (Green and Pleasant Land) a preservationist attitude arises with low-input agricultural systems adopted to conserve a range of ecosystem services. In the World Markets scenario, the focus is on achieving high economic growth and agricultural production by removing barriers to trade. The NEA estimated changes in UK land cover (from a 2007 baseline) by the 2060s under these different scenarios. Under World Markets, the area of arable land is projected to increase by 4% from current levels by 2060. This would primarily be at the expense of semi-natural grassland and upland areas (both declining by 3% each) and a reduction in woodland cover by nearly 1%. Such a scenario would result in estimated emissions of 40 MtCO2 per year from soil carbon losses, compared to present day

Step 1: What is the current and future level of risk or opportunity?
emissions of around 25 MtCO2. There would also be accompanying adverse impacts on biodiversity and water quality, but these have not been modelled. However, there is also the potential for significant reductions in the area of land used for agriculture as a result of increased droughtiness. If this land were to be replaced with woodland and semi-natural grassland, then there would be substantial gains in carbon stocks, especially in lowland areas. Under the Green and Pleasant Land scenario soil carbon stocks are projected to increase by 9% and forest carbon stocks by 23%. This reflects an assumption that broad-scale afforestation programmes are largely successful at replacing farmland that is no longer economically viable due to reduced water availability. The projected losses of coastal habitats, particularly saltmarsh and sand dunes, from continued and increased sea level rise will have implications for carbon storage. This has, however, not been modelled. Future projections of GHG emissions and removals do not account for either the positive or negative implications of climate change on natural carbon stores, reflecting fundamental uncertainties even with regard to present-day conditions. (High magnitude/medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	Policies and programmes are in place across the UK to restore degraded peatlands, particularly in the uplands. In Scotland, a programme of peatland restoration has been undertaken through Peatland Action, within the context of the National Peatland Plan. Increasing the rate of restoration to 22,000 ha per year, as set out in the Report of Proposals and Policies 2, is a key action in Scotland's statutory National Planning Framework 3. Around £45 million was invested by water companies in upland catchment management schemes in England between 2010 and 2015 covering an estimated 60,000 ha. Some £27 million was paid to farmers and landowners who took up moorland restoration options under the Higher Level Scheme (HLS) between 2007 and 2013. Around 200,000 ha of deep peat in the uplands are now covered by these options. In the lowlands, raised bogs in the Humberhead Levels and the north-west of England have been undergoing extensive restoration following the gradual phasing out of peat extraction for horticultural markets. Some fen restoration has also been occurring in the East Anglian Fens, and in the Somerset Levels. Despite these efforts there is evidence that damaging practices on peatlands continue, including on protected sites. The extent and

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	frequency of burning regimes have increased in recent decades across extensive areas of blanket bog in northern England and Scotland. All four UK countries have targets to increase the proportion of woodland cover, e.g. from 10% of land area to 12% by 2060 in England and from 18% to 25% by 2050 for Scotland. Where new woodland is being planted, or harvested areas being restocked, there is the potential to change tree species, and information resources and tools have been developed to indicate the different species that could be used in UK conditions. Diversification is also essential to reduce pest and disease risk. There has been a reported increase in the number of conifer species being ordered from nurseries for the public forest estate in England and Scotland in recent years. In the private sector, the take-up of diversification and other adaptation measures is limited. If current new planting and restock rates continue without other measures for diversification, the potential for species change is only approximately 1% of the current forest area per year. Selecting the right planting material for a particular site is key to ensuring subsequent tree establishment and productivity. Using tree planting material from different locations (termed 'provenances') is being promoted in order to better suit changing climatic conditions. There is, however, little information on provenance growth comparisons over the longer-term and little systematic evidence across the main UK tree species on which to base provenance selection recommendations for future growing conditions. More work needs to be done on selecting provenances for drought tolerance for future climate conditions. Tools are available to help reduce wind damage from moderate storms by informing decisions on the timing of harvesting and thinning for conifer species. However, no such guidance is available for broadleaved species. Climate change mitigation policy does not currently account for the potential direct and indirect implications of climate change on terrestrial carbon stores and does not account at all for blue carbon. The inventory also currently underestimates GHG emissions from managed peatlands in both the uplands and lowlands. However, DECC are currently in the process of incorporating the IPCC's Wetland Supplement into the UK's GHG Inventory
Confidence	High

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**More action needed** Further action is needed to improve the condition of degraded soils, restore peat habitats, better protect soils from damaging practices and encourage the wider uptake of soil conservation. Further action is also needed to diversify the existing forest stock in the UK and to better understand provenances that are drought-tolerant. There is also a need to consider the nature of the planting stock (species and genetics) when restocking woodlands to ensure that their carbon sequestration function is maintained. Action is also needed to ensure that the UK GHG inventory fully captures all carbon stores and that GHG emission projections from the land use, land use change and forestry sector account for the impacts of climate change on carbon stores.
Confidence	High

Ne6: Risks to agriculture and wildlife from water scarcity and flooding

Step 1: What is the current and future level of risk or opportunity?
Current Freshwater species are highly sensitive to low flows, as the quantity of water determines the level of dissolved oxygen available. Low flow conditions can also reduce dilution of pollutants and in extreme cases cause water bodies to dry out, leading to a loss of living space. High flows and their associated sediment loads can cause significant ecological damage, e.g. to fish spawning beds. Water quality can also be adversely impacted during periods of heavy rainfall due to increased transport of diffuse pollutants from land to water and effluent discharge from point sources (e.g. sewage outfalls). Long-term trends in flow are difficult to distinguish from inter-annual variability. Rising trends in river flows between the 1960s and 1990s are evident in the western and northern regions of the UK, although this may not be directly attributable to observed atmospheric and ocean warming. Present day abstraction demand would exceed the available resource required for the natural environment during periods of low flow if they were left unrestricted in the majority of catchments in the eastern half of England, as well as for a small number of catchments in north-west of England, Northern Ireland and Scotland. An estimated 13% of all rivers in England and 4% in Wales are currently at risk of not meeting good ecological status due to over-abstraction. Abstraction for irrigation currently causes 4% of Significant Water Management Issues (SWMIs) in Scottish water bodies. Abstraction for other purposes (such as renewable energy generation and public water supply) causes a further 17% of SWMIs.

Step 1: What is the current and future level of risk or opportunity?
Over 40,000 hectares of agricultural land were inundated during the 2007 floods in England, causing an estimated £50 million of damage. The floods and storm surge in 2013/14 caused an estimated £19 million of damage to agriculture. (Medium magnitude/medium confidence) Future Future projections of river flows imply changes across the seasons, with increases in average winter flows and reduced spring and summer flows. No clear pattern is projected in the autumn. If current environment flow requirements are fixed into the future, then the majority of catchments in the UK are projected to not have enough water available during dry periods in the 2050s and 2080s. Only the central-west area of England and northern most catchments in Scotland are expected to have sufficient water resources to meet both environmental requirements and demand for abstraction during dry periods. There will therefore be an increased risk of water restrictions in the land use sector, which will have potential consequences for agricultural businesses particularly those specialising in crops that are dependent on supplementary irrigation. Revising environmental flow requirements so they are set as a proportion of future river flows (i.e. are not fixed at current levels) would be likely to increase the amount of water available for abstraction in water-stressed catchments. However, the consequences of any long-term reduction in absolute flows for meeting Water Framework Directive targets have not been investigated at a national scale. Flood risk may further reduce land availability and capability in vulnerable locations (notably in river and coastal floodplains). Land that is regularly flooded is only capable of supporting lower-value crops, pasture or woodland. The area of BMV or PAL in the UK at risk of flooding is projected to increase. Using an indicative 1in 75 year average risk level, flooding from fluvial, coastal and pluvial sources is projected to increase from 570,000 hectares (present day) to 750,000 hectares in the context of a 2°C rise in global mean temperatures by the 2080s; and to 940,000 hectares in the context of a 4°C rise. (High magnitude/medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	Under the provisions of the Water Framework Directive, all UK surface water bodies (rivers, lakes, estuaries and coastal waters), should have good ecological status by 2028. Achieving this goal will be challenging, particularly in England where the proportion of surface water bodies meeting good ecological status has remained at around 23% between 2008 and 2012. The lack of significant or sustained improvements in water quality suggests that persistent and underlying pressures are not yet being adequately addressed. This is particularly the case for diffuse pollution from agriculture, which accounts for around one-third of WFD failures but is technically difficult and costly to manage, with implications for farming livelihoods. Any climate-driven changes in low or high flows will further challenge meeting the WFD timeline, and make it harder to ensure that water bodies remain in good condition in the longer-term. However, there is no clear mechanism in place that accounts for the consequences of changes in flow for meeting the WFD targets. Understanding of the ecological resilience to extreme (drought) flows and associated recovery from drought is also lacking. This means there is a key gap in the evidence base for assessing environmental flows under climate change. The abstraction regime is a key mechanism for managing risks from low flows. The current licencing regime was established over 50 years ago and does not provide a pricing framework that is sufficiently responsive to changes in water scarcity. However, the Government has committed to reform the licensing regime in England and published a consultation document in early 2016 on the steps it intends to take. In the shorter-term, the Environment Agency and Natural Resource Wales operate the Restoring Sustainable Abstraction programme, targeting areas where abstraction may be causing particular problems for protected sites (SSSIs, SACs and SPAs). Around 80% of these licences are for public water supply or agricultural abstractions. By March 2015 nearly half of the licences had been reviewed, leading in many cases to a reduction in licence volumes or the introduction of conditions to restrict abstraction during times when water is scarce. One-fifth of licences have been revoked. The programme is due to be completed by 2020. Reducing demand for water so that abstraction pressure is kept to a minimum is also an important adaptation. Autonomous responses are unlikely to deliver significant reductions in agricultural water use in the absence of a stronger price signal. Investment in improved water storage infrastructure, new technology, or drought-resistant varieties also has long lead times. In the longer term, fundamental changes to agricultural systems in areas of water stress may happen autonomously. However, this may not

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	occur if the policy framework is based on maintaining agricultural systems in-situ, as is the arguably case with the Common Agricultural Policy. The way land is used and managed can either enhance or reduce high and low flows. Incentivising management practices that increase the natural capacity of soils and vegetation to store water or retard runoff rates requires policy intervention as the recipients of the benefits tend to be located downstream. Some policies are in place to incentivise sympathetic management, mainly in the form of agri-environment schemes under Pillar II of the CAP along with some catchment-scale initiatives. However, management practices continue that are likely to be reducing the natural capacity of soils to manage flows, particularly in the uplands. New and improved flood and coastal defences are built to protect agriculture land as part of the wider national flood risk management programmes. For example, 74,000 hectares of agricultural land in England saw an improvement in the level of flood protection in 2011/12.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**More action needed** Further action is needed to improve the condition of water bodies and to encourage the wider uptake of management practices that help to reduce the impacts of low and high flows. This will have a range of co-benefits for managing climate and non-climate related risks and avoid lock-in to a pathway where the majority of the UK's rivers and lakes are ecologically degraded in the future. Ecological restoration can also take many decades, meaning that there are long lead-in times for action. There is a need for more strategic planning for increased water scarcity in vulnerable locations, including re-evaluation of land use options and if necessary investment in storage infrastructure to maximise use of surplus winter rainfall. Further action to reduce demand in water-stressed areas is also required, including water pricing based upon the full value of the resource. This can only be achieved through implementing reforms of the abstraction licencing

Step 3: Are there benefits of further action in the next 5 years?	
	regime and, in the longer term, reviewing the setting of environmental flow indicators.
Confidence	High

Ne7: Risks to freshwater species from higher water temperatures

Step 1: What is the current and future level of risk or opportunity?
Current Many aquatic species have limited thermal ranges. Changes in water temperatures can exceed their thermal tolerance which can cause loss of species. In addition, warmer waters can also cause death by anoxia due to lower dissolved oxygen content. Water temperatures have increased in rivers and lakes at similar rates to regional air temperatures since the 1970s or 1980s with an average warming of 0.03°C/year reported between 1990 and 2006. There have been detectable temperature increases at 86% of sites in England and Wales. This temperature change has modified the circulation of some lakes, particularly the process of stratification in which the thermal profile becomes more evident as a series of distinct layers, reducing circulation of water, oxygen and nutrients. There is some evidence of a response to changes in water temperature, for example with reductions in fish species in some catchments. In one site, spring invertebrate abundances have declined by around 20% for every 10°C rise as species typical of cooler-water conditions have been lost. To date, increased temperature has not directly caused any water bodies to fail to meet good ecological status under the Water Framework Directive. The effects of temperature changes on freshwater ecology are often masked by other factors, notably changes in water quality. (Medium magnitude/high confidence) Future Future projected temperature increases imply that this risk will increase with further negative effects on sensitive species. Reductions in flow are also likely to lead to greater increases in river temperature in summer. Smaller, shallower lakes are likely to be at risk with reduced circulation increasing the risk from cyanobacterial blooms and deoxygenation. Larger deeper lakes are likely to be more sensitive to longer periods of stratification reaching greater depths causing deoxygenation and loss of fish assemblages. Continued decline in species adapted to cold conditions (e.g. arctic charr) and those with complex life cycles (e.g. salmon) may be expected and with potential for invasive fish species such as Common Carp, European Catfish and Roach. Projected future changes in water quality remain highly uncertain due to the complex interaction between climate change with land use change, which will vary by catchment. Few studies have been undertaken, but some projections show increased risk of algal blooms and suspended solids. (Medium magnitude/medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	The primary mechanism for managing the risk of higher water temperatures is the Water Framework Directive. Increasing water temperatures, combined with changes to flow, will make meeting the WFD targets even more challenging. However, there is no clear mechanism in place that accounts for the consequences of changes in water temperature for meeting the WFD targets. There have been some efforts to reduce the impacts of higher water temperatures on rivers through planting of riparian woodland, which provides localised shading and cooling. This has, however, been somewhat opportunistic to date, although the Woodland Creation Grant in England provides additional points for riparian planting linked to the 'keeping rivers cool' data-set. The amount of planting would have to be significantly increased to match the level of risk under medium or high future climate projections. There would be benefits for managing a wide range of climate and non-climate related risks from further riparian tree planting, as long as the right trees are planted in the right places. Widespread riparian planting also has long lead in times. For some species (e.g. Arctic fish such as vendace) translocation is being trialled as a last resort option. There is however a lack of evidence on the scale of possible translocation required, as well the potential wider ecological implications.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Research priority.** Research is needed to further refine the strategic approach to riparian tree planting, which is currently based on the Keeping Rivers Cool 'shade map'. This will inform the development of a strategic programme of riparian woodland creation targeted to provide cooling for sensitive water bodies of high biodiversity and/or cultural importance (e.g. salmon rivers). Further research is also needed into the costs and benefits of

Step 3: Are there benefits of further action in the next 5 years?	
	a possible cold-water species translocation programme. Such an assessment will provide the early steps to inform better decisions in the near future.
Confidence	Medium

Ne8: Risks of land management practices exacerbating flood risk

Step 1: What is the current and future level of risk or opportunity?
Current Degraded and compacted soils can exacerbate flood risk by increasing the speed of rainwater run-off and silting up rivers. Field studies have shown that some land management practices can cause soil compaction, due to the use of machinery or presence of livestock on waterlogged soils, resulting in damage to soil structure, reduced aeration and penetration of plant roots, and the potential for increased erosion due to reduced water infiltration and increased runoff from overland flow. While a number of small-scale studies have found locally occurring increases in soil compaction, there has been no systematic study of the national extent, or severity of this issue; as a result, it is not currently possible to provide a quantitative assessment of the current state or trend across the UK. There is evidence that some land management practices have a particularly adverse impact on downstream flood risk, including maize cultivation on slopes and over-stocking of livestock. There has been more than a five-fold increase in the area of land in the UK under maize, from 27,000 hectares in 1988 to 196,000 hectares in 2014. Of this, the majority (93%) was grown in England. Nearly one-third (31%) of national maize production in 2010 was located in the south west of England where a survey of over 3,000 sites found that the soil structure of three-quarters of fields under maize were damaged to the extent that rainfall is unable penetrate the upper soil layers, resulting in silt-laden run-off during periods of heavy rainfall. (Medium magnitude/medium confidence) Future Warmer, wetter winters and drier summers in the future could increase rates of soil weathering and increase soil erosion (as noted in Ne.5 above). This could in turn increase downstream flood risk. This risk will be exacerbated where soils are degraded and compacted due to land management practices. (Medium magnitude/medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	As noted in NE.5, land managers are required to take measures to prevent erosion in order to qualify for the full single farm payment under Pillar 1 of the CAP. However, in practice the low levels of inspection make it difficult for these requirements to be enforced. There is currently no process in place that requires land managers to assess the extent to which their practices may be exacerbating flood risk. Incentivising management practices that increase the natural capacity of soils and vegetation to store water or retard run-off rates requires can be challenging, as the recipients of the benefits tend to be located downstream. Voluntary agri-environment schemes funded under Pillar II of the CAP are important mechanisms for encouraging soil conservation, although reducing flood risk is not a priority objective. There have also been efforts to incentivise land management practices in sensitive catchments in order to improve water quality, such as the Catchment Sensitive Farming initiative in England. There is increased interest in the adoption of Natural Flood Management (NFM) schemes, which maximise the use of natural fluvial and landscape features to reduce flood peaks. As most of these schemes are still in the early stages the benefits remain to be fully established and are usually specific to the sites in which they are located. Results from experiments in the Pontbren catchment (central Wales) suggested land use changes (reduced grazing pressure or afforestation) could reduce run-off rates by 50% or more. Defra have invested £1.7m in three Multi-Objective Flood Management Demonstration Projects that aimed to generate hard evidence to demonstrate how integrated land management change, working with natural processes, can contribute to reducing local flood risk. The three projects, which date from 2009, are located in Somerset, Derbyshire and North Yorkshire in catchments ranging between 18-90 km2 within, or bordered on, upland areas with high rainfall and rapid runoff. Flood peak heights may be reduced by 4% or more on a 9 km2 catchment scale in the Derbyshire project, by 4% on a 69 km2 scale in the North Yorkshire project and by 25% on an 18 km2 scale in the Somerset project. These estimated effects apply to flood peaks in the order of 1-in-25 year events. The Demonstration Projects provide evidence that the use of NFM measures can reduce flood flows within catchments of up to 100 km2. However, it remains difficult to determine the overall significance of measures that store flood waters and manage run-off at the catchment scale, or how they will influence the magnitude and severity of more extreme floods (for example, 1-in-50 or 1-in-100 year events). A further challenge facing the wider uptake of NFM measures is that it is not possible to guarantee a specific standard of service for flood protection in the same

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	way as with conventional flood defences. NFM schemes also generally require ongoing maintenance, which is typically not included in capital costs.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**More action needed** There is a need to better understand the scale of land management practices that exacerbate downstream flood risk, in order to inform the specific policy interventions required. There is a need to review the potential for adverse flood risk outcomes due to the implementation of CAP policies, particularly under Pillar 1. Further action is also needed to deliver wider uptake of NFM in catchments where the approach can make a significant contribution to reducing peak flow and subsequent flood risk. NFM approaches should also be designed to maximise benefits for carbon storage, water quality and biodiversity. The economic case for the wider use of NFM measures as part of the suite of Flood and Coastal Erosion Risk Management practices needs to be strengthened. This could be through undertaking cost benefit analysis comparing the costs of repairing flood damage with the costs and benefits of incentivising changes in land management practices. The non-market benefits from NFM, e.g. in terms of carbon storage or water quality, should also be included in any such assessment.
Confidence	High

Ne9: Risks to agriculture, forestry, landscapes and wildlife from pests, pathogens and invasive species

Step 1: What is the current and future level of risk or opportunity?
Current There has been a rise in recorded non-native species in terrestrial, freshwater and marine environments in the UK. Of the 3,050 non-native species currently recorded in GB, 1,919 are considered to be established; and of those, 179 are considered to be exerting a negative impact on native biodiversity. Invasive species like rhododendron are presently substantial problems for forestry, affecting ground and understorey flora, and competing for water and nutrient resources and inhibiting natural tree regeneration. The increase in this risk is primarily due to human activity at present, exacerbated by the expansion in global trade. Climate change is currently a background factor. In addition, lack of natural competition may be an additional factor especially in landscapes of reduced biodiversity. However, each pest, pathogen and invasive non-native species has its own distinctive characteristics. There have been several recent examples of new tree pest and pathogen problems in the UK, many of which cause tree mortality, either rapidly or over a few years. For example, Chalara fraxinea (ash dieback) is a new disease in the UK that was first reported in 2012. By May 2016 it had been recorded in 39% of the 10 km squares in England and 15% of those in Scotland and Wales. (High magnitude, medium confidence) Future A warmer climate provides an increased likelihood of pests and diseases that were previously limited by climate (notably cold winters) to persist and disperse. There is an increased risk from expansion of vectors for bluetongue and of airborne spread of Foot and Mouth. Small changes in climatic conditions around critical thresholds may result in dramatic changes in parasitic nematodes in livestock. Insect pests are generally expected to become more abundant due to range expansions and phenological changes, including higher overwinter survival rates. Wetter winters may increase the risk of liver fluke, which is vectored by water-sensitive lymneid snails. The colonisation and expansion of non-native species is much harder to predict than range changes in native species. Those species which are already native in continental Europe and colonise naturally, for example through airborne dispersal will typically have co-occurred with many British species. In these cases the risks are likely to be relatively small and easily anticipated. With species colonising from other parts of the world as a result of human travel and trade, the consequences are less certain and climate change will add to the uncertainty as species which would not previously have been able to survive in the UK start to be able to do so. While recent milder winters have been suggested to have increased the problem of evergreen invasives, there is limited firm evidence. Species such as rhododendron might increase their elevation range in upland western areas if there are warmer conditions, increasing costs of control, and perhaps also increasing disease spread as rhododendron is a host for Phytophthora ramorum. Particular insect pests are likely to increase with warmer conditions, although predicting the influence of climate change on individual species depends on understanding pest ecology and natural enemy responses. Changes in climate may affect introductions and dispersals. For example, a shift towards warmer wetter winters is likely to favour the spread of fungi and related organisms e.g. Phytophthora. (High magnitude, low confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	No
Justification	There is a strong policy framework in place to manage this risk, which is based on independent scientific reviews. A Tree Health and Plant Biosecurity Expert Taskforce reported in May 2013 and the first UK Chief Plant Health Officer took office in April 2014. A UK Plant Health Risk Register has been produced and maintained, along with a Plant Biosecurity Strategy and a Tree Health Management Plan, which addresses the recommendations of the Tree Health and Plant Biosecurity Expert Taskforce. Livestock diseases are covered by the EU Animal Health Strategy. The Animal and Plant Health Agency and the Forestry Commission are responsible for monitoring and responding to pests and disease threats to agriculture and forestry. Both have embedded climate change into their planning and surveillance arrangements. There is also a Great Britain Invasive Non-native Species Strategy, as well various policy mechanisms such as WFD, Habitats Directive and Marine Strategy Framework Directive and the EU Regulation on Invasive Alien Species. International frameworks are also in place, through the UN Convention on Biological Diversity and the Bern Convention. Risk assessment procedures are now increasingly used to identify problem species and to prioritise actions. There has been progress in areas specifically aimed at addressing the risks from climate change, particularly through research to better understand the nature of the risks. Actions include the Tree Health and Plant Biosecurity Initiative research programme, research to fill the evidence gap on the effects of climate change on pests and diseases that affect livestock, and for environmental change factors to be considered for each risk in the new UK Plant Health Risk Register.
Confidence	High

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	No
Type of benefit	**Sustain current action** Continue to implement surveillance and bio-security measures. Continue

Step 3: Are there benefits of further action in the next 5 years?	
	current research efforts into the impact of climate change on long-term risks.
Confidence	Medium

Ne10: Risks to agriculture, forestry, wildlife and heritage from change in frequency and/or magnitude of extreme weather and wildfire events

Step 1: What is the current and future level of risk or opportunity?

Current

Wind damage to forests is a major problem to forestry in the UK and across Europe where wind and snow storms cause approximately half of all damage to forests. Storms cause immediate damage (loss of timber stock, costs of clear-up), disruption to markets and processing and can increase subsequent risk of damage from insects, pests and wildfires.

Drought can have a major effect on agricultural yields, ecosystems and biodiversity as well as water resources and aquatic biodiversity. Long-term monitoring has shown that the 1976 drought had impacts, including the death of beech trees, at Lady Park Wood, the effects of which are still apparent today. Studies on the effects of drought in the mid 1990's showed differential effects on different species of plants and invertebrates. The 2003 drought caused a decline in forest productivity and carbon sequestration across Europe.

Wildfire represents a sporadic but serious risk to the natural environment in the UK. It can affect forestry, agriculture and multiple habitats (grassland, heathland, woodland, peatland etc.). While wildfire can damage woodlands with loss of timber, habitat and ecosystem services, it also causes short-term disruption to local populations and infrastructure, and consequent costs, and may cause health risks. For example, the fire outbreak in April-May 2011 at Swinley Forest (near Bracknell, SE England) was the most resource-intensive fire incident in the history of the Royal Berkshire Fire and Rescue Service. When organic soils, particularly peat, are affected by fire, the damage can become extensive in depth and extent, because of the large fuel supply and difficulties of suppression, with implications also for increased carbon emissions and reduced water quality. There is a clear link with weather, climate and wildfire risk because wildfire risk particularly manifests during hot dry conditions. The link is though complicated because outdoor activities by people also increase during such weather and the vast majority of wildfires are caused by human causes.

During the 2003 heatwave the thermal heat index for cattle was exceeded for 5 days in the Midlands and southern England. Milk yields were largely unaffected, but there would have been welfare issues

(Medium magnitude, medium confidence)

Future

Predicting changes in storm tracks is highly uncertain. Storm damage also depends on storm timing (for deciduous species, because of the increased wind load if trees are in leaf, e.g. St Jude's Day storm in 2013 in England) and the state of the ground – wetter conditions will cause more overturning. Warmer autumns, with consequent later leaf loss are likely to increase the risk of damage in deciduous species. On a longer time-scale, wind damage also depends on soil wetness because waterlogging reduces rooting depth and consequently tree stability.

Step 1: What is the current and future level of risk or opportunity?
Projections of an increase in drier summers with increased soil moisture deficits would be expected to lead to a large increase in the number of fires and the area affected. Climate modelling suggests that risk will increase by up to 50% in some southern National Parks (e.g. New Forest, Dartmoor) and by 30-40% in other National Parks (e.g. Brecon Beacons, North York Moors, Cairngorms) by the 2080s. However, this modelling does not yet include indirect factors such as fuel loads, human behaviour and changes in land use. The risk of damage from wildfires is particularly likely to increase in the south and east of UK, especially SE England, where there are areas of heathland, high population density and associated conifer tree stands and plantations (e.g. Surrey, Berkshire, Dorset). Increased tree mortality from drought and from pest and disease may in turn increase wildfire risk. Wildfires in the UK are unlikely to become as severe as in Mediterranean regions, because of the usually fragmented nature of woodland cover, with areas affected usually accessible, and the consequent easier control. Increasing drought frequencies or more severe drought will change the balance between species in ecological communities and could lead to the local extinction of more vulnerable species. There is an increased risk of the thermal heat index for dairy cattle being exceeded in southern Britain on average for 20 days per year by the end of the century. This may have implications for the profitability of the milk industry due to either the reduction in milk yield and or the cost in running the cooling system to improve animal welfare. However, any reduction in the number of cold days and snow and icy conditions may be beneficial for livestock productivity, fertility and animal welfare. (Medium magnitude, low confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	No
Justification	The risk of wind damage is well-understood in UK forestry, particularly for productive conifer plantations in the uplands. The planning of rotation lengths, harvesting areas and thinning regimes usually take measures to reduce the risk. Further adaptation is not really possible, beyond current risk reduction planning strategies. The impacts of drought on forests can be reduced through ensuring a diversity of tree species, as set out in the UK Forestry Standard. Restoring catchment hydrology including through blocking drainage channels or introducing control structures may reduce risks to ecosystems in some situations, such as wet meadows, fens and peatlands and reducing fragmentation of habitats can increase resilience. Wildfire is included in the UK National Risk Register and National Risk Assessment in 2013, meaning it is recognised in the same way as other climate-related risks (e.g. flooding) and non-climate risks (e.g. pandemic flu). As such, it is a risk covered by the Civil Contingencies framework, which is the responsibility of the Cabinet Office. Fire events have been systematically recorded since 2009 with the Incident Recording System, meaning that data

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	is being collected on the magnitude, extent, and other characteristics of wildfires. Improvements in approaches to fire-fighting may have contributed to a reduction in large outbreaks in recent years. Emergency planning currently includes preparedness and contingency for wildfire but the full extent of the risk and the identification of vulnerable areas remains unknown. Wildfire guidance was included in the UK Forestry Standard in April 2014. This should help ensure widespread uptake of management practices that reduce risk, such as the use of fire breaks, surveillance systems and public warnings. However, it is also possible that the conversion to continuous cover management systems in recent decades, with an increase in deadwood and forest floor litter, may be increasing the risk of more intense or extensive fires. Planning habitat creation at a landscape scale may reduce vulnerability of heathlands to wildfire. The livestock industry has a high level of autonomous adaptation especially after extreme events (e.g. through livestock movements; transport of feed). A precautionary approach would incorporate more use of shelter for farm animals and further welfare standards linked to good practice.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	No
Type of benefit	**Sustain current action** Monitor impacts of extreme weather events on agricultural and forestry production. Continue to monitor impacts of wildfire and undertake further investigation of highly vulnerable areas, particularly those near to population centres.
Confidence	Medium

Ne11: Risks to aquifers, agricultural land and freshwater habitats from salt water intrusion

Step 1: What is the current and future level of risk or opportunity?
Current Inundation of salt water during storm surges can cause significant damage to agricultural crops and grassland. Regular inundation can result in soil salinisation with implications for the viability of the land for continued production. Saline intrusion can also affect groundwater as a result of over-abstraction (via pumps, boreholes or wells). The hydraulic gradient from the land to the sea can be weakened, and sometimes reversed, by the removal of freshwater. This removal can also be on a more permanent basis where there has been extensive land drainage (e.g. Norfolk Broads). Because sea water is denser than freshwater, the intrusion will (at first) occur in the lower parts of the aquifer, with the freshwater-seawater boundary moving landwards. The intrusion of salt water into coastal aquifers can impact on water availability in those districts. There can also be impacts on water quality, with 13 failures to meet good ecological status attributed to saline intrusion in the England and Wales and 12 in Scotland in 2014. However, these make up a very small proportion (<1%) of total failures. Freshwater and terrestrial habitats in the coastal zone are at risk of saline intrusion. Coastal grazing marsh habitat is particularly vulnerable to the modification of vegetation communities, which support a large proportion of overwintering and migrating birds in key locations. Regular inundation may eventually cause some of this habitat to become saltmarsh, which may partly compensate for losses at the seaward margin (see Risk 12 below) but this in turn requires identification of replacement grazing marsh habitat. (Low magnitude, medium confidence) Future Future risk to aquifers is expected to slowly increase. Sea level rise and associated storm surges will change the frequency of potential intrusion in vulnerable areas, but is not expected to significantly change the extent of area affected. A recent global meta-analysis concluded that many coastal aquifers (including those of the UK) are vulnerable to this impact. Abstractors may be adversely affected by rises in the salt content of groundwater boreholes. The Environment Agency has estimated that in the near-term (mid-2020s), some 500 ha of freshwater habitat in the coastal zone will be lost due to coastal squeeze in England. It has also been estimated that an average of around 4-6% priority freshwater habitats in the coastal floodplain could be lost per year due to salt water inundation, most of this being in designated areas. This does not include inundation caused by extreme storm surges. (Low magnitude, medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Possibly
Justification	The slow transitional time of saline intrusion of aquifers (even with higher rates of sea level rise) provides time to adapt. Vulnerable aquifers are known and can be monitored and alternative resources identified. Measures to manage the risk are known and already in use and are expected to be sufficient to mitigate any increase in risk with sea level rise. Some 770 ha of reedbeds and coastal grazing marsh have been created in England since 2011, which more than compensates for the 500 ha projected to be lost by the mid-2020s. As a further 220 ha is also potentially deliverable, it is very likely that there will be a net increase in the extent of freshwater habitats in coastal areas over the next decade or so. There have not been any estimates of the area of freshwater habitat that will need to be created to compensate for losses caused by saline intrusion in the 2030s and beyond.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	No
Type of benefit	**Sustain current action (England, Wales), watching brief (Scotland, Northern Ireland)** The risk to freshwater habitats in the coastal zone in the near-term is generally being managed with the continued creation of compensatory habitat. Monitor impacts on aquifers to assess whether risks are increasing.
Confidence	Medium

Ne12: Risks to habitats and heritage in the coastal zone from sea-level rise; and loss of natural flood protection

Step 1: What is the current and future level of risk or opportunity?

