

# The Economics of Climate Resilience CA0401

Synthesis Report

March 2013



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# HEADLINE MESSAGES AND RECOMMENDATIONS

# The Economics of Climate Resilience: developing evidence for the UK Government to inform the National Adaptation Programme and adaptation plans of the Devolved Administrations

The Economics of Climate Resilience (ECR) has been commissioned by Defra and the Devolved Administrations (DAs) to inform the UK's first National Adaptation Programme and the adaptation plans of the DAs.

The Climate Change Risk Assessment (CCRA) identified many climate change risks and opportunities. Unless appropriate adaptation action is taken to respond to these, the UK could incur significant costs – both financial and welfare costs – or miss out on important opportunities.

The analysis investigates current and likely adaptation actions and identifies the key barriers to actions being widely implemented, effective, timely and proportionate to the challenges facing the UK.

These issues have been investigated by addressing a series of 12 questions specified by government policy officials. Analysis is presented within nine reports which cover the five themes of the CCRA: agriculture and forestry; buildings and infrastructure; health & well-being; business & services; and, the natural environment.

The analysis draws on a vast base of published evidence and advice and input from experts across industry, the voluntary sector, the health service, local authorities, scientists, policy-makers, Non-Government Organisations, Non-Departmental Public Bodies, academia, researchers, trade associations and regulators, among others. Around 200 interviews with stakeholders were undertaken.

This synthesis report draws together the key findings and recommendations of the work for policy makers, with a particular focus on cross-cutting issues. They relate only to issues within the scope of the specified questions. Important issues outside the scope of the questions should be considered through separate analysis. The questions addressed in each report are of the following form:

**Given projected climate change and current and expected adaptation, is there a case for further intervention by Government or other bodies?**

## Headline messages: findings, barriers and recommendations (1 of 3)

Each individual report presents more detailed analysis and associated recommendations, shown in Annex 5.

### Overarching Findings

The analysis finds that many individuals and organisations are already taking, or are likely to take, action to adapt to climate change. In particular, in the areas within the scope of this analysis, actions are more likely to be taken effectively where:

- There are well understood risks, particularly in organisations with in-house capability to prepare and respond e.g. asset assessment in the Highways Agency or National Grid; emergency planning in hospitals
- There are few indirect risks or interdependencies with other sectors e.g. hospital continuity is weakened by dependence on the resilience of service providers
- Support networks exist for individuals and smaller organisations, particularly where they have fewer resources and cannot plan for the long term, e.g. vets and feed advisors for dairy farmers
- There is strong organisational structure and leadership and coordination between organisations, typically in large organisations in complex sectors e.g. health service
- There is a stable, supportive and transparent policy environment so organisations may plan and take effective action e.g. Civil Contingencies Act 2004 has contributed to resilience planning in hospitals. Although in some cases, even where there is stability, the current framework can hinder action (e.g. fisheries)
- Planning and processes are flexible and embedded into decision-making
- There has been previous experience of a climate change impact (although this can also weaken capacity) – this highlights the importance of sharing experiences and learning from others.

### Cross-cutting barriers

Although many actions are already being taken, the analysis suggests that particular barriers constrain wider implementation, or hinder the effectiveness of actions taken. Individual ECR reports highlight these barriers in detail. Cross-cutting barriers covering market failures, policy failures, behavioural constraints and governance issues, are as follows, **most of which relate to a lack of adaptive capacity:**

- **Market failures:** interdependency across infrastructure systems and supply chains can create costs on others that decision makers do not account for, e.g. information failures – information can often be too much, too little, out of date or confusing; there is a lack of user-friendly appraisal guidance to guide decision-makers in assessing costs and benefits of actions; and there is a lack of evidence on the costs and benefits of actions and the conditions under which they would be effective. In addition, small and medium sized organisations often lack the resources, skills and analytical tools to take effective action.
- **Policy failures:** lack of understanding of policy trade-offs, and conflicting policy objectives or missed opportunities to integrate climate change into policy can lead to maladaptation (e.g. retrofitting housing for emissions mitigation without accounting for adaptation) or lack of clarity.
- **Behavioural barriers:** often arise among vulnerable groups, who generally have relatively low adaptive capacity; may perceive they are at risk and can be marginalised from emergency planning processes
- **Governance issues:** arise from diversity in responsibility and co-ordination failure where sectors are fragmented and many parties are involved in adaptation actions

### Recommendations to address the barriers:

- **Conduct case study research to understand infrastructure and supply chain dependencies for sectors and organisations at high risk of climate change impacts** (currently and in the near, medium and long-term). Draw on lessons learned in relation to:
  - Identification of other actors or infrastructures with whom interdependencies are likely to exacerbate the risks of climate change most significantly
  - Development of plausible ‘what if?’ analysis to estimate the scale of potential costs associated with the exacerbated climate risk arising from those interdependencies
  - Develop climate-risk-focused adaptation roadmaps (or pathways where evidence allows) that account for these interdependencies

The ECR analysis finds this to be required for power infrastructure, hospitals, manufacturers and small businesses in particular.

- **Identify and empower appropriate organisations with accountability for co-ordinating the development, implementation, monitoring and review of cross-sector climate-risk-based roadmaps (or pathways) involving stakeholders as appropriate.** The ECR identifies a need for co-ordinated responses to flood risk at the community-level (including post-flood recovery), risks facing the agricultural and forestry supply and production chains; and, heat-related risks to human health (among others).

- **Learn from adaptive capacity assessments to identify key decision makers in businesses/organisations and understand the nature of climate information they need to make appropriate adaptation decisions.** Deliver relevant climate information to be integrated within decision-making frameworks.

## Cross-cutting barriers and recommendations to address them (3 of 3)

To build adaptive capacity; facilitate the implementation of near-term low-cost, no-regret actions; or prevent 'lock in' to inflexible or potentially maladaptive options, recommendations are to:

- **Engage businesses, communities and individuals collaboratively through an effective and constructive on-going dialogue to understand their requirements and challenges for adaptation.** Tailor communication to ensure it is effective and responsive to their needs. Facilitate sharing information and lessons learned through appropriate on-line and face-to-face fora. The ECR finds this is particularly required for communities (including individuals and businesses) at risk of flooding or overheating; agriculture and forestry landowners and managers; and healthcare providers including hospitals
- **Develop and operationalise – with appropriate monitoring and review - a comprehensive user-friendly hub of practical information to support communities (including businesses) at high flood risk** covering all relevant aspects of understanding flooding risk, and actions to prepare, respond and recover. The ECR finds this is required for local communities at risk of flooding.
- **Conduct ex-post evaluations of adaptation responses to assess their effectiveness.** Develop and operationalise a national adaptation evidence-hub populated with evidence on alternative adaptation actions including expected costs and benefits and conditions under which they are effective. The ECR finds this is particularly required for adaptation actions taken by strategic infrastructure sectors at high climate risk; actions to address post-flood mental health disorders and heat impacts on the health of the elderly; hospital adaptation actions; overheating in residential housing; and, communities at risk of flooding.
- **Deliver extension services to integrate climate change risk into decision making processes within small and medium sized organisations.** Identify and equip appropriate organisations with the required skills, knowledge and resources to support this and act as 'champions' initiating change. The ECR finds a particular need to provide those organisations (e.g. businesses, farmers) with appropriate support (such as skills training and financial) to manage the impacts of extreme weather events.
- **Integrate climate change adaptation considerations within new and existing policy and regulatory frameworks e.g. when policies are reviewed.** The ECR finds this to be particularly required for the housing policy framework, climate change mitigation policy mechanisms and national infrastructure regulators
- **Undertake an audit of groups vulnerable to climate change risks and associated voluntary groups who could support them.** Integrate voluntary groups within plans for climate change preparedness, response and recovery at a local level with collaboration and partnerships

# MAIN REPORT

# Climate change projections (UKCP09) suggest changing weather patterns by the 2050s, but with significant variation between regions and localities across the UK

The UK already faces some degree of risk from climate change and extreme weather, for example floods and heatwaves. Projections suggest the following overarching changes by the 2050s (relative to the 1961-1990 baseline unless otherwise stated):

- **Increases in mean summer temperatures:** By the 2050s, the southern part of England could see temperature rises of between +1°C and +5.2°C between the p10 low emissions and p90 high emissions scenarios (UKCP09) (Murphy et al., 2009). However, temperature increases are expected to vary regionally.
- **Changes in mean summer precipitation:** Mean summer precipitation is projected to **decrease** by 10% to 22% (depending on location) in the 2050s under the p50 medium emissions scenario. There is a general south to north gradient, with changes between -43% and +16% in South West England to changes of -23% and +6% in North Scotland between the p10 low emissions and p90 high emissions scenarios (Murphy et al., 2009). This could lead to longer periods of drought, particularly in the south east of England. As a result, there is a risk that water abstraction could become unsustainable due to declining availability of water sources (CCRA: Rance et al., 2012).
- **Changes in mean winter precipitation:** Mean winter precipitation in England is projected to **increase** by 9% to 17% (depending on location) in the 2050s for the p50 medium emissions scenario. The spread in projections is wide however, ranging from -2% for the p10 low emissions scenario in east Scotland to +41% for the p90 high emissions scenario in south west England.
- **Sea level rise:** Central (p50) projections suggest a sea level rise relative to the 1990s of between 18 and 26 cm between the low and high scenario in London and between 10 and 18 cm in Edinburgh (Lowe et al., 2009) by 2050. This will have an impact on the return period of storm surges.

As the earth's crust is moving upward in the northern parts of the UK, relative sea level rise will differ over the regions. The north is expected to be less affected by sea level rise than the south (Lowe et al., 2009).

- **Extreme weather events:** As the climate warms, weather patterns and the frequency of extreme events may also change (UKCP09, 2009; Solomon et al., 2007). Increased winter precipitation and sea level rise both contribute to an increased risk of flood events in the future. In addition to an increase in mean temperatures, the frequency and intensity of heat waves could increase in future especially in southern parts of England. The results of the ARCADIA project suggest that by the 2050s, one third of London's summer may exceed the Met Office heat wave temperature threshold (32°C). (CCRA: Capon and Oakley, 2012; Hall et al., 2009).
- **Changes in relative humidity:** Relative humidity is projected to decrease most in southern parts of England in summer. In winter, projected changes to the 2050s are limited.
- **Convective events:** There is no consistent signal in either the frequency or intensity of storms in the ensemble of UKCP09 climate projections. The changes that are seen are modest and the potential for significant changes appears to be small. (Murphy et al., 2009).

The ranges shown aim to reflect the degree of **uncertainty** around projected future climate (further explained in Annex 1) that should be considered when identifying and implementing robust adaptation options. This creates a challenge to decision-makers because determining the appropriate course of action in response requires consideration of the uncertainties. Taking account of those uncertainties, and learning over time, facilitates robust decisions.

