

# **Frameworks for delivering regular assessments of the risks and opportunities from climate change: An independent review of the first UK Climate Change Risk Assessment**

**Final Report**

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*The M1 and River Trent valley on 10 November 2000*

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## Executive summary

This report provides an independent evaluation of the first UK Climate Change Risk Assessment (CCRA) including the broader context, underlining objectives and outputs of the study. The review draws on several sources of evidence: literature addressing aspects of climate risk assessment, including work by other countries; semi-structured interviews and consultations with key actors who were directly involved in the CCRA or are potential end-users; documentation related to the management and advice surrounding CCRA; and the range of outputs published from CCRA.

The material addresses several important questions surrounding the architecture of the CCRA, the effectiveness of the UK approach (compared with methods used by other countries), and the role played by risk assessment within a broader enabling environment for adaptation in the UK:

### ***What were the main strengths and weaknesses of the approach taken in the first CCRA?***

All respondents felt that the CCRA had been a 'heroic effort' given the time available. There was also a widely held view that *the CCRA process was as important as the research outcomes*. Box 1 provides a summary of the technical achievements of the work. A key asset of the CCRA is the inventory of domestic climate risks generated through stakeholder consultation and synthesis of the scientific literature. This will provide a useful platform for future risk screening. Less-tangible benefits include more widespread use of *risk language* and spin-off research projects on risk methodologies and climate knowledge production.

#### **Box 1** Technical achievements and gaps of the 2012 Climate Change Risk Assessment at a glance

##### **What was done**

- Synthesis of current state of knowledge on climate risks and opportunities based on evidence drawn from **stakeholder workshops**, Government reports, peer-reviewed literature, and new analysis
- Provision of a baseline assessment for more than **100 climate change risks** disregarding current and future planned action, as well as socio-economic changes
- Analysis of **risks based largely on UKCP09 projections** for three time frames (2020s, 2050s, 2080s) and three emissions scenarios (Low, Medium and High) [but only for the 2080s under Medium emissions for marine environment]
- Comparison of **social, economic and environmental threats and opportunities** on a logarithmic scale
- Used a consistent method for analysing the **magnitude and confidence** in climate risks across sectors and over time (except where population trends alter the numbers of people affected by flooding, water scarcity and summer heatwaves/milder winters)
- Identification of **priorities for action in eleven sectors** (grouped into five themes: natural environment; buildings and infrastructure; health and wellbeing; business and services; agriculture and forestry)
- Published **reports** for individual sectors, themes, UK, national and regional levels

##### **What was not done**

- Quantification of present and future risks to the **same degree of detail for all sectors and scales**
- Treatment of future socio-economic changes and/or **existing adaptations** in a consistent way
- Analysis of **non-climatic interactions** within the system (such as technological change in agriculture)
- Evaluation of risks of **joint occurrence of multiple extremes** or cascading impacts
- Quantification of climate **risks from abroad** (e.g., changes in global food production)
- Assessment of **risks from major discontinuities and tipping points** (e.g., abrupt climate changes in the North Atlantic sector)
- Monetization of **wider/cross-sectoral impacts** (e.g., some indirect costs of major flooding)
- Assessment of **cost effectiveness** of different adaptation and/or mitigation programmes

On the other hand, a recognised limitation of the response function method used in the first CCRA is that risks from multiple climate drivers are difficult to quantify. Furthermore, the sectoral emphasis means that inter-dependent risks and those originating from outside the UK are partially addressed. There are concerns that some response functions were applied when not really appropriate or in simplistic ways. For example, estimation of changing crop yields based only on temperature changes is misleading. However, as part of a tiered process, the CCRA was intended to show where there is a case for more detailed analysis, such as within the Economics of Climate Resilience (ECR) study.

### ***How well has the CCRA identified the threats and opportunities posed by a changing climate?***

The main threats identified by the first CCRA include: hotter summers causing excess deaths; increased flood damages; and increased risk of water shortages, especially in southeast England. Potential benefits include: milder winters leading to fewer premature deaths; opening of new shipping routes between the UK and Asia due to melting of Arctic sea ice; commercial opportunities arising from the production of new crops, for food, pharmaceuticals and energy. However, truly national scale climate change risks could arise from concurrent extreme events, cascading interdependent risks, convergent processes of change, indirect cross-/multi-sectoral risks, or from outside the UK. The sector-level analysis provides a useful point of reference but is less amenable to the appraisal of such 'macro' risks.

The CCRA monetized around 100 individual climate change risks to give an initial assessment of the economic risks and scale of adaptation required. Again, given the mandated focus of the first CCRA on direct UK impacts, total economic costs including indirect and overseas impacts were not presented. The physical realm could also be expanded to the UK overseas territories but this is outside the scope of the Climate Change Act.

Some respondents were circumspect about the CCRA methodology, noting that the above caveats should be seen in the context of gross uncertainties about future socio-economic scenarios and regional climate projections. Under these circumstances there is an ever-present danger of giving false impressions of precision about future risks (particularly when extracting local information from models originally designed for national reporting).

### ***What are the key research gaps that need to be addressed now and in the future?***

Further analysis is needed of cross-sectoral and UK-global risks (involving for example water and energy, water and food security). These risks should be the focus for the second CCRA, accepting that the present evidence base is limited. Individual sectors such as agriculture, built environment, business, energy, health and transport sectors are also priorities, recognising that their risks and vulnerabilities are more heterogeneous than the CCRA might have suggested.

National-scale integrated assessment of multi-sector risks presupposes the existence of suitable modelling frameworks and data sets. Sectors such as flooding and water already have this spatial-modelling capability; others do not. An alternative approach might involve up-scaling and aggregating local risk models to the national level. In either case, the UK Research Councils could play a supporting role by developing thematic programmes along these lines

The need for a consistent set of socio-economic scenarios was recognised as a priority ahead of the first CCRA and this remains the case. In addition, the second CCRA will need to be mindful of technical developments in climate scenarios such as the new atmospheric composition pathways being developed for the modelling community: the Representative Concentration Pathways (RCPs) and Extended Concentration Pathways (ECPs).

### ***What can be learnt from the experience of other countries?***

Fifteen other national assessments were reviewed. Each is characterised by their own political leadership, institutional organization, stakeholder involvement, use of climate change information, decision analysis techniques, level of funding, technology development and evidence base. Differences also emerge due to practical decisions about the management structure of the study, time available, level of detail required, consistency of analysis between sectors, tendering and procurement process, institutional memory and modes of soliciting reviews. Experiences in the US further highlight the dangers of paying insufficient attention to public communication and outreach.

Like the UK, the majority of assessments apply a science-first framework, are typically scenario-led, seldom integrate risks across sectors, or take into account climate risks originating beyond state borders. Many are at the level of loosely structured, sectoral assessments that compound uncertainties at each step of the analysis, leading to rather generic adaptation statements. The Netherlands is a noteworthy exception because the rigorous scientific assessment of risks follows from clearly articulated policy objectives for flood protection, freshwater supplies, rural areas, ecosystems and biodiversity, and urban areas. The policy-first framework set out by The Netherlands is most closely akin to the model recommended for the second CCRA.

### ***What are the key recommendations for shaping the second CCRA?***

The next CCRA does not have to follow the same framework or methodologies as the first. In fact, a strong case can be made for a more focused assessment that would appear to meet the requirements of the Climate Change Act whilst addressing critical knowledge gaps and prioritised risks identified by the first CCRA. Six main recommendations emerged from this review:

1. **The terms of reference for the second CCRA should be drawn up by a working group including Defra, the ASC, the Environment Agency (in their new capacity as lead agency on adaption), and technical experts.** Thorough policy appraisal and engagement with stakeholders is needed from outset, with project deliverables tied more explicitly to policy objectives on adaptation. A policy-first approach requires clarity about who the end users are and their needs beyond simply knowing that the *customer for this work is Government at UK, national and regional levels*. This further implies prior appreciation of which elements of Government 'own' which nationally significant climate change risks (including those originating from outside the UK).
2. **The scope of the second CCRA should take forward a much narrower and deeper analysis of priority risks identified in the first CCRA and by related studies.** The programme should begin with work on international and imported climate risks, major inter-sectoral risks, convergent processes of change (involving climate, population, food, energy and water security), and future socio-economic scenarios.
3. **As required by the Act, the ASC will provide advice to inform preparations for the second CCRA (to be published in 2017). This advice should explore, amongst other things:**
  - How climate risk ownership varies across horizontal and vertical levels of governance;
  - The fitness of the UK's enabling environment for climate risk assessment and adaptation, for example, barriers to action;
  - Different ways of assessing and framing the risks and opportunities of climate change beyond monetization.
4. **Work on the second CCRA should begin in 2013 and follow a Foresight approach.** There was widespread support amongst interviewees for a Foresight-style project managed by Defra. In

this way, technical experts, panels and contributory studies could be procured as required. Experience from the *Foresight Future Flooding Project* suggests that this approach leads to consensus building and high quality outputs but the process can be slower and require more administrative resource. Time pressure was a major concern in the first CCRA and should be avoided in the second by commencing work as soon as the National Adaptation Plan (NAP) has been completed.

5. **The UK Government should take steps to improve the fitness of the wider enabling environment for regular climate risk assessment in the UK.** For example, measures for strengthening institutional memory and governance, sustaining long-term monitoring and reporting systems, promoting freedom of access to data and analytical tools, growing technical capacities in public and private sectors, allocating resources for strategic research programmes and bridging organisations, disseminating findings and advice at all levels of governance, and piloting different adaptation measures.
6. **The ASC should continue to be proactive when dealing with research councils and other agencies to shape programmes that promote good adaptation practice.** For example, the Living With Environmental Change (LWEC) challenge areas provide scope for mutual advancement of work on climate risk assessment and evidence collection for adaptation. Discussion is needed about the extent to which the ASC has a remit to comment on or shape adaptation work being led by the Environment Agency. The ASC should also continue to promulgate good practice on climate risk assessment and adaptation planning between nations.

### **Concluding remarks**

The UK Government has yet to fully articulate national adaptation objectives. This is a non-trivial issue since there are many different ways to frame desirable adaptation outcomes (such as lower economic impacts, greater social justice, human health and well-being). The adaptation objectives matter because they also shape the approach to climate risk assessment.

The first CCRA was successful if measured against the Terms of Reference laid before the contractors. An analytical framework was devised for assessing risks to those things that have social, environmental and economic value in the UK. The risks were monetized for the UK using the UKCP09 projections as requested by Defra. The greatest legacies of the work will probably be the preliminary collection and sifting of sector risks by stakeholders, and subsequent exposure of major knowledge and data gaps. These outputs provide a firm basis for a more focused and deeper risk assessment next time.