Current

Coastal habitats make up around 1.4% of total UK land cover. They fall into two broad categories: inter-tidal (between the mean and high water mark), and supra-tidal (above the high-water mark but still within the coastal zone). As well as being extremely valuable for wildlife, coastal habitats provide a range of vital services, including protection from coastal flooding and storm surges.

The Foresight coastal flooding project found that 28% of the combined English and Welsh coast was experiencing erosion rates greater than 10 cm/year. Almost two-thirds of inter-tidal profiles analysed in England and Wales have been shown to have steepened over the past hundred years which has been considered as indicative of erosion due to the combined effect of sea level rise and sediment depletion.

Large sections of the UK coastline (>50% in England) are protected by hard engineering structures which prevent natural adjustment of coastal systems to a rising sea level, including the migration of habitats inland to remain in a similar position within the tidal frame. This 'coastal squeeze' effect is most pronounced on the heavily defended coasts in the south and east of the UK. The NEA estimated that coastal margin habitats have declined by 16% due to development and coastal squeeze over recent decades, but also highlighted that this estimate is poorly quantified. Some areas on the south coast of England have lost 50% or more saltmarsh area between 1971 and 2001. However, some locations, notably on the west coast (e.g. Dee and Ribble estuaries, Solway Firth, Morecambe Bay) have experienced small gains in saltmarsh habitat, usually from expansion of the lower marsh onto adjacent sand or mud flats.

In NW Scotland, the distinctive machair habitat has been identified as particularly vulnerable to climate change. The main machair areas are separated from the foreshore by systems of coastal dune ridges that provide protection from the sea, but in places the dunes have been removed by erosion. Much of the machair is not only low-lying, but in some cases below the high water mark, meaning even small changes in sea level could have a large influence on the habitat.

Coastal habitats have also experienced the direct effects of climate change through changing temperature profiles, as similar to terrestrial and freshwater systems. This has been most evident with rocky inter- and subtidal species, which show warmer 'southern' species are shifting northwards with colder, 'northern' species declining.

There is increasing evidence that the overwintering distributions of many coastal wading birds have shifted in recent decades in response to warming. In the last decade, this has resulted in declines in usage of east coast sites in favour of The Netherlands. Seabird breeding populations in the UK increased in size over much of the last century, but since 1999 these populations have declined by an average of 7.5%. Climate change is considered to be one of the main drivers of these declines.

(Medium magnitude, medium confidence)

Future

The level of existing habitat loss on the coast implies that even under a low scenario for future sea level rise there will be continued loss of habitat without further implementation of adaptation measures that recognise the dynamic processes of the coast

The future magnitude of absolute sea level rise according to UKCP09 is between 12-76cm (1-7.5mm/yr) from 1990-2095, with the H++ scenario suggesting a higher upper end of 93-190cm (10-19mm/yr) by 2100. Some recent work suggests that values will be towards the upper end of the range and they will also continue beyond 2100 regardless of emissions scenario, meaning there is a long-term

Step 1: What is the current and future level of risk or opportunity?
commitment to sea level rise. The UK NEA projected coastal margin habitats losses to reach 8% by 2060. However, for higher sea level rise scenarios the potential losses may be significantly greater as the risk then increases of threshold effects due to the decreased buffering role of sediment supply in any adjustments, as for example due to the risk of a breach on a barrier coastline. Another study suggests that around 25% (32,000 ha) of protected coastal sites in England and Wales are projected to be lost. Up to 80% of inter-tidal habitats in England are estimated to be at risk of coastal squeeze as they are located seaward of fixed sea defences. The Environment Agency estimates that 1,200 ha of internationally protected (i.e. SAC/SPA) inter-tidal habitat in England will be lost due to coastal squeeze by the mid-2020s. Natural Resource Wales have estimated that around 2,300 ha of Natura 2000 coastal habitat will be lost by the end of the century due to coastal squeeze in Wales, of which some 260 ha will be lost by 2025. As the current evidence suggests an acceleration of sea level rise, the risk of coastal squeeze is likely to significantly increase with the possibility of the natural buffering resilience of coastal habitats and landforms being lost. It is also likely that areas that currently have not experienced major loss of habitat will experience it much more in the future. The risk is therefore of crossing a dangerous threshold and of becoming increasingly locked in to an unsustainable regime for coastal zone management that entails loss of habitat and the ecosystem services provided by habitat. (High magnitude, medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	The risk to coastal habitats from sea level rise is recognised at a strategic level with increased emphasis on long-term planning. Shoreline Management Plans are now well established in England and Wales and are being developed in sensitive parts of the Scottish coastline, although less so in Northern Ireland. Taken together, the SMPs in England have aspirations to significantly increase the length of coastline within which realignment will take place, from around 1% in 2000 to 9% by the 2030s, rising to 16% by the 2080s. However, the rate of implementation would need to increase five-fold from current levels for these ambitions to be delivered. Moreover, SMPs tend to be dominated by ‘hold the line’ policies which are very likely to cause increased loss of habitats even at the lowest level of future SLR projections with much larger losses likely for higher SLR projections. There is currently a clear policy mechanism through the Habitat Regulations requiring the creation of compensatory habitat for losses due to coastal squeeze. In England, over 800 hectares of inter-tidal habitat has been, or is

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	in the process of being, created under the Environment Agency's habitat creation programme. This will compensate for nearly 70% of the projected losses. A further 700 hectares has been identified for potential creation, although plans are not in place as to how these projects will be delivered. If they fail to materialise, then the required compensation will not be met.
Confidence	High

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**More action needed** More effort is needed to implement SMP policies and create compensatory habitat to allow dynamic readjustment of coastal landforms and habitats, particularly in terms of increased sediment supply and realignment opportunities. This will have range of co-benefits for managing climate and non-climate related risks and avoid lock-in to a pathway where the long-term viability of coastal habitats and the services they provide. Realignment schemes are complex and often involve multiple actors, meaning that there are long lead-in times for action. There is also a need to improve monitoring of habitat change and sediment budgets for all the UK coasts to better understand differential response and resilience to SLR (and extreme wave and storm events). Link this to further work to understand the resilience of coastal habitats/landforms to present and future SLR rates together with identification of potential thresholds for major loss under different adaptation options.
Confidence	High

Ne13: Risks to, and opportunities for, marine species, fisheries and marine heritage from ocean acidification and higher water temperatures

Step 1: What is the current and future level of risk or opportunity?
Current Extensive modification of maritime ecosystems has been attributed to long-term climate change. Sea and air temperature records in UK waters continue to show an upward trend, notwithstanding short-term variability. Ocean uptake of CO_2 has increased surface ocean hydrogen ion concentration by ~30% from pre-industrial levels to date, and decreased surface carbonate ion concentration by ~16%. Ocean acidification is expected to greatly intensify in the next 100 years unless strong and urgent greenhouse gas mitigation measures are taken at the global scale. Ocean acidification is a global scale threat but impacts will be felt at the local and regional level. It is highly likely that UK coastal waters, ecosystems and habitats will be significantly impacted this century if global CO_2 emissions continue to rise. In the North Atlantic, ocean acidification has been occurring more rapidly in the European region than either in the Caribbean or central Atlantic. Extensive changes in planktonic ecosystem have been observed in terms of plankton production overall, biodiversity and species distribution. In the North Sea, the population of previously dominant and important cold water zooplankton species has declined in biomass by 70% since the 1960s. Species with warmer-water affinities are moving northward to replace the species but are not numerically abundant or as nutritionally (i.e. less lipid rich) important. Over the last five decades there has been a progressive increase in the presence of warm-water/sub-tropical species into the more temperate areas of the North-East Atlantic and a decline of colder-water species. The seasonal timing of some plankton production has also altered in response to recent climate change. This has consequences for plankton predator species, including fish, whose life cycles are timed in order to make use of seasonal production of particular prey species. Recent warming has caused some cold-water demersal (bottom-dwelling) fish species to move northwards and into deeper water (e.g. cod, whiting, monkfish), and has caused some warm-water demersal species to become more common in new areas (e.g. John dory, red mullet). Centres of distribution have generally shifted by distances ranging from 48 to 403 km. Pelagic (blue-water) fish species are showing particularly marked distributional shifts, with mackerel now extending into Icelandic and Faroe Island waters (with consequences for management), whilst sardines and anchovies are shifting into Irish and North Sea environments. Climate change has been estimated to be reducing the maximum sustainable yield of cod in the North Sea by around 32,000 tonnes per decade. There is strong evidence that climate warming has influenced the relative timing (phenology) of fish annual migrations and spawning events in European waters, with potentially significant effects on population sizes and juvenile recruitment. Observed declines in salmon are strongly correlated with rising temperatures in oceanic foraging areas, with temperature affecting growth, survival and maturation of salmon at sea. The impact of climate change on marine mammals remains poorly understood, due largely to the difficulty of obtaining substantive evidence. There is evidence that locations where high catches of cod, haddock, plaice and sole occur, have moved over the past 80-90 years. Climate change may be a factor but fishing and habitat modification have also had an important effect. Commercial and recreational fishermen have responded to new opportunities in recent years, as warm-water species have appeared in greater numbers and their exploitation has become viable. Examples include boarfish, trigger fish, squid, anchovy, red mullet and seabass. In 2012, 937 tonnes of sea bass were landed in the UK and the Channel Islands, compared with 142 tonnes in 1984. International commercial landings, from the north-east Atlantic, of species

Step 1: What is the current and future level of risk or opportunity?
identified as warm-adapted (e.g. grey gurnard, red mullet, hake) have increased 250% in the last 30 years. (High magnitude, high confidence) Future As with organisms on land, a great deal of bioclimate envelope modelling has been carried out in order to anticipate future changes in the distribution and productivity of marine organisms. The ensemble projections suggest northward shifts for most fish species, at an average rate of 27 km per decade (the current rate is around 20km per decade for common fish in the North Sea). Most seabird species in the UK are at the southern limit of their range. As a result, changes in species' ranges due to climate change can be expected, with associated changes in overall population size. By the end of the 21st century, great skua and Arctic skua may no longer breed in the UK and the range of black guillemot, common gull and Arctic tern may shrink to such an extent that only Shetland and the most northerly tips of mainland Scotland will hold breeding colonies. Many other species could shift their distribution north, no longer breeding in south-eastern England. Many features for which marine protected areas have been designated are potentially vulnerable to climate change, meaning the on-going utility of marine protected areas as a conservation tool could be affected. Laboratory-based studies have shown that a wide diversity of marine organisms are potentially affected by the levels of surface ocean pH projected for 2100 under business-as-usual scenarios for future CO2 emissions. In general, echinoderms, molluscs, calcareous algae and corals appear to be more sensitive than crustaceans, fishes and non-calcareous algae. By 2060, over 85% of known deep-sea cold water coral reefs in UK waters (mostly to the west of Scotland) could be exposed to waters that are corrosive to them, and to many other shell-forming organisms, as a result of under-saturation of aragonite. Seven marine protected areas are designated for the protection of cold water corals. Projected changes to water temperature, acidity and primary productivity are also likely to have implications for marine fisheries and aquaculture. Overall, the UK is expected to benefit from slightly (i.e. + 1-2% compared to present) higher fishery yields by 2050. However, the Irish Sea and English Channel may see a reduction in yields by 2050s. Models suggest that cod stocks in the Celtic and Irish Seas might disappear completely by 2100, while those in the North Sea are expected to decline. In the short term, climate change is unlikely to have a significant effect on UK-farmed marine fish (aquaculture). Rising water temperatures could cause thermal stress for some farmed cold-water fish species (e.g. cod and Atlantic halibut) and inter-tidal shellfish. However, increased growth rates for some farmed fish species (e.g. Atlantic salmon) may result from rising water temperatures and new farmed species (e.g. sea bass, bream) may be able to be cultivated. Farmed species may become more susceptible to a wider variety of diseases as temperatures increase. Any increase in harmful algal and jellyfish blooms may lead to additional fish kills and closure of some shellfish harvesting areas. Ocean acidification may also pose a significant threat to the UK shellfish industry, but more research is required to better understand this risk. (High magnitude, medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Possibly
Justification	Policies for protecting and enhancing the marine environment and biodiversity are in place, primarily the EU Marine Strategy Framework Directive (2008), the Marine and Coastal Access Act (2009), the Marine (Scotland) Act (2010) and the Marine Act (Northern Ireland) 2013. The Marine Strategy Framework Directive (MSFD) establishes a framework within which Member States are required to "take the necessary measures to achieve or maintain good environmental status" in the marine environment by the year 2020 at the latest. The Government has recently consulted on a programme of measures to meet this objective for UK waters. Implementation of the MSFD may result in the establishment of a marine monitoring programme similar to that for surface water bodies under the Water Framework Directive. If effective MSFD indicators are put in place, then it should be possible to monitor whether Good Environmental Status is being achieved in UK waters. The MSFD has been written with the explicit knowledge that marine systems are dynamic and it includes adaptation and exception sections which require climate and environmental variability be taken into account. However, it is too early to tell whether implementation of the MSFD will translate into sufficiently reactive measures being taken by UK governments to alleviate such variability. The MSFD is one of the policies in place for conserving marine fisheries. Other policies are in place at both the EU and national levels, including reforms to the Common Fisheries Policy (CSF). Environmental conditions (including as a result of climate change) are one of the factors considered when setting quotas under the CFP. Quotas can be swapped each year between member states which could be used if distributions of managed stocks shift into new areas, or retreat from traditional ones. The area of marine protected sites in UK waters has increased substantially in recent years. However, in the context of resilience to climate change the spatial dispersion of new MPAs is critical. The MPA network will need to have the ecological coherence and flexibility to account for shifting species distributions. There has been a sustained reduction in hazardous pollution levels since 1990 and the proportion of fish stocks being harvested sustainably has increased since 2000. Statutory marine plans are in place, or in the process of being produced and key organisations in the sector have recently reported under the Adaptation Reporting Power, including the Marine Management Organisation and Seafish, the commercial fishing trade body. It is difficult to judge whether there is currently a significant adaptation shortfall, as mechanisms generally exist in the relevant legislation to enable climate change impacts to be addressed (for example through periodic

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	reviews). The scale of risk faced in the future may mean that current interventions are unlikely to be sufficient. This is particularly the case with ocean acidification, which has the potential to have catastrophic impacts on marine ecosystems in UK coastal waters. However, it is not completely clear if any additional or alternative action is needed for adaptation beyond measures to improve resilience.
Confidence	Low

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Research priority** Improve understanding of potential impacts of climate change on marine biodiversity and fisheries, especially changes in acidity, dissolved oxygen content, temperature and ocean stratification. Improve understanding of the social and economic implications for the UK fishing industry of changes in the distribution and abundance of fish stocks. Need to identify whether adaptation requires any additional or alternative actions to be taken.'
Confidence	Low

Ne14: Risks and opportunities from changes in landscape character

Step 1: What is the current and future level of risk or opportunity?
Current Landscape can be defined as an area, as perceived by people, which is the result of the action and interaction of natural and historic factors. These myriad benefits, tangible and intangible, may be particularly summarised in the context of 'sense of place' and they have important relations with human identity, health and wellbeing (Chapter 5). Changes in the natural environment have important implications for such relationships although it is important to recognise that landscapes have always been dynamic features that have evolved over previous millennia. National-scale mapping projects have shown how landscape character has changed in terms of both land cover and use over recent decades. Climate has been a contributing factor in these changes, both

Step 1: What is the current and future level of risk or opportunity?
directly through its influence on land cover and indirectly by influencing some land uses over others in specific locations. Future Responses to climate change, both adaptation and mitigation, provide another component of landscape change. At present, these have been most strongly evident through mitigation measures, such as the development of wind farms. However, adaptation requirements are also an important contributor to the planned expansion of woodland in the UK, which represents the most significant potential change in land cover in recent decades. Coastal landscapes are also modified through both planned (e.g. managed realignment) and unplanned (e.g. no active intervention) responses to sea-level rise. Changes in land cover and land use will undoubtedly continue to occur into the future and the magnitude of climate change (and responses to it) will be a key factor in influencing this change. Land use changes as a direct and indirect result of climate change may also have implications for UK's archaeological resource, as the majority of archaeological sites are within agricultural land. Changes in land use may reveal new sites, but this will usually be because that site is being damaged e.g. new artefacts are encountered because they are being brought to the surface by ploughing. (Unknown magnitude/unknown confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Possibly
Justification	Partly because of their intangibility, changes to landscape character are often undervalued in land use decisions and planning. The European Landscape Convention was signed by the UK Government in 2006 and reaffirmed in the 2011 Natural Environment White Paper. Implementation of the ELC in England is primarily through the identification of landscapes and the analysis of their characteristics and the forces changing them. This has been through initiatives such as Historic Landscape Characterisation, Seascapes Characterisation, the National Mapping Programme and National Character Areas. The landscape character of all 159 NCAs that make up England has been profiled and includes a qualitative assessment of factors driving landscape change, including climate change. They consider how all (not just protected) landscapes can change in the future, based on understanding how they have developed. They also provide a framework to measure the rate and impact of changes at a local level and their implications for the transformation of landscapes in the future. NCA profiles aim to influence land use planning, targeting of agri-

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	environment schemes, National Park management plans, etc. However, it is not clear how influential or effective the NCA profiles are being in influencing decision-making and communicating the dynamic features of landscape. Local planning authorities in England are also expected by the National Planning Policy Framework (NPPF) to prepare landscape character assessments "where appropriate." These should be integrated with assessment of historic landscape character, and for areas where there are major expansion options, assessments of landscape sensitivity.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	No
Type of benefit	**Watching brief** Monitor the use and effectiveness of tools such as the NCA profiles to help people and decision-makers better understand and visualise changes in landscape as a direct and indirect result of climate change.
Confidence	Medium

Chapter 4 - Infrastructure

Urgency scores for infrastructure					
Risk descriptor	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
In1: Risks of cascading failures from interdependent infrastructure networks (Section 4.4 to 4.9)	UK				More action needed to enhance arrangements for information sharing in order to improve understanding of critical risks arising from interdependencies.
In2: Risks to infrastructure services from river, surface water and groundwater flooding (4.4 to 4.9)	UK				More action needed to manage increasing risk to existing assets and networks and ensure increased risk is accounted for in design and location of new infrastructure.
In3: Risks to infrastructure services from coastal flooding and erosion (4.4 to 4.9)	England, Wales	Northern Ireland, Scotland			More action needed to manage increasing risk to existing networks (including flood and coastal erosion risk management infrastructure) from sea-level rise and increased rate of erosion.
In4: Risks of sewer flooding due to heavy rainfall (4.5)	UK				More action needed to deliver sustainable drainage systems, upgrade sewers where appropriate and tackle drivers increasing surface runoff (e.g. impermeable surfacing in urban areas).
In5: Risks to bridges and pipelines from high river flows and bank erosion		UK			More research needed on implications of projected changes in river flows on future risk of scour/erosion.

Urgency scores for infrastructure					
Risk descriptor	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
(4.5, 4.7, 4.8)					
In6: Risks to transport networks from slope and embankment failure caused by heavy rainfall events (4.7)	UK				More action needed to locate and remediate embankments and cuttings at risk of failure.
In7: Risks to hydroelectric generation from low or high river flows (4.8)				UK	Monitor impacts and be ready to adapt operations given observed impacts.
In8: Risks to subterranean and surface infrastructure from subsidence (4.5, 4.6, 4.7, 4.8)				UK	Monitor changes in temperature and rainfall patterns to update assessments of subsidence risk.
In9: Risks to public water supplies from drought and low river flows (4.5)	England, Wales		Northern Ireland, Scotland		New policies needed to deliver more ambitious reductions in water consumption and establish strategic planning of new water-supply infrastructure. More action needed to put in place reforms of the water abstraction licencing regime.
In10: Risks to electricity generation from drought and low river flows (4.8)				UK	Continue to monitor risks including as a result of deploying carbon capture and storage. Ensure appropriate siting of new infrastructure and use of cooling

Urgency scores for infrastructure					
Risk descriptor	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
					technologies.
In11: Risks to energy, transport and digital infrastructure from high winds and lightning (4.6, 4.7, 4.8)		UK			More research needed on the implications of increased vegetation growth rates on future risks of damage from falling trees during storms.
In12: Risks to offshore infrastructure from storms and high waves (4.7, 4.8)		England, Scotland		Northern Ireland, Wales	More research needed to assess climate risks to existing and planned off-shore renewable energy infrastructure.
In13: Risks to transport, digital and energy infrastructure from extreme heat (4.6, 4.7, 4.8)			UK		Continue current actions to reduce risks, maintenance and renewals of infrastructure networks.
In14: Potential benefits to water, transport, digital and energy infrastructure from reduced frequency of extreme cold events			UK		Continue current actions to reduce risks, including cold-weather planning and response.

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In1: Risks of cascading failures from interdependent infrastructure networks

Step 1: What is the current and future level of risk or opportunity?
Current Infrastructure networks do not operate in isolation, with services reliant on power, fuel supplies, and ICT. Transport links including local roads are important for logistics and to allow staff to travel to work. Vulnerable services, such as hospitals, are often not aware that their power supply is at risk from cascading failures. However, failures caused by interdependencies are not systematically recorded Recent events have highlighted a few examples of interdependencies, such as interruptions to the supply of biomass to power stations following flooding of the Port of Immingham in December 2013. In the same month, flooding of the M23 motorway and railway station hampered the ability of staff to travel to Gatwick airport. Disruption to passenger services in the North Terminal at Gatwick airport overwhelmed the staff numbers available. Outputs from various research projects are beginning to quantify the scale of interdependency risks at the national level, but the scale of the risk remains largely unknown. (High magnitude, low confidence) Future No modelling or evidence available. (High magnitude, low confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	The importance of interdependencies between networks is recognised and the Cabinet Office has begun focusing on cross sector vulnerabilities. Individual infrastructure operators are also reviewing their dependency on other networks, in particular their reliance on power, ICT, and critical road and rail links However, as yet there is no systematic national assessment of interdependency risk, nor a comprehensive plan to address it. The onus rests with individual organisation to identify and manage interdependent risks in the same way as they would any other business risk.
Confidence	Medium.

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**More action needed** Common standards of resilience would help with investment planning, and help emergency planners better understand the potential for service disruption arising from assets in their area. A good example of a common standard is ETR138, the 'resilience to flooding' adopted within the electricity transmission and distribution sector. Enhanced arrangements for information sharing on critical risks of interdependence are also required. This will help to create the right institutional conditions for adaptation in the next five years and in the long-term.
Confidence	Medium

In2: Risks to infrastructure services from river, surface water and groundwater flooding

Step 1: What is the current and future level of risk or opportunity?

Current

Flooding directly damages infrastructure assets and can result in significant disruption to services. The 2007 floods affected five water treatment works, most dramatically at Mythe in Gloucestershire which cut off supply to 350,000 people for up to 17 days. Some 42,000 households also lost power and the flooding of motorways left 10,000 people stranded for several hours. During the flooding in winter 2013/14 an electricity substation at Gatwick airport was flooded, causing power loss in the North terminal and severe disruption over the busy Christmas period. The flooding of an electricity sub-station in Lancaster resulted in 55,000 households losing power in December 2015. A telephone exchange was flooded in York, significantly disrupting telecommunications and causing loss of broadband services. A data centre was also flooded in Leeds.

Flooding was directly responsible for approximately 340,000 passenger delay minutes on the rail network between 2006 and 2013 (5% of all delays). Around 163,000 delay minutes were caused by flooding on the strategic road network between 2006 and 2014 (7% of all delays). The number of customer minutes lost from the high voltage electricity network from flooding between 1995 and 2011 was nearly 14,000 (1% of total). Although less frequent than other weather related causes of disruption such as storms and snow, flooding caused the longest average length of disruption per incident.

Assets and networks across all infrastructure sectors are already exposed to river and surface water flooding (Table In.1).

Table In.1: Number/length of infrastructure assets and networks in the UK located in areas exposed to a 1:75 or greater annual chance of flooding from rivers and/or surface water (present day)

Step 1: What is the current and future level of risk or opportunity?

Receptor	River	Surface water
Clean and wastewater sites	54	138
Electricity generation sites	19	0
Electricity transmission and distribution substations (>5,000 customers)	225	15
Strategic road network (km)	2,225	3,733
Rail network (km)	813	1,228
Rail stations	86	442
Mobile phone masts	841	605
Active landfill sites	107	256

Not all of the above assets and sites are themselves necessarily at high flood risk, as there could be local resilience measures in place or in some cases the asset may be on higher ground (e.g. railway embankment).

The number of ports, airports and digital infrastructure assets (data centres and telephone exchanges) located in high flood risk areas is not known at a UK level.

(High magnitude/medium confidence)

Future

Modelling for CCRA2 suggests the number of assets and length of existing infrastructure networks located in areas exposed to a high risk of river or surface water flooding is projected to significantly increase with climate change (Table In.2).

Table In.2: Projected change in number/length of infrastructure assets and networks in the UK located in areas exposed to a1:75 or greater annual chance of flooding from rivers and/or surface water under a trajectory of a 4ºC rise in global mean temperature by the end of the century.

Receptor	River	Surface water
Clean and wastewater sites	+21%	+49%
Electricity generation sites	0%	0%
Electricity transmission and distribution substations (>5,000 customers)	+9%	+4%
Strategic road network	+57%	+54%
Rail network	+56%	+50%

Step 1: What is the current and future level of risk or opportunity?

Rail stations	+37%	+22%
Mobile phone masts	+59%	+25%
Active landfill sites	+2%	+4%
Notes: Assumes no additional adaptation beyond current plans.		

(High magnitude/medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	The Cabinet Office Critical Infrastructure Resilience Programme was established following the widespread flooding in 2007. The work is sponsored by the National Security Council, chaired by the Prime Minister. The programme aims to support operators in both the public and private sectors to build the resilience of their services. In 2009, following recommendations in the Pitt Review, the Cabinet Office worked with Government Departments to develop Sector Security & Resilience Plans (SSRPs). These focused initially on the resilience of the UK's critical national infrastructure to flooding, but have been broadened to consider the range of weather and non-weather related hazards set out in the National Risk Assessment. A public summary of the plans is published each year. Despite the policy framework largely being in place, there is no published account of what has been achieved by efforts in recent years to improve the resilience of infrastructure systems to flood risk. Most sectors do not report on the resilience of their assets, networks and services. Few systematically describe the disruption that has been caused by flooding, and the actions that have been taken as a result. This is particularly the case with the non-regulated sectors (i.e. ports and digital networks) and for local infrastructure, especially minor road networks. However, it is possible to assess vulnerability to flooding for some sectors. The electricity transmission and distribution sector has developed cross-industry technical standards for managing current and future flood risks to the network. These standards provide a consistent approach across the industry to identify the most critical assets at the highest level of risk, accounting for climate change, in order to prioritise action. Application of these standards is used to make a business case to the regulator for funding resilience measures that provide value for money to the consumer through the price control process. As a result, it is possible to determine that electricity substations serving one million customers are due to benefit from flood protection measures by the end of the decade through planned

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	investment of £172 million between 2011 and 2023. This programme is under review, and guidance (ETR 138) may be reviewed further following the National Flooding Resilience Review and any improved climate change modelling. To truly assess vulnerability to flooding there needs to be consideration of the resilience of systems as well as of the assets that combine to create systems. Networks may be resilient even if individual assets fail, if services can be provided by alternative means. The Cabinet Office has set a benchmark that "as a minimum essential services provided by Critical National Infrastructure (CNI) in the UK should not be disrupted by a flood event with an annual likelihood of 1 in 200 (0.5%)". It is not explicitly clear how this benchmark has been interpreted by each specific sector, or the exact extent to which this standard is now in place. It is therefore uncertain to what extent this risk is being managed autonomously.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**More action needed** There is a need for the development of consistent indicators of network resilience to flood risk across all critical national infrastructure sectors and networks. This will help to create the right institutional conditions for adaption in the next five years and in the long-term. Consistent indicators of resilience will allow for improvements to be measured over time, so enabling better decisions in the near future, especially in relation to longer-term major risks, i.e. to build early interventions within an iterative adaptive management framework.
Confidence	High

In3: Risks to infrastructure services from coastal flooding and erosion

Step 1: What is the current and future level of risk or opportunity?