# The Economics of Climate Resilience (ECR) was commissioned to inform the development of the UK's National Adaptation Programme and adaptation plans of the Devolved Administrations (DAs)

## Objectives of the ECR

The UK's first Climate Change Risk Assessment (CCRA), published in January 2012, assessed one hundred climate change risks and opportunities facing the UK. Government will be publishing the first National Adaptation Programme (NAP) in 2013 to respond to these risks and opportunities; it will cover a five year period (2013 - 2018).

To contribute to the evidence base underpinning the NAP and adaptation plans of the DAs, policy-makers across government identified a requirement for additional analysis on particular issues. The scope of the ECR was therefore framed as described in the following box.

**To inform the NAP and adaptation plans of the DAs, this analysis seeks to understand the extent of current and expected adaptation actions, the relative effectiveness of those actions, and the barriers to their implementation. It investigates whether there is a case for further intervention by government or other bodies.**

## Scope and phases of the work

### Phase 1: 11 months

The ECR was originally scoped out several years ago during the planning phases of the CCRA. The intention was to consider 20 climate change metrics identified by the CCRA and then to explore the costs and benefits of 10 -20 actions to address some of them. However, it was decided by policy leads that to inform the NAP, they needed a different form of evidence. In addition, given the wide programmes of on-going work on major issues, such as flooding analysis by the Environment Agency and water abstraction reform by Defra, the need to avoid duplication meant that the approach would lead to a narrow focus. Defra therefore changed the scope, and instead, a series of 12 policy questions was identified by officials across government to fill current gaps in the policy evidence-base on the case for intervention.

The questions have been addressed in 9 reports drawing on economic thinking to underpin the analysis in terms of the drivers of behaviour and the rationale for intervention by government or other bodies, though not cost-benefit analysis. Where interventions are required, relevant criteria relate to: effectiveness, efficiency and equity. This synthesis report draws together the main conclusions of Phase 1.

### Phase 2: 2 months

Recognising the need for tools and guidance on how to make robust adaptation decisions in the context of uncertainty, a practical and pragmatic framework to assess the costs and benefits of adaptation actions is also presented within the ECR. This describes the approaches available – including social cost-benefit analysis, real options analysis, robust decision-making and multi-criteria analysis; how to select the most appropriate for a particular circumstance and how it can be applied in practice. Phase 2 of the ECR is the subject of a separate report and is not included in this synthesis report.

# The ECR addresses a series of policy questions set by policy officials across government

## Selection of the policy questions

The ECR answers 12 policy questions, which were selected after a process of cross-government engagement by Defra. The criteria for the selection of the questions used by Defra were:

- The likelihood, timing and consequences of the climate risk or opportunity. Risks were both sector-specific or cross-sectoral
- The degree to which there is a current gap in the policy evidence base
- The extent to which the ECR could add value (given current data and knowledge available) to inform policy making while not duplicating on-going research across government

The specific areas of focus of the questions took several months of engagement by Defra. The areas of focus vary significantly in terms of the number of climate risks they cover (both direct and also secondary impacts of those risks), the groups affected by the climate risk, the geographical areas and therefore the depth and breadth of the analysis required to address them. Data available on each also differs.

## Formulation of the questions

The questions are all of the form:

**“Given projected climate change and current and expected adaptation, what is the case for further intervention in relation to...”** Figure 1 completes each of the questions.

The questions fall within the five themes of the CCRA: agriculture and forestry, buildings and infrastructure, business and services, health and well-being and the natural environment. They refer to both climate change risks and opportunities.

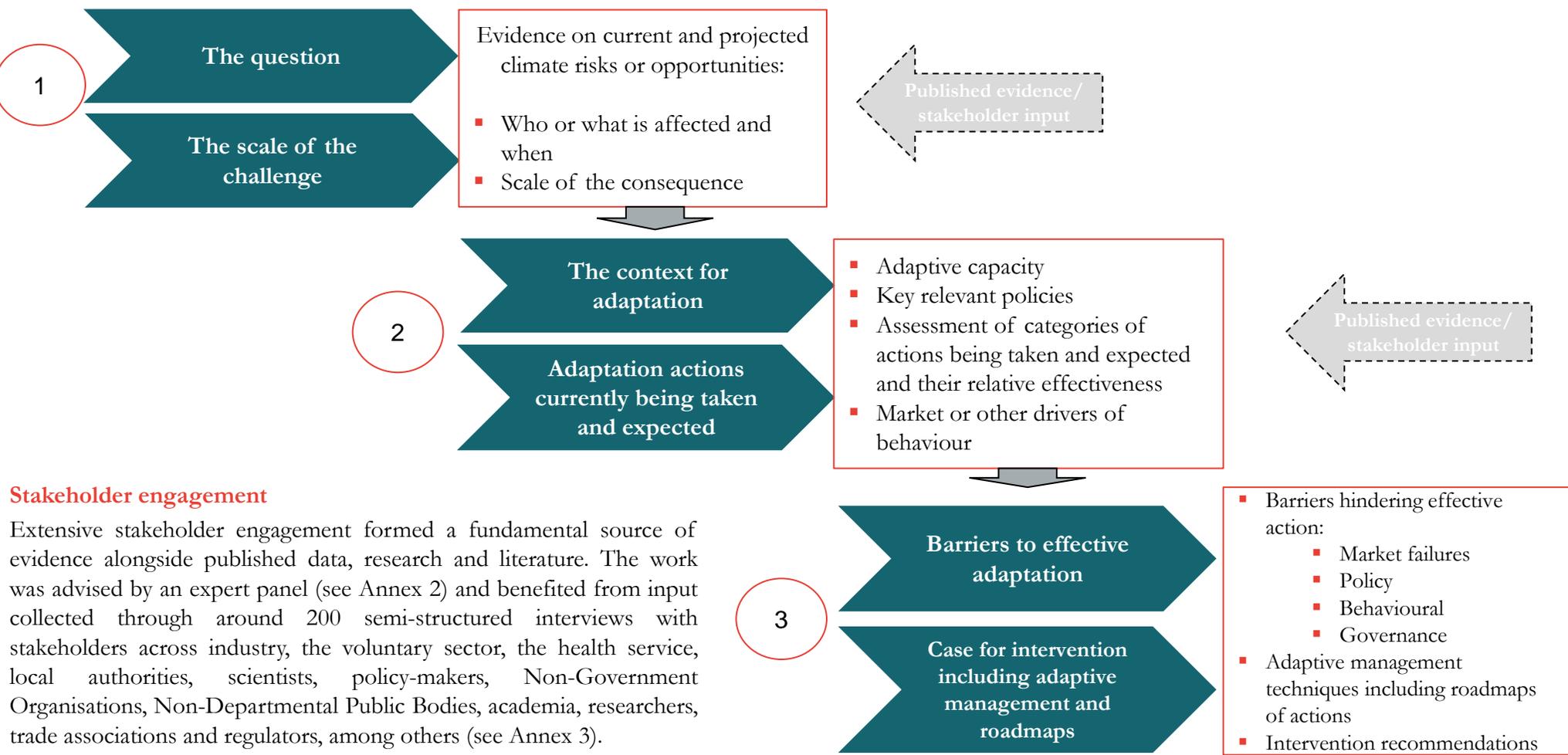
Figure 1: The policy questions

Agriculture and forestry	
1	...agricultural productivity (yields of wheat, sugar beet, potatoes and grassland) and production
2	...forest productivity and associated ecosystem services
Buildings and infrastructure	
3	...strategic road and rail delays from flooding, rail buckling and landslides
4	...power generation and transmission, seasonal demand for energy
5	...energy demand for cooling in residential properties and associated CO <sub>2</sub>
Business and services	
6	...business continuity with particular reference to the chemicals and automotive manufacturing sectors
Health and wellbeing	
7	...the continuity of services from NHS hospitals at risk of flooding
8	...the impacts on human mental health following floods
9	...community resilience following flooding
10	...the impacts of heat-waves and hotter summers on the health of the over 65s
Natural environment	
11	...the movement of wild sea fin-fish in response to sea temperature change
12	...implementation of natural flood management measures

# The ECR analytical framework is applied to address each specific question

As shown in Figure 1, the questions vary significantly in terms of the number of climate change risks they cover, the degree to which they are amenable to quantified analysis, and the extent to which they relate to risks covered within the CCRA set of metrics. This diversity means that answering each question requires a slightly different approach, e.g. some are more quantified than others. Underpinning each answer, however, is the same overarching structure, as shown in Figure 2.

**Figure 2: method of addressing the questions**



## Stakeholder engagement

Extensive stakeholder engagement formed a fundamental source of evidence alongside published data, research and literature. The work was advised by an expert panel (see Annex 2) and benefited from input collected through around 200 semi-structured interviews with stakeholders across industry, the voluntary sector, the health service, local authorities, scientists, policy-makers, Non-Government Organisations, Non-Departmental Public Bodies, academia, researchers, trade associations and regulators, among others (see Annex 3).

# Each report begins with an assessment of the scale of the challenge. Climate change impacts differ markedly across sectors and locations

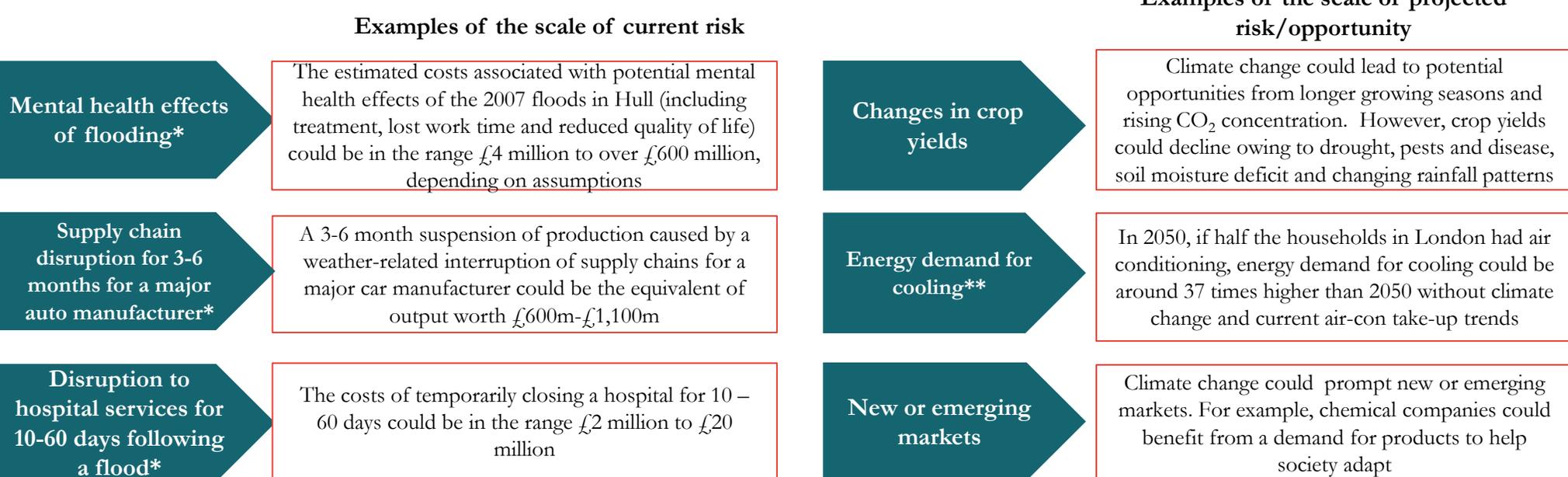
## A note on uncertainty

The scale of the challenge or opportunity that climate change presents varies significantly across areas, groups and timeframes. Common to all is uncertainty around the impacts given the long time-frame that is often under consideration (to the 2050s). Annex 1 describes climate change uncertainty. In addition, uncertainty relates to **socio-economic factors** (including changes in demography, composition and rate of growth of economic, activity and cultural factors), **technological development** (which affects the nature of risks faced and the costs and effectiveness of actions) and **external factors** (for example actions taken by other countries).