Whether or not the first CCRA delivered value for money is harder to answer. Given the high cost and effort of the exercise, some might be concerned that many interviewees found greater value in the process than the project outcomes. However, the cost and science-led methodologies of the CCRA are not out of line with the majority of international comparators. With the benefit of hindsight, most of the high profile threats and opportunities identified by the first CCRA seem obvious. However, there is a strong counter argument for due diligence and a thorough trawl of risks in the first cycle of the CCRA.

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## 1. Introduction

Climate variability and change have the potential to affect all aspects of UK society. Although the climate outlook is highly uncertain, scientific evidence points to a range of risks and opportunities for communities, the economy, and environment. Understanding this risk landscape is an important step towards improving climate resilience and planning for the future.

The UK Climate Change Impacts Review Group undertook the first synthesis of potential climate effects in 1991<sup>1</sup>. However, earlier assessments can be traced from the late 1970s for individual sectors such as agricultural, water, industry and energy consumption<sup>2</sup>. These studies pre-dated widespread availability of climate model scenarios so were based on relatively simple climate sensitivity and analogue methods. Nonetheless, they established an enduring principle that future impacts can be inferred from known relationships between climate and socio-economic indicators (e.g., weather dependency of crop yields, space heating and cooling, and river flows).

The first Climate Change Risk Assessment (CCRA) was a major analysis of the main risks and opportunities for the UK arising from climate change over the next 80 years. The body of work is intended to support UK Government and Devolved Administrations, and other organisations in shaping a collective National Adaptation Programme by 2013.

The purpose of this report is to provide an independent review of the methods and structure of the first CCRA with a view to strengthening the development of successive assessments within the context of national adaptation planning. This work is being undertaken in parallel with a project commissioned by Defra to guide the design of the next CCRA.

### 1.1 Setting the scene

The Civil Contingencies Act 2004 requires the Government to carry out an annual assessment of the risks of civil emergencies in the UK<sup>3</sup>. This includes emergencies arising from an event or situation that threatens serious damage to human welfare and/or the environment. However, the Act only covers risks that are likely to happen in the next five years; not those that could materialise over longer time-scales. Risks from natural hazards include coastal flooding, volcanic eruption, inland flooding, drought, low temperatures and heavy snow, heatwaves, storms and gales. In each case, the responsible Government department, Devolved Administrations and emergency responders must make arrangements to manage the impact and consequences of an emergency.

The Climate Change Act 2008 (henceforth the Act) takes a longer-term view on building the UK's capability to adapt to climate hazards as well as to gradual changes in average climate conditions. The Act requires that:

- A UK-wide climate change risk assessment takes place every five years;
- Reporting authorities prepare climate change adaptation reports under the direction of the Secretary of State;
- A National Adaptation Programme (NAP) is put in place and reviewed every five years.

In addition, the Act set up an Adaptation Sub-Committee (ASC) of the Committee on Climate Change. This independent expert body has an advisory role in the preparation of the CCRA, and is

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<sup>1</sup> Parry (1991)

<sup>2</sup> Parry (1978); Arnell and Reynard (1989); Palutikof (1983); Lough et al. (1983)

<sup>3</sup> Cabinet Office (2012)

required to report to Parliament on the UK Government's progress in implementing the NAP<sup>4</sup>. As will be shown, the way in which the Act was interpreted and operationalized by Government shaped the structure and content of the first CCRA Evidence Report.

The contract for the first CCRA was awarded in September 2009 to a consortium of consultants led by HR Wallingford. This was just a few months after the launch of the UKCP09 projections (June 2009) and the inaugural meeting of the ASC (July 2009). A change of Government in May 2010 ushered in the Coalition's 'new localism' decentralisation agenda. Public Service Agreements (PSAs) (including 27 "Lead the global effort to avoid dangerous climate change") were scrapped in June 2010, with Local Area Agreements and National Indicators (including NI 188: Adapting to Climate Change) abolished by October 2010.

Meanwhile, compliant with the Act, the first batch of Adaptation Reporting Power reports<sup>5</sup> began to be received by Defra (September 2010). Defra's advice to reporting authorities conceded that the work of the CCRA should ideally follow these organisational reports but *the timetables don't quite align this time*<sup>6</sup>. In September 2011 the Environment Agency took over responsibility from the UK Climate Impacts Programme (UKCIP) for the delivery of the Adaptation Advice Programme to 2015.

Several major studies and policy documents emerged during the course of the first CCRA. For example, The Royal Commission on Environmental Pollution reported on *Adapting Institutions to Climate Change* (March 2010), and on the *Environmental Impacts of Demographic Change* (February 2011). Likewise, there were Foresight reports on *The Future of Food and Farming* (January 2011) and on *The International Dimensions of Climate Change* (July 2011) which was commissioned and part-funded by Defra. In the same year Defra also published *The National Flood and Coastal Erosion Risk Management Strategy for England* (May 2011) and *Water for Life* (December 2011). The *UK National Ecosystem Assessment* provided a comprehensive analysis of the benefits of the natural environment to society and the economy (June 2011).

Hence, the conduct of the first CCRA coincided with a period of scientific advance in climate modelling and appraisal of international risks, considerable policy development and reform, with a direct bearing on adaptation planning in the UK. It is important to keep these contextual points in mind when reviewing what was done under the first CCRA.

## 1.2 Study objectives

This review contributes to discussions about the development of subsequent CCRA, and helps to shape advice in the formative stages of the first NAP, which is due to be published in 2013. This review assesses the decisions underpinning the architecture and methodology of the first CCRA and explores how other countries have conducted risk assessments as part of their NAPs.

The project focuses on three main aspects:

- Overall structure of the first CCRA method - assessing the robustness and usefulness of the current approach, including treatment of uncertainty, and prioritisation of risks;
- Strengths and weaknesses of the UK's first approach, the lessons that can be learnt from the CCRA as well as from the risk assessments of other countries;
- Options for strengthening the wider enabling environment, including the evidence base and governance structures, ahead of the second CCRA in 2017.

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<sup>4</sup> Defra (2012)

<sup>5</sup> <http://www.defra.gov.uk/environment/climate/sectors/reporting-authorities/reporting-authorities-reports/>

<sup>6</sup> <http://archive.defra.gov.uk/environment/climate/documents/interim2/report-faq-110126.pdf>

The ASC have separately commissioned Paul Watkiss Associates<sup>7</sup> to review coverage of economic impacts in the first CCRA. Defra are also conducting a review and forward look for the second CCRA.

This report begins by describing the approaches to evidence gathering. Section 2 provides a summary of the first CCRA headline messages and methodology, including the roles played by Defra and the ASC. Section 3 captures the findings of earlier reviews of the first CCRA commissioned by Defra. Section 4 surveys the approaches to climate risk assessment adopted by other countries. Section 5 gives a summary of interviewee perspectives on what was accomplished by the first CCRA and opportunities for the second. Finally, section 6 takes stock of all the evidence gathered and sets out recommendations for the ASC within the broader context of the NAP.

### **1.3 Study methods**

The study draws on literature covering climate risk assessment frameworks and their place within adaptation planning. Reference is also made to national risk assessments conducted outside of the UK, and to the lessons that can be learned about the effectiveness of alternative architectures and modes of governance<sup>8</sup>. This part of the review was assisted by published inventories of national studies<sup>9</sup>, accounts of how adaptation is occurring<sup>10</sup> and practical experiences elsewhere<sup>11</sup>.

The study also included questions and/or interviews with key actors to explore the factors that shaped the methodological development and architecture of the first CCRA (Annex 5). A few individuals were asked to fill in specific details; the majority were questioned using semi-structured interviews conducted face to face and by telephone. The prime intention was not to revisit detailed technical issues as this was the purpose of earlier deliberations<sup>12</sup>. Instead, the emphasis was on exploring the first CCRA as a process, the lessons learnt, and the forward thinking needed for the second CCRA. This included key research priorities and scope for improving the enabling environment for regular assessments of climate risks and adaptation planning in the UK.

Further insight to procedural matters was gained from careful examination of Government scoping studies, minutes and correspondence surrounding the first CCRA. Particular attention was given to the advice offered at various stages in the process and the extent to which this contributed towards achievement of the first CCRA objectives which were ***to help Government create an enabling environment for the UK to adapt and identify priorities for action*** (Annex 1).

## **2. The First UK Climate Change Risk Assessment (CCRA)**

This section provides a brief overview of the first CCRA methodology, governance structure, and key outcomes. The main issues raised by peer review processes are covered in section 3.

### **2.1 Project methodology and management**

The CCRA was the first assessment of its kind for the UK and the first in a 5 year cycle<sup>13</sup>. Although the Terms of Reference are open to a range of interpretations, the contractors were required to use the

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<sup>7</sup> Watkiss and Hunt (2012)

<sup>8</sup> Biesbroek et al. (2010)

<sup>9</sup> Watkiss et al. (2009)

<sup>10</sup> De Bruin et al. (2009); Ford et al. (2011); Tompkins et al. (2010); Urwin and Jordan (2008)

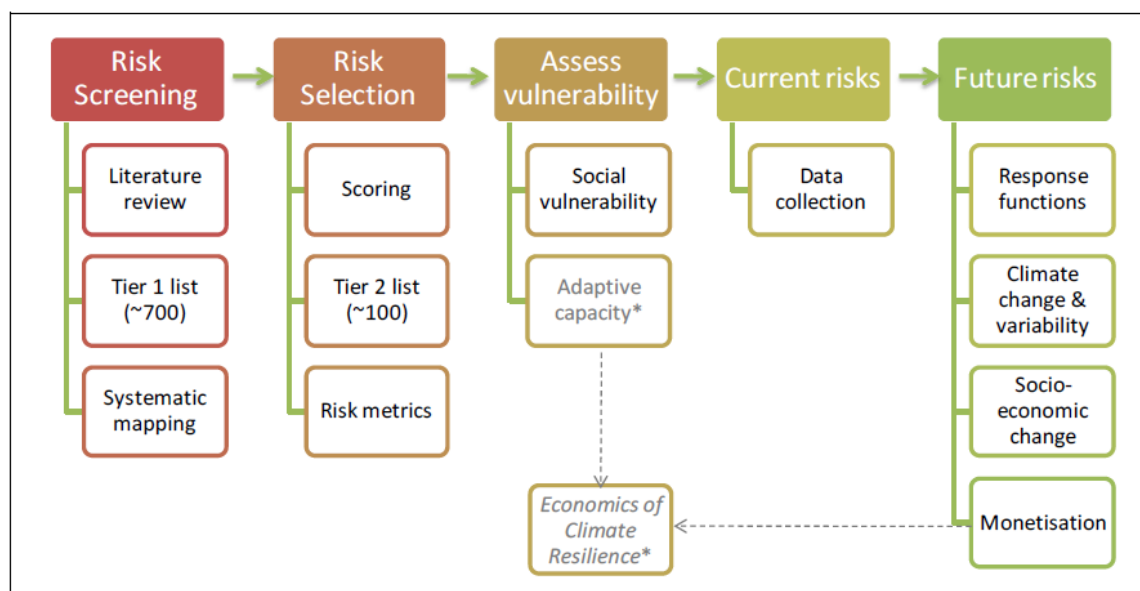
<sup>11</sup> Smith et al. (2009)

<sup>12</sup> <http://randd.defra.gov.uk/Document.aspx?Document=Peerreviewercomments.pdf>

<sup>13</sup> <http://www.defra.gov.uk/environment/climate/government/risk-assessment/>

UKCP09 projections, and the UK broken down by sector, and 9 government regions plus the Devolved Administrations were the prescribed units of assessment (Annex 1). The project spanned three years from initial scoping of the risk assessment methodology and economic analysis by Defra in February 2009 to laying before Parliament on 26 January 2012 (Annex 2). By and large the objectives of the Terms of Reference were met by the contractors.