Current

Global average sea levels rose by 15cm over the 20th century. Relative sea levels have risen more in the south than the north of the UK, due to the added influence of post-glacial rebound. The east coast in particular is prone to damaging storm surges, with major surges occurring in January 1953 and December 2013 (both estimated as 1 in 200 year events).

Assets and networks across all infrastructure sectors are already exposed to the risk of coastal flooding (Table In.3)

Table In.3: Number/length of infrastructure assets and networks in the UK located in areas at 1:75 or greater annual chance of flooding from the sea (present day)

Receptor	Number/length
Clean and wastewater sites	45
Electricity generation sites	6
Electricity transmission and distribution assets	86
Strategic road network (km)	662
Rail network (km)	356
Rail stations	51
Mobile phone masts	307
Active landfill sites	35

The number of ports, airports, oil and gas terminals and digital infrastructure assets (data centres and telephone exchanges) located in areas exposed to a 1:75 or greater annual chance of coastal flooding is not known at a UK level. However, there is evidence that a number of ports were affected by the 2013 sea surge. For example, the Port of Immingham near Grimsby was severely impacted when tide levels reached half a meter above the dock gates. Critical power and IT services were lost and the port ceased operation for a number of days. 75% of the port area was flooded, including businesses located within the port boundary. Immingham is strategically important for petro-chemicals and fuel, including biomass for energy generation. Many ports only handle specific cargos, with the largest specialised ports handling twice as much traffic or more as their next biggest competitor. This lack of redundancy means any disruption to major ports will have wider economic consequences. (High magnitude/high confidence)

The whole of the UK's nuclear fleet of power stations are located in the coastal zone, as they rely on seawater for cooling. Nuclear power stations are all protected from coastal flooding and tidal surges to a high standard. The Office for Nuclear Regulation expects nuclear licensees to provide a conservative safety justification against flooding from whatever source with a return period of 10,000 years.

Stretches of the UK coastline are actively eroding, a natural process that can be exacerbated by heavy or prolonged rainfall and coastal storms. Less than 1% (11 km) of the rail network in England is located in areas potentially at risk of coastal erosion now and within the next 20 years. These areas are all protected by sea walls. However, coastal defences can fail, with potentially highly disruptive consequences. This was seen at Dawlish during the 2013/14 winter storms where an 80 m section of

Step 1: What is the current and future level of risk or opportunity?

sea wall collapsed, severing the main rail connection to south-west of England for around two months. Less publicised was the loss for 17 weeks of the link between Harlech and Barmouth in North Wales. The length of the rail network in England exposed to coastal erosion is expected to increase to 38 km by the 2050s and to 62 km by 2100

(Medium magnitude/high confidence)

Future

UK sea level rise is projected to be 50 to 100 cm by the end of the century and the potential size of storm surges may also increase over the same period. Modelling for CCRA2 suggests the number of assets and length of existing infrastructure networks located in areas exposed to a high risk of flooding from the sea is projected to significantly increase with climate change (Table In.4).

Table In.4: Projected change in number/length of infrastructure assets and networks in the UK located in areas exposed to a 1:75 or greater annual chance of flooding from the sea under a trajectory of a 4°C rise in global mean temperature by the end of the century.

Receptor	% change
Clean and wastewater sites	0%
Electricity generation sites	+25%
Electricity transmission and distribution assets	+27%
Strategic road network	+48%
Rail network	+46%
Rail stations	+20%
Mobile phone masts	+92%
Active landfill sites	+136%

The length of railway in England exposed to coastal erosion is expected to increase from 11 kilometres to 38 kilometres by the 2050s and to 62 kilometres by 2100. The length of major road at risk is projected to increase from 1km in the next 20 years to 12km by the 2100s.

Projected rises in mean sea level rise could increase scour potential by 16% for vertical structures, such as sea walls. Coastal defences will be particularly vulnerable where the 'toe' height of defence foundations is exposed to stronger and near continual wave action. Analysis for CCRA2 suggests a positive correlation between mean sea-level rise and the length of defences in England that become vulnerable to potentially rapid deterioration. With 1m of sea-level rise, the length of coastal flood defences becoming highly vulnerable doubles, from 110 km at present to around 220 km. Assuming those vulnerable defences fail over time, the area at risk of coastal flooding in England would grow by 2000 km2, potentially putting an additional risks 400,000 properties at risk.

(Medium magnitude/medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	Shoreline Management Plans are in place for the full length of the English and Welsh coastlines and in some parts of Scotland. SMPs set out coastline management policies (hold the line, no active intervention etc.) to the 2100s. SMPs are developed by Coastal Protection Authorities and decisions about the appropriate strategy for an area of the coast are made by the local authority responsible. SMP policies have generally been agreed in the absence of detailed cost/benefit appraisal, and affordability considerations may mean that continuing to hold current defence lines may prove to be unaffordable in practice. This means that despite best intentions, SMPs may underplay the true risk of coastal flooding and erosion. However, local authorities have the flexibility to review their SMPs whenever they wish to do so, making them responsive to evolving situations on their coastlines. SMPs are regarded as living documents that can respond to changing risk scenarios. A National Policy Statement designated under the Planning Act 2008 establishes the parameters for the development of new nuclear plants in England and Wales and identifies sites considered suitable for such development. The Nuclear NPS has identified locations for any new nuclear build that are considered to be defendable. These sites were initially selected at a strategic level based on specific criteria, which included the potential effects of climate change, and then any specific applications for sites have to provide detailed information on how climate change effects will be taken into account, including coastal erosion and increased likelihood of storm surge and rising sea levels. This process was most recently applied with the application for Hinkley Point C, Somerset. Climate change projections were applied to determine whether the development may increase flood risk elsewhere or have any impact on coastal processes in the Severn Estuary. Ports are not subject to economic regulation. As a result, there is a general lack of data regarding the overall resilience of ports compared to most other regulated sectors. This means it is difficult to tell whether lessons from the winter of 2013/14 have now been learned and whether the disruption witnessed is unlikely to be repeated. However, evidence from Adaptation Reporting Power reports and other sources suggest that action is occurring, with some ports raising quays by as much as 50cm, as well as taking action to protect supporting road infrastructure from flooding. Ports in the Humber region are investing in improved protection against storm surges, including a 1-in-1,000 year standard of protection for the Port of Immingham. This involves a significant upgrade to the port's dock gates.
Confidence	Medium.

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**More action needed** There is a need to assess whether 'hold the line' policies within SMPs are realistic and affordable in the context of sea level rise, and to identify infrastructure assets at risk should holding current defence lines be economically unviable. This is needed to avoid lock-in to a particular pathway over the next few decades and will help to create the right conditions to adapt later where changes with long-lead in times are likely to be required, such as the relocation or rerouting of infrastructure networks inland.
Confidence	Medium.

In4: Risks of sewer and surface water flooding due to heavy rainfall

Step 1: What is the current and future level of risk or opportunity?
Current Widespread flooding in 2007 damaged 55,000 properties, with the majority of damage blamed on drains and sewers being overwhelmed by heavy rain. The floods highlighted that traditional piped sewer systems cannot readily be adapted to deal with increased rainfall, particularly in densely populated urban areas. Half of the national sewer network is reported to be currently at or beyond capacity. There is a risk that sewer and surface water flooding may be exacerbated by the paving over of front gardens in urban areas. The proportion of urban front gardens in England that are paved over jumped from 28% in 2001 to 48% in 2011. As only 4% of all UK residential paving sales in 2013 were of permeable design, it is highly likely that the majority of surfaces being used to pave over front gardens are impermeable (e.g. concrete block paving, asphalt, etc.). (High magnitude/high confidence) Future Without additional action being taken, it is estimated that a combination of climate change, population growth and continued urban infill development all have the potential to increase the amount of surface water entering the sewer system. This is likely to lead to: - increased frequency of the sewerage system / urban drainage network exceeding its capacity and increased frequency of surface water flooding when this occurs; - increased sewer flooding of ~ 50% over next few decades; - increased Combined Sewer Overspills (and associated impact on water quality); - reduced capacity for new development (new waste water) in the sewer networks; and

Step 1: What is the current and future level of risk or opportunity?
- increased operating costs (associated with pumping more surface water and waste water treatment). (High magnitude/medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	The priority adaptation to the risk of increased sewer flooding is to reduce the amount of surface water allowed to enter the sewer network. Reducing surface water in sewers can be done with a variety of techniques including SuDS and 'green and blue' infrastructure that can also being other benefits. This is likely to be required alongside 'traditional' drainage techniques. Water companies are responsible for the management of sewer flooding and are expected to develop Drainage Strategies to inform their business planning and future delivery, so that they manage flood risk and pollution incidents in a changing climate. As a result, water companies have committed to reduce the number of properties affected by sewer flooding by 33% over the forthcoming Asset Management Plan period (AMP6, 2015-2020). It is unclear to what extent water companies are employing SuDS to reduce sewer flooding over the next five years, although some companies (e.g. Welsh Water, Thames Water) have made specific commitments to implement SuDS in their current Business Plans. There are, however, a number of barriers to water companies widely retrofitting SuDS, which include: Reducing surface water in sewers can only be done gradually over the long term, making it difficult to justify current investment to regulators and customers Uncertainties in implementing and maintaining SuDS compared to traditional drainage, including around costs, effectiveness and timescales of when benefits will be realised. This makes it more difficult to justify to regulators and customers. Capacity and resources in water companies to appraise, design, build and maintain a SUDS and green infrastructure. Water companies may not be able to implement all the types of surface water reduction actions on their own. It is likely to require coordination with other authorities and planning processes that govern surface water e.g. highways authorities responsible for road drainage and flooding authorities responsible for surface water flooding.

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	As well as retrofitting, ensuring that new development does not further add to the risk of sewer flooding is also a priority for managing this risk. In England, the National Planning Policy Framework requires local planning authorities to prioritise SuDS when determining planning applications for development in flood risk areas. The policy was strengthened with effect from 2015 so that SuDS should also be an expectation for all major developments (> 10 dwellings and major commercial development). The government said that it would keep this under review, and the Housing and Planning Act 2016 introduces a new requirement for the Secretary of State to review the provision of sustainable drainage in developments. In Scotland, the Water Environment (Controlled Activities) (Scotland) Regulations 2005 require all surface water from new development to be treated by a sustainable drainage system (SUDS) before it is discharged into the water environment, except for single houses or where the discharge will be into coastal water. There is some evidence that SuDS uptake in new development remains low, although there is no monitoring in place within any of the UK nations. It is therefore uncertain whether key barriers to the use of SuDS are being addressed. These include developers retaining the automatic right to connect new homes to the public sewer system (for surface water) without regard given to their capacity and the issue of who has responsibility for the on-going maintenance of SuDS once they are in place.
Confidence	High

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**More action needed** There is a need for higher uptake of SuDS in new development and for widespread retrofitting of SuDS schemes and green infrastructure into the built environment in order to relieve pressure on the public sewer system. Embedding long term planning (drainage strategies) in the management of sewer networks will help overcome barriers to water company action to reduce surface water in sewer networks. There is also a need to improve coordination between surface water processes; water company management of sewer networks, roads authority road drainage and local authority surface water management. As well as directly reducing vulnerability to sewer and surface water flooding, this will also have benefits for managing a range of non-climate

Step 3: Are there benefits of further action in the next 5 years?	
	related risks, including improvements to water quality, biodiversity and amenity. SuDS are in most cases also cost-effective to implement now.
Confidence	High

In5: Risks to bridges and pipelines from high river flows and bank erosion

Step 1: What is the current and future level of risk or opportunity?
Current High river flows can cause localised riverbank erosion, undermining structures such as bridges and exposing buried pipelines. In the 2009 Cumbria floods several bridges were lost, most notably in Workington which caused loss of life and severe disruption to the town. More recently, in the 2015 winter floods, a major bridge connecting the town of Tadcaster was lost which has caused major transport disruption and the rupturing of gas pipelines. (Medium magnitude/medium confidence) Future Increased winter precipitation and river flows will increase scour at bridges, potentially increasing the rate of failure to an average of 1 bridge per year in the UK. There has not, however, been any national-level modelling of how risk may increase in the future. There are some significant uncertainties on the structural integrity of road and rail bridges, many of which were built over a century ago. It is also not known at a national level which bridges are used for gas pipelines/electricity cables, although service providers have this mapped at the local level. (Medium magnitude/low confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	Systemic adaptation is not strongly evident across the railway network, but there is evidence of site-specific measures being incorporated in each of the Network Rail routes. This has mostly centred around embankment stability, coastal defences, and bridge stability. In Scotland, routine helicopter surveys inspect riverbanks for erosion. However it is not known how much adaptation is taking place nationally. Similarly, it is not clear from the available evidence whether there has been a

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	systematic evaluation of this risk to either the trunk road network or to local highway bridges.
Confidence	Low

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Research priority** More research is needed to identify the number of bridges at risk of scour now and in the future and the amount of adaptation underway nationally. This will provide the early steps to enable better decisions in the near future (next 5 years), especially where measures may be required that have long lead times such as relocating or rerouting bridges.
Confidence	Medium

In6: Risks to transport networks from slope and embankment failure caused by heavy rainfall events

Step 1: What is the current and future level of risk or opportunity?
Current There are 20,000 km of engineered cuttings and embankments supporting the UK's transport infrastructure. Older, less well compacted earthworks such as those supporting the rail network are deteriorating at a faster rate than newer earthworks built to more modern construction standards. In England and Wales, 5% of earthworks (embankments, cuttings and rock cuttings) were classed as being in a poor condition in 2012/13, with a further 48% classed as being in a marginal condition. There were, on average, 67 earthwork failures a year across the rail network between 2003/04 and 2013/14, of which 55 were in England and Wales and 12 in Scotland. There were some significant fluctuations during this period, with 107 failures in 2007/08 and 144 failures in 2013/14. The Western region has the highest average number of failures (14 per year between 2004/05 and 2012/13). The busy West Coast and East Coast lines averaged 9 and 7 failures a year respectively. (Medium magnitude/high confidence) Future

Step 1: What is the current and future level of risk or opportunity?
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 SE England and likely to be the most significant geohazard to UK infrastructure. Increased incidences of natural and engineering slope failure effecting the road and rail network in the winters of 2012/2013 and 2013/2014 demonstrate their vulnerability to the type of intense rainfall events that are expected. (Medium magnitude/medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	There is considerable investment being delivered to renew and repair rail embankments and cuttings, as part of the £2.3 billion being spent on renewing civil engineering structures between 2013/14 and 2018/19. An average of £100 million a year is due to be spent on earthwork renewals during the current price control period (2014/15 to 2018/19), an increase from the average of around £75 million a year in the previous period (2009/10 to 2013/14). Expenditure on track and earthwork drainage renewals has also increased, from around £50 million a year in the previous price control period to nearer £70 million a year in the current period. 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. There is therefore a significant backlog that will require sustained investment over the next 40-50 years to clear. Models have been developed to forecast the amount of investment and volume of renewals required. However, these models do not account for projected changes in climate but instead assume that the weather experienced in the future will be similar to what is has been in recent years. The regulator (ORR) has previously raised questions as to the extent that Network Rail is embedding climate resilience into specifications for the design of its assets, or in the standards the company sets for asset maintenance and renewal. This suggests that there is an adaptation shortfall for rail. In contrast to the rail sector, the strategic road network has been built since the 1950s, using modern materials and design standards, and has been maintained more consistently over recent decades. Disruptions to the network from severe weather can be managed in the same way as other causes, such as roadworks and major accidents, as lasting physical damage to roads and assets is unlikely.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**More action needed** Further action is required to ensure that projected increases in heavy rainfall events are factored into long-term renewal programmes for earthworks, especially for the rail network. This will reduce vulnerability now, and is likely to be cost-effective to implement given that the risk is increasing with further asset deterioration combining with heavier and more frequent rainfall events.
Confidence	Medium

In7: Risks to hydroelectric generation from low or high river flows

Step 1: What is the current and future level of risk or opportunity?
Current No data. (Unknown magnitude/unknown confidence) Future Hydropower output may be reduced (particularly in summer) and increased in winter (representing an opportunity) and is vulnerable to both extreme flooding and drought. Excess water levels may need to be sluiced from reservoirs, potentially leading to environmental damage downstream. (Unknown magnitude/unknown confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	No
Justification	Impacts of increased or reduced hydropower generation can be managed using normal operation procedures on the national grid.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	No.
Type of benefit	**Watching brief.** Monitor impacts and be ready to adapt operations given observed impacts.
Confidence	Medium

In8: Risks to subterranean and surface infrastructure from subsidence

Step 1: What is the current and future level of risk or opportunity?
Current The deformation of the ground has the potential to damage the foundations of buildings and other infrastructure. One of the most widespread forms of subsidence is the shrinking and swelling of clay soils due to excessive rainfall, drought or land use changes. Susceptibility to shrinkage of soil is influenced by the rainfall of the preceding two year period. Increased temperatures also lead to more evaporation and evapotranspiration which, in turn, leads to further drying and shrinking soils. Susceptibility of underground infrastructure assets, such as gas pipelines and electricity cables, as well as some above ground assets like electricity pylons and telecommunication towers is high in areas with where clay soils dominate, such as around London and the east of England. Over one-third (35%) of high voltage (132-400kV) subterranean electricity cables and 12% of high pressure natural gas pipelines in England are located in areas of high susceptibility to shrink-swell subsidence. As well as subterranean infrastructure, some surface infrastructure assets are also located in areas of high susceptibility, including 10% of cleanwater treatment works, 15% of small (<50m) telecommunication masts and 8% of high voltage (<400kV) electricity pylons. Over one-fifth (22%) of Category 1 rail line, 29% of major train stations and 9% of the major road network is located in high-susceptibility areas. According to the British Geological Survey, shrink–swell is the most damaging geo-hazard in Britain today, costing the economy an estimated £3 billion over the past 10 years, although this is primarily in the form of damage to residential and commercial properties. In addition to being a recognised landslip trigger (as mentioned in In5) shrink-swell effects also cause disruption to track alignment on railway embankments composed of high plasticity clay soils. Modern compaction methods ensure that the clay fill in highway embankments has a low permeability, which together with the road surfacing and effective drainage measures, mean that rainfall infiltration into road foundation soils is relatively low and hence shrink-swell is a much lower risk. (Unknown magnitude/unknown confidence) Future No data available on future risks from subsidence. (Unknown magnitude/unknown confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Not clear at this stage
Justification	Infrastructure operators understand this risk well and there are established processes in place to monitor the risk and manage assets accordingly.
Confidence	Low

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	No
Type of benefit	**Watching brief** Monitor changes in temperature and rainfall patterns and use to update assessments of subsidence risk.
Confidence	Medium

In9: Risks to public water supplies from drought and low river flows

Step 1: What is the current and future level of risk or opportunity?
Current Across the UK, there is currently an overall supply/demand surplus of around 2,000 Ml/day. There are, however, modest deficits in water resource zones (mainly in some parts of southern England) although these deficits are all lower than the target headroom.[2] (Medium magnitude/high confidence) Future Deficits are projected to be widespread by the 2050s under a high population growth and a high climate change scenario, in the absence of additional adaptation interventions beyond those included in the current water company Water Resources Management Plans. The north-west of England and the Yorkshire and Humber regions are projected to be highly susceptible, as well as London and the south-east. Deficits are also projected in other parts of the UK including areas of south Wales and the central

[2] The safety buffer companies should plan to have between water supply and demand in order to continue to provide an agreed level of service to their customers.

Step 1: What is the current and future level of risk or opportunity?
belt of Scotland. At a national scale, the UK is projected to be in deficit by 800 – 3,000 Ml/day (5 – 16% of the total demand for water at that time) in the 2050s and by 1400 – 5,900 Ml/d (8 – 29% of the total demand for water at that time) in the 2080s. (High magnitude/high confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	Water supply in the UK is regulated under the Water Acts of 2003 and 2014 (England and Wales), the Water Resources (Scotland) Act 2013 and Water and Sewerage Services (Northern Ireland). Water companies are required to prepare Water Resources Management Plans (WRMPs) every five years. These set out how water companies plan to balance water supply and demand over the next 25 years, taking into account the effects of climate change as well as other factors such as population growth and reductions in abstraction required to improve the ecological condition of rivers and lakes. Water companies also submit their business plans to the economic regulator as part of a five-yearly process known as a Periodic Review. These are used by the regulator to set limits on the price customers pay for the supply of water and treatment of wastewater, the outcomes companies must deliver, and the incentives in place to support delivery. Regulators use the WRMPs to assess the measures companies' need to undertake to manage the risk of supply-demand deficits. The latest Periodic Review was completed in December 2014. This sets price limits for the next Asset Management Plan period, AMP6, from 2015 to 2020. The next WRMPs are due in 2019 to inform AMP7. The 2014 Water Act introduced a 'resilience duty' that requires Ofwat and the Secretary of State to secure the long-term resilience of water company supply systems and ensure that water companies take steps for the purpose of enabling them to meet, in the long term, the need for the supply of water. Water companies already plan for droughts as part of their Business Plans, and the Water Act also includes an additional power for the Secretary of State to direct water companies to plan for droughts of a specified magnitude. In the current round of WRMPs, water companies have put forward plans to deal with projected deficits in their regions over the period to 2040. Collectively, these would reduce demand by 300 Ml/day, reduce leakage by 230 Ml/day and increase supplies by around 870 Ml/day. These measures, if fully implemented, are likely to be sufficient to deal with supply-demand deficits at the national scale under low to medium climate change

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	projections by the 2050s, though not the high-end estimate of the potential deficit. Reducing demand Steady progress has been made in reducing demand and leakage over the previous decade. Consumption per person in England has fallen from 155 litres per day (l/day) in 2003 to 141 l/day in 2013. The proportion of households in England that are metered has increased at a rate of about 2% a year since 2000, with around half of all households now metered. However, metering levels are much lower in the rest of the UK. Since 2010, Building Regulations in England have required all new homes to be designed so their water use is no more than 125 litres per person per day. Some local authorities require more ambitious standards, and it is estimated that around 35% of homes built in 2013/14 were designed to use 110 litres per person per day. The demand-side measures in WRMPs would go some way to reducing consumption per person, but only to around 135 l/day by 2040. Previous analysis by the ASC suggests more ambitious levels nearer to 115 l/day are technically feasible by 2040 with the wider uptake of cost-effective water efficiency and recycling measures. Almost all (90%) of the collective 300 Ml/day reduction in demand currently proposed by 2040 will have been achieved by 2025. This suggests that the next round of WRMPs in 2019 could ramp-up effort on demand-side measures in the second half of the 2020s and into the 2030s in order to deliver more ambitious, but technically achievable, reductions in consumption by 2040. More action is likely to be needed to achieve more ambitious levels of demand reduction, given the scale of behavioural change and uptake of technologies required. Customers do not generally comprehend the level of risk they are exposed to, and so are not in a position to express well-formed preferences about willingness to pay for improvements in resilience. Reducing leakage Leakage rates fell sharply after the drought of 1995 but have since levelled off at around 22% of total public water supply. There was a slight increase in leakage rates in 2010 and 2011 when cold winters caused more pipes to burst. Leakage rates in cities in England and Wales (around 25% of supply) fall within the range of other European cities, where leakage levels vary from 5% to 50% of total supply. Steady progress on leakage is a necessary political precursor to interventionist action on demand. Without evidence that leakage is being actively managed to tolerably low levels, customers will not be willing to take active steps to manage demand themselves. Targets on leakage are designed to move companies to a Sustainable Economic Level of Leakage (SELL). A zero leakage level is unlikely to be economically viable due to the increasing expense of finding and fixing

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	smaller leaks, once significant leaks are dealt with. The cost of eliminating leakage would outweigh the costs of balancing water supply and demand by other means. In the AMP5 round (2010-2015) Ofwat approved water company investments in England and Wales to deliver a modest reduction in leakage of 51 Ml/ day (or 2% of current leakage), stating that more ambitious targets over this timescale would represent poor value for customers and the environment based on current evidence. However, reducing the cost of fixing leaks will reduce the SELL and enable more cost-effective leakage reductions to be planned. In the AMP6 round (2015 to 2020), water companies are committed to reducing leakage levels from 3,281 Ml/d to 3,123 Ml/d (that is, by 158 Ml/d by 2020) – equivalent to a drop of about 5%. Increasing supply Supply-side measures begin to dominate in the current round of WRMPs from 2025 onwards. Measures such as effluent re-use, reservoir construction and the development of new and existing groundwater sources account for nearly all of the proposals to deal with future deficits from the mid-2020s onwards. Collectively, these measures are expected to bring an additional 870 M/l day of supply to the system by 2040, nearly three-times more than the expected savings from demand-side measures. Additional supply-side measures that are not in the current plans may also potentially be available, and could be included in the next round of WRMPs in 2019. These include options such as desalinisation and bulk transfer schemes between water companies. Proposed reforms to the abstraction regime may also potentially deliver extra sources of water, through improved catchment management, increased on-farm water storage and river restoration. However, there is some uncertainty on the feasibility, viability and potential scale of some of these measures. Furthermore, a number of supply-side measures have long-lead in times and therefore require long-term planning. This is particularly the case with water supply infrastructure with a significant land-requirement such as reservoirs. Gaining planning permission for large-scale infrastructure can be time consuming. The process has been streamlined in England through the National Policy Statements and Nationally Significant Infrastructure Projects consenting regime. NPSs have been in place for energy, transport and wastewater infrastructure since the mid-2000s, but there is currently no NPS for water supply. The absence of strategic long-term planning for water-supply infrastructure means that new development could be occurring in locations that may be required for water infrastructure in the future. It also means that investments being currently planned are not being tested for their effectiveness over extended timescales.
Confidence	High

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**More action needed** Although the policy framework is broadly in place through the WRMP process and the new resilience duty under the 2014 Water Act, more action is needed in the next five years to (a) enable a significant ramping-up of demand-side measures and (b) put in place a more strategic, long-term planning process for supply-side infrastructure. More action will be needed in the next five years to ramp-up demand-side measures in the next round of WRMPs from 2019. Consideration will also be needed of whether the current economic regulatory regime should place further emphasis on the need for more ambitious reductions in consumption and leakage. Other policy interventions may also need to be considered, such as further regulations on water efficiency in new development or more proactive rolling out of metering. The next round of WRMPs should also start considering the feasibility of implementing further supply-side options that may be needed in the second half of this century, and consider the lead times that would be necessary to take such action. Consideration should be given to the need for a National Policy Statement on water supply infrastructure to be produced within the next five years that provides more certainty for the implementation of supply-side measures. Consideration should also be given to whether revisions to national planning policies are required, in order to ensure the safeguarding of land that may be required for new water-supply infrastructure in the future. More action is also needed in the next five years to integrate drought planning with the WRMP process. This could include more stress testing of both WRMPs and Drought Plans with a wider range of climate change (particularly low flow and drought) scenarios. There is also a case for the next round of WRMPs to look further ahead (i.e. operate on a 50-year rather than 25-year time-frame).
Confidence	High

In10: Risks to electricity generation from drought and low river flows

Step 1: What is the current and future level of risk or opportunity?
Current Around 60% of all power plants in England are cooled with sea and tidal water, including all nuclear generation. 12% of power plants rely on freshwater for cooling, together accounting for nearly one-quarter of total capacity (16GW). Almost all electricity generation that relies on freshwater abstraction is situated in catchments that currently have sufficient water available. Only two power stations in England that rely on freshwater for cooling are located in areas where there is not enough water available for abstraction and the environment during an average summer. These power stations have a combined capacity of 0.5 GW. The remaining power stations reliant on freshwater are located in the lower reaches of large rivers like the Trent and the Humber that are at a very low risk of being significantly affected by low flows even in a dry year. As well as the volume of water for cooling, its temperature is important. Average temperatures of water bodies in the UK have been increasing in line with increases in air temperatures (see Chapter 3). During the 2003 heatwave power stations in inland France (including nuclear) were forced to cease operation as discharges would have led to water temperature limits in the natural environment being exceeded. (Low magnitude/high confidence) Future Increases in water scarcity and water temperatures in the future may reduce the capacity and effectiveness of freshwater cooling water systems. Freshwater used for cooling is returned to the environment at a higher temperature. Any increases in average water temperature due to climate change may therefore increase the likelihood of cooling water causing environmental damage when it is returned. This could in turn result in some power stations being unable to abstract during periods when water temperature is high because of potential environmental damage, or when there is insufficient water available in a catchment. Energy companies have, however, identified this as a 'low-to medium 'risk. Changes to energy generation in the future may increase demand for freshwater in some locations. Some scenarios of the future energy mix suggest a wider deployment of technologies that are relatively water-intensive, such as carbon capture and storage (CCS). Plants fitted with carbon capture consume from 44% to 84% more water per unit of power than traditional fossil fuel fired power stations, due to an increase in cooling and process uses. Future generations of capture technology may perform better in this regard. The fitting of CCS to gas and coal power plants currently located in Yorkshire, and potentially in Teeside could add pressure to three catchments, two of which may become at risk of water stress by the 2050s with climate change. The overall impact of CCS on water resources is uncertain, as the technology can use tidal water for cooling. (Low magnitude/medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Unlikely
Justification	Water use for power generation is licensed by the relevant environmental regulator and will be subject to proposed water abstraction reforms in England and Wales. Water should remain abundant for those sites located on the coast and near major estuaries. Defra and the Welsh Government have published plans delivering reforms to the for abstraction regime that, if implemented, will begin to be effective from the early 2020s. Various options exist for managing the competing demands for water more efficiently on a catchment by catchment basis. In the meantime, the Environment Agency and Natural Resources Wales are reviewing the most environmentally sensitive licences under the Restoring Sustainable Abstraction programme.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	No
Type of benefit	**Watching brief** Additional adaptation activity is not needed at present. Even if abstraction reform goes ahead there remains a need to ensure appropriate new infrastructure siting and cooling technology choices. The evidence for risks to energy generation due to higher water temperatures and/or reduced river flows should be kept under review, with long-term monitoring of risk levels and adaptation activity.
Confidence	Medium