## Assessing the relevant scale of the challenge in the ECR

Given the diversity of the policy questions, both current and projected future risks are considered. Figure 3 outlines some examples. Further detail on the scale of the challenge is within each of the individual reports.

Figure 3: examples of the scale of the challenge posed by climate change



Notes: \* Based on the impacts of past extreme weather events, not climate change projections \*\* Based on scenario modelling of UKCP09 medium emissions scenario p50

# The context for adaptation, in terms of relevant policies and adaptive capacity, needs to be understood in order to develop an effective adaptation response

## The role of policy

All actions within the economy take place within the existing policy framework. As such, it has a significant and important influence on adaptation actions either directly (e.g., through subsidies for adaptive actions, legislative requirements for particular actions or outcomes, and influencing behaviour through market mechanisms or guidance), or indirectly through wider policy. Government has a range of objectives and many are interdependent as actions to achieve one can affect the ability to achieve another.

A stable, supportive and transparent policy environment facilitates organisations in their ability to plan and take effective action. Adaptation increasingly features more prominently in government policy making. For example, each Central Government Department published in March 2010 (updated in May 2011) an adaptation plan explaining its proposed actions to address climate change risks. Important links with these plans, and the wider policy framework that influences adaptation have been referenced in each report.

## Examples of policy influence on adaptation found in the ECR

- The **UK agriculture sector** is heavily influenced by the policy landscape at national and EU levels. Some of these policies facilitate effective adaptation (such as the Soil Protection Review and Catchment Sensitive Farming).
- For **hospitals**, the Civil Contingencies Act 2004 and Industry Standards (e.g. BS NHS 25999 and PAS 2015) provide incentives to take action to ensure resilience. At the **community** level, the Scottish Government publishes a Guide to Emergency Planning for Community Groups to provide advice to community groups on how to work with local responders to plan for emergencies, and the Heatwave Plan facilitates and encourages local level action.

However, some policies can constrain adaptation action, largely as an indirect effect of achieving other objectives. For example:

- In the **fishing** sector, policies largely determined at the EU level, such as fishing quotas and other restrictions, can constrain the sector's flexibility to adapt, particularly through quota constraints and the degree to which their allocation is based on historic activity.
- In the **residential sector**, policies tend to focus on climate change mitigation as opposed to adaptation, so potentially miss opportunities to enhance resilience to overheating.

**This suggests that there is need to embed adaptation into policy design to ensure trade-offs across objectives are explored transparently and to maximise opportunities as policies are designed and reviewed.**

# Adaptive capacity is essential to develop and deliver appropriate adaptation responses. This has been assessed within each report

## Adaptive capacity

The **ability of a system/organisation to design or implement effective adaptation strategies** to adjust to information about potential climate change (including climate variability and extremes), moderate potential damages, and take advantage of opportunities, or cope with the consequences\*

The presence of adaptive capacity is a **necessary condition** for the design and implementation of effective adaptation strategies, so as to reduce the likelihood and the magnitude of harmful outcomes resulting from climate change (Brooks and Adger, 2005).

The ECR used existing frameworks (PACT (Ballard et al, 2011) and “the weakest link” (Tol and Yohe, 2006)) to assess the areas of capacity that need most development to get to the desired end point (Lonsdale et al, 2010)

**Adaptive capacity is most needed at the point of decision-making (including monitoring and evaluating). The ECR considers it in two forms:**

- **Structural adaptive capacity** which considers the ability of the sector as a whole to adapt - i.e. the role and size of different organisations involved) including interdependencies, sector complexity, decision lifetime and activity levels, and the risk of maladaptation; and,
- **Organisational adaptive capacity** which considers the ability of the organisations themselves to adapt - including resources available (such as financial, human, technological), organisational structure and decision making processes

By exploring the requirements for, and existence of, adaptive capacity of the relevant sectors and actors for each policy question, a series of findings begin to emerge regarding where requirements for adaptive capacity are higher and when they are lower. These are detailed in Annex 4. Adaptive capacity would be expected to change over time, especially as a result of measures introduced to build it, so it needs to be monitored and updated over time.

\* Ballard et al (2011), CCRA – modified IPCC definition to support project focus on management of future risks

## Common findings about adaptive capacity across the questions addressed highlight specific areas that can be strengthened to aid effective adaptation

Good adaptation is founded on strong adaptive capacity. That is, where the community or organisation is informed, is willing and able to adapt, and is engaged. There is significant variability in adaptive capacity of organisations within sectors, particularly in terms of sector, size of organisation and business model.

Common findings on adaptive capacity from the individual reports are set out in Annex 4.

In summary, the ECR found that adaptive capacity is strengthened when:

- **There are well understood risks**, particularly in organisations with in-house capability to prepare and respond e.g. asset assessment in the Highways Agency or National Grid; emergency planning in hospitals
- **There are few indirect risks or interdependencies** with other sectors e.g. hospital continuity is weakened by dependence on the resilience of service providers; natural flood management is only effective if co-benefits are realised
- **Support networks exist** for individuals and smaller organisations, particularly where they have fewer resources and cannot plan for the long term, e.g. vets and feed advisors for dairy farmers
- There is **strong organisational structure and leadership and coordination between organisations**, typically in large organisations in complex sectors e.g. health service
- **There is a stable, supportive and transparent policy environment** so organisations may plan and take effective action (e.g. Civil Contingencies Act 2004 has contributed to resilience planning in hospitals). Although in some cases, even where there is stability, the current framework can hinder action (e.g. fisheries)
- **Planning and processes are flexible** and embedded into decision-making
- There has been previous **experience of a climate change impact** (although this can also weaken capacity) – this highlights the importance of sharing experiences and learning from others

### Building adaptive capacity

Actions are required to build and strengthen adaptive capacity in order to respond to the scale of the challenge identified in each report. Some actions will be generic, e.g. education, training, strengthening coordination, while others are specific to the climate change risk e.g. increasing access to flood resistant building design or awareness of a flood risk.

# Different categories of adaptation actions are already being taken, or are expected, in response to climate change

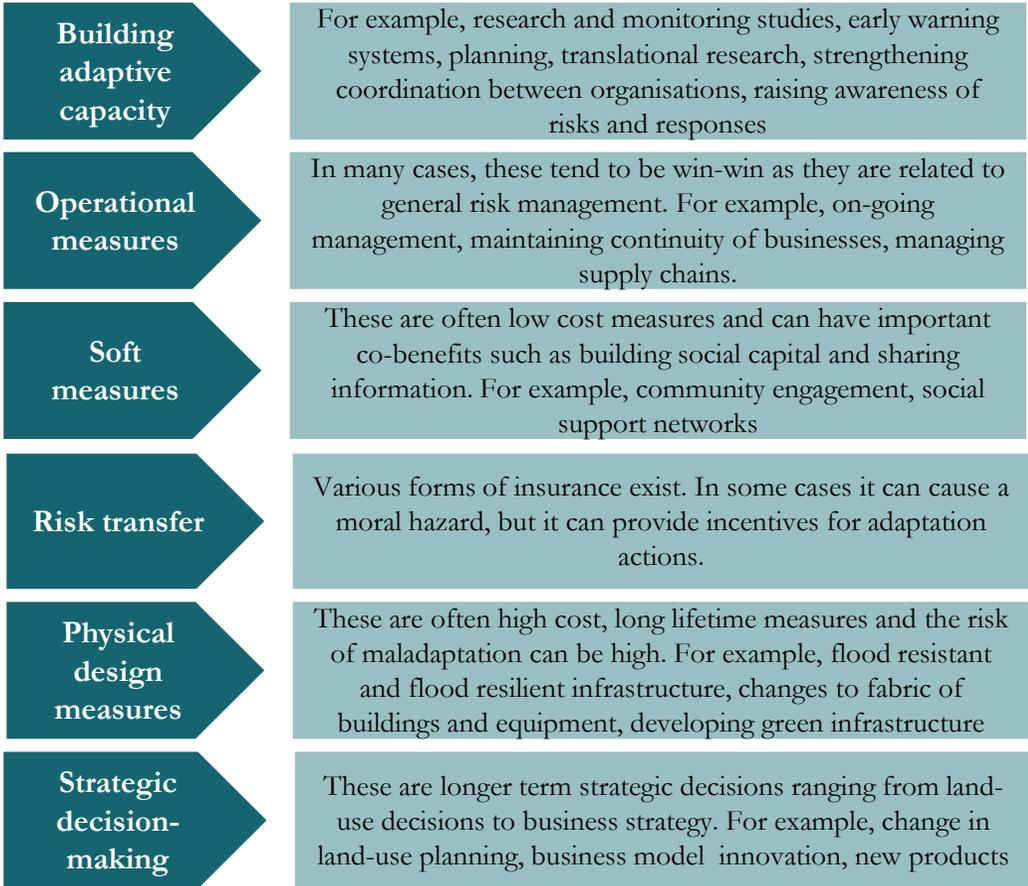
The ECR reports each set out categories of adaptation actions that are already being taken, or are expected to be taken, in relation to the policy questions. Adaptation actions include those that build adaptive capacity, as well as actions that reduce vulnerability to a specific risk or exploit opportunities. These categories were identified through published literature, discussions with experts and interviews with stakeholders. The types of actions (identified across the ECR reports) are set out in Figure 4.

The actions include adaptation that is:

- **Reactive:** a reactive response to climatic stimuli as a matter of course (without direct intervention of a public agency). For example, during a heatwave people may buy air conditioning units; and/or,
- **Planned:** tends to be anticipatory adaptation, undertaken or directly influenced by governments or collectives as a public policy initiative. Conscious responses to concerns about climate change. E.g., the Heatwave Plan for England sets out actions that should be taken by health and social sectors

The ECR analyses categories of adaptation actions by assessing the extent of current adaptation and adaptation that would be anticipated in the absence of further intervention; summarising barriers and enablers to the effective implementation of the actions; and, assessing the relative effectiveness of those actions.