The general approach of the first CCRA was based on the first three (of eight) stages in the UK Climate Impacts Programme (UKCIP) *Risk and Uncertainty Framework*<sup>14</sup>. These are: Stage 1 – identify the problem and objectives; Stage 2 – establish the decision-making criteria; and Stage 3 – Assess risks (Tier 1: broad level; Tier 2: detailed level). Figure 1 shows the tasks of the analytical steps in Stage 3. Participatory techniques based on stakeholder workshops were central to the preliminary risk screening, scoring, and short-listing of risk metrics for quantitative analysis in later stages (Figure 1). Overall, the methodology took 14 months to develop between the first meeting of the ASC with contractors (September 2009) to final advice to the Secretary of State (November 2010). This left three months to complete the sector analyses before the first drafts were circulated for review.



\* Ongoing studies to inform the National Adaptation Plan

**Figure 1** Summary of the first CCRA methodology and links with the Economics of Climate resilience project<sup>15</sup>

The UKCIP framework<sup>14</sup> is widely respected and cited by at least 150 studies worldwide. However, it is generally applied to individual organisations rather than whole sectors or cross-sectoral assessment. Therefore, the contractors devised a non-linear, qualitative scoring system for the first CCRA in order to rank perceived magnitude and likelihood of risks ('low', 'medium' and 'high'). This enabled cross-comparison between eleven sectors and between three criteria (social, economic and environmental risks and opportunities).

Levels of confidence were assigned to available evidence, ranging from very low (e.g., non-expert opinion) through to high (e.g., reliable analysis with strong theoretical basis). Plots were used to

<sup>14</sup> UKCIP (2003)

<sup>15</sup> Defra (2010a; 2012)

summarise the magnitude and timing of Tier 2 risks; scorecards to show lower, central and upper risk estimates based on the range of UKCP09 projections for three time periods: the 2020s (2010 to 2039), 2050s (2040 to 2069) and the 2080s (2070 to 2099) (see Annex 3 and 4). Box 1 provides a summary of the technical achievements of the first CCRA and what remains to be done.

The first CCRA findings were disseminated in a high-level *Summary Report*; detailed description of the methodology and outputs under five themes in an *Evidence Report*; summary and evidence reports for each of the 11 sectors; detailed technical report of the *Method for Undertaking the CCRA*; syntheses of the sector risks for Devolved Administrations; and information packs summarising risks for nine Climate Change Partnerships across England. The *UK Climate Change Risk Assessment: Government Report* subsequently set out the main priorities for adaptation under five key themes with commentary about the attendant uncertainties.

Figure 2 shows how the potential opportunities and threats were presented. Possible negative risks include: hotter summers causing between 580 - 5900 excess deaths per year by the 2050s; increased flood damages costing between £2 - £12 billion per year by the 2080s; increased risk of water shortages, especially in southeast England by the 2080s. Potential benefits include: milder winters leading to between 3900 - 24000 fewer premature deaths per year; opening of new container shipping routes between the UK and Asia due to melting of Arctic sea ice; commercial opportunities arising from the production of new crops, for food, pharmaceuticals and industry.

**Box 1** Technical achievements and gaps of the 2012 Climate Change Risk Assessment at a glance

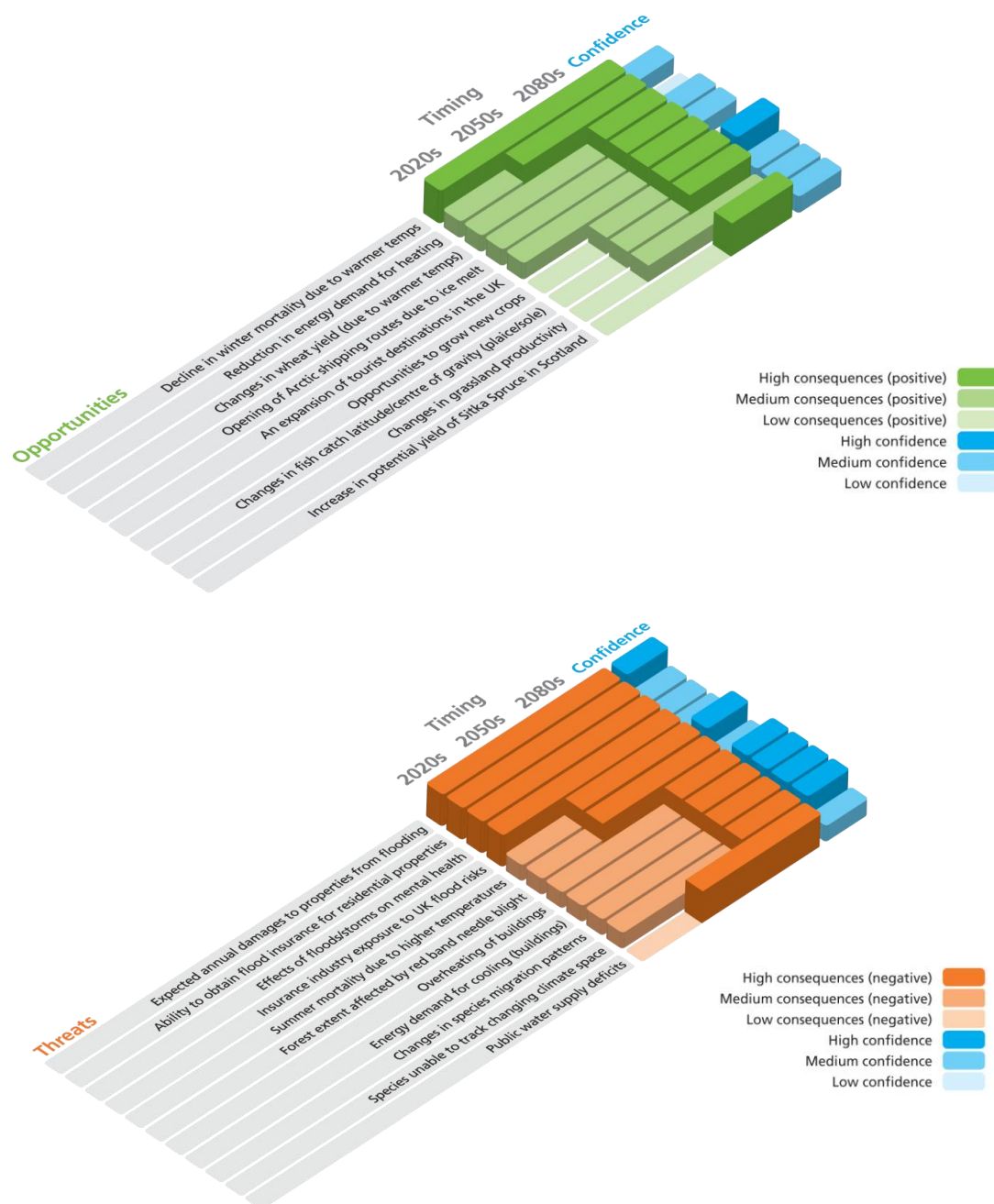
**What was done**

- Synthesis of current state of knowledge on climate risks and opportunities based on evidence drawn from **stakeholder workshops**, Government reports, peer-reviewed literature, and new analysis
- Provision of a baseline assessment for more than **100 climate change risks** disregarding current and future planned action, as well as socio-economic changes
- Analysis of **risks based largely on UKCP09 projections** for three time frames (2020s, 2050s, 2080s) and three emissions scenarios (Low, Medium and High) [but only for the 2080s under Medium emissions for marine environment]
- Comparison of **social, economic and environmental threats and opportunities** on a logarithmic scale
- Used a consistent method for analysing the **magnitude and confidence** in climate risks across sectors and over time (except where population trends alter the numbers of people affected by flooding, water scarcity and summer heatwaves/milder winters)
- Identification of **priorities for action in eleven sectors** (grouped into five themes: natural environment; buildings and infrastructure; health and wellbeing; business and services; agriculture and forestry)
- Published **reports** for individual sectors, themes, UK, national and regional levels

**What was not done**

- Quantification of present and future risks to the **same degree of detail for all sectors and scales**
- Treatment of future socio-economic changes and/or **existing adaptations** in a consistent way
- Analysis of **non-climatic interactions** within the system (such as technological change in agriculture)
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- Quantification of climate **risks from abroad** (e.g., changes in global food production)
- Assessment of **risks from major discontinuities and tipping points** (e.g., abrupt climate changes in the North Atlantic sector)
- Monetization of **wider/cross-sectoral impacts** (e.g., some indirect costs of major flooding)
- Assessment of **cost effectiveness** of different adaptation and/or mitigation programmes

The Evidence and Sector Reports recommend ways of addressing knowledge gaps through continued research and monitoring. In particular, it was recognised that further work is needed to improve understanding of inter-relationships between risks to enable more integrated assessment. The *CCRA Recommendations Report*<sup>16</sup> includes a matrix of gaps and lessons learnt during the first assessment. Some suggestions – such as improving response functions for prioritised risks – are based on the premise that the same risk assessment methodology would be applied in the second CCRA.



**Figure 2** Potential opportunities and threats for the UK that could result from climate change, as identified by the first CCRA, based on projections for the Medium emissions scenario (central estimate).

<sup>16</sup> Defra (2010b)

## 2.2 Role of Defra

Under PSA 27 Defra was assigned overall responsibility for the development of a cross-government adaptation framework, and for ensuring that the *UK is adapting well across a range of key areas*<sup>17</sup>. In August 2010, the Coalition Government set out the principles of its new approach to adaptation in response to the Environmental Audit Committee's enquiry on *Adapting to Climate Change* (March 2010). The main thrust of the response was that Government has a duty to provide evidence of climate risks to support effective decision-making; but local communities and businesses should take ownership of risks and more responsibility for delivery of adaptations<sup>18</sup>.