In11: Risks to energy, transport and digital infrastructure from high winds and lightning

Step 1: What is the current and future level of risk or opportunity?
Current High winds are a significant cause of disruption to electricity networks, causing 20% of all customer disruption between 1995 and 2011. Over 2 million customers suffered power cuts in the winter storms of 2014/15, of which 16,000 were without power for more than 48 hours. The majority of damage and disruption to the network from high winds is due to trees and branches falling onto power lines. Tree-related faults on the UK's electricity distribution network significantly increased between 1990 and 2006. The observed increase in the duration of the growing season, which has gained ten days in Northern Europe since the 1960s, is likely to be contributing to this trend. Lightning strikes were responsible for 8% of total disruption to electricity distribution networks between 1995 and 2011. On the rail network, 5% of all passenger disruptions between 2006 and 2013 were due to high winds. As with electricity networks, the majority of damage is caused by trees or substantial branches being blown on to railway tracks, blocking services, causing damage to trains and bringing down cabling. There are an estimated 2.5 million trees growing near to the rail network and during the winter of 2013/14 there were 1,500 incidents of trees and other foreign objects being blown onto tracks. It is estimated that 60% of wind-blown trees came from land not owned by Network Rail. High winds can cause disruption to both road and ferry network operations and prevent high sided vehicles crossing bridges, typically over relatively short periods of time. Extreme high winds can also close mainland road networks. Even a short restricted closure to bridges from high winds will lead to impacts on journey time reliability and knock on effects to the economy in terms of disruption to the movement of goods and services. (High magnitude/high confidence) Future Between a 4% to 36% increase in the numbers of faults due to lightning by the 2080s is projected (for low and high climate scenario respectively) for the electricity transmission and distribution network. There is no statistically significant change in impacts caused by wind or gales based on the current relationships between weather and faults. Longer growing seasons are likely to result in further increases in vegetation growth rates which will, in the absence of additional management, increase the number of tree-related faults and disruption. No projections exist for future storm or lightening damage to rail services. (High magnitude/low confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Possibly
Justification	There are vegetation management procedures and standards in place for both electricity distribution and rail networks and a significant amount of action being taken: Electricity network operators have a statutory requirement to keep overhead power lines clear of vegetation for public safety reasons. Since 2006 operators have also been required to undertake a risk assessed programme of “resilience vegetation management”. The Energy Networks Association (ENA) produced an Engineering Technical Report (ETR132) in 2006 to guide implementation against this requirement. The standard requires operators to deliver proactive tree cutting and felling programmes targeted towards critical overhead lines, to improve performance in storm conditions. Across the electricity distribution companies, £8 million a year was spent on implementing resilience vegetation management between 2011 and 2015. This is projected to increase to £15 million a year from 2016 to 2023, resulting in total expenditure of around £158 million over the period 2011 to 2023. Network Rail has launched a Vegetation Management Capability Development Programme to introduce new standards and action to manage lineside growth. The budget for vegetation management was increased by £10 million (60%) in 2014/15. However, there is limited modelling of the potential impacts of future increases in the length of the growing season for tree-related faults. It is also not clear whether sufficient action is being taken to improve resilience to the projected increase in faults to the electricity distribution network caused by lightning strikes.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Research priority** There is a need for further modelling of the risk of increased tree-related faults due to increased vegetation growth rates. There is also a need for better understanding of projected changes in maximum wind speeds and the frequency of such events. If maximum wind speeds were to increase it would have an impact on the strength design of overhead electricity lines, poles / pylons. More research will help to create the right conditions to adapt later if it becomes apparent that additional interventions are likely to be required to manage the change in risk.
Confidence	Medium

In12: Risks to offshore infrastructure from storms and high waves

Step 1: What is the current and future level of risk or opportunity?
Current Offshore infrastructure is vulnerable to high wind speeds, large wave heights, strong currents, fog and lightning. These climate hazards can cause disruptions to maintenance, operations and movements of the infrastructure and personnel. More extreme events can lead to oil and gas production time being lost and wind turbines will cut out and stop producing power at speeds above 25 m/s. It has been estimated that extreme weather conditions have caused about 80% of North Sea offshore turbines to sustain failing grouted connections, causing some turbines to tip and no longer stand vertically. This has primarily been in monopole turbines, which can experience bending movement in the grouted joints between the monopole and the transition piece, resulting in the need for urgent repairs. Current expectations are that monopole foundations will rarely be used in the deeper waters in which wind farms in many UK waters have been consented. However, it is unclear currently how effectively the generation of offshore turbines currently deployed in the North Sea will withstand repeated exposure to extreme winds. A further risk to offshore turbines arises from scour and erosion of sediment around foundations leading to the potential for engineering failure in the foundations. Extreme weather conditions are likely to increase the frequency of occurrence of unacceptable degrees of scour, particularly around turbines located on sandy seabed. Many existing North Sea offshore turbines are located on potentially mobile seabed sediment. Increases in the prevalence of extreme weather causing stronger tidal and wave-induced currents at the seabed could result in greater mobility of sediment and more scour incidents. Such effects would be expected to be most significant in monopoles in relatively shallow water, and therefore be of more importance for windfarms in the southern North Sea. Further concerns arise from the potential for sediment movement to lead to increased exposure of

Step 1: What is the current and future level of risk or opportunity?
underwater power transmission cables. The exposure of buried cable in itself may not cause damage, but exposed cables will be more vulnerable to interactions with fishing gear etc. and rectification will be required for both engineering and safety reasons. Relaying or repairing cables requires highly specialised vessels and personnel, and the global increase in the demand for these vessels for wind farm installations may make access to them at short notice both difficult and costly. There is minimal evidence on risks to other offshore assets such as oil and gas rigs from storms and high waves, other than the consideration of weather in safety cases for rigs. Adverse weather also affects installation, maintenance and operation, by restriction movements of people and equipment (i.e. helicopters and ships are unable to access rigs during periods of adverse weather, so could be slow to repair damage). (Medium magnitude/low confidence) 2 Future The risks of extreme weather on off-shore developments, including small scale tide and wave, remains largely untested and it will be some time before monitoring data reveals how robust generation equipment, including turbines, are to fatigue. Climate projections show significant uncertainty with regard to changes in wind speed and wave height and power. A systematic review of the current and future exposure of offshore assets to climate impacts, including ocean acidification, is lacking. (Medium magnitude/low confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	National Marine Planning policies require off-shore infrastructure to be resilient to climate change, and these policies need to be strongly implemented through the regulatory processes. In all assessments of proposals, the consenting process requires third party certification or verification to ensure turbines and associated plant does not pose a risk to its environs. Where concern remains additional measures are put in place to provide suitable surety to the decision makers, including use of specialist consultants to assess risk, use of tracking equipment in the event of damage, or other mitigation measures. Like all industries the assessment of risk is based on tried and tested formula which includes modelling of extreme storm events based on past, current and future expectations. This package of measures is intended to ensure that risks to the infrastructure are minimised. The designs of modern off-shore turbines require greater account to be taken of the engineering requirements to be able to withstand the force and duration of extreme weather and associated meteorological and oceanographic conditions that may arise with projected levels of climate

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	change. The uncertainties in the predicted consequences of climate change for storminess, wind speed and wave height emphasise the need for adequate design parameters to ensure structural integrity is maintained. New generations of higher capacity and greater size of turbines have provided opportunities to review the apparent inadequate levels of precaution in engineering parameters of earlier turbines that have limited their ability to withstand current weather conditions, and the greater intensity of storms and stronger winds predicted to occur in future years.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Research priority** There is a need to assess whether off-shore wind turbines that have been deployed in recent years, as well as those due to be installed in the next five years, are being designed effectively. This is needed to avoid lock-in to particular technology pathway and will help to create the right conditions to allow further adaptation should structures not show the necessary robustness at some time later in their operating life. The impacts of extremes on other marine technologies (i.e. wave and tidal) also requires more research, both in terms of impacts on individual installations as well as part of adjacent farms or co-located technologies. For example, whether particular configurations of installations on the sea bed may potentially compound scour effects.
Confidence	Medium

In13: Risks to transport, digital and energy infrastructure from extreme heat

Step 1: What is the current and future level of risk or opportunity?
Current The most significant risk from higher temperatures to rail infrastructure is buckling. In 2003, 137 rail buckles cost £2.5m in delays and repairs. Met Office analysis of historical fault data on electricity transmission and distribution networks found that heat faults are a relatively low risk compared with other weather-related causes of faults. (Low magnitude/medium confidence) Future Rail buckling events are expected to be four to five times more frequent by the 2050s. By the 2080s the annual cost of buckling and heat related delays under a high climate change scenario could increase eight-fold. Temporary speed restrictions on the rail network are expected to increase by a factor of four, from 0.5 days to two days per summer season. More extreme temperatures will also (i) increase the number of days where track maintenance cannot be carried out, this will be significant across the UK but even in Scotland there will be threefold increase, (ii) increase overhead power cable sagging in hot weather, and an attendant increase in de-rating frequency of 2-7 times higher in South and East of England; and (iii) increase in the exposure of staff working outdoors to heat stress. Increases in ambient temperatures across the UK due to climate change could lead to line de-ratings (reduction in maximum capacity) of 6 – 10% for typical distribution lines and 2 – 4% for typical transmission lines under a high emissions scenario for the 2080s. De-ratings on underground low voltage cables would be within 2 – 4% in the 2080s (high emission scenario) and 2 – 7% for cables carrying 11 kV and above for the same timeframe . Higher temperatures also reduce the efficiency of transformers, with projected reductions of 4 – 7% for 11kV and 3 – 5% for >33kV transformers for the 2080s (UKCP09 high emission scenario at the 90% probability level). Some components could de-rate by as much as 27% in some summer days in the 2080s. This climatic component of de-rating adds to the effect of other drivers that, based on current projections, are expected to place greater pressures on the need to uprate cables. For example load increases, which include low carbon loads such as electric vehicles, have been recorded at up to 2% per year by some distribution network operators. (Medium magnitude/medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	The rail network has a range of funding pressures, and adequate investment over time to avoid heat-related impacts is not certain. The amount of investment needed to adapt rail assets to higher temperatures is unknown at present. The electricity transmission and distribution sector is likely to be able to cope with higher temperatures using established operational procedures. Assets and equipment abide by international standards that operate reliably in climates more extreme than the UK's.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Sustain current action** Planned levels of future activity are appropriate, but continued implementation is needed to ensure that increasing risk is managed in the future.
Confidence	Medium

In14: Potential benefits to water, transport, digital and energy infrastructure from reduced frequency of extreme cold events

Step 1: What is the current and future level of risk or opportunity?
Current Cold weather (including snow and ice) is a major cause of disruption to transport services, and electricity transmission and distribution. For example, snow and ice account for 30% of weather-related delays (~7% of all delays) to rail services in England and Wales, 16% of weather-related delays to the strategic road network in England, and 13% of weather-related impacts to the UK high voltage electricity distribution network. Snow and ice continue to be a problem for airports, as evidenced by the heavy snow of December 2010. (High magnitude/high confidence) Future The average number of extreme cold days is likely to diminish over the course of the century. Cold winters will still be possible, but are expected to become increasingly unlikely. For both road and rail networks, there will be potential benefits arising from fewer snow and ice days reducing winter disruption and maintenance costs. There are also likely to be benefits for water supply networks, with reduced pipe-freeze. The electricity transmission and distribution sector is projected to experience decreases in faults by between 70% and 90% due to reduced snow, sleet and blizzard conditions. Some research suggests that in the future, arctic ice loss could predispose the winter and spring atmospheric circulation over the North Atlantic and Europe to negative NAO regimes, and hence cold winters. However, there is considerable uncertainty in the evidence base regarding how the frequency of cold winters may change over the next few decades, with greater confidence in a long-term projection in the reduction in the frequency of cold winters. A H++ scenario involving AMOC slowdown and low solar activity would reduce average winter temperatures from around -5°C, with daily temperatures falling to -18°C. This scenario is unlikely this century but is physically plausible and cannot be ruled out. (Medium magnitude/medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	No
Justification	Autonomous adaptation to the decreasing incidence of severe cold weather events can be expected. However, there is a danger of complacency, given that extreme cold weather events are still likely to occur in the future.
Confidence	High

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	No
Type of benefit	**Sustain Current Action** Planned levels of future activity are appropriate, but continued implementation is needed to ensure that the risk continues to be planned for and managed in the future.
Confidence	High

Chapter 5 - People and the built environment

Urgency scores for people and the built environment					
Risk descriptor	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
PB1 - Risks to health and wellbeing from high temperatures (5.2.2, 5.3.2, 5.5.3)	England	Northern Ireland, Scotland, Wales			There are approximately 2,000 heat-related deaths per year across the UK. The risk to health is likely to increase in the future as temperatures rise. Around 20% of homes in England overheat even in the current climate. There is some evidence that the risks of overheating in hospitals, care homes, schools and offices will increase in the future. There is more evidence for England than for the devolved administrations. Policies do not exist at present to adapt homes or other buildings to higher temperatures.
PB2 - Risks to passengers from high temperatures on public transport (5.3.9)		Wales	England	Northern Ireland, Scotland	The action underway in London to assess and manage risks of overheating on public transport should continue, together with similar action as needed elsewhere in the UK.
PB3 - Opportunities for increased outdoor activities from higher temperatures (5.2.3)				UK	Leisure and other activities are likely to be taken up autonomously by people as the climate warms.
PB4 – Potential benefits to health and wellbeing from reduced cold (5.3.3,	UK				Currently there are between 35,800 and 49,700 cold-related deaths per year across the UK. Climate change alone is projected to reduce the health risks from cold, but the number of cold-related deaths is projected to decline only slightly

Urgency scores for people and the built environment					
Risk descriptor	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
5.5.4)					due to the effects of an ageing population increasing the number of vulnerable people at risk. Further measures need to be taken in the next 5 years to tackle large numbers of cold homes and reduce cold effects on health, even with climate warming.
PB5 - Risks to people, communities and buildings from flooding (5.2.5, 5.3.4, 5.5.1)	England	Northern Ireland, Scotland, Wales			Under the most optimistic flood defence investment scenario for England, the level of risk declines but remains high by mid-century, and future spending plans for the devolved administrations are unclear. Increases in flood risk cannot be avoided under a 4°C climate scenario even if the most ambitious adaptation pathway considered in this report were in place.
PB6 - Risks to the viability of coastal communities from sea level rise (5.2.6, 5.2.7)		UK			Research is needed to better characterise the impacts from sea level rise on coastal communities, thresholds for viability, and what steps should be taken to engage and support affected communities.
PB7 - Risks to building fabric from moisture, wind and driving rain (5.3.4, 5.3.6, 5.3.7)		UK			More research is needed to better determine the future level of risk and what adaptation further steps might be appropriate.

Urgency scores for people and the built environment					
Risk descriptor	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
PB8 - Risks to culturally valued structures and the wider historic environment (5.3.8)		UK			Climate-related hazards damage historic structures and sites now, but there is lack of information on the scale of current and future risk, including for historic urban green spaces and gardens as well as structures.
PB9 - Risks to health and social care delivery from extreme weather (5.4)	England	Northern Ireland, Scotland, Wales			There is some evidence of inconsistent planning for extreme weather across the UK. Surveys indicate that many Clinical Commissioning Groups, NHS providers, GPs and Local Authorities may not have appropriate plans in place.
PB10 – Risks to health from changes in air quality (5.2.2, 5.3.5, 5.5.5)		UK			More research is needed to understand the influence of climate change on ground level ozone and other outdoor air pollutants (especially particulates), and how climate and other factors (behaviour) affect indoor air quality.
PB11 - Risks to health from vector-borne pathogens (5.5.2)		UK			Further work is needed to improve the monitoring and surveillance of vector species and related infectious disease, and to assess the extent to which current efforts are focussed on those infections that pose the biggest long-term risks.
PB12 - Risk of food borne disease cases and outbreaks (5.5.6)				UK	Regulations in place to monitor and control food-related hazards should be kept under review.

Urgency scores for people and the built environment					
Risk descriptor	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
PB13 - Risks to health from poor water quality (5.5.6)			UK		Current policies and mechanisms to assess and manage risks to water quality in the public water supply should continue to be implemented.
PB14 - Risk of household water supply interruptions (5.2.4)			UK		Policies are in place to safeguard the continuity of public water supplies during droughts and from burst pipes in cold weather. These risks should be kept under review to make sure long-term risks continue to be managed appropriately.

PB1: Risks to health and wellbeing from high temperatures

Step 1: What is the current and future level of risk or opportunity?

Current

High temperatures have a negative effect on human health and wellbeing. There is a robust relationship regarding the effect of temperature on acute mortality. High temperatures are also associated with an increase in hospital admissions for respiratory causes, and there is some evidence suggesting an increase in GP consultations. At the UK level, there are around 2,000 heat-related deaths per year (high magnitude, high confidence).

Indoor exposure to heat is likely to drive much of the current risk as people spend roughly 90% of their time indoors. Dwelling types that have been found to be more prone to overheating include 1960s – 1970s and newly built, post-1990s mid- and top-floor purpose-built flats that lack sufficient ventilation and protection from solar gains.

In England, several independent studies have found that thermal comfort thresholds for overheating in dwellings are exceeded in the current climate; living rooms were measured as exceeding 28°C for more than 1% of occupied hours in 4 – 27% of dwellings and bedrooms exceed 24°C for more than 5% of occupied hours in 47 – 92% of cases (two separate studies in 2007 and 2009). In the 2010/11 English Housing Survey Energy Follow Up Survey, 20% of respondents reported experiencing problems with overheating. If it is assumed that these findings are representative of the country, millions of homes would therefore be exceeding overheating thresholds annually even in a cool summer (high magnitude, high confidence). There is a lack of evidence on current temperature trends in buildings other than homes in England, and in all building types in Scotland, Wales and Northern Ireland. This includes schools, hospitals, work places and prisons.

Future

The frequency of exceedance of overheating thresholds is projected to increase in the future. Events such as the 1976 and 2003 heatwaves in the UK are likely to become the norm between 2030 and 2050. The intensity of heatwaves in Europe is projected to increase in the future by between 1.4°C and 7.5°C for a rise in global mean temperature of 2°C. Uncertainties remain in the magnitude of the increased intensity because of sensitivity to the modelling of the physics associated with vegetation and drying of the soil. The UK's population is projected to increase from 64 million in 2012 to 73 million by 2035 and 86 million by 2085 according to the ONS principal population projection. The UK population aged over 75 is projected to increase from 8% in 2015 to 18% by 2085.

A key study that updates the information used in CCRA1 estimates that annual UK heat-related mortality is projected to increase by 66% in the 2020s, 257% in the 2050s and 535% in the 2080s from a baseline of 2,000 deaths per year today, from the combined effects of climate change (medium emissions scenario) and population growth, assuming no adaptation over and above today's levels (high magnitude, medium confidence).

Another study for London suggests that 80-92% of flats and 56-61% of detached dwellings would exceed overheating thresholds in a heatwave event in 2050 (high emission scenario, median result). Although this study was for Greater London only, it suggests that millions of people may be affected annually just within this area alone, assuming that physiological adaptation to these higher temperatures does not take place (high magnitude, low confidence).

Some quantitative data on mortality risk is also available broken down for each country:

England:

High temperatures currently contribute to around 1% of annual mortality. The Heatwave Plan for England states that there were over 2,000 deaths attributed to the 2003 heatwave, 680 excess deaths

Step 1: What is the current and future level of risk or opportunity?
during the heatwave in 2006, and 300 in 2009. Heat-related mortality in the 2050s is expected to increase to between 1.8 and 26.1 per 100,000 population, depending on the region, based on the UKCP09 medium emissions scenario (high magnitude, medium confidence). Wales: There are currently around 2.4 excess deaths per 100,000 population (which with a population of 3.1 million equates to 74 excess deaths per year). Heat-related mortality in the 2050s is estimated to increase to between 3.1 and 14.3 per 100,000, based on the UKCP09 medium emissions scenario. Assuming no population growth, this equates to between 96 and 443 deaths. With population growth this figure would be higher (high magnitude, medium confidence). Scotland: There are currently around 0.7 excess deaths per 100,000 population (which with a population of 5.4 million equates to 38 excess deaths per year). Heat-related mortality in the 2050s is estimated to increase to between 1.3 and 5.2 per 100,000, based on the UKCP09 medium emissions scenario. With no population growth, this would equate to 70 – 281 deaths. With population growth this figure would be higher (high magnitude, medium confidence). Northern Ireland: There are currently around 0.9 excess deaths per 100,000 population (which with a population of 1.85 million equates to 16.7 excess deaths per year). Heat-related mortality in the 2050s is estimated to increase to between 1.5 to 6.1 per 100,000, based on the UKCP09 medium emissions scenario. With no population growth this would equate to 28 – 113 deaths. With population growth this figure would be higher (medium magnitude, medium confidence).

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	It is plausible that some degree of autonomous physiological adaptation will take place in response to gradual increases in mean temperature. However, it is less likely that this will occur in response to higher extreme temperatures, particularly if overall temperature variability increases, as people are less able to adapt to sudden increases in temperature over a short period of time. There is some evidence that people lack awareness of the risks to health from high indoor temperatures, and thus they are less likely to take measures to protect themselves. The presence of air conditioning in housing is currently low in the UK (at about 3% of homes). Although uptake may increase autonomously in the future, relying on air conditioning to deal with the risk would be a maladaptive solution as it expels waste heat into the environment – thereby

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	enhancing the urban heat island effect – and can increase carbon emissions if powered from non-renewable electricity sources. Current Building Regulations for England require some degree of solar shading in new homes to limit overheating, but in order to help minimise fuel/power use for cooling rather than to protect health. There are no policy levers to control overheating through passive cooling or other means in existing or new homes, which may also be at greater risk of overheating following energy efficiency interventions that increase air tightness. Guidance and awareness raising policies for heatwaves are in force across the UK. Public Health England publishes an annual heatwave plan which includes an element of all-year planning for prevention, and response measures when a heatwave warning is issued. Wales no longer have a formal Heatwave Plan, but do publish public health guidance (Extreme Weather Public Health Alerts & Advice for Wales 2015). Local health boards in Scotland provide guidance for the public on protecting themselves in hot weather. Northern Ireland does not produce a heatwave plan, but responding to heatwaves is covered under the national emergency planning system. There have been some surveys of the effectiveness of these plans, but it remains unclear how effective these are at changing people's behaviour.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes, for homes. Further evidence is needed to ascertain the size of the risk in other types of buildings.
Type of benefit	**More action needed (England), research priority (Northern Ireland, Scotland, Wales)** England: Individual dwellings have average lifetimes of well over 50 years, and building in adaptation measures to new designs in England now would therefore avoid lock-in to a maladapted housing stock in the future. Studies vary on the cost and feasibility of retrofitting cooling measures in dwellings after they are built. ASC analysis has suggested that passive cooling measures are more cost-effective than air conditioning. Another study has suggested that retro-fitting passive cooling measures could range from £1 – 32K per dwelling depending on house type, and for some dwellings overheating cannot be eliminated through future retrofit measures at any cost (which suggests that getting the original design right is crucial).

Step 3: Are there benefits of further action in the next 5 years?	
	It is important to consider total building performance when designing policies to change the environmental quality inside homes. In particular in relation to climate change, policies to improve energy efficiency and reduce fuel poverty should be considered together with new steps to reduce overheating risk. There is a lack of evidence on the benefits of acting on overheating risks in other types of buildings other than homes. More research is also required to better understand how people react in hot weather and the effectiveness of measures to encourage the public to protect themselves. Devolved administrations: There is a lack of evidence on the total level of risk and the benefits of acting for all types of buildings in the devolved administrations. More research is also required to better understand how people behave in hot weather and the effectiveness of measures to encourage the public to protect themselves. Research has been commissioned by the Scottish Government to quantify heat-related risks to people in buildings in Scotland. Depending on the results of this research, there might enough evidence to justify the need for new policies to build resilience to heat in the existing and new building stock in Scotland.
Confidence	Medium

PB2: Risks to passengers from high temperatures on public transport

Step 1: What is the current and future level of risk or opportunity?
Higher temperatures have been cited as a risk to the effective functioning of urban transport networks because of risks to commuter comfort and health. It is well known that underground trains, especially those operating in the "deeper" underground lines in London (e.g. Central and Bakerloo), are vulnerable to overheating in prolonged hot weather. Transport for London scored overheating as one of the two highest risks to tube services in its second Adaptation Reporting Power report, along with flooding. The wider level of risk across the UK is not well quantified (at least in the published literature). The current and future magnitude of this risk on an annual basis is unknown and it therefore has low confidence.

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	No
Justification	The current and future level of risk is not well understood, although work is underway to address the risk in London, where problems of overheating are likely to be most acute. For example, under the 'Cooling the Tube' programme, future tunnel temperatures have been modelled by Transport for London using the UK Climate Projections to test the effectiveness of different cooling strategies. Many adaptations are already being put in place to mitigate the risks from heat on the underground. For example, in 2010, new S-stock trains started to replace older stock on the Circle, District, Hammersmith and City and Metropolitan lines, which have built-on air conditioning. London Underground also publishes 'beat the heat' guidance posters in the summer months urging passengers to carry a bottle of water and seek help at the next station if they feel unwell. It was reported in Sept 2015 that Tfl planned to replace the non-opening windows on routemaster buses to improve ventilation at a cost of £2m.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Unknown; as the future level of risk is highly uncertain, it is difficult to know what the benefits of further action being taken now would be.
Type of benefit	**Sustain current action (England), research priority (Wales), watching brief (Northern Ireland and Scotland).** England: The action underway in London to assess and manage risks of overheating on public transport should continue, together with similar action as needed elsewhere. Wales: given the relatively high potential for heat related health impact (see PB1), uncertainty and lack of information on the level of action for Wales, more research should be undertaken to assess the size of the risk and potential need for additional adaptation. Northern Ireland and Scotland: Given the uncertainties in the size of the risk and relatively lower magnitude of risk of overheating in PB1, this risk should continue to be monitored but further action is not currently justified.
Confidence	Medium

PB3: Opportunities for increased outdoor activities from higher temperatures

Step 1: What is the current and future level of risk or opportunity?
Current Climate change is increasingly recognized as a factor that may influence the recreational use of outdoor environments. Despite awareness of the pervasive effects of climate change, its effects on outdoor recreation have only recently been studied in detail. The magnitude of the current benefit is unknown and this benefit therefore has low confidence. Future Climate change would have differing impacts depending on the activity. For example, in one study the number of people partaking in certain outdoor recreational activities-such as boating, golfing and beach recreation is estimated, under medium emissions scenarios, to increase by 14 to 36% over the next few decades. A study conducted in Switzerland also projected a significant increase in the use of outdoor swimming pools, with increases of > 30% expected for August and September in the future. In Scotland, the improved summer climate in the highlands and a sunnier east coast could lead to greater consumer confidence that Scotland can provide a reasonable expectation of weather conditions conducive to outdoor activities and touring. In winter, ski resorts could well continue to receive a reasonable supply of snow while access roads may be less prone to blockage by snow and ice. These projections have high uncertainty however and there is little evidence published for the UK. Across the UK as a whole, the future magnitude of benefit is unknown and this benefit therefore has low confidence.

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	No
Justification	Autonomous adaptation to take advantage of any benefits is thought to be plausible, though there is little evidence to support this assumption made by the authors.
Confidence	Low

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	No
Type of benefit	**Watching brief** Expert judgement from the report authors is that autonomous adaptation will occur in response to this risk.
Confidence	Low

PB4: Potential benefits to health and wellbeing from reduced cold

Step 1: What is the current and future level of risk or opportunity?
Cold-related mortality is significant, with the estimated number of cold-related deaths between 35,800 and 49,700 deaths per year across the UK. Poor quality housing (cold homes) is thought to be a major determinant of the burden of cold related mortality and morbidity. The greatest cold risk for a given temperature is in London, the South West of England and Wales. Higher temperatures from climate change will reduce the risk of cold-related deaths but this will be offset to a large extent by the increase in the older population. One study estimates that that total number of deaths will only decline by around 2% from a baseline of 41,000 deaths across the UK, by the 2050s (medium emissions scenario, includes population growth). This risk therefore still has a high magnitude in the future (low confidence). England: Current: The cold weather plan for England suggests that there are over 20,000 cold-related deaths per year in England (24,000 for England and Wales)(high magnitude, medium confidence). Fuel poverty is a measure of how difficult people find it to heat their homes to an acceptable level and is linked to the risk of cold-related mortality. There were an estimated 2.35 million (10.4% of all households) fuel poor households in England in 2013. Future: It is estimated that the number of cold-related deaths in the 2050s may decline from 62.9 – 77.3 per 100,000 to 44.1 – 58.4 per 100,000 depending on the region (mean estimates for a UKCP09 medium emissions scenario). The risk will remain at a high magnitude therefore, with a slight decline in impact compared to today (low confidence). Wales: Current: In 2011, 26% of households in Wales were fuel poor. There are around 74-102 deaths per 100,000 population from cold (which with a population of 3.1 million equates to 2,295 - 3,160 deaths per year) (high magnitude, medium confidence). Future: The same study projects a reduction in cold-related mortality in the 2050s to between 55 - 75 per 100,000, based on the UKCP09 medium emissions scenario. Assuming no growth in population, this would equate to 1,705 – 2,325 deaths per year (high magnitude, low confidence). Scotland: Current: There were estimated to be 940,000 fuel poor households in 2013, equivalent to 39% of all households. There are around 48 - 72 excess deaths per 100,000 population (which with

Step 1: What is the current and future level of risk or opportunity?
a population of 5.4 million equates to 2,590 - 3,890 excess deaths per year) (high magnitude, low confidence). Future: The same study projects a reduction in cold-related mortality in the 2050s to between 34 – 54 per 100,000, based on the UKCP09 medium emissions scenario. Assuming no growth in population, this would equate to 1,836 – 2,916 deaths per year (high magnitude, low confidence). Northern Ireland: Current: In 2011 in Northern Ireland 42% of households were classed as fuel poor, the highest in the UK. This is partly due to a high percentage of off gas grid households (who therefore use alternative, more expensive fuels to heat their homes). There are around 40 - 60 excess deaths per 100,000 population per year (which with a population of 1.85 million equates to between 740 - 1,110 excess deaths per year) (high magnitude, low confidence). Future: The same study projects an increase in heat-related mortality in the 2050s to between 29 – 43.5 per 100,000, based on the UKCP09 medium emissions scenario. Assuming no growth in population, this would equate to 536 – 805 deaths per year (high magnitude, low confidence).