**Figure 4: Types of adaptation actions identified across the five themes**



# The ECR reports use a common framework to assess the extent to which adaptation actions are currently being implemented, or are anticipated, and their relative effectiveness

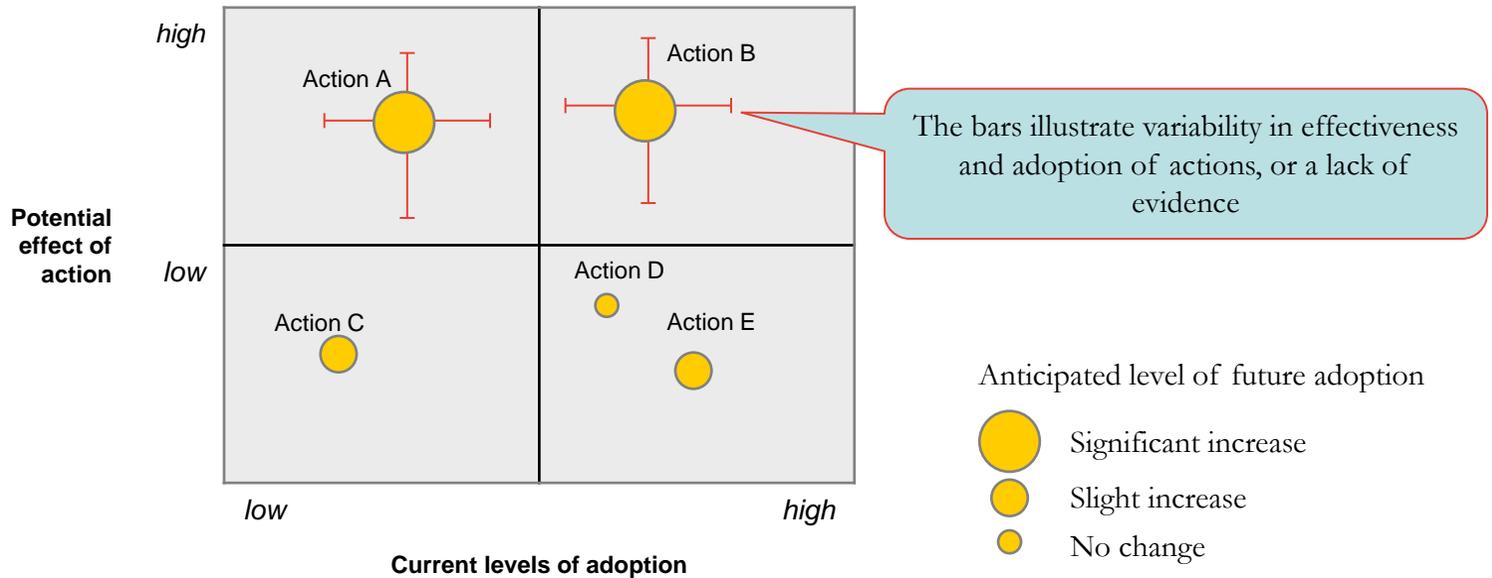
The ECR summarises the analysis in the reports by highlighting the current and anticipated extent of adoption of the categories of actions along with the relative effectiveness of those actions when taken (if appropriately designed and implemented). The framework is shown in Figure 5 – each yellow circle represents a category of actions. In relation to each question addressed by the ECR, one of these summary diagrams is presented in each report with particular categories of actions plotted.

The effectiveness of actions will vary significantly depending on the particular conditions under which they are implemented – a proportionate assessment of the associated costs and benefits should be carried out before implementation (including potential benefits and costs of taking action now to build flexibility to take further action in the future, or to allow time for learning).

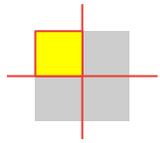
All the adaptation actions described are dependent on, and impact upon, many other actions within the sector and between sectors. The actions must not be considered in isolation.

Barriers are likely where we observe effective action but low uptake (top-left quadrant of Figure 5). Barriers may also exist where actions are being taken but are less effective, or ill informed, or could lead to maladaptation, or they are not being implemented widely (lower quadrants).

**Figure 5: Summary of effectiveness of actions and current and future adoption**



## Findings across the themes

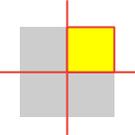


The actions in the top-left quadrant are relatively effective, but not widespread; this may indicate significant barriers to implementation. Examples of actions across the reports in this quadrant include:

- **Agriculture and Forestry:** Key actions include development and selection of climate resilient varieties & breeds, species and provenances, and management of ecosystem services especially at a landscape/catchment scale. Forestry specific actions include woodland creation, bringing forests into management and use of alternative silvicultural systems. For agriculture, water management, soil management and best practice farming management are important.
- **Buildings and Infrastructure:**
  - **Transport:** The actions include are systems-wide interventions related to transport management as well as responses to specific risks (e.g. fluvial and coastal flooding)
  - **Power:** Measures which could be important include energy efficiency, demand side management and distributed generation; however these have to be considered together with other drivers affecting the system as a whole
  - **Residential building:** Most measures in this sector are in this quadrant; key actions include active cooling, green infrastructure, shading, night ventilation, changing behaviour and cultural norms and increasing thermal mass
- **Business:** Key actions include the integration of climate change into product strategy and business models. Other important actions include supply chain assessment and management to mitigate interruptions. In some cases actions related to design and planning of facilities can be positioned in this quadrant.
- **Health and Well-being:** Many actions for this theme are in this quadrant and include infrastructure provision in hospitals, community engagement, social support and information provision
- **Natural Environment**
  - **Natural Flood Management:** This includes measures to reduce run-off (e.g. farm management), or attenuate flows (e.g. riparian tree planting). Effectiveness varies but can be important in reducing flooding for frequent events and in small catchments.
  - **Fish:** Important measures can include changing locations (smaller vessels only), consumer market development, and increasing vessel capacity.

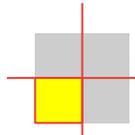
In many cases, the barriers preventing more widespread adoption of these measures relate to constrained adaptive capacity. Barriers are discussed in further detail in the next section.

## The reports also found actions that are effective and widespread, as well as those that are less effective

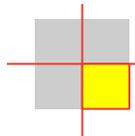


The actions in the top-right quadrant are considered effective and appear to be widespread, suggesting less need for intervention. There may be opportunities for enhancement, but actions required are mainly monitoring and review, to ensure they remain effective in the face of a changing climate and are good value for money. Examples from the individual reports include:

- **Agriculture and Forestry:** The use of new varieties and investment in storage infrastructure are well established in the sector. However, there could be a risk of maladaptation to poorly understood risks
- **Buildings and Infrastructure:** For closely regulated and less fragmented sectors (e.g. strategic transport and power generation) several measures are in this quadrant (e.g. management of overheating and surface water in transport, and flood defences, capacity and network expansion measures in power). However, there is a risk of maladaptation if climate change is not adequately incorporated into decision making
- **Business:** Business continuity management and process risk management are well understood and fairly widely adopted. Their effectiveness depends on the extent to which climate risks are considered as part of these plans
- **Health and Well-being:** Existing systems for planning, alert/early warning systems and service continuity are well established and consider a wide range of contingencies
- **Natural Environment:** Natural Flood Management is not widespread. In terms of maximising opportunities from new fish species, actions include changing location (larger vessels), and in some cases, export market development and changing gear



There are a number of actions that are considered less effective. This may be due to barriers or they are driven by factors that are not closely linked to climate change risks. These actions may not be priority areas for intervention, but with appropriate support could play a greater role.

- 
- **Agriculture and Forestry:** Land management measures such as farming practices, fire management are important in both sectors but do not necessarily address specific climate-related risks
  - **Buildings and Infrastructure:** Measures in this quadrant tend to be those which are low cost, easy to implement actions (e.g., changing clothing), or respond to risks are hard to characterise (e.g., landslide mitigation), or as in the housing sector include measures which may be ineffective if climate change risks are not integrated into decision making
  - **Business:** Insurance is an important measure but most current products may not be effective over the longer term; other measures include building capacity of suppliers
  - **Health and Well-being:** There are few measures in these quadrants and include service provision (e.g. mental health services)
  - **Natural Environment:** Natural flood management may not be effective where there is an immediate need, or where there are a large number of people affected. For opportunities from new fish species, actions can include income diversification, and in some cases, export market development and changing gear

# In each of the policy questions, barriers to effective adaptation have been identified by understanding market and other drivers of behaviour

## Identification of barriers

The framework for the identification of barriers used for all the policy question analyses is shown in Figure 6.

**Figure 6: Framework for identifying barriers to effective adaptation**

Market failures	The degree to which there are market failures relating to, for example, skills and information; the ‘public good’ nature of some assets or resources; and externalities
Policy failures	The framework of regulation and policy incentives (grants, subsidies, funding etc.) can all affect business behaviours and the degree to which adaptation is implemented effectively
Behavioural failures	Decision-making behaviour and willingness to act; inertia
Governance failures	Institutional decision-making processes

The common barriers from the reports are identified next.

Specific barriers are identified in each of the ECR reports. A series of cross-cutting barriers can however be identified

The barriers are explained in full in each report in line with the framework of Figure 6. This synthesis report has drawn out common cross-cutting barriers, which are shown in Figure 7. Given the focus on cross-cutting barriers, many are market failures – individual reports highlight more specific question-related policy, behavioural and governance barriers. These barriers would need to be addressed through intervention by government or other bodies.

Figure 7: Cross-cutting barriers

Market failure	<b>Infrastructure interdependency:</b> one sector creates external costs on another sector that are not accounted for in decision-making regarding its own resilience
Market failure	<b>Supply chain interdependency:</b> lack of transparency and understanding in the supply chain can lead to external effects of one company on another (particular problem for small organisations)
Market failure	<b>Information failures:</b> including too much and too little information on risks and appropriate responses; incomplete or out of date information; lack of user-friendly appraisal guidance to guide decision-makers
Market failure	<b>Evidence gaps:</b> on the costs and benefits of adaptation actions and the conditions under which they are effective
Market failure	<b>Lack of adaptive capacity (resources, skills, analytical tools):</b> particularly in small and medium sized organisations to take effective adaptation decisions
Policy failure	<b>Conflicting policy objectives:</b> lack of understanding of policy trade-offs or missed opportunities to integrate climate change into policy can lead to maladaptation (e.g. retrofitting houses for emissions' mitigation without considering adaptation) or lack of clarity
Behavioural failure	<b>Vulnerable groups in society:</b> these groups tend to have low adaptive capacity and can be marginalised from emergency planning processes; they often do not recognise they are at risk. Short term thinking of others in communities can also constrain action
Governance failure	<b>Diversity in responsibility and co-ordination failure:</b> where sectors are fragmented and many parties are involved in adaptation actions

It is important to observe that most of these barriers relate to limited or constrained adaptive capacity

## Adaptation actions need to be taken in the context of uncertainty: adaptive management is an important and effective approach to making robust decisions

The projected nature and impacts of climate change in the UK over future decades, particularly when considering out to the 2050s and beyond, are subject to uncertainties (Annex 1 provides more detail). These uncertainties relate not only to projected climate changes, but also socio-economic and political changes.