The Adapting to Climate Change (ACC) Programme was established in 2008 as a cross-government initiative coordinated by Defra to develop an evidence base on climate impacts and to help drive more effective working on adaptation across departments. Project management of the first CCRA fell within this remit. The initial steering group for the first CCRA (up to ~50 people) was deemed too large and too unwieldy so was reduced to around 20 people and an accompanying In-House Expert Group (IHEG). This comprised of representatives from Defra, Cabinet Office, Environment Agency, Natural England, the Greater London Authority, Scottish Natural Heritage, the Devolved Administrations, Forestry Commission, and UKCIP. The membership of the IHEG changed throughout the course of the first CCRA with levels of participation falling away in latter stages of the process.

By April 2009 Defra had received a detailed scoping study for the risk assessment and adaptation economic analysis<sup>9</sup>. The study addressed three main aspects: options for the methodological approach; options for the assessment architecture; and advice on the resources required. A clear recommendation was given to explicitly link the CCRA analysis with Government policy objectives and end use (i.e., transforming adaptation). Other recommendations were to undertake a tiered national-regional assessment consistent with policy frameworks, a sectoral approach, with mechanisms for capturing cross-sectoral themes and indirect effects of climate change.

Three key recommendations were not followed by Defra. First, the suggestion that the CCRA should be closely aligned with Government policy objectives (although guidance on procedure in the HM Treasury Green Book was followed). Second, that the assessment should begin by focusing on current climate variability and existing adaptation deficit. Third, Defra was warned not to tender the CCRA as a single project as this could split the expert base.

Since adaptation objectives have yet to be made explicit the first recommendation is problematic. Both parties recognize that the second and third could have been stated more forcefully in the scoping document. Defra's decision to procure by a contractor approach was partly to obtain best value for money and partly to assemble a project team with obvious independence from Government. The contractor-led model also reduced the risk of blurring accountabilities by creating another bureaucratic structure alongside the ASC. Furthermore, steps were taken by Defra to ensure that key expertise was secured by the consortium.

The CCRA management was overseen throughout by three high-ranking civil servants plus Defra's Chief Scientific Advisor. This structure is unlike other national assessments which are typically coordinated by senior figures drawn from research centres and scientific administration. For example, the committee overseeing the 2008 US National Assessment represented federal agencies, government departments, and research funders<sup>19</sup>. In comparison, most of the Defra project team was relatively junior, and did not see the project through from beginning to end<sup>20</sup>. This affected

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<sup>17</sup> Treasury (2007)

<sup>18</sup> Defra (2010c)

<sup>19</sup> Morgan et al. (2005)

<sup>20</sup> High staff turnover rates are systemic to the UK civil service. See for example the arrangements for the Civil Service Fast Stream which promotes postings of 12 to 18 months duration: <http://www.civilservice.gov.uk/recruitment/fast-stream>



some aspects of the institutional memory and working relations with other actors, including the newly formed ASC which was establishing its own work programme and procedures. For instance, the advisory process of the ASC was regarded by Defra officials as overly cumbersome and a contributory factor in the slow start to the first CCRA analyses (see the counterview in section 5.1).

### **2.3 Role of the ASC**

The ASC was established by the 2008 Climate Change Act to provide *advice, analysis, information or other assistance on request* through the Committee on Climate Change (CCC). This involves the exercise of three main functions: advice to national authorities on adaptation to climate change (section 38); advice on reporting the impacts of climate change (section 57); reporting on progress in connection with adaptation (section 59). The desirable experience of ASC members falls within a list set out for the CCC taken as a whole including: business competitiveness; climate change policy; climate science; capacity of national authorities to adapt; economics; emissions trading; energy production and supply; financial investment; technology development and diffusion.

Despite the small membership, the ASC at the time of the first CCRA had wide-ranging sectoral and technical knowledge covering: agriculture, climate change (economics, scenarios, impacts, adaptation, and vulnerability), energy, engineering, flood risk and water management, forestry, international development, natural environment (economics, fauna, and regulation), public health, spatial planning, and statistics. On the other hand, the ASC was less qualified to provide analysis and advice on marine and fisheries, leisure, mining, retailing and transport - sectors that were amongst those identified by the academic peer review as weakly addressed by the first CCRA (section 3.1).

Several issues emerge from the detailed correspondence between the ASC and Secretary of State. From outset, concern was expressed by the ASC about the limited time available for method development and to respond to feedback (particularly in the case of the AEA). Questions were also raised about the analysis of cross-sectoral and international impacts, and need for closer integration of the CCRA and AEA. The ASC further recommended that a continuity plan be developed to sustain stakeholder engagement beyond the first CCRA in order to strengthen the evidence base and implementation of adaptation actions. Following the advice of the ASC a water sector pilot study was undertaken to test the methodology and a peer review process was established.

After signing off the method in September 2010, the ASC qualified that *the real test will come in applying this approach to a range of sectors to deliver meaningful results*. Several outstanding issues were raised with Defra including the policy relevance of the information delivered by the first CCRA; the benchmarking of future risks with respect to current impacts from climate; the method of prioritizing risks for urgent action; the need to distinguish climatic and non-climatic drivers of risk; and the extent to which existing adaptation arrangements might reduce anticipated risks. This advice was given at a late stage (November 2010) in the technical assessment and the ASC recognised that the scope for Defra to act was limited. Nonetheless, these issues continue to be pertinent to the second CCRA and are revisited in section 5.

## **3 Reviews of the first CCRA**

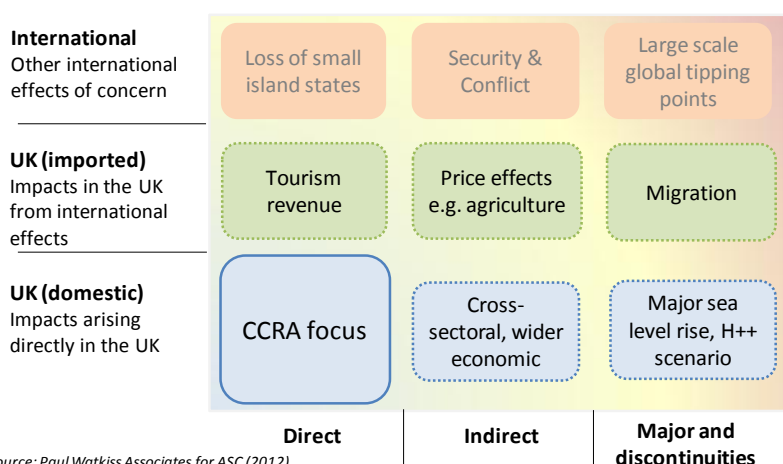
The CCRA has already been extensively peer reviewed. The following sections summarise the key findings of an independent academic review, and other ongoing evaluations commissioned by Defra.



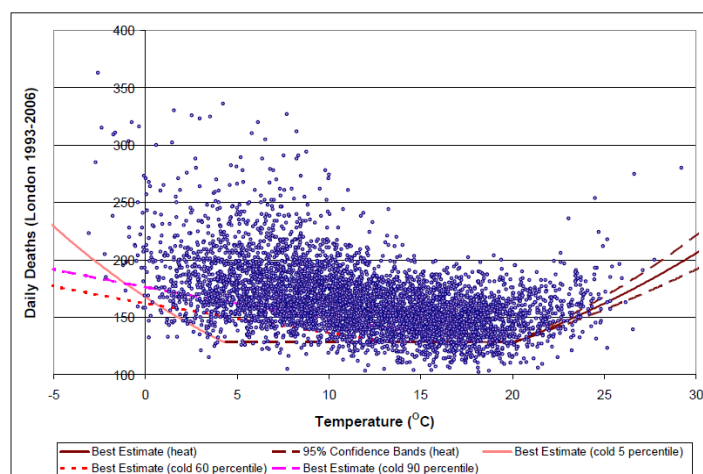
### 3.1 Academic peer review

Defra assembled a panel of academic experts to review the first CCRA Evidence Report in autumn 2011, as well as two/three reviewers to consider each of the detailed sector reports in 2010 and 2011. The panel was asked to comment on the key conclusions emerging from the CCRA and to remark on underlying methods and caveats. The main issues identified by the panel concerned<sup>12</sup>:

- **Method development:** The climate risk assessment was not equivalent to climate impact assessment; the latter is net of any adaptations that might occur and is highly conditional on the future climate that materialises as well as on the range of options available at that time. Any extension of the work to impact assessment would, therefore, require national socio-economic scenarios.
- **Geographic scope:** Overall climate risk was understated by focusing almost exclusively on direct impacts to the UK. Risks from outside the UK also need to be evaluated, as would indirect single-/ multi-sectoral risks (Figure 3).
- **Evidence base:** The response function methodology underpinning the first CCRA depends on good supporting data on the causes and consequences of average and extreme weather conditions (see for example Figure 4). However, such data are not available to the same extent in all sectors. Furthermore, more data and risk metrics in one sector (such as flooding) can give the misleading impression that this sector is more important than another (such as retailing) about which much less is known.



**Figure 3** The first CCRA in the context of examples of other direct, indirect and global risks from climate change



**Figure 4** Heat and cold related exposure response functions against daily deaths for London (1993-2006). Source: Hames and Vardoulakis (2012)

- **Ranking and weighting risks:** The study assumed that environmental, social and economic risks can be ranked as high, medium or low in equivalent ways. However, there is no widely accepted method for normalising incommensurable risks.
- **Sector coverage:** Further work is needed on omitted or partially addressed sectors that contribute a substantial fraction of the national economy (e.g., mining/minerals; retailing and other tertiary activities; transport; and the construction industry). There were also varying degrees of aggregation (bundling) of risks between sectors.
- **Monetization:** Ideally, damage estimates would be calculated in transparent and consistent ways within and between sectors.
- **Climate scenarios:** Extreme events and concurrent climate risks were relatively under-represented compared with risks associated with changing mean conditions because there is even less confidence in climate model predictions of these rare phenomena. The risk framework was 'top down' which meant less attention was placed on climate vulnerability and coping thresholds. Although the former is generally used in national risk assessments (see section 4.2), these contrasting perspectives are not mutually exclusive.
- **Knowledge gaps:** A research plan is needed to fill current knowledge gaps and to mobilise the required resources. This includes monitoring networks to detect impacts in real-time and mechanisms for improving access to data.
- **Legacy planning:** A plan is needed to safeguard data and models assembled during successive 5-year iterations of the CCRA. Procurement and management arrangements are needed to sustain technical capacities and facilitate transfer of data and knowledge between successive assessments.