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes. The risk to health from cold is projected to decline somewhat over time as winters warm, but will still be the largest weather-related driver of mortality in the 2050s without additional action. It is important that policies are further developed and implemented to address fuel poverty without increasing the risk of overheating.
Justification	The current level of risk of cold-related mortality across the UK remains high compared to other NW European countries. Fuel poverty levels are used as a proxy indicator for exposure to cold, and have seen little change over the last decade. In England, the Department of Energy & Climate Change (DECC) supports fuel poverty schemes in local authorities. The main home energy efficiency policy, the Energy Company Obligation was amended in 2014 after just over one year of operation. The Autumn Statement 2015 announced ECO would be replaced by a “new cheaper energy efficiency supplier obligation” in April 2017 to run for 5 years. The new supplier obligation aims to upgrade the energy efficiency of over 200,000 homes per year. The new obligation will primarily aim to improve energy efficiency for fuel poor households. CCC (2015) estimated that annual funding of at least £1.2 billion a year would be needed to meet the government's target of an EPC C rating by 2030 for fuel poor households in England. In Northern Ireland, initiatives such as the Warm Homes Scheme and energy efficiency grants have been in place and helped several thousand households. A cold weather payment scheme has been set up to help households afford the cost of heating. However, there is as yet no evidence

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	on how this scheme and the other initiatives have helped to reduce vulnerability. Further work is needed to determine the level of action and its effects in Wales and Scotland.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**More action needed** Further work is needed to understand the effects of current policies in England and Northern Ireland to reduce fuel poverty on cold-related mortality; to understand the level of action and its effects in Scotland and Wales; and to put in place steps to ensure that further insulation of the housing stock does not increase overheating risk in the summer.
Confidence	Low

PB5: Risks to people, communities and buildings from flooding

Step 1: What is the current and future level of risk or opportunity?
Flooding is a threat to life. Studies from other populations have shown that significant mortality events are mostly associated with flash flooding. There is no precise estimate of flood mortality for the UK, as the definition of a flood death can vary. Mortality associated with flooding can include related car accidents, and other accidents, e.g. from persons falling into fast flowing water. The wider social impacts of flooding are not well quantified but include lack of access to services and loss of school and work days. All income groups are at risk of adverse consequences. Large systematic reviews of epidemiological evidence suggest that flooding has adverse effects on mental health and wellbeing. The main epidemiological evidence relates to common mental disorders (i.e. anxiety and depression) and measurable post-traumatic stress syndrome. There are a wide range of values given for the number of people affected after a flood event. England: Current: According to Sayers et al. (2015) for the ASC, there are 2.3 million residential properties located in areas at any degree of risk of flooding across England, of which 690,000 (3%) are at 1:75 or

Step 1: What is the current and future level of risk or opportunity?
greater risk. This equates to 1.4 million people at 1:75 or greater risk. The Environment Agency estimates that there are 4.25 million people living in areas at any degree of risk from flooding. Sayers et al. 2015 estimates that the direct Expected Annual Damages (EAD) alone from flooding to residential properties is £270 million for England (high magnitude, medium confidence). After the 2007 floods, insurers handled 180,000 claims and paid out over £3 billion, with 17,000 people having to be found temporary accommodation. Future: Assuming no population growth and a continuation of current levels of adaptation (i.e. the standard of protection provided by flood defences reduces in areas where the benefit cost case is weakest, but is maintained in areas with the highest standards today), Sayers et al. suggests that by the 2050s the projected number of people at 1:75 or greater risk rises to around 1.7 million under a 2 degree scenario and 2.2 million for a 4 degree scenario. For the 2080s, the projections suggest 2 million people under a 2 degree scenario and 2.9 million people under a 4 degree scenario. Expected annual damage to residential properties is projected to rise by between 22 – 78% in the 2050s and 47 – 160% in the 2080s depending on climate scenario (high magnitude, medium confidence). Wales: Current: According to Sayers et al. 2015, there are 160,000 residential properties at any degree of risk from flooding across Wales, of which 51,000 (4%) are at 1:75 or greater risk. This equates to 95,000 people at 1:75 or greater risk. Current expected annual damage to residential properties is estimated to be £22 million (medium magnitude, medium confidence). Future: Assuming no population growth and a continuation of current levels of adaptation, by the 2050s the projected number of people at 1:75 or greater risk rises to around 119,000 under a 2 degree scenario and 166,000 for a 4 degree scenario. For the 2080s, the projections suggest 142,000 people under a 2 degree scenario and 209,000 people under a 4 degree scenario (medium magnitude, medium confidence). Expected annual damage to residential properties is projected to rise by between 35 – 110% in the 2050s and 59 - 220% in the 2080s depending on climate scenario (medium magnitude, medium confidence). Scotland: Current: According to Sayers et al. 2015, there are 180,000 residential properties at any degree of risk from flooding across Scotland, of which 97,000 (4%) are at 1:75 or greater risk. This equates to 200,000 people at 1:75 or greater risk (medium magnitude, medium confidence). Current expected annual damage to residential properties is estimated to be £42 million (medium magnitude, medium confidence). SEPA estimate that there are 134,000 residential properties located in areas at any degree of flood risk. Future: Assuming no population growth and a continuation of current levels of adaptation, by the 2050s the projected number of people at 1:75 or greater risk rises to around 220,000 under a 2 degree scenario and 242,000 for a 4 degree scenario. For the 2080s, the projections suggest 236,000 people under a 2 degree scenario and 286,000 people under a 4 degree scenario (medium magnitude, medium confidence). Expected annual damage to residential properties is projected to rise by between 43 - 99% in the 2050s and 73 - 190% in the 2080s depending on climate scenario (medium magnitude, medium confidence). Northern Ireland:

Step 1: What is the current and future level of risk or opportunity?
Current: According to Sayers et al. 2015, there are 56,000 residential properties at any degree of risk from flooding across Northern Ireland, of which 23,000 (2%) are at 1:75 or greater risk. This equates to 56,000 people at 1:75 or greater risk (low magnitude, medium confidence). Current expected annual damage to residential properties is estimated to be £8.1 million (low magnitude, medium confidence). Future: Assuming no population growth and a continuation of current levels of adaptation, by the 2050s the projected number of people at 1:75 or greater risk rises to around 67,000 under a 2 degree scenario and 76,000 for a 4 degree scenario. For the 2080s, the projections suggest 73,000 people under a 2 degree scenario and 98,000 people under a 4 degree scenario (low magnitude, medium confidence). Expected annual damage to residential properties is projected to rise by between 33 - 62% in the 2050s and 60 - 150% in the 2080s depending on climate scenario (medium magnitude, medium confidence).

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes; even under the most ambitious investment scenario for England the level of risk declines but remains at high magnitude by mid-century, and future spending plans for the devolved administrations are unclear. The risk cannot be managed under any adaptation scenario considered in this report in a 4 degree world.
Justification	England: The optimal investment scenario for England identified by the Environment Agency in their long-term Investment scenarios (LTIS) report suggests that if expenditure on flood risk management were to be sustained at £750-800 million per year (2014 prices) and within a decade or so increased to £850-900 million per year, across the full fifty year period, it would be sufficient to reduce total expected annual flood damage by 12% by the 2060s. However, even under this optimal scenario, the total number of properties exposed to high levels of flood risk (in areas with 1-in-30 annual chance of flooding of greater) is expected to increase and average annual damages would remain at around £1billion per year (high magnitude, medium confidence). This analysis also assumes that the money available is spent in as cost-beneficial a way as possible, that in effect there is no population growth (i.e. that any new development does not lead to increased flood risk), and emissions rise in line with a medium emissions scenario. Sayers et al. presents a separate analysis based on assumptions about the uptake of a series of different adaptation measures at the national level. The' Enhanced Whole Systems' adaptation scenario is broadly in line with the assumptions and level of adaptation implied by the LTIS optimal scenario. The Sayers results suggest that under this best case adaptation scenario there might be a net reduction (£25 million) in expected annual damages

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	(EAD) under a 2ºC scenario (low population growth) or no net increase with high population growth. EAD increases by £220-250 million under a 4ºC scenario by the 2080s at the UK level depending on the population growth scenario (high magnitude, medium confidence). In this scenario, the number of people living in areas at 1:75 or greater risk still increases in England, and across the UK under both 2 and 4 ºC scenarios. In the enhanced whole system scenario, the beneficial effect on expected annual damages comes from adaptations such as take up of receptor level protection, forecasting and warning, and these measures do not influence the numbers of people affected but do reduce annual damage estimates. Land use planning policy in England aims to avoid inappropriate new development in the floodplain. In England, around 250,000 new homes were built on the floodplain between 2001 and 2014. The majority (183,000) of these homes were in lower risk area (where annual chance of flooding is less than 1 in 200 once current flood defences are taken into account) and in towns and cities on rivers (e.g. London, York, Reading and Oxford) and on the coast (e.g. Hull, Southampton, Portsmouth and Bristol). Approximately 68,000 new homes (3% of all new homes in England) were built in areas with a 1 in 100 or greater annual chance of flooding. Of these, 23,000 were built in areas of high flood risk (a 1 in 30 or greater annual chance of flooding even accounting for flood defences if they are in place). The actual risk of flooding inside a property depends on the characteristics of the site and the building design. National planning policy is clear that new developments in flood risk areas should be made safe for their lifetime, without increasing flood risk elsewhere, and appropriately flood resilient and resistant. Developers are responsible for commissioning detailed flood risk assessments for sites in areas at risk and proposing mitigation measures in terms of enhanced drainage and safe entry and egress routes. There are many anecdotal examples of development in flood risk areas that have incorporated appropriate design measures. However, developers, decision-makers and other authorities currently bear no long-term liability if flood risk assessments are incorrect or understate the true nature of the risk, and flooding subsequently occurs. Some Flood Risk Assessments are poor quality or missing from planning applications. The Environment Agency has a statutory role to scrutinise planning applications in flood risk areas. Where the Environment Agency provides advice and is informed of the outcome, it is almost always followed, with only 4% of planning applications proceeding against a sustained objection by the EA. The Environment Agency is not able to respond to every individual planning application with bespoke advice. Thus, small-scale applications or changes of use are more likely to proceed with inadequate flood risk assessments. Permeable paving can help to manage surface water flood risk. Sales of permeable paving, which helps to reduce the risk of surface water and sewer flooding, is on a rising trajectory, yet still accounted for only around 10% of all UK block paving sales in 2013. The uptake of sustainable drainage systems in new development is low (an estimated 15% of new development in England). Provisions in the Flood & Water Management Act to establish a consenting regime for SuDS and remove the automatic right for new

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	development to connect to public sewers have not been introduced, with the emphasis instead on strengthening planning policy. Uptake of property-level protection (PLP) in England has been low, with 3,174 properties taking up PLP up to 2015 and 3,074 either planned or in the works for 2016-2021. Northern Ireland: It is reported that spending on capital works by DARD Rivers Agency (now part of the Dept. for Infrastructure) to provide new or improved river flood defences is of the order of £8million per annum. Northern Ireland Water is also spending a total of almost £20million from 2015/2016 – 2020/2021 to upgrading their sewerage systems to alleviate out-of-sewer flooding at properties across Northern Ireland. It is not known what effects this investment has had on the number of properties in areas at risk of flooding. Northern Ireland's Strategic Planning Policy Statement was published in September 2015. The SPPS provides a strategic planning policy framework for the reformed two-tier planning system which became operational on 1 April 2015. The policy applies to the whole of Northern Ireland. Its provisions must be taken into account by Councils in the preparation of Local Development Plans and all decisions on individual planning applications and appeals. The aim of the SPPS in relation to flood risk is to prevent future development that may be at risk from flooding or that may increase the risk of flooding elsewhere. It is considered that the current uptake of Property Level Protection (PLP) in Northern Ireland is low. There are no firm data available on this but it is known that a small number of homeowners at risk have arranged their own installations. To tackle this, a 'Homeowner Flood Protection Grant Scheme' was launched by DARD (now DfI) Rivers Agency in January 2016 and is currently being implemented. This will provide grant assistance to facilitate the fitting of Individual Property Protection measures to homes that meet the eligibility criteria. Consideration is being given to extending this scheme to non-domestic properties. Northern Ireland is the only part of the UK without a flood forecast/alert service. The Rivers Agency is a government responder to flood emergencies, providing advice to drainage agencies and other responders on the potential flood impacts associated with heavy rainfall weather conditions. In the case of the coast, the Agency liaises with the UK Coastal Monitoring and Forecasting Service (UKCMF) regarding the likelihood of tidal surges and will inform fellow responders should there be potential tidal conditions which could lead to serious coastal flooding. Incidents are handled at a local level by the individual emergency services, district councils, Health and Social Care bodies and other locally based organisations, without an overarching coordination group. Scotland: The Flood Risk Management (Scotland) Act 2009 transposed the EU Floods Directive. Part 3 of the Act put in place a framework for the Scottish

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	Environment Protection Agency (SEPA) to prepare a National Flood Risk Assessment (NFRA, first published in 2011) flood hazard and risk maps (first published in 2013) and flood risk management plans to the timescale required by the Directive. The review of flood risk management plans in 2021 must account for the likely impacts of climate change. In 2015, SEPA published 14 new flood risk management strategies for each Local Plan district. These will be transposed into delivery plans called local flood risk management plans in 2016. The Act also replaces the 1961 Act by giving local authorities a 'general power' to take forward a full range of flood risk management measures. As well as retaining a duty to maintain flood defences, the 2009 Act gives local authorities powers to deliver flood protection schemes that will contribute to the implementation of agreed flood risk management plans and are consistent with requirements laid down by Scottish Ministers. At present however, information on current and future investment plans and the impact on the number of properties at risk is not available for Scotland. Likewise, figures on the level of development in the floodplain were not available at the time of publication. Flood risk management legislation promotes the implementation of a more sustainable and integrated approach to managing surface water (drainage and flooding), which includes a significant change away from more traditional hard engineering (e.g. underground storage) to managing water on the surface and reducing water in sewers using 'green and blue' infrastructure (including sustainable urban drainage systems). According to SEPA, coordination between the drainage and flooding authorities is happening in localised areas but needs to be improved. Uptake of PLP is also deemed to be low in Scotland, although actual uptake figures are not available. A report from JBA consultants estimated that 43,000 properties located in areas at 1 in 25 to 1 in 30 flood risk could benefit from PLP and that uptake would be cost-effective. Some local authorities in Scotland provide subsidy/discount schemes for PLP (for example, Scottish Borders Council) and the potential for PLP has also been identified in the FRM Strategies. Wales: In Wales, around £165 million was invested between 2011 and 2014 in flood and coastal erosion risk management. It is not known what effects this investment has had on the number of properties in areas at high risk of flooding. Investment in individual property protection measures began in 2010/11, and since then over 600 properties have benefitted, with over £850,000 invested by Natural Resources Wales. Analysis has not yet been done to consider what the cost-effective uptake of PLP in Wales would look like and therefore how far current investment goes towards an economically optimal level.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	England: Yes, as even in the most ambitious adaptation scenario, the residual risk remains at high magnitude in all scenarios and cannot be reduced from the current level in any adaptation scenario in a 4 degree world. Northern Ireland, Scotland, Wales: It is difficult to tell at present as there is a lack of evidence about the level of ambition of current and planned policies, and what effects these policies will have on future risk in particular. Risk levels for the devolved administrations follow similar trends to England in the Enhanced Whole System adaptation scenario analysed for the CCRA, but there is a gap in understanding of how current and future policies relate to this ambitious adaptation scenario.
Type of benefit	**More action needed (England):** Some further actions that could help to reduce the level of future risk to a lower level include: • Reviewing future plans for flood defence spending and considering how the Government should balance future flood defence investment against other measures such as property-level and community-level flood protection measures. • Improving the implementation of sustainable urban drainage systems/designing urban areas to better manage local flood risks • Better understanding of and accounting for the actual change in flood risk from new development on the floodplain • Capacity building at the community level **Research priority (Northern Ireland, Scotland, Wales):** More evidence is also needed to assess precisely how the current and planned level of action relates to the level of risk in Northern Ireland, Scotland and Wales.
Confidence	Medium

PB6: Risks to the viability of coastal communities from sea level rise

Step 1: What is the current and future level of risk or opportunity?
Current Monitoring and understanding sea-level rise at the local level is difficult as the actual level of sea-level rise at any one place depends on a wide range of factors including gravitational variation across the Earth and a number of oceanographic factors. The current level of risk to the viability of coastal communities from sea level rise is low (low magnitude, high confidence), Future The future risk to communities across the UK is uncertain and could be significant. More details are provided below: England: According to Sayers et al. 2015, for levels of sea level rise beyond 1 metre, there may be 200 km or more of coastal flood defences that are particularly vulnerable in storm conditions and may not be cost-effective to maintain in the future, which would lead to an increased risk to coastal communities that sit behind these defences (medium magnitude, low confidence). Wales: Some locations in Wales are known to be at risk from long-term changes to the coastline, such as the village of Fairbourne. Baseline rates of coastal erosion are between 30 and 100 metres per century. With sea-level rise, the rates could be 1.75 – 2.5 higher than the baseline due to strengthened wave action and other factors (equivalent to 52 – 250 metres per century). The Shoreline Management Plan for Fairbourne states that while the village's defences can and should be maintained for several decades (c. 40 years) in the long term the village is unsustainable. Scotland: Some coastal communities especially in the Hebrides, areas of the Solway Firth, Firth of Clyde and the coastline from Moray to Fife (including Aberdeen) might be at risk from increased storminess and wave overtopping, but there are uncertainties over the scale and timing of these risks. Northern Ireland: It is not known what the current or future level of risk to coastal communities in Northern Ireland is.

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	The Coast Protection Act 1949, Land Drainage Act 1991, Flood Risk Regulations 2009 and the Flood and Water Management Act 2010 provide the primary legal framework for flood and coastal erosion risk management in England and Wales. Local plans may also include some consideration of

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	climate change (see above). In Scotland, the Flood Risk Management (Scotland) Act 2009 and the Coast Protection Act (1949) provide the primary legal framework for flood and coastal erosion risk management. Planning policy in each country aims to limit new development in areas that are undergoing coastal erosion. Shoreline Management Plans (SMPs) are non-statutory documents that indicate how local authorities and other bodies can plan and implement coastal management such as "hold the line", "no active intervention" and "managed realignment" strategies. SMPs exist for coastal areas in England and Wales. Where appropriate (e.g. in Ayrshire) similar arrangements exist in Scotland, and Northern Ireland does not currently implement SMPs. SMPs consider several epochs between now and the end of this century and cover coastal communities and coastal economic and natural assets. As with other policies on coastal management however, these plans do not consider the risks and impacts of loss of existing coastal communities and what measures should be taken to manage this change. Other organisations such as the National Trust have done similar pieces of work for their own assets.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Research priority** There is a need to assess across the need for long-term plans – in addition to planning policies and shoreline management plan - for coastal communities that are at risk of being lost as a result of sea level rise.
Confidence	Medium

PB7: Risks to building fabric from moisture, wind and driving rain

Step 1: What is the current and future level of risk or opportunity?
Building fabric can be damaged following a flood through moisture penetration and the deposition of salts and sediments, as well as subsequent damp and mould growth. Moist atmospheric conditions can also affect the fabric of buildings. During warmer spring and autumn weather, the moisture removal capacity of outdoor air may be reduced, meaning additional ventilation may be required to adequately remove moisture produced inside a building. Reverse condensation, or interstitial condensation, may occur in spring and autumn seasons, when damp walls are heated by solar radiation to the extent that moisture can migrate towards the cooler interior of the building where it may lead to interstitial condensation. In many locations across the UK, particularly in coastal areas, buildings may be exposed to driving rain. The installation of full-fill cavity wall insulation in locations with wind-driven rain can lead to damp, as the insulation retains water that penetrates the façade, and can bridge moisture into the inner walls. There have been no population-wide studies that link the prevalence of mould in buildings to flooding or other climate change risks. The percentage of homes with damp and mould problems in England has decreased from 10% of dwellings in 2003 to 5% in 2011 (which with a total dwelling stock of 23 million equates to about 1.1 million homes (high magnitude, high confidence). The Scottish House Condition Survey (2014) states that around 67,000 (2.8%) homes suffer from penetrating damp and 226,000 (9.3%) from condensation, but trends are not available. There are no projections of damage caused by damp/mould, driving rain and wind in the future (unknown magnitude, low confidence).

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Unknown
Justification	Policy mechanisms are in place to combat building fabric issues such as damp and mould. For example, Part C of the Building Regulations for England and Wales covers resistance to moisture. As yet, however, there are no published studies that assess the effectiveness of these regulations or other policies and actions in protecting buildings against damp, mould, wind and driving rain. There are also no national level data in the UK about the current and necessary future level of adaptation of buildings to damp, mould, wind and driving rain.
Confidence	Low

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes – further research is needed to better understand the degree of risk and whether additional action is needed.
Type of benefit	**Research priority** Further research is needed to understand the following: • The degree of current and future risk of different types of buildings or buildings in different areas to driving rain, mould, and damp. • What adaptations are taking place at a national level, and how widespread these are.
Confidence	Low

PB8: Risks to culturally valued structures and the wider historic environment

Step 1: What is the current and future level of risk or opportunity?
Climate change is likely to affect culturally-valued buildings and their immediate surroundings, such as parks and gardens, from the effects of extreme events (flooding, erosion or land instability, wind storms) and longer-term, chronic damage to a building's materials. Although some strategic planning, risk assessment work, case and scoping studies have been done, and there is some understanding of how climate change might affect historic building materials, there is little or no systematically collected quantitative information on the level of current and future risk for the UK's historic buildings and their surroundings, or historic urban greenspaces and gardens. Many listed buildings are in private hands. There is therefore no national-level estimate of what risks these buildings are under from climate change (unknown magnitude, low confidence).

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	Although the risks to historic buildings and gardens are not quantified at the national scale, there are plenty of case study examples which show that there are impacts from extreme weather now, and these are likely to increase in the future (see chapter 5 text for examples).

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	Work is in progress to better understand risks and adaptation options (including weather proofing and additional flood protection). High level policy goals and strategies have been published in the past, for example by Historic England. Some estimates of the scale of buildings under threat have been made; e.g. based on coarse modelling, 5,000 listed buildings, 300 scheduled ancient monuments and 12,000 other archaeological sites are thought to be located in areas at risk from flooding in Wales. There are thought to be around 800 listed buildings at risk from flooding in Scotland. Historic buildings are also included in other policy documents, such as surface water management plans. However, the scale of uptake of adaptation measures is unknown. Many listed buildings are also in private hands. There is no estimate therefore of what risks these buildings face from climate change or how owners view adaptation.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Possibly, but difficult to ascertain this without further evidence on the scale of current/future risk and adaptation underway.
Type of benefit	**Research priority** Measures should be put in place in each of the four UK countries to better quantify the current and future risks to the historic built environment from climate change, and assess appropriate measures to put in place.
Confidence	Medium

PB9: Risks to health and social care delivery from extreme weather

Step 1: What is the current and future level of risk or opportunity?
Current Floods, storms, snow, cold weather and hot weather/ heatwaves affect health system infrastructure and service delivery through effects on staff, buildings and equipment. Heatwaves cause problems with the functionality of hospitals as well as the thermal comfort of patients and staff. Overheating in hospitals and associated negative impacts for example were reported during the 2003 heatwave in England. Research indicates that older designs are at less risk of overheating than more modern buildings. The risk of heat-related mortality is larger in care homes

Step 1: What is the current and future level of risk or opportunity?
than in the general population, even after accounting for the differences in underlying health of the occupants. Qualitative studies suggest that problems may occur associated with poorly adapted equipment, structural design and care practices. Damage to healthcare infrastructure has been reported in recent flood events (e.g. the loss of regional blood centre in Southwest England in 2007). There have been incidents of hospital flooding in the 2015/16 winter floods, with impacts on non-urgent care. In England, there are currently 166 hospitals and 1,163 care homes that are located in areas at a 1-in-200 or greater chance of flooding in any given year (low magnitude, low confidence). In Wales, there are currently 10 hospitals and 45 care homes that are located in areas at a 1-in-200 chance of flooding or greater in any given year (low magnitude, low confidence). In Northern Ireland, no hospitals are currently located in areas at 1:200 or higher risk of flooding. There are 19 emergency service stations, 37 GP surgeries and 16 care homes that are located in areas at a 1-in-200 chance of flooding or greater in any given year (low magnitude, low confidence). In Scotland, between 0 -2 hospitals are located in areas at 1:200 or higher risk of flooding, and there are 84 emergency service stations, 10 GP surgeries and 53 care homes located in areas at a 1-in-200 chance of flooding or greater in any given year (low magnitude, low confidence). Percentage estimates are also available in Chapter 5. Cold spells and snow storms are very disruptive due to staff not being able to travel to work (e.g. winter 2010-11). Cold weather can also affect healthcare infrastructure and increase demand on health services (see examples in chapter text). Future Future projections indicate an increase in number of GP surgeries, care homes, emergency service stations and hospitals in the flood risk zone, with the largest change in risk generally shown for care homes (medium magnitude, low confidence). By the 2050s under a 4 degree scenario, the number of hospitals in England located in areas at 1 in 200 annual chance of flooding or greater increases to 187 - 200 and the number of care homes increases to between 1,338 – 1,454. Under a 4 degree scenario in the 2050s, the number of assets in Northern Ireland located in areas at 1 in 200 annual chance of flooding or greater increases to 23 - 24 for emergency service stations, 40 for GP surgeries and 18 - 19 for care homes, with no hospitals at risk. By the 2050s under a 4 degree scenario, the numbers of hospitals in Wales located in areas at a 1-in-200 annual chance or greater increases to 13 - 14 and the number of care homes increases to 62 – 64. Under a 4 degree scenario by 2050, the numbers of Scottish assets located in areas at 1-in-200 annual chance of flooding or greater increases to 105-107 for emergency service stations, 12-13 for GP surgeries and 64-66 for care homes. The projections above assume no population growth, and the ranges are across the different adaptation scenarios considered in the CCRA. Future projections of risk are not available for other hazards.