Uncertainties are particularly problematic for planning large, high cost adaptation options with long lifetimes, as such investments are costly to modify and their design is dependent on what assumptions are made today about climate over the investment's lifetime. If decisions are made without considering these uncertainties, there is a risk of over or under adaptation, wasted investments or unnecessary retrofit costs (Reeder and Ranger, 2011). Adaptation decisions must therefore be robust in the face of a fast changing and uncertain climate (Hall, 2007).

In the ECR, adaptive management as an approach is illustrated in a pragmatic way through **climate risk-based roadmaps** which allow appropriate actions to be identified and mapped out for implementation over time (where there is a case for doing so, based on cost-benefit analysis). They allow for incremental implementation of adaptation measures, and leave options open across a range of possible future scenarios. Importantly, they make explicit the need for constant monitoring and reviewing of actions taken, and allow further steps to be taken and iterated, consistent with a strategic direction and the unfolding information about the future.

The approach allows parties to learn over time and for new information to be reflected in decision making processes. The essence of the approach is to be clear on the direction of travel, or the vision for the desired outcomes or the management/goals, and the uncertainties about how to achieve these outcomes (Murray & Marmorek, 2004). Roadmaps should be developed involving stakeholders and account for interdependencies across adaptation actions and risks.

In the long term, the direction of travel may need to change, and incremental changes may no longer be sufficient as the vulnerabilities and risks may be so sizeable that they overwhelm even robust human use systems. Transformational adaptations will then be required: those that are adopted at a much larger scale, that are truly new to a particular region or resource system, and that transform places and shift locations (Kates et al, 2012). Anticipating transformational adaptation is extremely difficult because of uncertainties about climate change risks and adaptation benefits, high costs, and institutional and individual mindset that prefers to maintain existing resource systems and policies than create massive change.

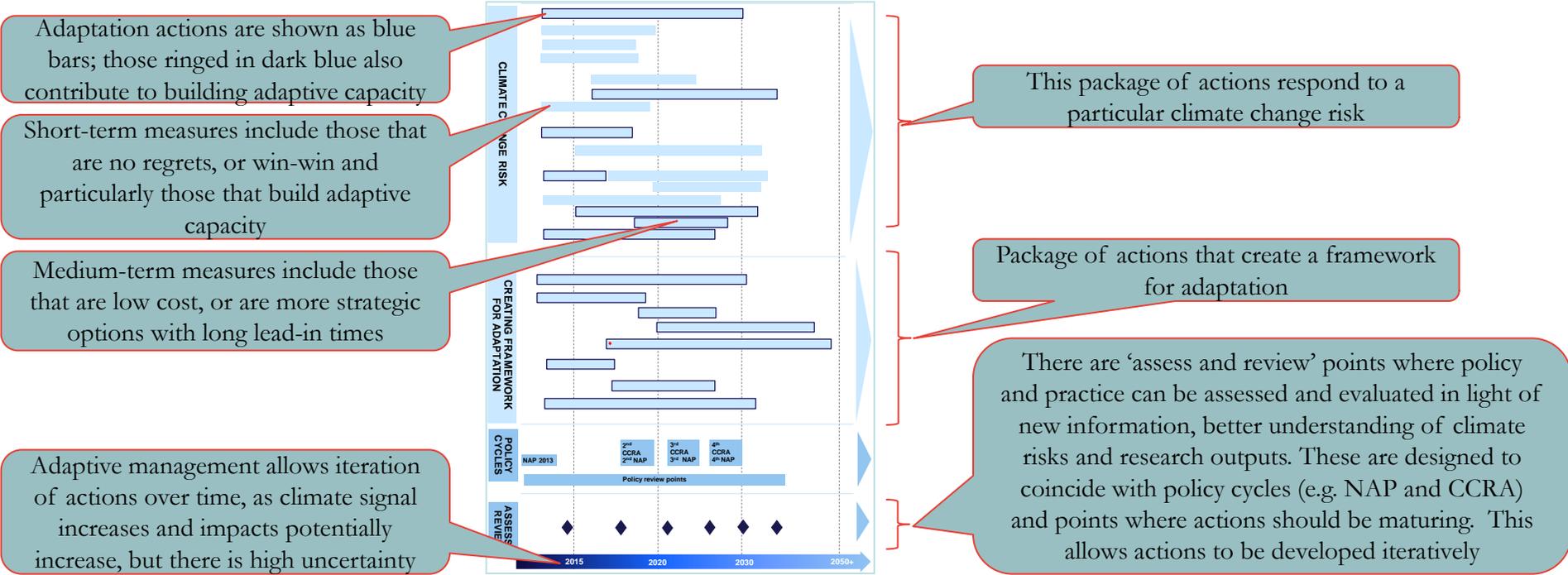
# Following an adaptive management approach, the ECR suggests illustrative roadmaps as a pragmatic tool to map out the delivery of adaptation actions over time

An example roadmap is shown in Figure 8. The roadmaps are risk-based and are intended to show ‘packages’ of actions that can be implemented over time to respond to particular climate risks.

The roadmaps used in the ECR differ from more detailed ‘adaptation pathways’ which are similar but require “known thresholds” for climate change risks and the limits of adaptation actions against those thresholds. Given the range of risks considered in each report, this has not been possible in the ECR. The roadmaps build in deliberate review points where actions can be reviewed and assessed in light of new information, allowing for learning. To develop these roadmaps and deliver effective adaptation, the barriers would need to be addressed.

Before implementation, in line with the more detailed pathways approach, actions should be subject to a full assessment of the costs and benefits of action (thresholds and limits of adaptation would need to be understood first). Phase 2 of the ECR presents a framework to identify the appropriate appraisal technique along with guidance on how it can be implemented, using two worked examples.

**Figure 8: Example illustrative roadmap**



# To facilitate the implementation of adaptation responses in line with adaptive management, barriers must be addressed through intervention

## Identifying the case for intervention

The case for intervention by government or other bodies is likely to exist where:

- **Organisations or individuals lack the adaptive capacity** to be able to adequately prepare for climate change. It is critical to **target vulnerable groups** who are often lacking in adaptive capacity and must rely on others' adaptive actions.
- There are **significant barriers or constraints** to implementing effective adaptation action. This may be because markets lack the required information to allow appropriate signals to be sent to parties to take appropriate action.
- **The UK may otherwise become 'locked in'** to a path that could lead to **maladaptation** or removes **the flexibility required to adapt effectively, especially in the context of the associated uncertainties.**

Before implementation, interventions should be assessed against the government's standard criteria of efficiency (whether benefits outweigh the costs); effectiveness (whether vulnerability to climate change is reduced); and equity (distributional consequences) (Cimato and Mullan, 2010).

**Whether actions are implemented should be guided by appropriate and proportionate assessment of the costs and benefits of action (including those that can be monetised and those that cannot) relative to the alternatives (including no further action). This must include the consideration of expected benefits and costs of buying time and flexibility to adapt in the future.**

Intervention is likely to be required to allow effective adaptation strategies to be developed in the context of uncertainty. Within each ECR report, intervention recommendations specific to the policy question are presented (see Annex 5). Considering all the specific recommendations, the ECR has identified cross-cutting recommendations, which are presented next.

# Each of the 9 ECR reports presents specific interventions to address the main barriers. Several cross-cutting recommendations for government or other bodies can be identified

## Barriers

## Recommendations

Infrastructure interdependency

Supply chain interdependency

Co-ordination failure

**Conduct case study research to understand infrastructure and supply chain dependencies for sectors and organisations at high risk of climate change impacts** (currently and in the near, medium and long-term). Draw on lessons learned in relation to: (i) Identification of other actors or infrastructures with whom interdependencies are likely to exacerbate the risks of climate change most significantly (ii) Development of plausible ‘what if?’ analysis to estimate the scale of potential costs associated with the exacerbated climate risk arising from those interdependencies (iii) Development of climate-risk-focused adaptation roadmaps (or pathways where evidence allows) that account for these interdependencies

The ECR analysis finds this to be required for power infrastructure, hospitals, manufacturers and small businesses in particular.

**Identify and empower appropriate organisations with accountability for co-ordinating the development, implementation, monitoring and review of cross-sector climate-risk-based roadmaps (or pathways) involving stakeholders as appropriate.** The ECR identifies a need for co-ordinated responses to flood risk at the community-level (including post-flood recovery), risks facing the agricultural and forestry supply and production chains; and, heat-related risks to human health (among others).

Misaligned policy objectives

**Integrate climate change adaptation considerations within new and existing policy and regulatory frameworks e.g. when policies are reviewed.** The ECR finds this to be particularly required for the housing policy framework, climate change mitigation policy mechanisms and national infrastructure regulators.

Vulnerable groups in society

**Undertake an audit of groups vulnerable to climate change risks and associated voluntary groups who could support them.** Integrate voluntary groups within plans for climate change preparedness, response and recovery at a local level with collaboration and partnerships.

Each of the 9 ECR reports presents specific interventions to address the main barriers. Several cross-cutting recommendations for government or other bodies can be identified

Barriers

Recommendations

Information failures  
Evidence gaps on the costs and benefits of adaptation

**Learn from adaptive capacity assessments to identify key decision makers in businesses/organisations and understand the nature of climate information they need to make appropriate adaptation decisions.** Deliver relevant climate information to be integrated within decision-making frameworks. The ECR finds this to be an essential component of building adaptive capacity for businesses, NHS hospitals, farmers, forestry managers

**Engage businesses, communities and individuals collaboratively through an effective and constructive on-going dialogue to understand their requirements and challenges for adaptation.** Tailor communication to ensure it is effective and responsive to their needs. Facilitate sharing information and lessons learned through appropriate on-line and face-to-face fora. The ECR finds this is particularly required for communities (including individuals and businesses) at risk of flooding or overheating; agriculture and forestry landowners and managers; and healthcare providers including hospitals.

**Develop and operationalise – with appropriate monitoring and review - a comprehensive user-friendly hub of practical information to support communities (including businesses) at high flood risk covering all relevant aspects of understanding flooding risk, and actions to prepare, respond and recover.** The ECR finds this is required for local communities at risk of flooding.

**Conduct ex-post evaluations of adaptation responses to assess their effectiveness.** Develop and operationalise a national adaptation evidence-hub populated with evidence on alternative adaptation actions including expected costs and benefits and conditions under which they are effective. The ECR finds this is particularly required for adaptation actions taken by strategic infrastructure sectors at high climate risk; actions to address post-flood mental health disorders and heat impacts on the health of the elderly; hospital adaptation actions; overheating in residential housing; and, communities at risk of flooding.