### 3.2 Concurrent evaluations of the first CCRA

The contractors for the first CCRA were commissioned (in February 2012) by Defra's ACC team to provide recommendations on the methodology, research, and stakeholder engagement needed for the second CCRA. The contractor team were not mandated to critique how successfully the first CCRA had been managed, or to comment on the future procurement process.

Their report will give an overview of the first CCRA project structure, processes and reflections on the detail of the first CCRA methodology (e.g., sector coverage, use of UKCP09 climate projections, treatment of social vulnerability, scoring system and thresholds). The report will provide a list of research gaps (building on the CCRA Research Gaps Report [D.1.6.1], and Evidence Report, then set out options for addressing research needs in the near- or long-term (including work that is already underway). The report will also evaluate the extent to which the stakeholder engagement in the first CCRA was effective in obtaining information for the risk assessment. In addition, a Recommendations Workshop for the second CCRA was hosted by the contractors in March 2012. Their final report with recommendations is due in late May 2012.

The first CCRA found low risks when expressed in economic terms (no more than 1% of current GDP in the 2050s and 2080s, regardless of the greenhouse gas emissions scenario). However, it is suspected that these relatively modest risks arise from the narrow coverage of the first CCRA (see Figure 3). Hence, the ASC commissioned a rapid analysis to frame the monetisation exercise within the first CCRA and to investigate possible gaps in the economic assessment using evidence from existing literature<sup>7</sup>. The resulting matrix categorises risks to the UK as direct (primary), indirect (cross-sectoral or multiplier effects), and major (catastrophic) depending on whether they physically occur in the UK, are imported from outside the UK, or are a consequence of global change (Figure 3).

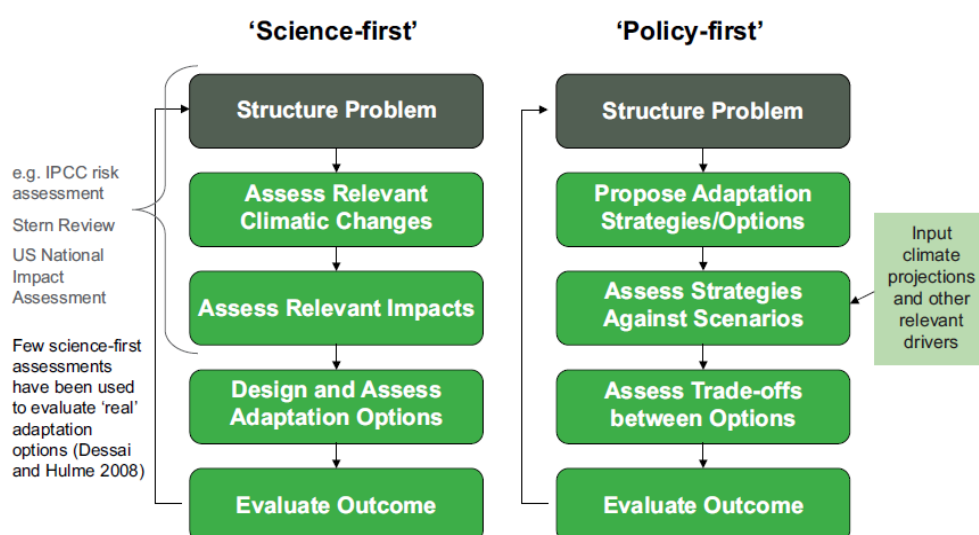
The review confirms that the focus of the first CCRA was on direct, domestic effects (as required by the terms of reference) and that the evidence base is relatively sparse for other cells in the matrix. Nonetheless, the authors conclude that the economic impact of these omitted categories *could be very sizeable, and could together be of the same order of magnitude as direct domestic effects*. For example, the UK water ‘footprint’ is subsidized by a net import of 46,554 million m<sup>3</sup>/year of ‘virtual’ water embedded in manufactured and agricultural produce<sup>21</sup>, much of which originates from regions that could face increased water scarcity under climate change.

## 4. Climate risk assessment in other countries

This section begins with a typology for risk assessment then considers the architecture and methodologies of climate change studies undertaken by other countries. National assessments have been reviewed before<sup>9</sup> and within the second CCRA Recommendations Report led by HR Wallingford. This section takes updates earlier syntheses and works with the premise that the risk assessment is best regarded as an integral (rather than distinct) part of the national adaptation strategy.

### 4.1 A typology of risk assessment

At the very highest level, a national climate change risk assessment may sit within a ‘science-first’ (also known as ‘top-down’, ‘scenario-led’, ‘predict-then-act’) or ‘policy-first’ (sometimes referred as ‘bottom-up’, ‘vulnerability-based’) decision framework (Figure 5). The former is typically deterministic; beginning with climate change projections and ending with a wide range of impacts that are used to frame adaptation options. Invariably, uncertainty is compounded at each stage of the analysis and is never fully characterised. Conversely, the latter begins with a suite of adaptation options that may be socially, economically and technically feasible then evaluates their performance using quantitative sensitivity testing or narrative scenarios<sup>22</sup>.



**Figure 5** Comparison of stages involved in science-first and policy-first approaches to identifying and evaluating adaptation options. Source: Dessai and Hulme (2007) and Ranger et al. (2010)

<sup>21</sup> Chapagain and Hoekstra (2008)

<sup>22</sup> Wilby and Dessai (2010)

Risk assessment frameworks may be further defined by the degree of formality of procedures and structures versus the degree of information content<sup>23</sup>. In practice, different policy areas may apply different frameworks for risk assessment – requiring tradeoffs between specificity/detail and generalization/simplification between sectors. Table 1 shows a typology originally developed for the regulation of environmental and health risks associated with chemicals.

Information frameworks at the general policy level (such as for the European Union) are based on highly aggregated data, seldom originating from the same source and with varying degrees of accuracy (Type IV, Table 1). These frameworks are suited to dealing with new and/or surprising information, or sudden revelations of previously unknown risks<sup>23</sup>. In contrast, treatment of information may be more systematic and ordered if the object of a specific policy, or if clearly-bounded demands are made for evidence. According to these two criteria, the first CCRA would be defined as a science-first, clearly structured framework in which the focus is on delivery of specific pre-defined information on risks using quantitative methods (Type I, Table 1).

**Table 1** A typology of information frameworks for risk assessment emphasizing their epistemic orientation and degree of formalism with respect to procedures and content. Adapted from: Assmuth and Hildén (2008)

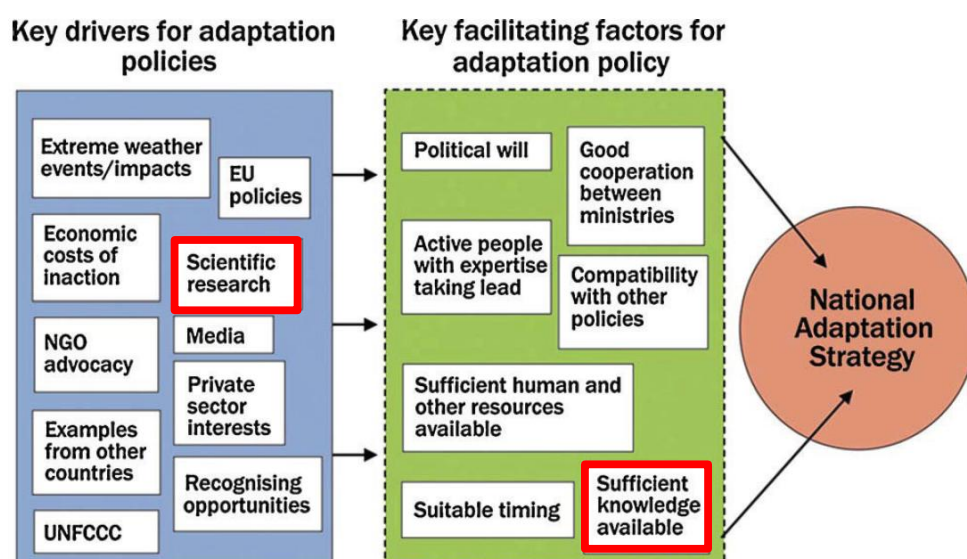
	Clearly structured frameworks with specific procedures	Loosely structured risk-orientated frameworks
<b>Science-first</b>	Type I: Focus on delivery of specific pre-defined information on risks using scientific, usually quantitative methods. Dominated by procedures in ‘exact sciences’ (including uncertainty analysis) and pragmatic application of risk assessment.	Type II: Risks and risk factors are treated as (idealized) realities and information is assumed value-free. Strong emphasis on factual and quantifiable information, wide array of different attempts to measure and specify risks.
<b>Policy-first</b>	Type III: Focus on the use of specific information following predefined decision rules. Formalized assessment procedures exist for individual risks and receptors but procedures are weakly developed for multiple, cumulative or complex risks. Procedures for the clarification and account for management and social aspects are typically undeveloped.	Type IV: Concerned with the relations, causes and significance of risks. Information is political. Policy arguments are mixed with and covered by scientific rhetoric.

The eventual shape of national risk assessment and adaptation programmes is defined by many factors including political leadership, institutional organization, stakeholder involvement, use of climate change information, decision analysis techniques, barriers to adaptation, level of funding, technology development and diffusion, and research. Successful adaptation programmes are expected to manifest all these elements to varying degrees<sup>11</sup>. Other practical considerations include the management structure of the study, time available, level of detail required, consistency of analysis between sectors, tendering rules and procurement process, institutional memory and modes of soliciting reviews<sup>9</sup>.

Ultimately, the assessment architecture depends on the evolving socio-cultural context and key drivers shaping policy (Figure 6). Defra leads on developing a robust approach to domestic adaptation to climate change. This includes agreeing an adaptation policy framework, ensuring that local areas are adapting to climate change, and providing a robust evidence base to support decision-makers. This places particular onus on Defra’s delivery bodies, the Environment Agency and Natural England, to ensure effective implementation in the areas of flood risk management, water supply, coastal management and natural environment. Note that in the idealized form of Figure 6,

<sup>23</sup> Assmuth and Hildén (2008)

scientific research/knowledge (about climate risks) is both a driver and facilitating factor in adaptation policy. However, it is not singled out as being more or less important than other elements (such as cooperation between ministries, sufficiency of human resources).