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	There are policy frameworks in place to improve the consideration of climate risks by the healthcare sector. For example, in England various reporting and guidance arrangements are in place to assess the resilience of health and social care assets to extreme weather. The Health and Care System Adaptation Report 2015 was requested by Government under the Adaptation Reporting Power (ARP) and was produced by a cross system working group (DH, NHS England and Public Health England). The Sustainable Development strategy for Scotland (2012) requires each NHS Scotland body to produce a sustainable development action plan. Each of the health boards in Scotland is in the process of producing climate change plans. In Northern Ireland, the Health and Social Care Trusts' Business Continuity Management plans would deal with any consequence management of severe weather. DHSSPS (now DoH) also provide guidance for caring for patients during heatwave events. However, there is some evidence of inconsistencies in terms of planning for extreme weather in the health and social care sector, that suggest a continuation of current levels of action would not manage the drivers of vulnerability and exposure to the risks. For example: • Although the NHS standard contract requires providers to demonstrate progress towards climate change adaptation in England, fewer than 20% of Clinical Commissioning Groups that responded to a survey said that they have local plans in place to address risks from severe weather or future climate change. • It has been observed that the continuing trend towards greater levels of personalisation, devolution and fragmentation of health and social care are creating a more complex web of responsibilities for preparedness and response to climate related risks. • The risks of access to patients by healthcare professionals may also change in the future as home-based care becomes more common. Impacts from extreme weather on transport networks may become more important. • Problems of organisational management and communication between different groups of health and social care personnel may make response to severe weather events less efficient. Although individual service providers may be familiar with severe weather plans and protocols, problems of communication between personnel in different parts of the health and social care system can present a difficulty in implementing severe weather plans efficiently. Low-energy and relatively low cost options are available to adapt existing hospitals and design new buildings for improved thermal comfort and operational resilience during heatwaves. However, current government

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	policy does not place responsibility on the relevant agencies to address overheating in hospitals and care homes.
Confidence	Low

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**More action needed (England)** Policies are needed to reduce vulnerability now. Those Clinical Commissioning Groups that do not currently have severe weather plans linked to their Sustainable Development Management Plans (SDMPs) need to put them in place and monitor impacts on infrastructure and patients. The potential for cost-effective adaptation to overheating in healthcare facilities is thought to be high. Low-energy and relatively low cost options are available to adapt existing hospitals and design new buildings for improved thermal comfort and operational resilience during heatwaves. Plans are also needed that consider how the future move towards home-based care alters the risks to patients and healthcare delivery from extreme weather. This work is needed now to create the right conditions for future care models to be flexible and resilient to shocks from extreme weather. **Research priority (Northern Ireland, Scotland, Wales)** More evidence is needed to assess how current plans in the devolved administrations relate to the current and future level of risk. The potential for cost-effective adaptation to overheating in healthcare facilities is thought to be high, but the risk in Northern Ireland, Scotland and Wales is currently unknown. Plans might also be needed that consider how a greater reliance on home-based care may alter the risks to patients and healthcare delivery from extreme weather.
Confidence	Medium

PB10: Risks to health from changes in air quality

Step 1: What is the current and future level of risk or opportunity?
Current Determinants of outdoor air quality include levels of ground-level ozone, NOx, particulates (PM10, PM2.5), and aeroallergens (mould and pollen). At present, between 6 and 9 million people across the UK suffer from chronic respiratory conditions (asthma and chronic obstructive pulmonary disease) that make them especially vulnerable to air pollution (high magnitude, high confidence). The increased proportion of diesel-fuelled traffic in the UK, and the failure of Euro emission standards for diesel cars to deliver the expected emission reductions of NOx, have resulted in difficulties meeting EU air quality limit values for nitrogen dioxide (NO2), prompting infraction proceedings by the European Commission against the UK. Climate-sensitive air pollutants include ground level ozone, PM2.5, NOx and aeroallergens such as pollen. There is sufficient evidence that short-term exposure to ground-level ozone increases mortality, respiratory hospital admissions and, acknowledging more uncertainty, cardiovascular hospital admissions. Although higher ambient temperature can lead to increased ozone concentrations, studies have concluded that future changes in emissions are a more important driver of future ozone concentrations than changes in the climate. Higher temperatures may trigger regional feedbacks during stagnation episodes (still weather) that will increase peak ground level ozone, but these effects are not as important a driver of future concentrations as future emissions. Average ozone levels over Europe are expected to decrease generally in future in conjunction with lower emissions of ozone pre-cursors; except in one scenario where high methane emissions offset this increase. In polluted areas with high nitrogen oxides levels, warming is likely to trigger feedbacks in local chemistry and emissions, increasing levels of ozone. Recent studies have suggested that the occurrence and persistence of future atmospheric stagnation events in mid latitudes which influence air pollution levels, may increase due to climate change, but these effects are very uncertain. The effects of weather and climate variability have been studied for pollen, but not for all species. Higher temperatures, the presence of high concentrations of carbon dioxide, different patterns of rainfall and humidity may be associated with extended growing seasons. Between 1970 and 1999, the onset of the birch pollen season in London has occurred earlier by 4 days per 10 years. The impacts of climate change on future pollen-related disease include changes to length of pollen season, pollen abundance, and changes in allergenicity. There is a very complex relationship between pollen abundance and seasonality and climate factors, and this also varies by pollen species. Some thunderstorms have been associated with increased hospital admittances for asthma exacerbations ("thunderstorm asthma") with the suspected cause the production of NOx. Projections of future changes in thunderstorm activity are very uncertain. Future The overall impact from climate change on air quality is uncertain, so it is not possible to determine the magnitude of the future risk (unknown magnitude, low confidence).

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Unknown
Justification	The need for action to reduce the impacts of climate change alone on air pollution is unclear. There is an obvious need to put in place measures to reduce the effects of emissions on air pollution. Current policies are not currently sufficient to control current air quality levels to within EU guided limits, but the justification for further action in the future due to climate change is uncertain.
Confidence	Low

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Research priority** Research is needed to assess how changes to climate other than increasing temperatures, such as changing wind patterns and blocking episodes, could impact on air pollution levels. Long-term data on the number of children and adults living with chronic respiratory conditions would also be valuable.
Confidence	High

PB11: Risks to health from vector-borne pathogens

Step 1: What is the current and future level of risk or opportunity?
This risk relates to the incidence of Lyme disease (the only vector-borne disease affecting people that is established in UK), and the introduction of new vector-borne diseases (such as West Nile fever, dengue, chikungunya and Zika). Climate extremes are known to have major effects on host-pathogen interactions in a variety of ecosystems. For example, the 1976 heat-wave, and 1976-1977 16-month UK drought, led to reduced river flows, ground and surface water. Disease impacts were detectable in animals (including livestock, wildlife and fish) and plants in terrestrial, freshwater and marine ecosystems.

Step 1: What is the current and future level of risk or opportunity?
Quantitative predictions of the impact of climate change are uncertain, but it is likely that the range, activity and vector potential of many ticks and mosquitoes will increase across the UK up to the 2080s. Higher temperatures in the future will increase the suitability of the UK's climate for invasive mosquito species, such as Aedes albopictus (an important vector of dengue, chikungunya and Zika). Projections for 2080s, under a variety of emission scenarios, only indicate a small risk of malaria transmission in the UK. Tick species that transmit Lyme Disease are currently distributed throughout the UK. The Ixodes ricinus ticks are mostly encountered in the countryside, but are also present in urban parks. Lyme disease may shift in altitude and incidence in the UK in response to climate change. However, future trends in agriculture, land use, wild animal populations and tourism will play as large or a larger role as climate in determining future patterns of the disease. The future magnitude of impact is uncertain, but as the current magnitude is thought to be high and the published evidence suggests that the risk will increase, expert judgement is that the future risk will also be high magnitude. This risk has low confidence.

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Unknown
Justification	Once a vector such as a species of mosquito or tick establishes itself, it is very difficult to eradicate, so the most important strategies for managing this risk relate to early warning systems and surveillance. Surveillance and monitoring activities are underway in all four UK countries, but it is not known how effective these are at controlling emerging vectors and the extent to which the programmes are able to prioritise funding for surveillance of vectors and pathogens that pose the biggest risk from climate change. England Surveillance activities are in place for ticks, and endemic and invasive mosquitoes. Public Health England is developing its capability to model and predict potential future changes in infection incidence related to climate change for some diseases. PHE is also involved in a global horizon scanning programme to identify emerging infectious disease outbreaks and their potential threat to the UK. Invasive species policies do not currently consider human health. For example, the risk of invasion of the Asian Hornet has only been highlighted due to impact on bee health but may also impact on human health. Thus, at present the contingency plan for introduction of Asian hornet is likely to fail to address any health issues.

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	Wales The Public Health Wales Communicable Disease Surveillance Centre (CDSC) exists to monitor the incidence of disease vectors and pathogens. Scotland Health Protection Scotland (HPS) is the Scottish National Surveillance centre for communicable diseases, and has responsibility for pathogen surveillance. Northern Ireland The Health Protection Service within the Northern Ireland Public Health Agency (PHA) has the lead role in protecting the population from infection and undertakes surveillance and monitoring of pathogens.
Confidence	Low

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Research priority** There are likely to be benefits from improved monitoring and surveillance of emerging infections. Better understanding is needed of the eco-epidemiological drivers that determine the distribution of the UK's existing arthropod vectors and the pathogens that they might carry at finer spatial scales than is possible from current studies. Improved knowledge of which vectors transmit which pathogens is also required. Better ongoing surveillance for the importation of exotic arthropod vectors and pathogens would also be beneficial. Field-based research could be conducted to understand the impact of environmental change and climate change adaptation strategies on disease vectors.
Confidence	High

PB12: Risk of food borne disease cases and outbreaks

Step 1: What is the current and future level of risk or opportunity?
Current Salmonellosis incidence is sensitive to temperature; incidence increases by 10% per degree increase in temp above 6°C. However, salmonella incidence is declining due to improvements in control measures. Across England and Wales, there were around about 7,500 cases of salmonellosis recorded in 2013, down from just over 14,000 in 2004. Infection with campylobacter is now the most important source of food borne disease in the UK. In 2012, there were 65,000 reported cases of campylobacter infection across England and Wales, the highest total level of infection since 2000. Campylobacter shows a strong seasonal pattern but the reasons for the spring increase in infections are not well understood. Several epidemiological studies have reported a positive association with temperature but the relationship is non-linear. An association with rainfall has also been reported although not in studies from the UK. The magnitude of the current risk is low (high confidence). Future There are a large number of pathways through which climate change may affect food borne disease and contamination. Only a few of these pathways have been investigated. Modelled studies project an increase in the risk of salmonella but these studies do not take into account that the overall number of cases are currently declining. Overall, there are limited grounds for assuming that an increase in average temperatures would tend increase the transmission of campylobacter. On the basis of this evidence, the magnitude of the future level of risk is low (low confidence).

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	No
Justification	The future level of risk is currently projected to be low, and therefore it is thought unlikely that there would be a significant adaptation shortfall.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	No
Type of benefit	**Watching brief** The relatively high level of regulation regarding food safety from farm to fork provides the UK with a high level of capacity to adapt climate change. As climate change moves the climate into unknown territory this could make current regulations and food monitoring inadequate to deal with future threats, such as emerging disease. Thus, activities such as horizon scanning and ongoing monitoring are needed. Early warning systems or food risk detection systems may also play an important role in mitigating and adapting to climate change induced food threats. See also risk It2 (imported food safety risks).
Confidence	Medium

PB13: Risks to health from poor water quality

Step 1: What is the current and future level of risk or opportunity?
Current There is limited evidence regarding the association between gastro-intestinal pathogens and rainfall. In the UK outbreaks of cryptosporidiosis have been linked to heavy rainfall affecting public drinking water supplies. There has been an expansion of the geographical ranges of some harmful warmer water phytoplankton species into higher latitudes. The transmission of marine pathogens (through sea water and shellfish) is also sensitive to higher sea surface temperatures. Evidence is very limited for the UK, although there is evidence from the Baltic Sea. The current level of magnitude of the risk is unknown, and it therefore has low confidence. Future We do not currently have any evidence related to the future risks from gastro-intestinal pathogens in drinking water related to climate change. Increasing sea temperatures around the UK may result in an increase in marine vibrio infections. However, the public health implications of this are not clear, that is, whether it would lead to a detectable increase in human disease. The level of magnitude is unknown and this risk therefore has low confidence.

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	No
Justification	Policies are in place to deal with future health issues arising from risks to water quality. In England for example, current water quality is monitored by the EA according to national and international standards. There is a lack of evidence suggesting that these standards need to be improved. CEFAS have also developed an early warning and forecasting tool for Vibrio.
Confidence	Low

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	No – there is insufficient evidence to suggest that further action over and above what is already happening is needed in the next 5 years.
Type of benefit	**Sustain current action** Policies and mechanisms are in place to deal with future risks to water quality in public supplies. There may be a lack of action with respect to private water supplies, but these represent a fairly small percentage of the total supply.
Confidence	Medium

PB14: Risk of household water supply interruptions

Step 1: What is the current and future level of risk or opportunity?
Current The UK has experienced repeated periods of low precipitation. Some of these have lasted longer than anything experienced recently (e.g.mid 1880s to early 1900s). The most severe and widespread drought conditions in the UK in relatively recent times were those peaking in 1976 where nationally rainfall was 59% of the 1981 – 2010 average. There was also a period of low rainfall beginning in 1995 which put public water supplies at risk in some areas. The most obvious community-level manifestation of drought is periodic hosepipe bans that tend to affect mostly Southern, South Eastern England and the Midlands. Less frequently there are restrictions on the industrial and agricultural use of water that temporarily effects employment. Even more rarely there are restrictions on domestic supplies that can affect health and wellbeing, but standpipes have not been used in response to a drought since 1976. A range of health issues arise when tankers, standpipes and/or bowsers are used. The current magnitude of risk annually is unknown and this risk therefore has low confidence. There is

Step 1: What is the current and future level of risk or opportunity?
also an unknown risk to households connected to private water supplies. Water supply interruptions can also be caused by flooding and cold weather. Over the winter of 2010/11, 450,000 customers in Northern Ireland experienced supply problems due to pipe bursts caused by freeze-thaw conditions. These events are quite rare so it is difficult to provide an estimate of magnitude that is akin to an annual average. Future The future risks to health from droughts are amongst the most difficult to estimate because the science of estimating prolonged and extensive low rainfall patterns is insufficiently advanced. As temperatures rise this may dry the ground and create conditions in which droughts become more likely. Analysis of H++ scenarios for the CCRA looking at the upper end of the impacts that might be expected suggests that 6 month long droughts in summer might be more frequent with rainfall deficits of up to 60% of current averages. Medium term multi-annual droughts of up to 18 month duration may become more common. Longer term droughts, similar to those in the historical record, remain possible (unknown magnitude, low confidence). The probability of cold events that cause problems with water supply is likely to decline in the long-term as winters become warmer.

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Possibly
Justification	Water utility companies are mandated to account for drought in their water resource management plans. When droughts occur, emergency powers can be used to restrict water supplies and advice is issued to reduce consumption (e.g. hosepipe bans, requests to water gardens with water that has already been used). Plans to avoid health and wellbeing impacts ensure that vulnerable individuals who need access to plentiful water are not adversely affected (e.g. dialysis patients or those with high laundry requirements). However, a community's ability to cope with severe droughts where standpipes need to be used is not well-researched in the UK as it is such a rare event. Water companies also have to ensure that pipe leakages are managed to a sustainable economic level. Following the 2010/11 incident, Northern Ireland Water also took various steps to improve security of supply and communication with customers on pipe bursts. Its future distributional input estimates, which include the amount of water lost to leakage, have decreased from 583.91Ml/d to 564.47Ml/d over the last 3 years.
Confidence	Low

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Sustain current action** Policy levers are in place to deal with the public health implications to security of water supplies from droughts and cold weather. Continued testing and implementation of measures to maintain security of supply remains important to allow for adaptation if the risk increases in the future.
Confidence	Low

Chapter 6 - Business and industry

Urgency scores for business and industry					
Risk descriptor	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
Bu1: Risks to business sites from flooding (6.2.2, 6.2.3)	England	Northern Ireland, Scotland, Wales			More effort is needed in England to address flood risks and inform businesses of their current and future exposure and what steps they might take to limit impacts. More research needed elsewhere in the UK to understand uptake of flood protection measures by businesses and how spending plans on defences and other measures may or may not protect individual businesses.
Bu2: Risks to business from loss of coastal locations and infrastructure (6.2.2, 6.2.3)		UK			More research needed on costs and benefits of adaptation options for different coastal areas.
Bu3: Risks to business operations from water scarcity (6.2.4, 6.2.5) NB: Also see related infrastructure risk In9.			UK		Sustain current actions to create more flexible abstraction regimes and promote water efficiency among businesses.
Bu4: Risks to business from reduced access to capital (6.3)				UK	Monitor and research action by regulators, banks and insurance firms, and information disclosures by UK companies.
Bu5: Risks to business from reduced employee		UK			More research needed on disruption to ICT, power and transport infrastructure which prevents workers accessing

Urgency scores for business and industry					
Risk descriptor	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
productivity, due to infrastructure disruption and higher temperatures in working environments (6.4.2, 6.4.3, 6.4.4, 6.4.5)					premises or working remotely, and on impacts of higher temperatures on employee safety and productivity.
Bu6: Risks to business from disruption to supply chains and distribution networks (6.5) NB: Also see related international risks It1 and It3.			UK		Sustain and monitor the uptake of existing guidance which helps businesses improve the resilience of supply chains and distribution networks, particularly at the international level.
Bu7: Risks and opportunities for business from changes in demand for goods and services (6.6)				UK	Monitor sales of adaptation goods and services within the UK, and by UK companies.

Bu1: Risks to business sites from flooding

Step 1: What is the current and future level of risk or opportunity?
Current and future risk UK: Flooding poses a significant risk to business sites, both in terms of damage to assets and in preventing employees from being able to access work premises. Recent analysis found the number of non-residential properties at risk of flooding (1:1000 year or less) is approximately 1.1 million. Of these the number at risk of significant flooding, which is defined as flooding more frequent than 1:75 (a 1 in 75 or greater chance of flooding in any given year) is 420,000. Based only on the direct impacts of flooding, expected annual damages to non-residential properties are £800 million. Based on current levels of adaptation, the risk posed by flooding to businesses is projected to increase in the future. The size of the increase depends mostly on the level of climate change (2°C, 4°C), and to a lesser extent population growth. By the 2050s, the number of non-residential properties in the UK at risk of significant flooding is projected to increase between 16% and 42%. Expected annual damages are projected to increase between 26% and 69%, equivalent to a £200 million to £550 million increase. [Scenario: 2°C or 4°C , not including population growth and assuming the continuation of current levels of adaptation] For individual UK countries: England: For the present day, approximately 960,000 non-residential properties are at any degree of risk (1:1000 year or less) of flooding in England. Of these, 360,000 are at risk of significant (1:75 year or less) flooding. The direct impacts of flooding result in expected annual damages to non-residential properties of £590 million. Floods in 2007 were estimated to cost businesses in England £740 million in clean-up costs and lost business. Between 7,000 and 8,000 commercial buildings were estimated to have been affected. On average, it took affected businesses 26 weeks to return to full capacity, with some businesses closing down permanently. More recently, the floods in the winter of 2013/14 were estimated to cost small businesses £831 million. By the 2050s, the number of non-residential properties at risk of significant flooding in England is projected to increase between 16% and 43%. Expected annual damages are projected to increase between 26% and 68%, equivalent to a £150 million to £400 million increase. [Scenario: 2°C or 4°C , not including population growth and assuming the continuation of current levels of adaptation] By the 2080s, the number of non-residential properties at risk of significant flooding in England is projected to increase between 31% and 71%. Expected annual damages are projected to increase between 49% and 130%, equivalent to a £300 million to £750 million increase. [Scenario: 2°C or 4°C , not including population growth and assuming the continuation of current levels of adaptation] (High magnitude, Medium confidence) Northern Ireland: Present day estimates suggest approximately 15,000 non-residential properties in Northern Ireland are at risk of flooding (1 in 1000 year or less). Of these, 7,000 are at risk of significant (1 in 75 annual chance or greater) flooding. The direct impacts of flooding result in expected annual damages to non-residential properties of £19 million.

Step 1: What is the current and future level of risk or opportunity?
By the 2050s the number of non-residential properties in Northern Ireland at risk of significant flooding is projected to increase between 37% and 58%. Expected annual damages are projected to increase between 36% and 62%, equivalent to a £7 million to £12 million increase. [Scenario: 2°C or 4°C , not including population growth and assuming the continuation of current levels of adaptation] By the 2080s the number of non-residential properties in Northern Ireland at risk of significant flooding is projected to increase between 45% and 92%. Expected annual damages are projected to increase between 63% and 140%, equivalent to a £12 million to £27 million increase. [Scenario: 2°C or 4°C , not including population growth and assuming the continuation of current levels of adaptation] (Medium magnitude, Medium confidence) Scotland: For the present day, approximately 42,000 non-residential properties in Scotland are at risk of flooding (1:1000 year or less). Of these, 25,000 are at risk of significant (1:75 year or less) flooding. The direct impacts of flooding result in expected annual damages to non-residential properties of £120 million. Analysis by the SEPA (2016) finds that for the period 2016 to 2021, approximately 29,000 non-residential properties are at risk of flooding. Annual average damages from all sources of flooding (coastal, fluvial and pluvial) for this period are estimated to be £91 million. By the 2050s, the number of non-residential properties at risk of significant flooding in Scotland is projected to increase between 9% and 21%. Expected annual damages are projected to increase between 19% and 60%, equivalent to a £23 million to £72 million increase. [Scenario: 2°C or 4°C , not including population growth and assuming the continuation of current levels of adaptation] By the 2080s, the number of non-residential properties at risk of significant flooding in Scotland is projected to increase between 17% and 38%. Expected annual damages are projected to increase between 40% and 120%, equivalent to a £50 million to £150 million increase. [Scenario: 2°C or 4°C , not including population growth and assuming the continuation of current levels of adaptation] (High magnitude, Medium confidence) Wales: For the present day, approximately 86,000 non-residential properties in Wales are at risk of flooding (1:1000 year or less). Of these, 34,000 are at risk of significant (1:75 year or less) flooding. The direct impacts of flooding result in expected annual damages to non-residential properties of £59 million. Total damages to businesses in Wales from the 2013/14 winter flooding were estimated to be £3.4 – 4.6 million. Forty-six businesses in Wales were estimated to have been affected. By the 2050s the number of non-residential properties in Wales at risk of significant flooding is projected to increase between 19% and 50%. Expected annual damages are projected to increase between 29% and 96%, equivalent to a £17 million to £57 million increase. [Scenario: 2°C or 4°C , not including population growth and assuming the continuation of current levels of adaptation] By the 2080s the number of non-residential properties in Wales at risk of significant flooding is projected to increase between 34% and 73%. Expected annual damages are projected to increase between 55% and 200%, equivalent to a £32million to £118 million increase. [Scenario: 2°C or 4°C , not including population growth and assuming the continuation of current levels of adaptation] (Medium magnitude, Medium confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	UK: The level of flood protection that national governments will be able to justify to the taxpayer may fall short of business needs in some areas. The incentive for governments to prevent flood damage to individual businesses is also limited, as economic activity tends to be displaced or postponed during a flood rather than lost altogether. Business continuity plans support businesses to prepare, respond and recover from a flood event. The proportion of private sector organisations reporting that they have a business continuity plan in place in the UK rose from 42% in 2008 to 58% in 2013. Extreme weather events such as flooding are consistently the main reason for businesses activating these plans. Around four-fifths of businesses with continuity plans in place report that the benefits of having a plan exceed the costs of producing one. This suggests business continuity plans are a cost-effective adaptation measure. Despite the benefits identified, the uptake of business continuity plans remains relatively low, particularly among micro businesses and businesses in the construction sector. Only 25% of businesses with fewer than 10 employees have a resilience plan in place that specifically includes severe weather. Uptake of commercial flood insurance is extremely high. The vast majority (95%) of small businesses arrange commercial insurance cover for their premises, and almost all of these (97%) did not experience difficulty in securing this insurance. A significant price rise to the extent it becomes unaffordable was the only circumstance in which some thought they might stop getting insurance. Awareness of flood risk, and the potential impact of flooding for businesses, appears to be limited. Even among those who are aware of their flood risk status, it is rare for this to cause problems in getting insurance. The businesses interviewed that were at risk of flooding had not installed flood protection measures in response to this status. Based on an online survey of 1,200 small business members, 9% in flood risk areas reported difficulties accessing flood insurance and 6% reported that they have been refused cover. This equates to around 75,000 smaller businesses across the UK facing difficulties in finding affordable insurance and 50,000 being refused. Therefore access to flood insurance for small businesses appears to be an issue at only the margins currently, but there is the potential for this issue to affect a higher proportion of businesses due to future climate change. England: The Environment Agency's Long Term Investment Scenarios (LTIS) for flood and coastal erosion risk management estimate that the optimal investment profile in the first 10 years (to 2024) is around £750 to £800 million a year in

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	present day costs. They expect this to rise from the 2020s to the 2040s to £850 to £900 million a year, although this could be influenced by the choice of different risk management approaches. This is estimated to be sufficient to reduce total expected annual flood damage by 12% by the 2060s. However, there are expected to be 3,000 more non-residential properties in areas at a 1-in-30 or greater annual chance of flooding in the 2060s than there are now, even if all worthwhile community flood defences are built and all existing flood defence assets are optimally maintained and renewed. Sayers et al. present a separate analysis based on assumptions about the uptake of a series of different adaptation measures at the national level. The Enhanced Whole Systems adaptation scenario is broadly in line with the assumptions and level of adaptation implied by the LTIS optimal scenario. The Sayers results suggest that under this best case 'enhanced whole system' adaptation scenario there might be a small net reduction (£25 million) in EAD under a 2°C scenario (low population growth) or no net increase with high population growth. EAD increases by £220-250 million under a 4°C scenario by the 2080s at the UK level depending on the population growth scenario (high magnitude, medium confidence). Whilst there are plans to invest at the levels broadly consistent with the LTIS optimal scenario between 2015 and 2021, as yet there is no wider strategy that aims to reduce the residual risk of flooding that the LTIS suggests will remain by mid-century even if all worthwhile flood defence projects are funded. For businesses, there is also the option of supporting local flood defence and risk management schemes - for example through public-private partnerships such as the Humber Estuary Local Enterprise partnership. Between April 2011 and March 2015, £134m of partnership funding contributions were provided towards new flood and coastal erosion management schemes, compared with £13m in the previous four years. Defra expect that the 6-year investment programme could attract over £600m of contributions in total, of which £270m has already been secured, and potential funding contributions to cover the remaining £330m have been identified. Of the £270m secured contributions £61m is from private sources (including private businesses and companies); £89m is from Local Enterprise Partnerships and other public bodies, for example local councils, highway authorities (over and above the Local levy); and £120m is from the local levy. Flood warnings provide information to businesses ahead of a potential flood event. These allow decisions to be taken on moving stock, employees and other assets to reduce damages and disruption. The number of businesses actively registered for the Environment Agency's free Flood Warnings Direct (FWD) scheme has increased from about 25,000 in 2007 to 51,000 in 2015. However, analysis by the ASC in 2014 suggested less than one-fifth of businesses in areas at high risk of flooding had actively opted-in to receive the full FWD service (ASC, 2014). Given that the FSB (2015) finds that 78% of small businesses in flood risk areas are aware of the Flood Warnings Service offered by the Environment Agency or the devolved agencies of Scotland,

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	Wales and Northern Ireland, it suggests that awareness of the service is not the issue but perhaps awareness of the relative risk. In response to the Pitt Review, the Environment Agency launched the Extended Direct Warnings (EDW) service, which automatically registers all fixed-line telephone numbers identified as within flood risk areas. The service provided through the EDW is less comprehensive than the FWD, but should ensure most businesses receive at least a basic warning ahead of potential flood events. Permeable paving used in hard surfacing around business premises can improve drainage and reduce the risk of surface water flooding. While the use of permeable paving within the commercial sector has increased in recent years, it remains a relatively small part of total paving activity in England. Impermeable paving remains the dominant paving type in commercial projects, with 86% of block paving supplied for commercial sector projects in 2013 in England being impermeable. Northern Ireland: Sustainable Water - A Long-Term Water Strategy for Northern Ireland (2015-2040), published in March 2016, contains a long-term vision to manage flood risk and drainage in a sustainable manner, which will help to address the future risks from climate change. The Strategy also includes the following aims relevant to the vulnerability of business site locations: Ensure a sustainable water sector to support the Regional Development Strategy 2035. Sustainable Drainage Systems (SuDS) are the preferred option for managing surface water in new developments. Sustainable Catchment Management. A holistic integrated approach to rural and urban drainage provision. Improve Flood Resistance and Resilience in High Flood Risk Areas including extending the Homeowner Flood Protection Scheme to non-domestic properties. Provide effective, efficient flood emergency information and communication systems. Provide information and warnings regarding extreme weather events. The Water and Sewerage Services Act (Northern Ireland) 2016 introduces new restrictions to the right to connect surface water drains to the public sewer network. The 2016 Act sets out further grounds for refusal of a connection on the basis that there is suitable alternative means of dealing with the surface water or that such means could reasonably be provided. It makes clear that suitable alternatives include sustainable drainage systems. Scotland: SEPA has produced Flood Risk Management Strategies for 14 Local Planning Districts (LPDs) which aim to help individuals, local communities and businesses to understand their local flood risk and its management. Businesses in Scotland can sign up to Floodline to receive Flood Alerts and

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	Warnings. Over 1,900 businesses have registered. This may be an underestimate since business owners or managers may have signed up to the service as individuals but receive flood warnings specifically for their business premises rather than their own personal properties. SEPA has also developed guidance for businesses on creating flood plans and advice on flood insurance. Research for the UK conducted in 2013 (which included some respondents from Scotland) suggests that the proportion of private sector organisations saying they have a business continuity management (BCM) plan in place increased from 42% to 58% between 2008 and 2013. Other research suggests that in general the smaller the business, the less chance there is that they have a plan in place. Around four-fifths of surveyed businesses report benefits from having a BCM plan in place. Under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 it is a general requirement for new developments with surface water drainage systems discharging to the water environment to have sustainable urban drainage systems in place. Scottish Planning Policy aims to avoid increased surface water flooding through requirements for SuDS and minimising the area of impermeable surface (Scottish Government, 2016). It also states that proposed arrangements for SuDS should be adequate for the development and appropriate long-term maintenance arrangements should be put in place. There is limited evidence to assess whether the proportion of commercial sector projects which have made use of permeable paving, or other surface water flood mitigation measures, is increasing. The Scottish Government commissioned JBA Consulting (2014) to assess the flood risk benefits of property level protection. JBA Consulting concluded that "PLP can be an effective approach to managing flood risk in Scotland" but that "take up has been limited". Wales: In Wales between 2011 and 2016 around £285 million was invested in flood and coastal erosion risk management. It is not known what effect this investment has had on the number of non-residential properties in areas at high risk of flooding across Wales. However, there is evidence of investment in improved flood defences which protect local businesses on a case-by-case basis. One example is the £6.7 million Lower Swansea Vale project which provides protection to 284 businesses and industrial premises employing more than 10,000 people. The project has also implemented other measures such as flood warning, awareness raising and emergency planning within the area. By law, Natural Resources Wales must produce Flood Risk Management Plans, at the River Basin District scale, for the whole of Wales every six years starting from 2015. They also provide a business flood plan template, and report that more than 1,000 communities and individual businesses in Wales now have their own pre-prepared flood plans. The Welsh Government published interim sustainable urban drainage systems (SuDS) standards in 2015. These also include standards for

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	biodiversity and amenity. The Welsh Government is still considering how to progress Schedule 3 of the Flood and Water Management Act 2010, which relates to standards for the design, implementation and maintenance of SuDS. Natural Resource Wales carried out a review of the December 2013 and early January 2014 coastal storms, which concluded that more needed to be done to ensure coastal communities are resilient to future flooding. Natural Resource Wales launched a delivery plan at the beginning of 2015 setting out how recommendations from the review of 2013/14 coastal floods would be taken forward.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**More action needed (England)** More action is needed to ensure that businesses have the right incentives, information and tools to adapt to increasing flood risk. Around four-fifths of businesses with continuity plans in place report that the benefits of having one exceed the costs of producing one, suggesting they are cost-effective to implement. However, the uptake of such plans remains low, particularly among SMEs. Measures such as property-level protection (PLP) and permeable paving would help many businesses reduce vulnerability now. More generally, information and tools for flood risk would affect site decisions and investments, thereby preventing lock-in and helping businesses retain flexibility for an uncertain increase in future flood risk. **Research priority (Northern Ireland, Scotland and Wales)** More research is needed to understand future spending plans and the uptake and impact of flood protection measures in Northern Ireland, Scotland and Wales.
Confidence	Medium