**Deliver extension services to integrate climate change risk into decision making processes within small and medium sized organisations.** Identify and equip appropriate organisations with the required skills, knowledge and resources to support this and act as ‘champions’ initiating change. The ECR finds a particular need to provide those organisations (e.g. businesses, farmers) with appropriate support (such as skills training and financial) to manage the impacts of extreme weather events.

## While undertaking the ECR, a range of challenges and suggested areas further work were identified

- **Challenge 1: Lack of evaluation evidence on the effectiveness, efficiency and equity considerations of adaptation interventions and the conditions under which they are effective**

Suggested further work

- Require the ex post evaluation of a wide range of public sector interventions** to develop the evidence base on their costs and benefits, with guidance on how other bodies can undertake them in the future
- Commission case studies to explore the process of delivering adaptation actions – use these to disseminate lessons learned**
- Commission case studies to build a better understanding of the risks of maladaptation**
- Conduct research on the skills that facilitate and enhance the effectiveness of adaptation actions** – for example, the behavioural responses health care providers could take in the event of extreme heat to help patients.
- Build evidence on the effectiveness, efficiency and equity considerations of small-scale quick-win and no-regrets actions by individuals to mitigate climate risks. Particular consideration should be given to the limits of these adaptation actions.**

- **Challenge 2: The economics of adaptation often requires an understanding at the location- or context-specific level.**

Suggested further work:

- Local limits to adaptation and thresholds must be assessed to inform the development of adaptation strategies**
- Defra and relevant government departments should develop better analytical capability to assess packages of adaptation**

measures to allow interactions and synergies to be better understood

- Mechanisms for sharing information at the community-level should be evaluated to identify best practices**

- **Challenge 3: Cross-cutting issues are likely to have a significant effect on the costs and benefits of adaptation. For example, technological change, changing demographics and shifts in vulnerable groups**

Suggested further work

- Research appropriate measures to speed up the process of recovery of communities after an extreme weather event. This includes exploring technological developments and how these impact on adaptive capacity and the costs and benefits of action. For example the use of rapid-drying technologies by insurance companies when residential properties are flooded, and cleaning of possessions (to avoid the need for disposal).
- Research to track demographic change and how this can affect adaptive capacity.

- **Challenge 4: Evidence was developed using bottom-up analysis for the ECR. For some issues, this creates the challenge of identifying wider applicability.**

Suggested further work

- As per the suggestion to address Challenge 1, a series of case studies is required in relation to particular risks, with common themes identified. These should be undertaken over time to allow tracking of the development of adaptive capacity, technology and effectiveness of adaptation actions.

# ANNEXES

# Annex 1: Understanding climate change projections

## Climate projections

A climate projection is the projection of the response of the climate system to a given global annual CO<sub>2</sub> emission scenario (in gigatonnes of carbon). Climate projections are given for 30-yr time periods. Using different emissions scenarios (low, medium or high) in the projections results in different changes in climate variables for the projected time period, where changes are always given relative to the baseline climate in 1961 to 1990.

In the UK Climate Projections (UKCP09), changes in climate variables are projected for seven future overlapping 30 yr time periods, each time stepping forward a decade. The 2050s used below refers to a time period of 2040 to 2069, where projections are made at a resolution 25km over land.

## Uncertainties in climate projections

There are three major sources of uncertainties in estimating future climate change:

- Natural Climate Variability, caused by the chaotic nature of the climate system and external factors like changes in solar radiation.
- Representation of the Earth's climate system in climate models, caused by an incomplete knowledge of the climate system and the inability to model it perfectly.
- Uncertainty in future greenhouse gas emissions, caused by the assumptions taken on socioeconomic factors, GDP, energy use and energy mix.

The uncertainties mentioned above are accounted for in the UK Climate Change projections (UKCP09). Probabilities distributions are attached to climate change projections by using projections from multiple climate models and several variation of a single model.

## Sources for climate change data

For the ECR reports (Agriculture, Forestry, Transport, Power, Residential, Health and Natural Flood Management), the UK Climate Change Risk Assessment (CCRA) was used as the primary source of information on climate change, published in 2012. The CCRA reviewed the evidence for over 700 potential impacts of climate change in a UK context across 11 key sectors. The CCRA is cited as the primary source and where possible, the original source is also cited. For the business report, additional sources were also identified with a focus on the motor manufacturing and pharmaceutical industries. The report relating to fish relies on alternative sources as are cited in that report.

## Ranges

Where possible, the ranges for climate projections cited cover the UKCP09 low emissions scenario, 10% probability (10<sup>th</sup> percentile), meaning that the value is very likely to be exceeded, to a high emissions scenario 90% probability (90<sup>th</sup> percentile), meaning that the value is very likely not to be exceeded. In some case the medium emissions scenario, 50% (50<sup>th</sup> percentile) probability is cited, meaning that the value is as likely as not to occur; this is cited directly from the CCRA if there are no other ranges stated.

# Annex 2: Expert Panel

## Agriculture

- Professor Keith Goulding – Rothamsted Research
- Andy Whitmore - Rothamsted Research
- John Murlis – former Chief Scientist , Environment Agency
- James Hutton Institute

## Forestry

- James Morison – Forest Research
- Andy Moffat - Forest Research

## Buildings and infrastructure

- Professor Robin Hickman, Bartlett School, UCL
- Tom Worsley, Institute of Transport Studies, Leeds University
- Professor Michael Davies - Professor of Building and Physics at the University College London
- Professor Tony Day - TEAM Energy Services Ltd
- Paul O'Rourke - a sector expert with over 40 years' of power industry expertise.

## Business and services

- Chris Cromey-Hawke: supply chain specialist
- Dr Tom Downing: CEO Global Climate Adaptation Partnership

## Health and well-being

- Professor Paul Wilkinson – London School of Hygiene and Tropical Medicine

## Natural Environment

- Dr John Pinnegar - Centre for Environment, Fisheries & Aquaculture Science (Cefas)
- Miranda Jones - University of East Anglia
- Julian Wright and Bill Donovan – Environment Agency
- John Murlis - former Chief Scientist, Environment Agency

## Annex 3: Stakeholder list

### Agriculture

- Levy Boards: BPEX, EBLEX, HGCA
- Government: Defra, Environment Agency, Scottish Government, Welsh Government, Northern Ireland Executive, Natural England
- Suppliers/research: Aberdeen University, British Society of Plant Breeders, Campden BRI, Cranfield University, Leatherhead Enterprise Centre, Scottish Agricultural College, Syngenta, Warwick HRI
- Industry bodies and consultants: ADAS, Agricultural Industries Confederation, Country Landowners and Business Association, Institution of Grocery Distribution, National Farmers Union, LEAF, Potato Council, Processors and Growers Research Organisation, Royal Horticultural Society
- Retailers: Marks and Spencer, Tesco, Waitrose, ASDA

### Forestry

- Managers of public forest: Forestry Commission England, Forestry Commission Scotland, Forestry Commission Wales, Forest Enterprise, Forest Research
- Large commercial owners: Confor, Institute of Chartered Foresters, UPM Tillhill
- Government : Defra, Department of the Environment (NI), Energy and Climate Change Division (Welsh Government), Climate Change Legislation Team, The Scottish Government
- Other stakeholders: EWGS, Future Trees Trust, Independent Panel on Forestry, John Clegg Ltd, Rural Development Initiative, Sylva Foundation

### Transport

- Transport: Department for Transport, Eurotunnel, Highways Agency, Network Rail, Northern Ireland Executive, Office of Rail Regulation, Transport for London, Transport for Scotland, University of Birmingham, Welsh Government
- Power: Association of electricity producers, E.ON, National Grid, Scottish Power, Ofgem, AEP, EDF
- Built Environment: AECOM, ARUP, ARCADIA, BSRIA, B&Q, CREW, Daikin Air Con, Drivers Jonas Deloitte, GLA, NHBC, SIG plc., UKCIP, UCL, TEAM Energy, Technology Strategy Board, Toshiba Air Con

# Annex 3: Stakeholder list

## Business and services

- Industry Bodies: Association of British Insurers, Centre for Process Innovation, Chemical Business Association, Chemical Industry Association, Institution of Mechanical Engineers, Federation of Small Businesses, Society of Motor Manufacturers and Traders.
- Large Manufacturers: Akzo Nobel, Dow Corning, EBM-PAPST, INEOS, Schaeffler
- Government bodies: Department for Business, Innovation and Skills, Climate Change Committee Wales, Scotland 2020 climate group.
- Other: Carbon Disclosure Project; Malcolm Wilkinson, independent; Geoff Stevens, independent.

## Health and well-being

- Government bodies: Cabinet Office, Department of Health, Environment Agency, Health Protection Agency, NI Government, NHS Sustainable Development Unit, NHS Scotland, NHS Wales, Welsh Government
- Local government : Hull City Council, Gloucestershire County Council, Doncaster Council, Great Yarmouth Council, London Borough of Islington Council
- Research: University of Bath, University College London, Lancaster University
- Charities: Climate UK, Joseph Rowntree Foundation, National Council of Voluntary Organisation, National Flood Forum, SNIFFER Scotland
- Hospitals: Gloucestershire Hospitals NHS Foundation Trust and Aintree University Hospital NHS Foundation Trust

## Natural Environment: Fisheries

- Government : Marine Management Organisation, Marine Scotland
- Industry bodies: NFFO, North Devon Fisherman’s Association, Scottish Pelagic Fisherman’s Association, Seafish
- Research: Cefas, Marine Climate Change Impact Project
- Retail: Waitrose

## Natural Environment: NFM

- Government : Environment Agency, Forestry Commission England, SEPA, Welsh Government
- Research: James Hutton Institute, Tweed Forum, University of Newcastle
- Charities: National Trust, Woodland Trust

## Annex 4. Adaptive capacity

Adaptive capacity in the UK varies significantly from a sector structural perspective.....