**Figure 6** Key drivers and facilitating factors for the development of National Adaptation Strategies. The contributions by scientific research and knowledge are highlighted. Adapted from: Swart et al. (2009)

#### 4.2 National assessments in other countries

An earlier synthesis of national studies<sup>9</sup> grouped them into four categories based on similarities in their broad aims and objectives, methodologies, architecture and outputs:

- Category A: Studies which draw together the current state of knowledge on climate change and to inform rather than deliver specific actions.
- Category B: Studies which assess national risks, linked to appropriate responses and preparedness, often in relation to discrete major hazards (as opposed to climate trends).
- Category C: Studies which assess vulnerability, including to present climate variability.
- Category D: Studies which advance adaptation actions, typically involving significant levels of local stakeholder engagement.

By combining the risk framework typology in Table 1 with the above categories it is possible to classify recent national assessments (Table 2). In line with Figure 5, a broad distinction is made between those studies that have adaptation thinking at the forefront (Types III and IV, e.g., Denmark and Sweden) and those that begin from a climate science/impact perspective (Types I and II, e.g. Australia, USA). This difference is very apparent even from the structure of the reports. Overall, there is a propensity for science-first studies (Types I and II) that assemble information on risks to inform adaptation (Category A). There are relatively few vulnerability-based (Category C) assessments – Canada and Sweden being rare examples. The first UK CCRA is weighted towards ‘science-first’ in the absence of explicit adaptation goals (Type I-A).

Perhaps the most distinctive work on policy-first, adaptation options appraisal belongs to The Netherlands<sup>24</sup>. Four scenarios are used to test options. These set out climate changes to 2100 using narratives for atmospheric circulation (a relatively straightforward approach that is being followed in Australia, but markedly different from UKCP09). Nationally, adaptations to flooding are designed to yield equitable outcomes in terms of risk-reduction for all members of society. The Dutch Delta Commission (2008:16) expressed this vision very succinctly: *A human life is worth the same everywhere and the probability of a fatality due to a disastrous flood must therefore be assessed on a common basis, to be agreed throughout society*. In The Netherlands, that probability was set at one in a million, and is the starting point for an integrated plan of action<sup>25</sup>. The anticipated cost of the Delta Programme was expected to be 1.2 to 1.6 billion Euros per annum until 2050.

**Table 2** Examples of national risk assessment and adaptation programmes including the UK.

Country	Report	Year	Lead agency	Type
Australia	<i>Climate change risks to Australia's coast: A first pass national assessment</i>	2009	Department of Climate Change	I-A
Belgium	<i>Belgian national climate change adaptation strategy</i>	2010	Flemish Environment Nature and Energy Department	II-A
Canada	<i>From impacts to adaptation: Canada in a changing climate 2007</i>	2008	Natural Resources Canada	II-C
Denmark	<i>Danish strategy for adaptation to a changing climate</i>	2008	Danish Energy Agency	IV-D
Finland	<i>Evaluation of the implementation of Finland's National Strategy for Adaptation to Climate Change 2009</i>	2009	Ministry of Agriculture and Forestry	IV-D
France	<i>French National Climate Change Impact Adaptation Plan 2011-2015</i>	2011	Ministry of Ecology, Sustainable Development, Transport and Housing	I-A
Germany	<i>German strategy for adaptation to climate change</i>	2008	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety	I-A
Iceland	<i>Iceland's Climate Change Strategy</i>	2007	Ministry for the Environment	I-A
Ireland	<i>Ireland National Climate Change Strategy 2007-2012</i>	2007	Department of the Environment, Heritage and Local Government	I-A
Japan	<i>Wise adaptation to climate change</i>	2008	Ministry of Environment	II-A
Netherlands	<i>Working on the delta: Acting today, preparing for tomorrow</i>	2012	Ministry of Infrastructure and the Environment; Ministry of Economic Affairs, Agriculture and Innovation	IV-D
Spain	<i>Evaluación Preliminar de los Impactos en España por Efecto del Cambio Climático</i>	2005	Ministerio de Medio Ambiente	I-A
Sweden	<i>Sweden facing climate change – threats and opportunities</i>	2007	Swedish Commission on Climate and Vulnerability	I-C
Switzerland	<i>Stratégie Suisse d'adaptation aux changements climatiques: Rapport intermédiaire au Conseil fédéral</i>	2010	Département fédéral de l'Environnement, des Transports, de l'Energie et de la Communication (DETEC)	I-A
UK	<i>The UK Climate Change Risk Assessment 2012 Evidence Report</i>	2012	Department for Environment, Food and Rural Affairs	I-A
USA	<i>Scientific Assessment of the Effects of Global Change on the United States</i>	2008	US Global Change Research Program; Committee on Environment and Natural Resources, National Science and Technology Council	II-A

<sup>24</sup> PBL (2011)

<sup>25</sup> Stive et al. (2011)

In most countries, political ‘ownership’ of climate risk generally lies with Departments of the Environment or Natural Resources (Table 2). In Australia and Sweden the lead agency has a specific climate change remit. In all cases the climate risk assessment is just one constituent of a much larger body of adaptation activities. A few studies have considered the structure and focus of different national assessments in order to draw out lessons learnt or to critically evaluate different approaches. For example, the Partnership for European Environmental Research (PEER) compared national adaptation strategies in Europe<sup>8</sup> under six themes:

- Motivating factors such as EU policies, emerging opportunities and trigger events (Figure 6);
- Maturity of science-policy interactions, availability of policy-relevant science, and existence of ‘bridging’ organisations (such as UKCIP);
- National communication strategies for raising awareness of risks as well as the potential for individual or collective adaptation;
- Types/degree of integration across sectors and at multiple levels of governance;
- Effectiveness of policy integration depending on strong leading department, vulnerable sectors, interdepartmental units and local input;
- Mechanisms for implementing, evaluating and revising adaptation strategies, including metrics to gauge progress.

Consistent with Figure 3, the PEER review found only superficial treatment of climate change impacts beyond the physical territory of Europe<sup>26</sup>; the focus in most national assessments has been much more on local and regional consequences (Figure 7, lower right). The authors also suggest that knowledge of impacts and vulnerabilities does not necessarily translate into cost-effective policy decisions due to the context specificity of adaptation. Furthermore, in weighing up the strengths and weaknesses of the national assessments it was concluded that the challenges of multi-level governance are often greater than finding technical solutions (Figure 7, top right corner)<sup>27</sup>.

	<b>Contributing significantly to achieving the NAS objectives</b>	<b>Hindering the achievement of the NAS objectives</b>
<b>Related to historical conditions and institutional development of the NAS</b>	<ul style="list-style-type: none"> <li>• targeted adaptation research</li> <li>• planning for implementation, review and funding</li> <li>• coordination between sectors and administrative levels</li> </ul> <b>STRENGTHS</b>	<ul style="list-style-type: none"> <li>• lack of coordination between sectors</li> <li>• lack of stakeholder involvement</li> <li>• unclear responsibilities between administrative levels</li> <li>• lack of specialised knowledge</li> <li>• scientific uncertainties</li> </ul> <b>WEAKNESSES</b>
<b>Related to current and future conditions and developments external to the NAS</b>	<ul style="list-style-type: none"> <li>• development and export of knowledge</li> <li>• spill-over of policy integration and multilevel governance for non-climate policies</li> </ul> <b>OPPORTUNITIES</b>	<ul style="list-style-type: none"> <li>• cross-level conflicts</li> <li>• cross-sectoral conflicts</li> <li>• lack of resources</li> <li>• lack of public support</li> <li>• global impacts</li> </ul> <b>THREATS</b>

**Figure 7** Generic strengths, weaknesses, opportunities and threats that are typical for several National Adaptation Strategies (NAS) in EU countries. Source: Swart et al. (2009:23)

<sup>26</sup> The 2011 French National Climate Change Impact Adaptation Plan includes a section on overseas territories.

<sup>27</sup> For a case study of different levels of integration see: Juhola and Westerhoff (2011)



Other studies discuss experiences in the US at federal and state levels. For example, the US *National Assessment of Climate Variability and Change* involved direct participation of eight federal agencies plus the Office of Science and Technology Policy, and a federal advisory committee<sup>19</sup>. The cost of the assessment was divided amongst agencies along their lines of responsibility and the process was managed by an interagency committee. Reports were subject to public and expert scrutiny, as well as a review by the President's Committee on Advisors on Science and Technology. A detailed survey of participants found generally positive responses to questions about leadership and overall organization but *considerable frustration over time constraints, lack of resources, and limited, or ineffectual, coordination*<sup>19</sup>.

A critique of the Second California Assessment emphasized the importance of having a common set of climate and sea level rise scenarios (as well as socio-economic projections at county-level) for all sectoral studies<sup>28</sup>. Scenarios and the impacts study findings were disseminated to local stakeholders via interactive web-tools. The need to place certain sectors (such as the timber industry) within a national and international climate context was also recognised. Furthermore, it was asserted that *ongoing, periodic assessment involving technical staff from state agencies is highly beneficial for both the scientists and for state agency decision makers*<sup>28</sup>. In other words, the consultative process of interaction was as important as the technical findings of the study.

Some commentators suggest that in undertaking immense climate assessments there is a danger that insufficient resource and attention are devoted to public communication and outreach<sup>29</sup>. Adequate provision should also be made for local decision support. One solution may be to establish an internet-based network to enable practitioners to pool resources, share expertise and feedback lessons to the providers of climate risk information<sup>30</sup>. For example, the Water Research Foundation (WRF) has established a *Climate Change Clearinghouse* for just this purpose<sup>31</sup>.

In summary, the majority of surveyed national assessments apply a science-first framework, are typically top-down, seldom integrate across sectors, or take into account climate risks originating outside of state borders. Many are at the level of loosely structured, devolved or sectoral assessments that lead to rather generic statements of principle<sup>32</sup>. The Netherlands is a noteworthy exception because the rigorous scientific assessment of risks follows from clearly articulated policy objectives for flood protection, freshwater supplies, rural areas, ecosystems and biodiversity, and urban areas<sup>24</sup>. As the next section will show, the framework set out by The Netherlands is most closely akin to the model recommended for the second CCRA.

## 5. Lessons learnt and opportunities for strengthening the second CCRA

This review included interviews with key actors to reflect on the lessons learnt from the first CCRA, the requirements for the second, and the scope for improving the broader enabling environment for regular climate risk assessment in the UK. A number of consistent themes emerged from the interviews. These include aspects of the study architecture, risk assessment methodology and project management. Direct quotations from reports and respondents are shown in *italics*. Where feasible, remarks are intentionally anonymous.

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<sup>28</sup> Franco et al. (2008; 2011)

<sup>29</sup> Ekwurzel et al. (2011)

<sup>30</sup> Romsdahl (2011)

<sup>31</sup> <http://www.theclimatechangeclearinghouse.org/ClimateChangeClearinghouse/ForTheWaterCommunity.aspx>

<sup>32</sup> Low et al. (2012)



### 5.1 Strengths and weaknesses of the first CCRA

Most interviewees recognised that the first CCRA was a '*heroic effort*' and that important lessons were learned by undertaking the work. The overarching impression was of a project team under immense time pressure to meet the schedule and requirements of the Act. Therefore, in reflecting on these experiences it is important to keep in mind that the first CCRA was the first step in an open-ended programme of work.