Bu2: Risks to business from loss of coastal locations and infrastructure

Step 1: What is the current and future level of risk or opportunity?
Current and future risk UK: Coastal flooding, erosion, sea level rise and tidal and storm surges can lead to loss of coastal business locations. Coastal flooding is estimated to contribute 24% of total expected annual damages to the UK from flooding, including both residential and non-residential properties. Reliance on maritime logistics and infrastructure can mean that certain sectors, for example, chemical manufacturing and oil and gas, are more exposed to coastal climate change impacts. UK tourist assets can be concentrated in certain coastal locations and therefore susceptible to coastal flooding. Limited coastal defences and industry wide coordination/understanding mean that UK-based tourism is more exposed than the oil, gas and chemical manufacturing industries. England: Coastal flooding is estimated to contribute 30% of total expected annual damages to the England, including both residential and non-residential properties. The number of non-residential properties at risk of coastal erosion is approximately 200 based on 2008 ordnance survey data. Taking into account management strategies as per Shoreline Management Plans, this number decreases to 12. VisitEngland (2015) estimated that in 2014, there were 18 million trips to the seaside on domestic overnight trips in England, 19% of all domestic overnight trips, with spend at £3.9 billion (21% of all spending on domestic overnight trips). There were also 144 million tourism day trips involving a trip to the seaside – or 11% of all day trips – with associated spending of £5.3 billion (12% of all spending on day visits). How much the tourism sector is at risk of coastal climate change has not been quantified. In the future, damages from coastal flooding in England could increase by around 175% by the 2080s from a baseline of £260 million present day. [Scenario: 4°C, not including population growth and assuming a continuation of current levels of adaptation]. (High Magnitude, Low Confidence). (High Magnitude, Low Confidence) Northern Ireland: Coastal flooding is estimated to contribute 8% of total expected annual damages to the Northern Ireland, including both residential and non-residential properties. The current level of risk to the viability of coastal communities and their businesses in Northern Ireland from sea level rise is thought to be low (low magnitude, high confidence), but the future risk is uncertain and could be significant. There is a lack of evidence on the number of non-residential properties, business or tourist assets in Northern Ireland at risk of coastal erosion. In the future, damages from coastal flooding in Northern Ireland could increase by around 60% by the 2080s from a baseline of £2.2 million present day. [Scenario: 4°C, not including population growth and assuming a continuation of current levels of adaptation] (High Magnitude, Low Confidence). (Medium Magnitude, Low Confidence) Scotland: Coastal flooding is estimated to contribute 16% or 21% of total expected annual damages to the Scotland, including both residential and non-residential properties. The current level of risk to the viability of coastal communities and their businesses in Scotland from

Step 1: What is the current and future level of risk or opportunity?
sea level rise is thought to be low (low magnitude, high confidence), but the future risk is uncertain. In the future, damages from coastal flooding in Scotland could increase by around 450% by the 2080s from a baseline of £26 million present day. [Scenario: 4°C, not including population growth and assuming a continuation of current levels of adaptation] (High Magnitude, Low Confidence). (High Magnitude, Low Confidence) Wales: Coastal flooding is estimated to contribute to 34% of total expected annual damages from flooding to Wales for the present day, including both residential and non-residential properties. The current level of risk to the viability of coastal communities and their businesses in Wales from sea level rise is thought to be low (low magnitude, high confidence), but the future risk is uncertain and could be significant. In the future, damages from coastal flooding in Wales could increase by around 300% by the 2080s from a baseline of £28 million present day. [Scenario: 4°C, not including population growth and assuming a continuation of current levels of adaptation] (High Magnitude, Low Confidence). Estimates suggest that, in the short-term (0 to 20yrs), no non-residential properties in Wales are at risk of coastal erosion. This is estimated to increase to 52 in the medium-term (20 to 50 years ahead) and 182 in the long-term (50 to 100 years ahead). This represents less than 0.1% of all non-residential properties in Wales. (Medium Magnitude, Low Confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	Many industrial facilities already have active risk management procedures and a level of existing protection, so autonomous adaptation is more likely. However, businesses in the tourism sector, particularly smaller ones, may be less aware of the risk and less able to protect themselves and will therefore be more exposed. Government commitments and autonomous adaptation discussed under step 2 for Bu1: Risks to business sites from flooding are also relevant here. England: Shoreline Management Plans (SMP) describe how a stretch of shoreline is most likely to be managed to address flooding and/or erosion. However, even when there is an aspiration to build or maintain defences to maintain the position of the shoreline, funding still often has to be secured for this. Defences may only be built or maintained if some or all of their cost is paid for by those who benefit from them. SMPs may or may not account for

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	projected sea level rise or maintain the existing standard of protection, and managed realignment may be subject to available land being identified. Northern Ireland: Shoreline management plans or other policies that assess and plan for changes to coastal locations have not been developed for Northern Ireland. Scotland: There are non-statutory Shoreline Management Plans in place for some locations in Scotland. In some cases management plans have been agreed with local councils to protect places of importance to the tourism industry from flooding and coastal erosion, for example West Sands, St. Andrews. Wales: Shoreline Management Plans (SMPs) are in place for the full length of the Welsh coastlines. SMPs set out coastline management policies (hold the line, no active intervention etc.) to the 2100s and are developed by Coastal Protection Authorities. The SMPs set out the risks to coastal areas from erosion and sea-level rise and indicate how local authorities and other bodies can plan and implement coastal management in terms of holding the line, managed realignment and no active intervention. It is not currently known how progress compares to the level of risk. These plans do not consider the impacts of loss of coastal communities and businesses, and what measures should be taken to manage this change.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Research priority** The possible realignment or retreat of coastal protection structures due to increasing erosion and flood risks may have an impact on businesses located in the affected areas. Research is required to understand the costs and benefits of different adaptation responses to loss of coastal locations for business, and therefore provide the early steps for cost-effective adaptation.
Confidence	Medium

Bu3: Risks to business operations from water scarcity

Step 1: What is the current and future level of risk or opportunity?
Current and future risk Water is used by industry for cooling and heating, washing products, dissolving chemicals, suppressing dust, and also as a direct input to products. Without sufficient water, production in many businesses would have to be reduced or stopped. England: Abstraction by industry, excluding agriculture and energy, is currently estimated to be around 848 billion litres in England in 2014. This represents 9% of total abstractions from all sources except tidal sources. Currently in England, abstraction demand is higher at times of low flows than the available resource once environmental flow requirements are taken into account, in catchments in the east and south, and a small number in the north-west. (low magnitude, medium confidence) In addition to varying by location, current risks of water scarcity also vary by sector; some industrial sectors are more water-intensive than others. WRAP published analysis of freshwater availability and use in the United Kingdom, which suggested that, using the Standard Industrial Classification (SIC) 2007, the manufacturing sector was the biggest abstractor in 2006, being responsible for approximately 45% of direct abstractions in England. The majority of this was accounted for the manufacture of chemicals and chemical products. Under the most extreme upper bound climate and population scenarios for the 2050s and 2080s, demand of more than 150% of the available resource is projected to be present in catchments in the east and south England. In several catchments in the west of England it is projected that at times of low flows, there would be no water available for human use assuming that ecological flow requirements as currently set out would be met (high magnitude, medium confidence). At lower climate and population scenarios, there would be sufficient water for human use in most catchments, with the exceptions being the catchments where demand is already higher at times of low flows than the available resource. Northern Ireland: Estimates suggest that abstractions for general industrial purposes in Northern Ireland account for approximately 6 million m3 per day. Food and drink and mining quarrying are relatively large abstractors of water within Northern Ireland. Please see Box 6.6 in Chapter 6 regarding analysis of water scarcity in Northern Ireland. Scotland: Analysis by HR Wallingford et al. (2015) shows that the current risk of water scarcity for businesses in Scotland is small. The catchments in Scotland with the largest absolute natural available resource (water available for human use once ecological flow requirements are satisfied) during times of low flows are the Rivers Tay and Spey. The catchments in Scotland with the least absolute natural available resource during times of low flows tend to be small, coastal catchments, although there are a few which are larger and more central. Non-domestic consumption of public water supplies was 410 million litres per day in 2014-2015. SEPA analysis identified the chemicals and food and drink manufacturing sectors as the largest industrial users of water in Scotland. Earlier analysis by CJC Consulting suggested that the major water using sectors in Scotland (comprising abstracted water and mains supply) were fish farming, malt whisky distilling and paper manufacturing. Long-term water scarcity lasting more than a few months, such as that experienced in parts of Tayside during 2003-2004 is extremely rare in Scotland. Typically, water scarcity is a short-term issue occurring mostly in summer. In terms of summer rainfall, while there is

Step 1: What is the current and future level of risk or opportunity?
some evidence of a decrease in parts of the north of Scotland by as much as 20%, the SEPA conclude that any changes in summer rainfall have so far not resulted in measurable trends in summer water scarcity. The Scotch Whisky Association commissioned the Scotch Whisky Research Institute to assess climate change risks. Their research noted that low flows in rivers affected a number of sites in recent years and that raised summer temperatures elevated water temperatures making the spirit production less efficient. In the future, projections suggest that under the most extreme upper bound scenarios for the 2050s and 2080s, considering both climate change and population growth, there is a general pattern of a lack of available resource across central Scotland. Only the northern most catchments of Scotland are projected to maintain a high level of water available under all future scenarios. The same research found that enhanced adaptation is most notable in the west where in a number of catchments the difference between a 'No additional action' and 'Current objectives+' scenario may make the difference between a projection of surplus or deficit. SEPA findings suggest that by 2050 the reduction from Q95 flows in some rivers in Scotland would be more than 25% and reduced rainfall and higher temperatures may lead to more than a doubling in the frequency of extreme low flow events from once every 40 years to once every 20 years. Less flow means less dilution of the pollutants that make their way into rivers and, combined with the higher temperature, could likely result in a reduction of water quality. This may mean more intensive treatment may be required for raw water used by businesses. Low flows may also affect where business sites are able to discharge water and may require new approaches and costs, for example use of tankers. Wales: Abstraction by industry, excluding agriculture and energy, is currently estimated to be around 111 billion litres in Wales in 2014. This represents 3% of total abstractions from all sources except tidal sources. Currently in Wales, abstraction demand is lower at times of low flows than the available resource once environmental flow requirements are taken into account in all but once catchment in southern Wales, where demand is slightly higher than the available resource (low magnitude, medium confidence). In addition to varying by location, current risks of water scarcity also vary by sector; some industrial sectors are more water-intensive than others. WRAP published analysis of freshwater availability and use in the United Kingdom, which suggested that, using the Standard Industrial Classification (SIC) 2007, the manufacturing sector was the biggest abstractor in 2006, being responsible for approximately 93% of direct abstractions in Wales. The vast majority of this was accounted for the manufacture of basic metals. Under the most extreme upper bound climate and population scenarios for the 2050s and 2080s, in large parts of Wales it is projected that at times of low flows, there would be no water available for human use assuming that ecological flow requirements as currently set out would be met (high magnitude, medium confidence). At lower climate and population scenarios, there would be sufficient water for human use in all catchments, with generally more water available for use in western Wales compared to eastern Wales.

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	No
Justification	UK: Evidence from the Federation House Commitment (FHC) shows a decrease in water intensity in the food and drink manufacturing sector. The Water use excluding that used in product at FHC sites fell by 16% between 2007 and 2013; and water intensity, measured in m3 per tonne of product, fell by 22% over the same period. 84% of FHC signatories' sites were in England, 2% in Northern Ireland, 10% in Scotland and 4% in Wales. The 'Courtauld 2025' voluntary agreement aims to cut the resource needed to provide food and drink by one-fifth from 2015 to 2025, and will include a specific target for reducing the impact associated with water use in the supply chain. Businesses are taking action to address water scarcity both domestically and in their operations overseas. Some other sectors also monitor their water use. Using self-reported data, the UK industry report for the construction sector shows that mains water use has decreased from 7.7m3 per £100,000 project value in 2004 to 4.4 m3 per £100,000 project value in 2015. However, other sectors have not established targets and do not monitor progress. Therefore there may be scope for further improvements in water efficiency in these sectors. England and Wales: One way of adapting to water scarcity is through reform of the water abstraction licencing regime. The English and Welsh Governments have set out proposals for abstraction reform which will be implemented in the early 2020s. If reforms are successful, measures such as allowing businesses to take water at high flows may mean pressures are less than they otherwise would be. The Environment Agency and Natural Resource Wales will also be able to instigate risk-based reviews to consider changes to abstraction limits. In certain catchments, businesses that use less water may have a competitive advantage and realise benefits through water trading, thereby creating incentives for businesses to invest in becoming more water-efficient. Following the 2014 Water Act, businesses in England will be able to choose their supplier of water and wastewater services from April 2017. Effective competition between suppliers may lead to increases in innovation and incentives for companies to offer water efficiency advice. There is evidence that sectors and businesses are taking steps to become more water efficient. In England, estimated abstractions by industry from all sources except tidal waters decreased from 1,360 billion litres in 2000 to 850 billion litres in 2014. Over the same time period, estimated abstractions by industry in Wales from all sources except tidal waters decreased from 270 billion litres in 2000 to 110 billion litres in 2014. For England, ASC (2015) found that "Both direct abstraction from freshwater sources, and consumption of public water supplies by industry, have fallen by around one-quarter since 2000. This has

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	been driven by a fall in production and improvements in water efficiency.” The Enhanced Capital Allowance Scheme for Water provides tax relief for businesses who purchase equipment and machinery that meets published water saving criteria. Practical support for water efficiency is available from water companies and other sources through water audits, tool kits and on line resources. In addition, the UK Water Partnership aims to foster cross-sector collaboration to address key challenges facing the water sector. Around 90% of non-residential customers in England are metered. Northern Ireland: The Northern Ireland Environment Agency (NIEA) Abstraction and Impoundment Licensing (AIL) team monitor and control water bodies in Northern Ireland. Industries that abstract over 10 cubic metres per day of surface, coastal or groundwater will be required to notify the NIEA, while Abstractions of over 20 cubic metres per day require a licence. The NIEA and AIL undertake periodic reviews of licences and can review licences at any time and can make modifications. Sustainable Water - A Long-Term Water Strategy for Northern Ireland (2015-2040), published in March 2016, includes an action to “manage and review abstraction licences to ensure sustainable water resources are available to meet society’s needs without compromising the environment. This will factor in the cost of future abstraction reductions (e.g. new treatment works or trunk main)”. Northern Ireland Water provides advice to businesses on how they can reduce how much water they use. Scotland: All abstractors have a duty under Regulation 5 of the Controlled Activities Regulations (CARs) to use water efficiently. The CARs were amended in 2011 to include emergency provisions to allow SEPA, in certain circumstances, to amend existing authorisations or issue new authorisations to cope with prolonged periods of dry weather. SEPA identify catchments under pressure from abstraction in River Basin Management Plans and work with appropriate stakeholders to develop site and sector specific solutions. SEPA is also consulting on a national water scarcity plan. All non-domestic customers in Scotland are metered unless it is not practicable to do so. In 2014/15 about 80% of Scottish Water connected non-household properties were metered. There are signs that water is being better managed by some businesses. Non-domestic water consumption in Scotland has fallen from 530 million litres per day in 2002/03 to 410 million litres per day in 2014/15. Resource Efficient Scotland, a free advice and support programme established by Scottish Government, published a guide to improving water efficiency and promote case studies of good practice. The Scotch Whisky industry reported in 2015 that net water use was down 14% from 2008 levels.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	No
Type of benefit	**Sustain current action** All four UK nations are taking action to increase flexibility and address future water scarcity. National-level reforms and strategies were published or consulted on within the last two years. There is also evidence that businesses, particularly in the food and drink industry, are taking steps to reduce their water use. Sustained effort will be needed to ensure that abstraction regimes are sufficiently flexible and that businesses are able to build on their existing progress in becoming more water efficient.
Confidence	Medium

Bu4: Risks to business from reduced access to capital

Step 1: What is the current and future level of risk or opportunity?

Current

In the UK, debt finance is the main source of capital in the private sector and particularly relevant for SMEs. Whilst on the increase, only a small fraction of British companies issue equity as a source of finance. Yet, those that do are firms that have a relatively large share of economic activity. Climate change could have an impact on access to capital through primary channels (exposure of assets to climate hazards and increasing exposure of the insurance industry) or through secondary channels (regulatory change in response to future climate, development of new tools to manage risks, changes in credit ratings and changes in market expectations and investor behaviour).

The supply of capital by UK banks is vulnerable to climate change because of three main factors:

Banks are exposed to vulnerable areas, for example through business with emerging markets, where along with other developing countries, climate change impacts are expected to be greatest in the first part of the century.

Risks can be locked in for long periods, for example through longer-term loans.

Many banks have little risk management expertise on the topic of climate change, for example when compared to the insurance sector.

Evidence from abroad suggests that access to capital can be particularly problematic in the aftermath of a disaster, if a bank has been directly impacted by the event or is revising its strategy. There is no evidence of this being an issue in the UK but it does apply to markets where UK companies operate.

Mortgage lenders have a very long time horizon in terms of their exposure to any changes impacting their assets. There is anecdotal evidence that mortgage lenders have started to use insurance industry data and techniques to stress test their portfolios for exposure to extreme weather events, but this appears more of an exception than a rule, suggesting that the level of vulnerability in this sector is uncertain.

Step 1: What is the current and future level of risk or opportunity?
There is potential for climate change to present a substantial challenge to the business model of insurers through an increasing correlation between weather-related events, as well as increasing correlation between different categories of risk, that could be affecting both the liability and asset sides of the balance sheet, as well as wider market-related impacts relevant to a broader set of investors. The three primary climate impact risks to the insurance sector are: Physical risks, which have real-economy effects and material impact on global stock of manageable assets. Transition risks (risks arising from a transition to a lower carbon economy), which may impact those insurers who invest in carbon intensive assets. Liability risks (parties who have suffered loss and damage from climate change), which can be more disruptive than individual extreme weather events. Financial capital is projected to be a key input for successful planning and implementation of adaptation. In the UK there is evidence that some companies experience difficulties in accessing finance for implementing their own adaptation and resilience measures. There is also evidence that investment in adaptation appears less attractive to funders because of the uncertainty, magnitude and time horizon of climate impacts, often lacking immediate demonstrable benefits. SMEs that have been flooded can experience difficulties when trying to access insurance or loans. Currently this appears to be a relatively localized and contained issue. Access to insurance is an important factor for companies seeking capital, as proof of insurance may be required by lenders. (Unknown magnitude, Low confidence) Future If banks start to internalise climate risks in their lending appraisals, it would have implications on the cost of capital for companies that are exposed to climate risks. Credit may become more expensive or limited for companies that are considered to be taking insufficient adaptation action. The extent to which businesses disclose the climate risks they are exposed to and how they are addressing these risks plays an important role, as banks will only be able to internalise risks with sufficient information. While there is little evidence that this is already being practised in the UK, there are signs that the financial sector's view of climate risk is changing. In anticipation of rising climate impacts the rating agency Standard & Poor's have initiated the development of methodologies to systematically assess impacts of climate change and weather-related events on the creditworthiness, of businesses, as well as for risks to the creditworthiness of countries and sovereign entities or sovereign risks. Research suggests what investors believe ('market sentiment', in the jargon) about the likelihood of different climate futures emerging can have material impacts in the short term. Factors, including climate change policy, technological change, asset stranding, weather events and longer-term physical impacts may lead to financial tipping points for which investors are not presently prepared. Short-term shifts in market sentiment induced by awareness of future, as yet unrealised, climate risks could lead to economic shocks, causing substantial losses in financial portfolio value within timescales that are relevant to all investors. Increasing levels of physical risks could present challenges, both to market-based risk transfer mechanisms and to the underlying assumptions behind general insurance business models. Weather catastrophe losses are on the increase, and are projected to continue to increase, in the future. The primary drivers of these increases are connected to economic growth. The value of insured assets is projected to increase as are the insurance premiums collected. Population migration to more coastal and more urban concentrations may also result in higher premiums. Additional factors, including weather and climate, contribute to the rest of the projected loss trend increase.

Step 1: What is the current and future level of risk or opportunity?
Increased losses from extreme storms and floods could raise the cost of financial capital and increase the volatility of insurance markets, if not properly anticipated. Insured flood losses under a 4 °C temperature rise in the UK could lead to insurance rate increases of 21% and £1.9 billion could be added to the £5.9 billion capital requirement. (Unknown magnitude, Low confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	There is evidence that the finance and insurance sectors are considering the risks posed to them by climate change and that some early autonomous adaptation is taking place. The Bank of England and Prudential Regulation Authority have committed to undertake further analysis and research on the potential systemic risks from climate change to the financial sector, partly through the Bank's research agenda, as published in February 2015. The initial phase will be completed in time to inform the next UK National Adaptation Programme, due in 2018. The Financial Stability Board have formed a Task Force, which will develop voluntary, consistent climate-related financial disclosures for use by companies in providing information to lenders, insurers, investors and other stakeholders. However, most of the existing research and expertise regarding climate change risk is focused on the insurance industry. There is considerably less research regarding banking and investment. Furthermore there is great uncertainty about how access to capital will change for businesses, SMEs in particular, and whether this could act as a barrier to their adaptation efforts. Research also suggests that the impacts of future climate change could impact the financial system far sooner than when the risks actually occur.
Confidence	Low

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	No
Type of benefit	**Watching brief** There is a large amount of research on the impacts of climate change on the insurance industry and insurers are advanced in modelling climate change risks. However, there is less understanding of the impacts on banking and investment, and the potential implications for access to capital, particularly for smaller businesses. Therefore it is important to monitor the affordability of insurance, access to adaptation funding and to investigate potential tipping points in companies' access to capital that might require intervention.
Confidence	Low

Bu5: Risks to business from reduced employee productivity, due to infrastructure disruption and higher temperatures in working environments

Step 1: What is the current and future level of risk or opportunity?
Current and future risk Infrastructure disruption According to a UK survey by the Chartered Management Institute et al. (2013), staff being unable to come into the office either due to travel disruption (63% of respondents) or school closures/child care costs (46%) were the most common impacts of extreme weather on surveyed organisations, followed by external meetings or business trips being cancelled (43%). The most common measures taken by surveyed organisations in response to extreme weather were to allow staff to work remotely (53%), to prioritise resources on key projects (34%) and to postpone work until the weather improved (29%). Using survey results from those living in flood risk areas in Scotland, Werrity et al. (2007) found that the mean work days lost by those affected ranged between 6.3 and 10.4 days depending on if annual, compassionate or unpaid leave was taken. The mean work days lost per household ranged from 0.7 to 1.4. Baglee et al. (2012) assessed that major ICT disruption due to climate change is considered to be relatively low for large businesses. Risks for smaller companies could be greater, particularly if they are located in relatively remote areas where they may be dependent on single electricity and telecommunications connections. Many homeworkers depend on ICT infrastructure to allow them to work remotely. Of people in work between January and March 2014, 4.2 million or 13.9% were homeworkers, two-thirds of whom were self-employed. Homeworking was most prevalent within the agriculture and construction industries. It is not known what proportion of those classified as homeworkers would be affected by weather-related disruptions to ICT infrastructure. Projections of future impacts of infrastructure losses on business productivity are not available.

Step 1: What is the current and future level of risk or opportunity?
(Unknown magnitude, Low confidence) Higher temperatures In general, when temperatures exceed certain thresholds in the workplace for a long enough period of time, the productivity of workers has been observed to fall. There is uncertainty regarding the amount of productivity loss and on the annual average impact across the UK. The 2003 European heatwave is estimated to have resulted in a loss in manufacturing output in the UK of £400 - £500 million, but it is unclear how much of this impact was due to reduction in worker productivity. Workers engaged in heavy outdoor manual labour, particularly in the agriculture, construction and heavy industry sectors, and depending on the sport, professional athletes, are likely to be at the greatest risk of heat stress. Employees working in offices built in the 1960s and 1970s could also be at risk of thermal discomfort. These types of building typically have poor ventilation systems and are often high-rise properties with single glazed windows that maximise solar gain. Modelling in UK CCRA 2012 suggested the future impacts on productivity could be large. Upper bound results suggested that the cost of loss in productivity due to building temperature could increase from a baseline of £770 million in 2010 to between £850 million and £1.6 billion in the 2020s; between £1.1 billion and £5.3 billion in the 2050s and between £1.2 billion and £15.2 billion in the 2080s. (High magnitude, Low confidence)

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	Research for the UK suggested that the proportion of private sector organisations saying they have a business continuity management (BCM) plan in place increased from 42% to 58% between 2008 and 2013. Evidence suggests that organisations often activate business continuity plans only after they have been impacted by an extreme weather event. Extreme weather was the most commonly cited reason for activating a BCM plan, cited by 69% of managers surveyed with BCM plans in their organisation. In congruence with this, the most commonly cited reasons for not implementing a BCM were "We rarely get significant levels of disruption in our business", "We deal with disruption as and when it happens" and "Not a priority," respectively cited by 45, 43 and 37% of surveyed managers without a BCM in their organisation. Therefore, BCM plans may increase in future as organisations become more likely to experience extreme weather events. While not necessarily linked to disruption from extreme weather events, increasing numbers of businesses have been offering workers the option of teleworking. The Confederation of British Industry (2011) reports that "Five years ago, just 13% of firms offered teleworking for employees in at least certain roles some of the time, but now nearly six in ten (59%) do so. This

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
	increase has been made possible by improved technology, allowing people to work more effectively away from the workplace. Businesses have an obligation under the health and safety at work regulations to ensure workplaces are adequately ventilated and temperatures during working hours are reasonable. To support businesses in meeting this requirement, the Health and Safety Executive has published workplace temperature guidance. However, there are no standard upper limits of acceptable working temperatures, so it is up to individual companies to determine what is reasonable. The Chartered Institution of Building Services Engineers (CIBSE) organised an overheating task force. This was in response to the challenge of building comfortable, low-energy buildings. For example, increasing indoor winter temperatures can lead to lightweight, highly insulated buildings that respond poorly in the summer. One of the task force's outputs was a technical memorandum to inform designers, developers and others responsible for defining the indoor environment in buildings about predicting overheating Little is understood about the impacts of heat on productivity and how this varies among occupations. Therefore there is little assurance that workplace temperature guidance and building standards are sufficiently accounting for this risk.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Research priority** There is a need for further research to better understand key interdependencies between business and infrastructure, the types of employment at greatest risk, and the effectiveness of planned or autonomous adaptation. Research will provide the early steps to understanding these interdependencies, and in the case of higher temperatures, adapting workplace temperature guidance and building standards. For example, how building temperatures can be kept in a tolerable range for thermal stress or thermal discomfort reflecting the building's use.
Confidence	Medium

Bu6: Risks to business from disruption to supply chains and distribution networks

Step 1: What is the current and future level of risk or opportunity?
Current and future risk The impacts of extreme weather events vary by type and among businesses, depending how diversified their supply chains and transportation routes are. Through their international supply chains, UK businesses are exposed to extreme weather risks from around the world. The value of UK imports has risen from £150 billion in 1990 to £548 billion (nominal prices) in 2014. Exports have increased from £139 billion in 1990 to £512 billion (nominal prices) over the same time period. As a proportion of GDP, UK international trade (imports plus exports) increased from 47% in 1990 to 57% in 2015. This demonstrates that UK businesses have become increasingly exposed over the last 25 years through overseas markets as part of their supply chains and distribution networks. At the UK level, the Business Continuity Institute's Supply Chain Resilience Report for 2015 found that adverse weather was third most cited reason for supply chain disruption over the previous 12 months, with 50% of surveyed businesses reporting it. Studies have found that share prices can fall by between 7% and 30% on average following failures in the supply chain, relative to benchmark companies. The Scotch Whisky Institute noted in 2011 that heavy snow and ice challenged the integrity of warehouses in the north of Scotland, causing operational and supply chain disruptions. One of the key current and future climate risks for supply chains and distribution networks is extreme weather causing damage and disruption to transport infrastructure (roads, rail, ports and airports). For the businesses concerned, this is likely to result in unfulfilled orders, breach of delivery contracts, loss of revenue and damage to reputation. Flooding in particular can have long-lasting impacts on transport networks and cause widespread disruption. Landslide disruptions have been noted to block roads and cause disruption to business in Scotland. For example, the Stob Coire Sgriodain landslide in June 2012 resulted in a goods train being derailed. The British Geological Survey has also documented landslides in the past 10 years at Glen Ogle, Penicuik and the 'Rest-And-Be-Thankful Pass'. High tides and stormy seas can disrupt ferry services to islands for several weeks each year causing raw material delivery problems, fuel supply issues and difficulty in shipping finished goods. Food, clothes and electronic equipment are important UK consumption goods which appear to be at comparatively high risk from international supply chain interruptions. The largest climate risks to supply chains appear to be in the earlier stages of product manufacture. These tiers of the supply chain are less likely to be understood and managed by UK businesses. A larger proportion of value in the earlier stages of production is generated in countries that are at a moderate or higher risk from climate change. Evidence suggests that disruptions in the earlier stages of supply chain are common. A recent survey by the Business Continuity Institute (BCI) found that 42% of supply chain disruptions originated below the first tier of immediate suppliers. Climate change is expected to increase the risk of weather-related disruptions, particularly for supply chains that involve more vulnerable countries, particularly in South and South East Asia, along with Sub-Saharan Africa. Domestically, the effects of climate change on UK transport infrastructure are significant; the length of railway line located in areas exposed to flooding more frequently than 1:75 years (on average) increases in the 2080s by 53% and 160%; the length of major roads by 41% and 120%; the number of railway stations by 10% and 28%. [Scenario: 2°C or 4°C , not including population growth and assuming the continuation of current levels of adaptation]

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	Many large companies are considering the risks from climate change to their supply chains and distribution networks and collaborating with their suppliers. This can have wider positive effects and increases the resilience of smaller businesses in their supply chains. A lot of guidance for businesses on managing their supply chains and distribution networks already exists. However, there is a lack of evaluation to provide sufficient assurance that this guidance is effective and affecting business decisions on the ground. Findings from the Chartered Institute of Purchasing and Supply (CIPS) suggest that many British firms do not fully understand supply chain complexity and that "inadequately trained supply chain professionals" amount to a skills gap. Guidance and research tends to be high-level and generic. There is a gap therefore, in assessing risks to specific sectors, key areas and vulnerable pinch-points, both for domestic and international supply chain interruptions. Little is known about how the resilience of UK infrastructure affects business' ability to create resilient supply chains and distribution networks.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Sustain current action.** International elements of UK businesses' distribution and supply chains are already impacted, and expected to be more at risk as they may take place in countries deemed highly vulnerable to climate change and less able to adapt. Despite the range of surveys and case studies, data are mostly limited to those reported by larger multi-national companies and it is difficult to evaluate the impact and effectiveness of existing adaptation measures, and existing guidance and tools. Therefore it is important to sustain action in this area to continue increasing understanding and enabling businesses with guidance and tools which are proven to be effective.
Confidence	Medium

Bu7: Risks and opportunities for business from changes in demand for goods and services

Step 1: What is the current and future level of risk or opportunity?