### Requirements for adaptive capacity are higher where there is...

- **High complexity** in the sector with multiple interacting organisations and a diverse requirements, roles and responsibilities – such as complex value chains with multiple tiers of companies; and where the sector is fragmented e.g. agriculture includes a large number of small farmers
- **Interdependency of adaptive capacity with others** – such as property or land tenants who are reliant on decisions made by their landlords; and those in care who are dependent on the adaptive capacity of their carers
- **Interdependency of operations** and a limited ability to manage risks, such as reliance on public infrastructure and service provision e.g. hospitals and the power sector are reliant on the resilience of other infrastructure services (water, transport etc)
- **Reliance on the natural environment and managing weather variations** can lead to a short-term focus in business planning, along with an inability to respond owing to natural constraints, e.g., fishing vessel operators and small farmers who can lose a year's yield in times of drought
- **Low activity levels but decision lifetimes are long** resulting in fewer opportunities to make decisions, e.g., decisions related to building houses, tree species planted in woodlands, land-use change, or major investments in infrastructure
- **Decisions to address one risk can increase vulnerability to another** - such as housing built without consideration of climate impacts may require retrofitting, buying air conditioning units can increase energy demand and CO<sub>2</sub> emissions

### Requirements for adaptive capacity are lower where there is...

- **Low complexity** in the sector because there are few organisations making decisions, e.g. power generation is dominated by a few companies who respond to one regulator
- **Co-ordination between organisations** occurs as part of operational planning, as is often carried out across hospitals or other healthcare providers
- **Regulated sectors** in which the regulatory requirements take due account of current and projected climate risks
- **Decision lifetimes are short** – frequently made decisions are more flexible, allowing for regular review and evolution with increased knowledge of climate risks. For example, plans to respond to a risk (e.g. the Heatwave Plan, flood plans, or business continuity plans) and regular management decisions (e.g. farmers planting crops, operational practices in fishing fleets)
- **Prior experience** of impacts associated with extreme weather conditions can enhance the ability to adapt in the future, e.g. Heatwave Plan was developed following the 2003 heatwave. However, there are instances where this can also weaken capacity, e.g. communities who have suffered from flood events may be less able to adapt to a further event

## Annex 4: Adaptive capacity

...as well as within organisations and across individuals

### Adaptive capacity is higher where there is:

#### Resources

- **Well understood risks** and organisations with in-house capability to respond (e.g. Highways Agency, Forestry Commission, National Grid, and emergency planning in hospitals)

#### Processes

- **Flexible planning and processes embedded into decision-making** – e.g., manufacturing can be shifted to alternative sites or supply chains can be diversified (generally in larger, multinational companies)
- **Partnerships and collaboration** – such as local authorities working with voluntary organisations
- **Operational planning that already accounts for similar risks to those expected to increase from climate change** – e.g., process risk management in the chemicals sector
- **Access to risk spreading mechanisms** – e.g. insurance

#### Organisation

- **Agents of change or champions** at the community level can make a real difference – e.g., a community member taking the initiative to set up support groups, as happened in Toll Bar following a flood
- **Strong leadership and culture** – e.g., corporations in the automotive sector are able to influence certain suppliers
- **Support networks** – particularly important for smaller organisations and individuals, and where long-term planning is limited (e.g. vets and feed advisors support dairy farmers; or where community groups connect individuals)

### Adaptive capacity is lower where there is:

#### Resources

- **Lack of awareness** of climate change and its relevance persists, and lack of willingness to accept the nature of a risk, e.g., some vulnerable individuals do not wish to accept that they may be ‘vulnerable’
- **Lack of financial support and skills to adapt** – e.g. individuals of low socio-economic status and small/medium-sized organisations
- **Lack of specialised skills and training** to understand and respond to climate change impacts, e.g. some private woodland managers may have other priorities and objectives, and lack of supply chain for addressing overheating in housing
- **Poorly targeted information** – information can be overwhelming e.g., generic information provided to farmers, or insufficient, e.g., individuals being unaware of their overheating risk

#### Processes

- **Limited ability to influence decision making** – e.g., tenants are dependent on landlords to take action to respond to certain risks
- **Lack of engagement with vulnerable groups** – e.g. the elderly at risk of overheating, or physically disabled

#### Organisation

- **Diversity of responsibility** with different objectives – e.g. different providers in the care home sector, multiple land-owners in catchment areas
- **Competing demands arise from different users** – e.g. farmers, industry and households all requiring water from the same catchment

# RECOMMENDED INTERVENTIONS FROM INDIVIDUAL REPORTS

### Given projected climate change and likely adaptation, what is the case for further intervention in relation to agricultural productivity (yields of wheat, sugar beet, potatoes and grassland) and production?

The ECR finds a case for intervention with the following recommendations:

- **Develop adaptation roadmaps at the appropriate scale to identify effective adaptation strategies to manage climate change risks. Undertake research to develop a better understanding of the dependencies across agriculture and the natural environment and other sectors, and ensure the roadmaps account for these.** Roadmaps should incorporate packages of actions; review points to allow learning and modifications to take place over time; incremental changes to existing processes (sharing information, etc.) and the potential for transformational actions (e.g. developing integrated pest management).

#### **Build adaptive capacity in relation to:**

- **Breeding activities by ensuring climate change adaptation is embedded within research programmes.** This is likely to require expertise to be integrated across the value chain.
- **Undertaking case study research involving cost-benefit analysis of a range of adaptation actions** implemented across a range of contexts to understand the conditions under which they are likely to be effective.
- **Identify appropriate bodies to be accountable for overseeing and advising on the translation of academic research into UK products, services and actions.** This would allow a greater level of understanding at the farm-level to help overcome behavioural barriers to adapting to climate change and breeding to develop climate-resilient traits specific to the UK. A national extension service, if appropriately designed to communicate practical, timely and easily accessible information, could offer significant benefits through disseminating and translating applicable research for farmers.
- **Identify appropriate local champions to co-ordinate actions to facilitate the delivery of cost-sharing practices across catchments.** This could be appropriate where smaller farms are currently constrained by low incomes, particularly in relation to large infrastructures, such as those for water or storage.
- **Identify appropriate existing communication channels and farmer support networks to deliver practical knowledge and best practice in relation to the management of pests and diseases and water constraints, in particular.** Behavioural barriers in relation to the uptake of new technologies or perceptions of longer term uncertainties could therefore be addressed

### Given projected climate change and likely adaptation, what is the case for further intervention in relation to forest productivity and associated ecosystem services?

The ECR finds a case for intervention with the following recommendations:

- **Enhance adaptive capacity by exploring practical and cost-effective ways to reduce the amount of under-managed woodland.** This should be complemented through the delivery of tailored, practical knowledge and advice to forest managers about appropriate management techniques, and addressing both behavioural barriers and market failures, which mean managers have little incentive better to manage forests (e.g. by creating market mechanisms or grants)
- **Encourage and facilitate through research and demonstration the planting of climate-resilient provenances and species to meet long-term timber production needs and ecosystem services delivery. Ensure timely and tailored information is available to forest owners and managers on the most climate-resilience provenances and species.** Information for forest managers must be practical, easily accessible and targeted – this is essential to build adaptive capacity.
- **Address remaining market failures to support the protection of ecosystem services.** Market mechanisms should be explored which facilitate the protection and enhanced delivery of ecosystem services from woodland. The Woodland Carbon Code, the development of the Environment Bank and biodiversity offsets are recent examples.
- **Undertake research and analysis to identify appropriate interventions to facilitate the co-ordination of forest adaptation action between owners at forest/catchment-scale. Implement effective interventions.** At the same time, efforts to encourage woodland creation to deliver cross-sectoral benefits (including enhanced resilience to climate change) need to be promoted.
- **Undertake case study analysis of adaptation actions through robust analysis of the costs and benefits of a range of actions and the conditions under which they are likely to be effective.** Adaptive capacity should be built by exploring practical steps to learn from overseas and UK practices to increase resilience. Monitoring, reviewing and sharing of lessons should be carried out

### Given projected climate change and likely adaptation, what is the case for further intervention in relation to strategic road and rail delays from flooding, rail buckling and landslides?

The ECR finds a case for intervention with the following recommendations:

- **Build adaptive capacity by:**
  - **Undertaking case study research in areas at risk of flooding or landslides to understand better the nature of interdependencies** within and across sectors. Case studies should include areas where single, or a limited number of, links are relied upon for access or to connect locations. Such case studies should be used to inform the development of cross-sectoral adaptation roadmaps at the appropriate geographical (or other) scale for strategic road and rail. Case studies could focus on the effects of flooding or landslides on major and minor roads and the cross-sectoral interactions between strategic road and rail and other policy areas such as business, land-use planning and other infrastructure providers
  - **Undertaking a series ex-post evaluations of adaptation actions** that improve the climate resilience of strategic road and rail. This information should be collated into a common and accessible format to share with transport agencies and enhance best practice. For example, on the supply-side, this should include the impacts of improved drainage on travel reliability and delays, and the costs and benefits of bridge scour action. On the demand-side, it should include the effectiveness of demand management and traffic flow management during times of floods.
- **Developing further the evidence-base on the risk of bridge scour** for strategic motorway and, importantly, non-motorway routes.
- **Incorporate a requirement within the Department for Transport’s transport appraisal guidance (WebTAG) for appraisal scenarios to reflect different probabilities of disruption** which may result from a range of projected extreme weather events, where appropriate. This would ensure that the associated costs are reflected in the ‘do minimum’ option, against which the relative costs and benefits of the intervention can be assessed
- **Maximise opportunities from renewal programmes to enhance resilience in an iterative way.** Given the level of investment in maintenance and renewal programmes on key strategic infrastructure, it is important that programmes build sufficient infrastructural resilience as new information emerges on the climate risk. For example, by considering alternative climate change emissions scenarios – including severe weather events - when planning the work
- **Maximise opportunities from traffic and travel demand management as an adaptation action.** Undertake research to:
  - Explore the use of traffic and travel management on non-motorway routes to manage flood-related delays; and,
  - Better understand traveller behaviour in response to traffic and demand management initiatives

### Given projected climate change and likely adaptation, what is the case for further intervention in relation to power generation and transmission, seasonal demand for energy?

The ECR finds a case for intervention with the following recommendations:

- **Build adaptive capacity of the sector by enhancing knowledge and understanding of interdependencies of the energy sector and adjacent sectors.** In particular:
  - Undertake system-wide modelling, or case study assessments, as appropriate, to explore different climate risk and adaptation scenarios to understand both how the resilience of one sector is affected by actions in another, and how adaptation actions can affect the system more widely .
  - Ensure climate change is appropriately factored into assessments of potential future interdependencies across infrastructure sectors, particularly in terms of technology, operations and actions taken in other sectors.
- **Require the assessment of potential climate threats – including extreme weather events – as a core component of the decision on how much capacity to contract through the Capacity Market.** Government’s current thinking is that the decision on capacity will be taken with reference to a reliability standard.
- **Ensure that the policy and regulatory framework is kept under review** in order for it to be able to provide the sector with the right incentives for climate change adaptation in a timely fashion.
- **Review and identify appropriate opportunities to embed consideration of climate change threats into the location, design and construction of new generation capacity.** Key decisions will be taken over coming years as generation capacity is de-commissioned and replaced, and as the transmission grid is updated – these offer important opportunities for the sector to develop solutions which deliver a higher level of resilience

### Given projected climate change and likely adaptation, what is the case for further intervention in relation to energy demand for cooling in residential properties and associated CO<sub>2</sub>?