#### Study architecture

How a climate assessment is framed matters. As noted above, the Terms of Reference for the first CCRA (Annex 1) were largely framed by science-policy objectives, but there are others. In place of monetized risks and opportunities the first CCRA could have been framed by questions of justice, equity and well-being<sup>33</sup>. What was done and how it was done also reflected the political context and evolving climate science at the time of commission and during the course of the project. For example, the Coalition's localism agenda is a marked departure from the centrally defined PSAs and National Indicators of the previous government. The first CCRA also commenced shortly after the publication of the UKCP09 projections at a time when the user community had only begun to work with probabilistic climate information.

Some respondents felt that more thorough policy appraisal and engagement with policy-makers was needed at outset, and that project deliverables should have been tied more explicitly to policy objectives on adaptation. This requires greater clarity about who the end users are beyond simply knowing that the *customer for this work is Government at UK, national and regional levels* (Annex 1). This further implies some prior appreciation of which elements of Government 'own' which nationally significant climate change risks – a strategy that is not necessarily well-served by a bottom-up appraisal of risks. Ideally, the evidence and policy cycles needed to support adaptation planning would have been better synchronised too.

As Figure 6 showed there is much more to adaptation planning than scientific research and knowledge of risks. The Act makes provision for an *assessment of the risks for the UK of the current and predicted impact of climate change* (section 56) but is not prescriptive about other enabling factors for adaptation policy. Therefore, it is important to recognise that the risk assessment will not facilitate adaptation in isolation of other components. Ideally, the CCRA would be approached as part of an *open-ended learning process and not as a standalone project or objective in itself*.

#### Risk assessment method

There was a widely held view that the CCRA *process is as important as the research outcome*. In other words there have been a range of non-tangible benefits and spin-off activities. For example, the Living With Environmental Change (LWEC) challenge areas<sup>34</sup> draw on the evidence needs for climate change adaptation arising from the first CCRA. It has been proposed that LWEC produces an Annual Report Card on the current state of research and knowledge for policy advisors. Large academic research projects have already been funded (for example by the European Research Council) to better understand user needs and the ethnography of UKCP09 and CCRA knowledge production<sup>35</sup>.

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<sup>33</sup> See for example the Delta Commission (2008) or Hulme (2009)

<sup>34</sup> [http://www.lwec.org.uk/sites/default/files/LWEC\\_PB\\_May\\_2011\\_Papers\\_part\\_2\\_Items\\_5-7\(part1\).pdf](http://www.lwec.org.uk/sites/default/files/LWEC_PB_May_2011_Papers_part_2_Items_5-7(part1).pdf)

<sup>35</sup> Advancing Knowledge Systems to Inform Adaptation Decisions (ICAD): <http://www.see.leeds.ac.uk/research/sri/project-icad/>

The agriculture, built environment, business, energy, health and transport sectors were also identified as priorities for further work, recognising that sectors are more heterogeneous than the risk analysis might suggest. For example, agriculture reflects the behaviour of ~160,000 small and medium enterprises, ranging from family run farms to agri-businesses. Under these circumstances the representativeness of workshop findings and Sector Report depends heavily on the mix of stakeholders participating. However, stakeholder engagement has helped to build networks and was fundamental to the collective learning process in the first CCRA, including more widespread (albeit sometimes inconsistent<sup>36</sup>) use of *risk language*.

Mixed views were expressed about the risk assessment methodology. Some end-users felt that it was *fiendishly complicated and impenetrable*; others thought that it was *an amazing job given the hugely varying levels of information and complexity of the task*. The first perspective suggests that more effort could have been invested in providing a concise and clear description of the methods that would be accessible to a range of audiences in government departments. In particular, any *heroic assumptions* (about the response functions) should be fully transparent. There was suspicion that the response function methodology was sometimes applied where not really appropriate or in simplistic ways. For example, estimation of changing crop yields based only on temperature changes alone is clearly misleading<sup>37</sup> so the CCRA contractors stress that this output *should not be interpreted as prediction of future yield change*<sup>38</sup>.

Information about the multiple drivers of risks to crop yields can be drawn from research literature. This is what has been done by the Economics of Climate Resilience (ECR) team who concluded that a detailed gap filling review was needed for agriculture to cover everything from possible risks and impacts through to the policy background and analysis. As part of a tiered process, the CCRA showed where there is a case for more detailed analysis, and has helped to shape the scope of the ECR.

Production of standardised confidence/magnitude tables for cross-sectoral and regional comparison was regarded by some as one of the novel contributions of the first CCRA. In practice, consistent sector and geographic coverage of risks was not always feasible because of variations in the availability of data, depth of knowledge, tools, and access to experts. For example, some work relied on UKIPO2 (MONARCH) research, prompting the view that *the biodiversity report could have been written 10 years ago*. Another sector specialist had *no faith in the top-down methodology*; in their opinion a vulnerability perspective would have been preferred (for biodiversity).

The scope of some sectors could have been more clearly defined, particularly where interdependencies are known to exist. For instance, loss of fisheries has relevance to several sectors reports: business, marine, and biodiversity. Country reports were compiled from the sector reports despite gaps in data, lack of comparability or relevance of some Tier 2 risks, leading to a *scrap-book feel*. One respondent felt that the stakeholder workshop for Wales had struggled to gain a sufficiently large sample and representative group of participants for all sectors.

Comparison of climate risks across sectors using a common approach is also problematic because the consequences are so different. For example, Figure 2 suggests that the top threats arise from flooding (annual damages, access to insurance, mental health, insurance sector), followed by increased summer mortality during heatwaves, then forest extent affected by red band needle blight. However, other national scale climate change risks could arise from concurrent extreme events, sequential, cross-sectoral, indirect risks, or from outside the UK. The sector-level analysis provides a useful point of reference but is less amenable to the appraisal of such ‘macro’ risks.

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<sup>36</sup> The Defra peer review observed that terms such as “risk” and “impact” were often used inter-changeably

<sup>37</sup> Semenov et al. (2012)

<sup>38</sup> Knox and Wade (2012)

The issue of benchmarking future climate risks was raised several times. The flood and coastal erosion sector is already adapting to climate change via allowances for sensitivity testing<sup>39</sup>. In this case, the business as usual scenario is not a world without adaptation which brings into question the credibility of the monetization. The counterview is that in order to compare risks across different sectors all have to be benchmarked in the same way. The zero adaptation assumption<sup>40</sup> also *reinforces the message that the research findings are not predictions*. Furthermore, any attempt to take into account adaptation would have to acknowledge differences in policies between England and the Devolved Administrations.

Others were much more circumspect about the first CCRA methodology, noting that the above concerns should be seen in the context of gross uncertainties about future socio-economic scenarios and regional climate projections<sup>41</sup>. Under these circumstances there is an ever-present danger of giving false impressions of precision about future risks when extracting local information from models originally designed for national reporting.

## **Management**

Initial scoping work for the first CCRA advised against procurement of the project as a single consultancy contract<sup>9</sup>. As noted before, different procurement strategies have their advantages and disadvantages, and Defra chose not to follow the advice. The main disadvantages of the consultancy mode are that competing consortia can divide the expert base and do not necessarily have access to the required national models. Consultancy may also limit the scope for using leading experts in all sectors, and there can be less buy-in across Government and the research community. The potential for building institutional memory is also diminished by out-sourcing the analysis, and there may be contractual issues around the sharing of data, tools and intellectual property. All these limitations were manifested to varying degrees by the first CCRA.

Several respondents would have preferred a Foresight-style project managed by Defra. In this way, Defra could have been supported by technical experts and panels and contributory studies commissioned as required. Experience from the *Foresight Future Flooding Project* suggests that this method of procurement leads to consensus building and high quality outputs. There is greater flexibility in the acquisition of expert input but the process may be slower and require more resources and procurement activity.

Prospects for retaining institutional memory and for developing technical capacity within Defra were diminished by junior staff changes in the ACC programme throughout the course of the first CCRA (see section 2.2). Senior officials were also striving to establish the right balance between size, expertise, and cost of the steering group. Other national studies have typically involved the appointment of an independent chairperson, and advisory group with secretariat, and sectoral working groups. This structure was not suitable for the first CCRA because the process had to be chaired, led and coordinated by Defra.

The ACC project team had to establish processes for capturing peer reviews and responding to advice. Some felt that interactions with the ASC could have been less adversarial and more solution-focused, with quicker turnaround for feedback, more sub-group interaction on request, and more coherent advice from committee members. Another believed that the *ASC approached the task with a degree of detachment but an establishment view*. In fulfilling the advisory role, it was perhaps inevitable that some project *scope creep* would occur. From the perspective of an ASC member this

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<sup>39</sup> Environment Agency (2011)

<sup>40</sup> Termed the “constant economy” in the 2009 French national assessment

<sup>41</sup> See for example the uncompromising critique of regional downscaling by Pielke and Wilby (2012)

was an essential investment of time that was necessary to strengthen the methodology of the first CCRA. As a consequence of these revisions and the rigid time-scale imposed by the Act, the period remaining for the sector analysis and linkage across reports was compressed.

Feedback from the Defra review was generally well-regarded and is in the public domain<sup>42</sup>. Peer review comments and consultant responses on the sectors reports are being compiled by ACC and will eventually be available on request. Fully transparent review processes are important for building trust, providing a record of the technical innovations, and for maintaining the good-will of the independent contributors.

There were various opinions about the effectiveness of the communication and dissemination strategy for the first CCRA. Initial scoping recommended an overarching communication strategy to set out the clear purpose and vision of the study and to manage stakeholder expectations<sup>9</sup>. One respondent suggested that professional science writers could have been even more widely used for the summary reports. Another saw the tiered products as a good way of reaching different audiences across Government. Others felt that the headline findings could have been sharper.

## ***5.2 Scope for improvement in the second CCRA***

This section compiles interviewee suggestions about priorities for the second CCRA (*which is due no later than five years after the previous report was so laid*). There is no reason to suppose that the architecture and methodologies of the second CCRA will be the same as the first. In fact, a strong case can be made for a more focused assessment that would appear to meet the requirements of the Climate Change Act whilst addressing critical knowledge gaps and prioritised risks identified by the first CCRA. The following interviewee remarks are grouped into those that relate to interim actions, risk methodologies, and management aspects. These build on the lessons learnt above.