Current and future risks and opportunities

Current risks

The BACLIAT vulnerability assessment sets out some common climate impacts for products and services (referred to as 'markets').

- Increasing or decreasing demand for some products and services.
- New properties required of existing products and services.
- Emerging markets for new products and services.
- Changing customer behaviour.
- Marketing opportunities.
- Unable to satisfy increased demand or segments of the market.
- Competitors' position enhanced or reduced by climate change.
- Advantages for early movers in response to changed markets and lifestyles.

These impacts are expected to occur to varying extents across sectors and regions, as well as internationally, with mixed implications for UK businesses. For example the finance and insurance sectors in the UK may face changes in demand for their existing products and services both in the UK and abroad. If the frequency or intensity of extreme weather events increases due to climate change those companies have to make subsequent decisions about changes in prices. Another example is the energy sector, with the UK being a net importer of energy. Disruption to infrastructure for energy transportation could affect the prices and availability of UK energy and fuel imports. Changes to the market would have implications for a wide range of sectors.

Examples of new characteristics and design features required of existing products and services include those within the construction sector, and requirements for more resilient buildings. The impacts of climate change on customer behaviour are uncertain, but particular sectors, such as food and beverages and retail, are already dependent on certain weather conditions and seasonal adjustments, which is likely to make them more vulnerable to sudden changes. In the utilities sector rising temperatures may result in reduced energy demand for heating but an increase in energy demand for cooling. The aggregate effect on the energy market is unknown.

Other examples include risks for UK businesses in the agriculture sector, who may lose traditional markets, local competitive advantage and face new competition in existing markets from global climate change.

Current opportunities

The UK is already a key provider of some adaptation goods and services, particularly in climate modelling, professional services including architecture and engineering, and finance and insurance products. The manufacturing, finance and insurance, construction and professional, scientific and technical activities sectors are noticeably seizing market opportunities related to climate change.

Based on the best of the limited data available, global sales of adaptation goods and services were estimated to be £69 billion in 2011/12. The UK is the seventh largest producer of adaptation goods and services globally, with sales by UK companies in 2011/12 of £2.1 billion, of which £0.3 billion were exports. Sales of adaptation goods and services grew by 2.6% per annum between 2009/10 and

Step 1: What is the current and future level of risk or opportunity?
2011/12. However, in real terms they remained constant over the short period of time data are available. The sector remains small – in total, adaptation goods and services sales represent less than 0.1% of all sales by businesses in the UK – and sales by UK companies appear to have grown more slowly than those of competitors in other countries. Companies report that they are already investing in technologies and products to address climate change. Responses to CDP suggest on the highest proportion of investment is to address risks associated with higher temperatures, followed by investments to reduce water use and address flood risks. Future risks and opportunities It is difficult to predict how markets and consumer behaviour may change over time and therefore assess how representative current risks and opportunities may be of those in the future. Qualitative assessments suggest that there may be future opportunities from climate change for a range of sectors. The sectors with more expertise are assessed to be the electricity, gas, steam and air conditioning supply, financial and insurance activities, and water supply including sewerage, waste management and remediation activities. Those with less expertise are administrative and support services, education and transportation and storage. The sectors assessed as having more expertise tend to also be the sectors assessed as having a high growth potential. Businesses in the UK agricultural sector may benefit subject to the health of the natural environment. The demand for adaptation products is expected to grow in the future, partly fuelled by public demand for weather-protection products. The UK Government has pledged to spend £2.3bn over the next six years on capital flood and coastal risk management activity with a further increase of £700 million announced in the 2016 Budget. Evidence suggests that UK tourism overall may experience increased demand due to climate change. Hotter drier summers could improve leisure activities across the country leading to an increase in demand and a potential increase in supply through new or expanded services. There are opportunities to expand services close to outdoor leisure facilities, such as sports grounds, gardens and natural parks or beaches. Opportunities for the UK hospitality industry are particularly expected at the fringes of the season (e.g. March and October) and in more northern destinations. Some types of tourism or tourism in specific areas could be negatively affected by climate change. For example, access may be affected if sea levels rise and erode beaches. This could lead to a reduction of services in some coastal areas. There may also be challenges for tourism dependent on heritage buildings or sites as these may be more difficult to retrofit. The tourism sector has been identified as a key climate sector in Wales, with expected expansion of tourist destinations due to milder weather. Some impacts are uncertain. In Scotland, the Glenshee Tourism Association has been reported as targeting ramblers, cyclists, historians and sightseers due to concerns about sustainability of the skiing industry. However, other evidence suggests Scotland may benefit from an improved summer climate and coast, conducive to outdoor activities and access roads to ski resorts may be less prone to blockage by snow and ice.

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	No
Justification	Identifying market opportunities and managing risks are core business activities – unless prevented by regulation or hampered by low adaptive capacity it is expected that companies will respond to growing risks and opportunities. Businesses in the finance and insurance sector, where a lot of the current risk is concentrated, tend to have a high adaptive capacity and there is evidence that the sector as a whole is acknowledging climate change as a risk. There are also efforts to better explore future risks and opportunities both in the UK and in Europe. UK firms may be able to incorporate useful outputs as they are developed. While there will be autonomous adaptation as a result of market forces, relatively little is known about UK companies' sales of adaptation goods and services and the potential for future growth. There are potential barriers to an increase in demand for climate change related services, as these include model and scenario projections and observations, forecasts, climate information, trends, economic analyses, counselling on best practices, development and evaluation of solutions. Current demand for these services is low due to a lack of awareness of the potential benefits (as climate change is not seen as an imminent issue by many businesses) as well as a lack of awareness that these services are available. Additionally, there is a lack of understanding from service providers of their target market. Climate information is often not tailored to specific localities or sectors, i.e. they currently provide mostly generic information and are therefore less appealing to customers. For opportunities in this sector to materialise, it will be important for businesses to address these barriers.
Confidence	Low

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	No
Type of benefit	**Watching brief** Identifying market opportunities and managing risks are core business activities– unless prevented by regulation or hampered by low adaptive capacity, it is expected that companies will respond to growing risks and opportunities. There is a risk that businesses will be unable to overcome

Step 3: Are there benefits of further action in the next 5 years?	
	adaptive capacity constraints, and therefore ongoing monitoring is important, including of research outputs which may be useful to businesses. Small businesses are generally likely to have lower adaptive capacity so would be the least likely to take adaptation action.
Confidence	Low

Chapter 7 - International dimensions

Urgency scores for international dimensions					
Risk descriptor	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
It1: Risks from weather-related shocks to international food production and trade (Section 7.2)	UK				At present there is no co-ordinated national approach to ensure the resilience of the UK food system. Coordinated approaches require broad participation across policy, industry and research.
It2: Imported food safety risks (7.2)		UK			There is a gap in surveillance systems to monitor food safety at source and through complex international supply chains.
It3: Risks and opportunities from long-term, climate-related changes in global food production (7.2)		UK			The UK may increase its comparative advantage in specific areas of agricultural production in the future. Trends in global agricultural production and consumption need further monitoring and assessment.
It4: Risks to the UK from climate-related international human displacements (7.3)	UK				A more pro-active strategy to work in partnership with other countries is needed to provide rapid legal and basic assistance to migrants and to build long-term resilience in exposed regions. Otherwise overseas development efforts will increasingly be diverted to provide humanitarian (i.e. emergency) aid.

Urgency scores for international dimensions					
Risk descriptor	More action needed	Research priority	Sustain current action	Watching brief	Rationale for scoring
It5: Risks to the UK from international violent conflict (7.4)		UK			Further evidence is needed to understand the appropriate balance between long-term development aid (resilience building, disaster risk reduction, state stability) and responsive interventions (peace-keeping, humanitarian aid).
It6: Risks to international law and governance (7.4)		UK			There is a lack of systematic monitoring and strategic planning to address the potential for breakdown in foreign national and international governance, and inter-state rivalry, caused by shortages in resources that are sensitive to climate change.
It7: Opportunities from changes in international trade routes (7.4)				UK	Potential changes in trade routes are already being assessed and the issue should continue to be monitored.

It1: Risks from weather-related shocks to international food production and trade

Step 1: What is the current and future level of risk or opportunity?
Food security encompasses availability, price and access to a healthy diet. The key issue surrounding food security in the UK is not systemic food insecurity, but rather the need for systemic resilience to international vulnerabilities in the food system: as an economically developed nation, the UK as a whole is unlikely to suffer prolonged issues with accessing sufficient food, but does experience issues related to price spikes and disruption to trade, which can impact UK households, especially lower income groups, and business, especially farmers. Current There are an estimated 350-500 thousands food insecure people living in the UK, who rely on food aid; and about four million people in the UK do not have access to a healthy diet (high magnitude, high confidence). Low income families are particularly sensitive to food prices. Even though price shocks may be muted as they pass from world markets to domestic retail prices, the poorest groups are more affected by these even muted changes. More than three quarters of raw food and over half of processed imported food arrive in the UK through a small number of trade routes. UK imports tend to be highly concentrated for a range of key commodities. For example, the majority of wheat imports into the UK are sourced from the EU (approximately 50%), Canada (34%) and the US (5%). Similarly high levels of concentration across import sources are evident for other commodity groups though the trading countries will differ. Brazil accounts for around 75% of UK soybean imports. International food system shocks are transmitted to the UK primarily through price volatility. UK food prices are particularly sensitive to events on world food markets. Volatility in UK food price inflation far exceeds that of non-food inflation over the last 15 years. The UK is also more exposed to world price shocks relative to EU Member States, reflecting the open nature of the economy. For example, the 2012 US drought led to an increase in price of soya, causing up to an estimated 25% of UK pig farmers leaving the industry by end of 2012 (~£10million drop in production output) (medium magnitude, high confidence). Losses from the 2012 drought have an estimated 1:20 return period. The issues of food price volatility are already high on policy agendas following, for example, global food price surges in 2008 and 2010. Of the 20 years from the end of 1992 to the 2012, eight showed a globally significant major production loss associated with one or more climate extremes. Future Changing patterns of weather, especially extreme weather, are likely to increasingly impact on global food production. The increasing global interconnectedness of food systems via trade increases the susceptibility of the food system to propagation and amplification of weather-related production shocks. It is very difficult to quantify these effects due to the myriad of influencing factors, but as the risks are medium now, without additional action they are projected to be high in the future. There are risks of increased year-to-year variability of global yields due to changing incidence and severity of extreme events. The increase in the likelihood of weather extremes as the century progresses would increase existing risks of production shocks and supply chain disturbance. These risks are well established and highly significant globally, both in terms of trends in concentration of risks and increased frequency of extreme events, in all plausible climate scenarios (high magnitude, medium confidence). The profile of global trade will amplify the underlying climate risks, since trade represents only a small part of total production, and major trade is restricted to a small number of large food producing countries.

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	The UK Government does not have an explicit policy on addressing the resilience of the food system, encompassing domestic production and international imports. Volatility of food prices is monitored, but it is unclear how these data are used for strategic, forward planning. Food security policy currently focusses on domestic sustainable intensification and agri-tech. Another focus of current actions is on ensuring a well-working market. Under "normal" conditions, and with a well-functioning and transparent market, a disturbance in one place will be buffered by the diversity of locations involved in trade. However, two structural issues are creating systemic global risks. First; international trade in commodities is increasing; many countries increasingly rely on trade to supply basic needs, which is a positive attribute when the market is stable but becomes a vulnerability if the market is disrupted. Secondly, the network structure is asymmetrical: some breadbasket countries supply large amounts to the market and thus are highly important nodes in the global market, connected to many countries around the world, concentrating risk. These factors mean that weather shocks to individual countries can be propagated into the global system. The impacts might be amplified if countries respond individually, for example through over-compensatory market responses such as export taxes, or by other factors such as the financialisation of commodity markets, biofuels, low levels of stocks, oil prices and exchange rates etc. As the system is global, no single country can manage it: what is necessary is to manage the resilience of the national system and, at the same time, to cooperate internationally to manage the global market. Furthermore, climate change is changing weather patterns and "normal" conditions are increasingly abnormal. In a world where extreme weather may be increasingly common, this can itself reduce resilience as it leads to often very vulnerable systems that are well adapted to normal conditions but without the ability to cope with unprecedented ones. It is important that resilience is encouraged by policy as a specific intervention, since the market will not naturally bear the costs of adapting to unprecedented conditions. Adaptation efforts focused solely on the UK's domestic production of food will have marginal success because of the global interconnected nature of food systems, and the current pressures on domestic resources such as water and soils (see Chapter 3).
Confidence	High

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**More action needed** At present there is no co-ordinated national approach to improving the resilience of the UK food system. A strategy for improved UK food system resilience, designed and implemented through coordinated cross-departmental actions, would enable assessment of risks and associated risk management strategies. Views on food price spikes differ between academic and government actors, suggesting that a collaborative exercise might be needed to underpin suggestions for policy changes. There are multiple benefits to the economy from improved management of knowledge to tackle the systemic vulnerability of the food system to climate and non-climate shocks, and from improved functioning of international trade and markets. These benefits include new trade potential and improved in-country sustainability of production. Many of these benefits require international co-ordination with the EU and WTO. Actions to support adaptation overseas, monitor international partnership and protect vulnerable populations from the effects of price spikes also have multiple benefits from humanitarian and geopolitical risk perspectives. Managing this risk systemically has multiple benefits of managing other food system risks.
Confidence	High

It2: Imported food safety risks

Step 1: What is the current and future level of risk or opportunity?
Food quality and safety can be directly affected by disease, toxicity and substitution if prices rise following a production shock. Climate change impacts could amplify existing quality and safety issues within supply chains. Risks include environmental contamination associated with increased flooding, increased pesticide use in response to new/emerging pests or diseases, and transmission of disease and toxicity through food. Foodborne pathogens, such as salmonella, and their associated diseases are more prevalent in higher ambient temperatures. While these risks are global, the interaction with supply chains represents an increasing level of imported risk to the UK. The risks in a 4°C world are significantly greater than those in a 2°C world. Mycotoxin risks are likely to increase with temperature and water stress during growth of major cereal crops: approximately a quarter of the global annual maize crop is contaminated and the toxins have been detected in cereal-based foods. These risks are often managed by temporary import restrictions,

Step 1: What is the current and future level of risk or opportunity?
disrupting international trade and cereal availability There is insufficient evidence to assign magnitude categories to the level of current and future risk for imported salmonella and mycotoxin (unknown magnitude, low confidence). Other disease outbreaks within the food chain have caused significant damages in the past.

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	Current policies establish controls on animal food imported from the EU and all types of food imported from countries outside the EU. The duties of port health authorities include: ensuring that only products that are safe to eat enter the food chain; safeguarding of animal and public health; and checking compliance with EU rules and international trading standards. However, as the case of the risk It1, the interconnected nature of food systems makes the scope for effective unilateral UK government intervention limited. In the case of food safety, the problem is compounded due to the difficulty of detecting disease, authenticity and toxicity. Changes in climate and geopolitics, coupled with the complex and international nature of supply chains, mean that addressing food safety through monitoring points of entry alone is unlikely to be an effective strategy on its own.
Confidence	Low, rising to medium by the 2050s – global nature of food systems leaves gaps in current risk management strategies, which will become increasingly important with time.

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Research Priority** More research is needed to improve the monitoring system, building on existing food safety quality regulation and enforcement carried out by the FSA.

Step 3: Are there benefits of further action in the next 5 years?	
	Research might include developing systems to monitor risks at source and along the supply chain, as well as planning imports around low risk areas that monitor food safety risks. Identifying elements of supply chains at risk allows targeting loopholes and provides consumer assurance. Other possible interventions include improved prediction, coordinated mechanisms for obtaining rapid expert advice, and maintenance of strategic food stocks. These actions might be carried out by the industry, but the potential risk would justify at least an impact assessment of different options. Actions that build resilience to food safety risks have multiple benefits to help managing food supply chain risk (It1).
Confidence	Medium

It3: Risks and opportunities from long-term, climate-related changes in global food production

Step 1: What is the current and future level of risk or opportunity?
Climate change will alter global agricultural systems, affecting production, trade and sustainability of agriculture in every region. This will alter the comparative advantage and signals to UK food markets and UK food production, resulting in a number of risks, depending on the still uncertain trajectories of agriculture in world regions. First, UK agriculture could gain comparative advantage in specific products, relative to the other regions of Europe, notably due to projected yield decline in southern European countries due to water scarcity and heat. Within Europe, overall yields under a business as usual projection (3.5 degrees of global warming compared to pre-industrial) have been projected to decrease by around 10% by the 2080s. This change is not evenly distributed, however, with Southern Europe experiencing 20% decreases. At the same time a strategic approach might be needed to manage potential risks to the sustainable intensification of UK agriculture: a domestic business opportunity could in turn lead to unsustainable practices. Rising wheat prices, for example, could affect UK production with consequences for longer-term soil productivity, landscape and biodiversity. Other plausible changes in comparative advantage due to changing economic geography of global production could result in increased food import dependency. If UK domestic production is also affected by weather extremes and the UK loses comparative advantage in certain crops (see Chapter 3), there will be a greater dependence on food imports and greater exposure to global food price volatility (risks It1 and It2). Both risk and opportunities are potentially high magnitude (low confidence), but quantifications are very scenario-dependent.

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	To ensure that autonomous adaptation happens to slowly-evolving changes in food imports, this concept should be built into planning for resilience of UK agriculture. There is likely to be a degree of autonomous adaptation within UK agricultural production responding to changing signals associated with shifting comparative advantage. Agronomic adaptation such as a change in planting date, increase in irrigation, or change in crop variety can reduce, or even reverse negative impacts on yield. However, in the longer term, by 2050 at the latest, more systemic changes and transformative adaptation are likely to be required. Identifying the appropriate longer-term investments will require monitoring of existing trends, and assessment of their likely sustainability. There is high uncertainty about the overall direction of global changes in agricultural comparative advantage. The management of current pressures on domestic resources such as water and soils will play an important part in realising this comparative advantage (see Chapter 3). Where comparative advantages favour the UK, the tendency towards unsustainable practices will need monitoring and management.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Research Priority** More research is needed to better understand and quantify potential changes in extremes and the potential for step-changes associated with crossing climatic tipping points; more evidence is needed to characterise market responses to fully quantify the cost of inaction. There are also no-regret actions that can be taken, as addressing this risk have multiple benefits of contributing to the present-day resilience of UK food security, the sustainable use of resources, and will have a positive humanitarian impact globally. Any action that manages demand (e.g. reducing food waste, changing diets and reducing obesity) will reduce the risk of both unsustainable practices and reliance on imports. Many of these

Step 3: Are there benefits of further action in the next 5 years?	
	actions have clear co-benefits for health, long-term food security and climate change mitigation. The high levels of uncertainty concerning long-term comparative advantage and the implications for domestic production and sustainability requires further research. There are however also significant benefits to managing the UK farm sector for systemic resilience to climate change. Resilience is beneficial for avoiding land use and technological lock in (see Chapter 3). Interventions toward ensuring well-functioning markets and international trade also bring significant co-benefits in reducing volatility in food trade and prices.
Confidence	High

It4: Risks to the UK from climate-related international human displacements

Step 1: What is the current and future level of risk or opportunity?
Current Involuntary displacement of people from their place of residence due to weather extremes has significant human health and wellbeing and economic costs. Most displacement from weather extremes is short duration and short distance, but has significant human and economic cost globally and potentially is significant for UK interests. Some displaced populations ultimately migrate more permanently. Global monitoring of displacement suggests >20 million people displaced per year in recent years (high magnitude, high confidence). The UK's annual average expenditure in overseas aid is currently £6bn. Future Displacement risks could be important for the UK in the future principally through increased demand for humanitarian assistance abroad. But there are also significant diaspora communities and economic linkages in the UK that are likely to be affected by changes in climate around the world. Longer-term environmental change also affects the relative attractiveness of destination areas. Climate change impacts will interact with longer-term economic trends to affect migration flows through, for example, disinvestment in areas at risk, including withdrawal of insurance, making them less economically attractive. These risks are not directly evident in migration flows to the UK to date, but represent risks to the long-term economic security of types of settlements in many regions of the world. These risks can affect UK's economic interests abroad and increase the demand for humanitarian assistance. Projections suggest that global demand for humanitarian aid could increase by at least 32% by 2030 (high magnitude, high confidence).

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	Managing risks associated with increased incidence of extreme weather globally involves policy and strategy on displaced people and migration, as well as on considering the demand for humanitarian assistance from the UK. For displaced populations, closing the so-called protection gaps is currently being discussed through international initiatives – these would ensure that currently absent protocols would be developed for relocation, assistance (including education and awareness raising) and return migration of displaced populations. Humanitarian assistance is a varying proportion of DfID's expenditure in any year. Unforeseen expenditure from weather-related disasters arises amongst others, diverting priorities from longer-term development and resilience building activity. At present around 5 percent of expenditure on humanitarian aid is allocated to disaster risk reduction globally. All projections about the requirements for humanitarian assistance, largely due to climate change, show significant increases in the forthcoming decades. This suggests that the UK will play an increasingly reduced role in providing humanitarian assistance around the world. The Ashdown Review (2011) on DFID priorities on humanitarian assistance suggested a more pro-active strategy to building resilience in disaster-prone regions.
Confidence	High

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**More action needed** UK responses will be shaped by and heavily dependent upon the effectiveness of EU responses. UK engagement with the EU policy framework on migration should ensure it incorporates and anticipates climate change impacts on existing migration flows. For the UK, national and EU level restrictions on regular migration authorised by law and policy is unlikely to reduce flows of international migrants linked to income and wealth inequalities and to effects of conflict or persecution either within or between states. It would conversely increase the risk of people smuggling and trafficking.

Step 3: Are there benefits of further action in the next 5 years?	
	Effective action involves a broader range of policy areas further than migration policy, including humanitarian assistance, development, urban resilience, peace and security. UK and EU co-ordination of these policy fields need to be integrated into international development policies and investment and migration policy. For example, the need for incorporation of displacement and complex emergencies in defence planning is already recognised in assessment of strategic trends. Managing this risk through increasing in-country long term stability and sustainable development has multiple benefits: for receiving countries, economies and people, to which UK economy and trade is also likely to benefit; as well as helping managing the other risks discussed in this chapter.
Confidence	High

It5: Risks to the UK from international violent conflict

Step 1: What is the current and future level of risk or opportunity?
Current Fragile states in crisis are unable to provide basic services to their citizens including implementation of the rule of law. Such failed states have had significant consequences on neighbouring states and regions and the demand for international assistance in humanitarian or more significant interventions. Food price volatility (Risk It1) also interacts with conflict risks, especially in states facing governance challenges. Evidence from food price spikes in the past decade suggests that Middle Eastern countries and Sub-Saharan Africa are sensitive to conflict associated with events on world food markets. The specific role of climate change in directly triggering conflict is contested. But there is strong evidence that many factors that increase the risk of civil war and other armed conflicts, such as poverty levels and income shocks, are sensitive to climate change and if these impacts are not managed, there would be an indirect effect on conflict from climate change. In addition, regions in conflict and post-conflict countries have low adaptive capacity and may themselves be highly vulnerable to future impacts of climate change. The average annual expenditure by the UK on humanitarian assistance, including to regions undergoing conflict is £6 billion (high magnitude, high confidence). Annual average UK defence expenditure (order of magnitude) £tens of billions. Future It is not possible to quantify the level of future risk, but it is thought that the risk will remain high resulting in continued high levels of expenditure on humanitarian aid. Global annual average aid demand is projected to increase of at least 32% by 2030 (high magnitude, high confidence).

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	The future risks to the UK are related to the capacity for international interventions and co-ordination with partner countries. First, state failure and poor governance may increase demand for military intervention to protect UK interests. Insufficient capacity to intervene may allow other countries or non-state actors to reduce UK influence in affected areas. Second, the breakdown of state structures can lead to greater insecurity for trade and transport, related to supply chain risks (Risk it2 above). There is a potential for the new Conflict, Stability and Security Fund (CSSF) to cause a shift toward more short term interventions (rapid response) at the expense of upstream prevention; and its ability to provide the synergistic policy action that allows for a joined up approach. There is also an observed shift of development expenditure toward humanitarian (emergency) aid. Current policies do not specify the optimal or minimum proportion of expenditure in long-term aid (including sustainable development and disaster risk reduction) versus humanitarian aid. There is, therefore, a gap in understanding the impact on this shift in development and state fragility expenditures in exacerbating geopolitical risks. Similarly, there is no evidence of a systematic review of impacts of UK funds in tackling geopolitical issues, for example by reaching the UN Sustainable Development goals or complying with the Sendai Framework for Disaster Risk Reduction.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Research Priority** Managing this risk through increasing in-country long term stability and sustainable development have multiple benefits: for receiving countries economies and people, to the UK economy and trade which are also likely to benefit; as well as helping managing the other risks discussed in this chapter. Co-ordination with EU and other countries on building stability, resilience and development in conflict prone countries would bring benefits associated with displacement risks (It4) as well as conflict risks.
Confidence	Medium

It6: Risks to international law and governance

Step 1: What is the current and future level of risk or opportunity?
Climate change impacts pose potential risks to international law and stability by undermining the capacity of global institutions to respond to local crises, including state failure, disease outbreaks, or environmental disasters. Increased pressure around the world for access to food, energy and water resources, exacerbated by climate change, could lead to an increase in resource protectionism and strategic bilateral agreements that secure long-term access to resources. Such trends could undermine global openness and trade with consequences for the food security risks (risk It1 and risk It3). Responses by key actors to secure resources are likely in anticipation of future climate change, and hence these risks are likely to manifest in the forthcoming decades. The impacts of climate change in future could also increase the risk of attempts to revise the principles of international law and governance, especially around the UN Law of the Sea which establishes the economic, territorial and sovereignty rights of coastal states over maritime spaces. Rising sea levels, coastal erosion and the migration of fish stocks, especially later in the century, may all lead to the disruption of international relations if countries increasingly question and over-ride international principles. Climate change will disrupt global precipitation patterns leading to changes in water availability and accessibility in trans-boundary water basins, potentially amplifying political tension between states. International legal mechanisms and river basin institutions can contribute to trans-boundary capacity to anticipate or respond to stresses and the ability to manage conflict effectively, though many such agreements will be fundamentally challenged by a lack of available and accessible water. The risk magnitude in the future is potentially high, but quantitatively unknown (unknown magnitude, medium confidence).

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	Yes
Justification	As with food security risks, there is a lack of systematic monitoring of the trends and early warning assessment of the risks of breakdown of governance, and the threats posed by inter-state rivalry over resources sensitive to climate change. This lack of early warning assessment, as well as planning and implementation is highlighted in the G7 report 'A new Climate for Peace'.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	Yes
Type of benefit	**Research Priority** There are multiple benefits of making climate change induced risks central to foreign policy planning, especially to address compound risks. These could include investments in disaster risk reduction, in transboundary institutions to resolve conflicts and development focussed on resilience of currently fragile states.
Confidence	High

It7: Opportunities from changes in international trade routes

Step 1: What is the current and future level of risk or opportunity?
Assessments suggest that the potential for increased shipping activity in the Arctic will not be realised before 2050 or beyond. The potential for growth is most closely identified with increased demand for local community supply operations and tourism. It is anticipated that increased fishing and resource development may also increase demand for destinational shipping but the extent of these activities in the future is uncertain (unknown magnitude, low confidence). Shipping industry sources suggest the UK has some capacity to benefit from increased access to the Arctic as a consequence of climate change. The main area where the UK could benefit is from increased tourism, trough, for example, increase in the number of UK registered cruise ships, if UK ports are increasingly used as a point of embarkation for passengers visiting the Arctic, and if UK domiciled tour and expedition operators are able to increase their market share. The UK could benefit from the provision of maritime services, especially from companies based in the City of London. UK companies are well placed to provide finance, insurance, underwriting, certification and classification, all of which will be necessary enablers of maritime activity in the Arctic. However, insurers and underwriters remain cautious about providing services to Arctic shipping due to the potential risks involved.

Step 2: To what extent is the risk or opportunity going to be managed, taking into account Government commitments and autonomous adaptation?	
Is there likely to be a significant adaptation shortfall in the future?	No
Justification	There have been assessments around this opportunity, suggesting that it is currently being monitored.
Confidence	Medium

Step 3: Are there benefits of further action in the next 5 years?	
Are there benefits of action in the next 5 years?	No
Type of benefit	**Watching brief** There are limited opportunities associated with the opening of the Arctic trade routes, principally for UK maritime tourism and the UK maritime services industries such as insurance. The length of trade routes between Europe and Asia is unlikely to fundamentally alter trade patterns, even with ice-free summer shipping routes. There is no evidence to suggest that it is worth further action at this stage. At the same time, it is worth considering that actions to take advantage of this potential opportunity have long lead times and hence it is worth keeping this opportunity on the radar.
Confidence	High