The ECR finds a case for intervention with the following recommendations:

- **Build adaptive capacity of the sector by increasing the skills and knowledge of the organisations within the supply chain** so that new build properties are designed to take account of climate change risks, including overheating.
- **Build adaptive capacity of the sector by developing the supply chain for retrofits**, to ensure that builders and architects have access to equipment and information that enables them to advise on effective adaptation, and that residents have access to advice on how to adapt houses effectively. Particular focus should be on behavioural change and passive measures, which are likely to be lower cost and not maladaptive.
- **Build adaptive capacity by undertaking analysis of the impacts, costs and benefits of alternative cooling options and the conditions under which they are effective.** This must include green infrastructure options. Use this to build best practice over time.
- **Undertake ex post evaluations of interventions such as design, low-cost retrofits and green infrastructure.** Use the emerging evidence to learn and develop best practice approaches and to disseminate guidance to those at risk.
- **Address information failures by ensuring targeted and engaging information is accessible for those at risk of overheating**, along with simple guidance of appropriate actions to lower their risk.
- **Review the housing policy framework to ensure that adaptation is considered alongside mitigation in a retrofit package.** Address policy imbalances where the focus is on mitigation actions only and not adaptation.
- **Allow for flexibility in relevant building regulations at a local level so that cooling options can be better explored** to prevent the need for costly retrofits. Consideration should be given to be flexible to the types of buildings and specific locations.
- **Facilitate energy efficiency improvements** through appropriate review of the relevant policy framework to ensure it remains supportive.
- **Build adaptive capacity of residents** through ensuring greater provision of targeted education and information on behaviour change and passive measures, such as keeping curtains closed during the day, opening windows at night etc.
- **Facilitate and support the effective implementation of planning policy by local authorities to ensure decisions adequately account for adaptation and consider efficient cooling options, where appropriate.** This includes passive measures as well as green space.

### Given projected climate change and likely adaptation, what is the case for further intervention in relation to business continuity with particular reference to the chemicals and automotive manufacturing sectors?

The ECR finds a case for intervention with the following recommendations:

- **Encourage and facilitate businesses to investigate their infrastructure and value chain dependencies. This should then be used by businesses to inform the development of risk-based adaptation roadmaps (in line with an adaptive management approach).** This involves encouraging businesses to review their business models to assess the degree to which suppliers and consumer markets served (and access to them) could be at high risk of climate change, or could offer opportunities. Where possible this should be based on a detailed assessment of individual climate risks, thresholds and what the limits of specific actions may be in reducing these risks.
- **Undertake work collaboratively (involving businesses and relevant stakeholders) to develop localised longer-term scenario projections of flood risks along with practical guidance for businesses on using them to inform investment decisions.** This is particularly important in areas assessed at high risk of flooding in the near-term (i.e. in the 2020s).
- **Collate a series of case study cost-benefit analyses of adaptation actions undertaken by businesses and identify the conditions under which they are effective. Identify a suitable business forum (possibly with government support) to act as a shared platform for evidence on the effectiveness of adaptation actions with practical guidance on their implementation.** Existing channels should be used to bring together businesses to share skills and experience in managing climate change risks.
- **Develop practical guidance for businesses to implement supply chain risk management plans, for both large businesses and SMEs, and to enhance resilience in their business models.**
- **Encourage co-located businesses to share information about how their activities may be interdependent, and develop joint risk management plans and roadmaps which are monitored, reviewed and updated at regular intervals (at least 3-5 years)**

### Given projected climate change and likely adaptation, what is the case for further intervention in relation to the continuity of services from NHS hospitals at risk of flooding?

The ECR finds a case for intervention with the following recommendations:

- **Build an understanding across hospitals of the interdependencies in service provision** (e.g. with water, power and transport infrastructure) **and with other healthcare providers.** This involves mapping linkages to identify the key points of risk, and appropriate scenarios to inform decision-makers. Share information across interdependent hospitals on resilience and planned actions to facilitate effective decision-making.
- **Assess the degree to which hospital resilience is affected by climate change risks to other sectors and the actions they are taking to adapt.** For example, this could be undertaken for particular areas as pilot studies.
- **Evaluate hospital adaptation actions (ex post) to build the evidence base** – the current lack of evidence could lead to maladaptive actions being taken, particularly as hospitals are upgraded over time.
- **Improve learning from past experience and embed best practice approaches to flood resilience consistently across the sector.** Build the evidence on how small-scale and low-cost actions could potentially be effective, for example, basement protection, re-locating key equipment within the hospital away from the basement. Gather detailed evidence of costs and benefits under different situations.
- **Carry out research to understand better ways of building resilience of emergency care outside the hospital and in the community.)**

## Annex 5: Recommended interventions from individual reports – health and well-being

**Given projected climate change and likely adaptation, what is the case for further intervention in relation to the impacts on human mental health following floods?**

**Given projected climate change and likely adaptation, what is the case for further intervention in relation to the impacts on human mental health following floods?**

The ECR finds a case for intervention with the following recommendations:

- **Share information across infrastructure providers and those in the healthcare and resilience sectors and develop resilience plans collaboratively. Undertake analysis using scenarios** to assess which actions may be effective under particular situations, the thresholds and the limits to adaptation. Assess the costs and benefits of actions under particular circumstances.
- **Provide a simplified single and trusted hub for information for members of communities, covering all aspects needed for effective recovery following a flood (such as medical advice, insurance claim handling and managing builders).** For example, a national flood website. Educate key figures in the community to share information. Use existing and trusted channels where possible.
- **Provide enhanced emotional support for individuals** by building and strengthening existing community groups and processes to share information, build trust of authorities among community etc. Undertake research into ways of sharing best practice and examples between communities e.g. information platforms, web-based resources.
- **Take action to ensure insurance companies are better aligned with the best interests of residents who have been flooded** by requiring rapid and effective technologies to be used where appropriate to dry homes, and for assets to be cleaned rather than necessarily replaced; any assets replaced must in turn be resilient, rather than like for like.
- **Provide education and training for emergency planners, local authorities, and community members** to ensure effective engagement with individuals and groups, building and applying emotional intelligence to empathise and empower communities to help themselves; and, build knowledge of risks and actions to minimise them (e.g. in Scotland, school children are taught about climate risks etc as resilience is integrated into the curriculum)
- **Investigate the feasibility of integrating voluntary groups within formal planning processes** to ensure vulnerable groups are not isolated (e.g. the Central Scotland's Memorandum of Understanding between statutory and voluntary sector responders)

### Given projected climate change and likely adaptation, what is the case for further intervention in relation to the impacts of heat-waves and hotter summers on the health of the over 65?

The ECR finds a case for intervention with the following recommendations:

- **Share information across healthcare providers** and develop plans collaboratively. Undertake analysis using scenarios to assess which actions may be effective under particular situations, the thresholds and the limits to adaptation. Assess the costs and benefits of actions under particular circumstances.
- **Build the evidence base on the costs and benefits of adaptation actions to lower heat-related impacts on health.** Assess (*ex ante*) the relevant baseline against which costs and benefits can be assessed, and undertake ex post evaluations after a heatwave.
- **Provide targeted and tailored information, appropriately communicated, to those at risk so that they are able to understand their extent of risk and heed advice.** Raise awareness among vulnerable groups in particular, along with those in the community able to support them.
- **Identify vulnerable people at the local level** – voluntary groups and community groups play an important role; involve them more formally in preparedness planning processes

### Given projected climate change and likely adaptation, what is the case for further intervention in relation to the movement of wild sea fin-fish in response to sea temperature change?

The ECR finds a case for intervention with the following recommendations:

- **Enhance the capability to monitor new and more abundant species, involving collaborative working of fishing vessel operators with the scientific community.**
- **Support the scientific and technical facilities, which can improve the understanding of new or emerging species in the UK EEZ. This would provide the information necessary for the industry better to anticipate opportunities and make necessary investments and changes quickly**
- **Use appropriate existing communication channels to engage with vessel operators and embed learning in relation to best-practice fishing behaviours for new, or more abundant, species.** This could be through expanding existing channels to ensure more information and guidance is collected, and making information available a clear, accessible and practical way to a wide number of operators of large and small vessels.
- **Undertake research and analysis into methods to increase the flexibility with which vessels can adapt, for example by trading quotas across operator of all sizes of vessel (large and small). Implement appropriate action to increase flexibility.** The ability to trade quotas internationally is being debated as part of the reform of the common fisheries policy.
- **Proactively support the diversification of consumer demand through the provision of information to consumers about a wider range of fish species and through marketing.** The media and retailers have been identified as particularly successful in raising awareness and increasing demand for niche species. Further options could be explored to support these activities, including educating consumers about different varieties of species, their preparation and taste.

## Annex 5: Recommended interventions from individual reports – natural flood management (NFM) measures

**Given projected climate change and likely adaptation, what is the case for further intervention in relation to implementation of natural flood management measures?**

The ECR finds a case for intervention with the following recommendations:

In order to ensure appropriate consideration of NFM measures at the option generation stage, there is a need to:

- **Use a checklist for flood management options to highlight the full range of options available, along with guidance on when each may be suitable for further analysis.** This should facilitate identification of opportunities for use of NFM in areas currently prone to flooding, or where flood risk is projected to increase.
- **Develop and collate evidence on the costs and benefits of actions taken, their effectiveness and the conditions under which they are likely to be effective, and when they are not.** The process of gathering such evidence should be continual as schemes develop in different locations and across different geographical scales.
- **Using existing or enhanced channels of communication, disseminate lessons learned from pilot projects in a clear and practical way to allow others to identify best practice.**
- **Support development of expertise in NFM, including land management, engagement with land-managers and underlying science.**
- **Undertake research to understand the drivers of flood managers' behaviour and identify potential efforts to “nudge” decision-makers to consider NFM as an option**

## Annex 5: Recommended interventions from individual reports – natural flood management (NFM) measures (continued)

### Given projected climate change and likely adaptation, what is the case for further intervention in relation to implementation of natural flood management measures?

The ECR finds a case for intervention with the following recommendations:

To enhance the appraisal of NFM measures:

- **Undertake assessments of the ecosystem benefits associated with NFM measures based on previous case studies.** This should draw on a range of appropriate appraisal methodologies, including monetisation and multi-criteria analysis. This should identify both the conditions under which ecosystem benefits are more likely and how they can be maximised, along with associated opportunity costs.
- **Incorporate resources for the ex ante pre-NFM measure baseline and the ex post monitoring and evaluation into the project planning processes**

To deliver NFM measures where they are likely to be effective:

- **Undertake a review of available funding streams and the associated appraisal requirements.** Identify where better alignment could be achieved in order to minimise complexity and increase transparency in obtaining partnership funding.
- **Investigate the effectiveness of alternative funding structures to increase overall longer term resilience.**
- **Assess the costs and benefits of organisations currently acting as champions,** to identify circumstances where champions are more likely to be effective.
- **Undertake wider stakeholder engagement (including activities at the community level) to raise awareness of NFM measures and enhance acceptance where they may be worthwhile**

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