### ***Interim actions***

Several actions were identified that could pave the way for the second CCRA. A scoping study could be commissioned on options for building institutional memory on adaptation within Government. This should include measures for assimilating memory within policies, documentation and processes. There is also a need for comprehensive policy appraisal on adaptation in order to place climate risks within their policy context and to clarify ownership by departments. This should enable the second CCRA to be *more demand rather than supplier-led*, so resulting actions for Government are clearer.

Some policy areas merit particular attention. For example, land use and management policy sits at the nexus of many risk areas (such as water, flood, agriculture, biodiversity, and energy). Greater clarity is also needed about the ownership of overseas risks. For instance, earlier work on UK food security was led by Defra<sup>42</sup>, but the Foreign and Commonwealth Office, the Department for International Development, and the Department for Business, Innovation and Skills all conceivably have a stake in the international and imported risks shown in Figure 3. Hence, one respondent felt that there is potential for the second CCRA to have broader appeal across Government (compared with widely acclaimed projects with narrower remits, such as the UK National Ecosystem Assessment).

Other scoping working could produce an inventory of risk assessment methods that can be reasonably applied given available data, models and systems-understanding. These would be

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<sup>42</sup> Defra (2008)

expected to range from highly analytical data intensive methods through to qualitative, expert judgements. One interviewee suggested that further work is needed to improve understanding of the processes of knowledge generation and innovation for adaptation (including the contributions made by education, research and development).

The localism agenda places greater onus on local authorities, communities and businesses to deliver adaptation solutions. Therefore, it would make sense for the second CCRA to be closely integrated with activities under the Adaptation Reporting Power. Indeed, with some technical support, the key infrastructure providers are clearly well-placed to provide informed views about climate risks to their operations as well as a degree of continuity between successive administrations.

### ***Risk assessment methods***

Widespread support was expressed for a more policy-centric approach in the second CCRA; one respondent suggested that the second CCRA should be *less fixated about the science*. Nonetheless, several opportunities for developing the risk assessment methodology have emerged.

By far the most frequent appeal was for a more holistic, cross-sectoral approach to climate risk (such as water and energy, or water and food). This should begin with systematic top-down, mapping (as with national risk register) to prioritise work on those ‘macro’ risks that really matter. It could also have the added benefit of narrowing the focus and deepening the analysis.

Risks from ‘perfect storm’ events should also be evaluated (including from concurrent extreme weather, converging trends, or cascading effects). Where possible, insights could be gained from the detailed study of historical analogues such as the flooding and near power-outage at Tewksbury in 2007. This would involve greater emphasis on current vulnerabilities, adaptive capacity and coping thresholds for climate extremes – a decision strategy that has found favour elsewhere. For example, the latest Upper Great Lakes water resources plan begins by asking stakeholders what conditions they could cope with and which would require substantial policy or investment shifts<sup>43</sup>.

Some UK water companies have already begun modelling the resistance and resilience of their water supply infrastructure to extreme events<sup>44</sup>. However, there are also remote and indirect climate risks to consider. For example, the extent to which climate change could disrupt critical supply chains for the materials needed to keep water treatment plants operating. For other sectors this might include the risk of climate shocks on international supply chains for food and business.

Successive CCRAAs will need to be mindful of technical developments in climate scenarios such as the new atmospheric composition pathways being developed for the modelling community: the Representative Concentration Pathways (RCPs) and Extended Concentration Pathways (ECPs)<sup>45</sup>. This poses a question about whether the second CCRA should rely entirely on climate scenarios provided by the UK Met Office, could use other regional scenario sets, or even take a narrative driven approach as in the Netherlands<sup>46</sup>. Risks associated with abrupt and irreversible climate change scenarios might also be considered.

National-scale integrated assessment of multi-sector risks presupposes the existence of suitable modelling frameworks and data sets. Sectors such as flooding and water already have this spatial-modelling capability; others do not. An alternative approach might involve up-scaling and aggregating local risk models to the national level. In either case, the UK Research Councils could

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<sup>43</sup> Brown et al. (2011: 524).

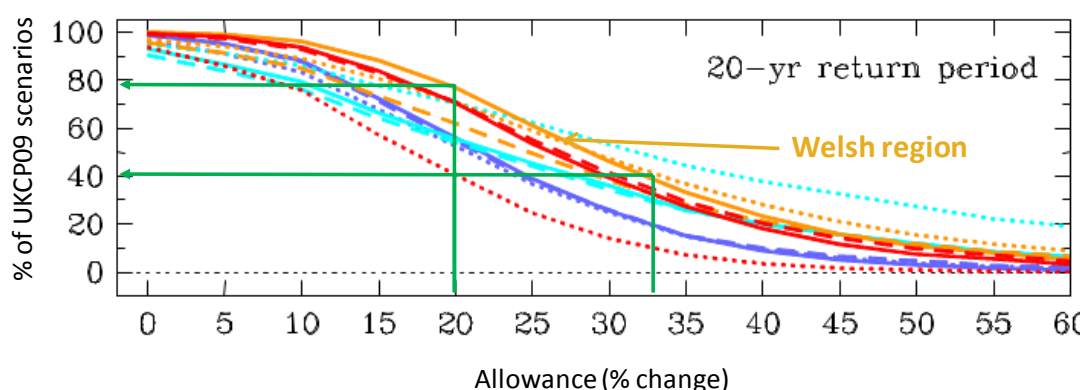
<sup>44</sup> Henriques and Spraggs (2011)

<sup>45</sup> Moss et al. (2010); van Vuuren et al. (2011); Meinshausen et al. (2011)

<sup>46</sup> National Research Programme Climate changes Spatial Planning (2007)

play a supporting role by developing thematic programmes along these lines (see section 5.3). Ideally, any new methodologies would be trialled first in weaker science or data poor areas to increase the likelihood of more widespread applicability (rather than more endowed sectors as in the first CCRA).

The need for a consistent set of socio-economic scenarios was recognised as a priority ahead of the first CCRA<sup>9</sup>. However, opinion is divided about the merits of exploring potential climate change impacts (i.e., climate risks combined with other societal pressures and responses) as opposed to risk assuming the present society in the future. Scenario-neutral, sensitivity tests<sup>47</sup> could be performed instead to explore trade-offs between risk reduction measures and inferred costs of adaptation (Figure 8). Social scientists could investigate variations between actual and perceived risks in different communities following recent work in Australia<sup>48</sup> and The Netherlands<sup>49</sup>.



**Figure 8** The trade-off between climate risk (% of UKCP09 scenarios) and a proxy for the cost of adaptation (allowance [% change]) when managing the 1 in 20 year flood. In this case (Welsh region), the old allowance (20%) would be insufficient defence against nearly 80% of the UKCP09 scenarios, whereas a higher standard of protection (e.g., 33% allowance) is insufficient 40% of the time. Source: Reynard (*pers. comm.*)

## Management

For the reasons cited in section 5.1, the Foresight model is favoured by most interviewees for delivering the second CCRA. To avoid a repeat of the time-pressure in the first CCRA, the procurement process could begin as early as 2013 (i.e., immediately after submission of the NAP). The Foresight approach would involve appointing an independent chairperson, then setting up advisory groups and a secretariat, and allocating work along key risk themes. Given the importance attached to cross-sectoral and international climate risks it would be appropriate to begin with dedicated working groups for these topics.

The existing governance architecture could be maintained if a Foresight approach was led by Defra. The second CCRA would move from *single contract procurement where the technical lead is a consultant to a situation where the technical lead is brought in-house or given to an expert panel*. Defra would then receive the technical information and produce the report for Parliament.

Research Council and government structures could also facilitate knowledge exchange between sectors and regions. Cross-department knowledge exchange and scrutiny of the second CCRA should

<sup>47</sup> Prudhomme et al. (2010)

<sup>48</sup> Raymond and Brown (2011)

<sup>49</sup> Botzen et al. (2009)

continue to involve Chief Scientists. However, the associated demands on departments (particularly during the review phase) should be agreed and resourced from outset.

An early task would be to set the overall project objectives, and prioritise the climate risks defined through consultation with government departments. The first technical assignment should then be to commission a systematic review of the existing evidence base on these risks, updating and infilling where necessary from the first CCRA. A consistent process for capturing knowledge gaps identified throughout the project life-cycle should also be established from outset.

Some respondents felt that the list of Tier 1 and Tier 2 risks collected from the first CCRA stakeholder workshops provides a *useful starting point and would not need to be repeated*. The information gathered could be used to identify gaps in coverage or undue bias from unrepresentative sampling of stakeholder opinions. For example, the transport sector report was dominated by road and rail metrics, with no consequence response functions employed for aviation or waterways.

In addition to the suggested improvements noted in section 5.1, some respondents felt that the communication and dissemination strategy should also make provision for a knowledge management portal to improve accessibility of the study results. This would include clearer, more transparent statements about risks for practitioners that lead to implementable responses. Again, this is where closer alignment with the Adaptation Reporting Power reports could add value. Defra's Local Air Quality Management Helpdesk<sup>50</sup> was cited as a good example of a portal designed to address technical questions, and to provide information and advice to Local Authorities.

### 5.3 Strengthening the wider enabling environment

International agencies and national governments have an important role in creating the legal, economic and policy environments in which different actors can respond to climate variability and change<sup>51</sup>. Enabling measures can take many forms ranging from routine environmental monitoring and reporting of change, through resourcing thematic research programmes, incentivising risk reduction measures, and providing advice.

**Table 3** Key elements of an enabling environment for risk assessment and adaptation planning

<ul style="list-style-type: none"> <li>• Institutional structures and regulatory environment; vertical and horizontal coordination of public/private actors; institutional memory</li> <li>• Scientific evidence and knowledge base (coverage and depth) on climate risks and opportunities</li> <li>• Monitoring, detection and reporting systems; access to primary data and climate change indicators</li> <li>• Research councils and programmes to deliver actionable information; resolving tensions between practical and blue-sky research</li> <li>• National technical capabilities, skills and training</li> <li>• Bridging/boundary organisations, guidance, information and decision-support tools</li> <li>• National communication (coordination amongst actors, dissemination strategy, managing expectations)</li> </ul>
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Table 3 provides a generic set of enabling activities and a basis for structuring the interviewee responses. Note also that Defra<sup>52</sup> and others<sup>53</sup> have assessed adaptive capacity at the level of individual sectors. The following paragraphs take a broader view of the enabling environment for adaptation within the UK.

<sup>50</sup> <http://uk-air.defra.gov.uk/news?view=140>

<sup>51</sup> Lal et al. (2012)

<sup>52</sup> Defra (2011)

<sup>53</sup> See for example Wilby and Keenan (2012) for a review of enabling activities for flood risk management

## ***Institutions and governance***

Enabling activities for climate risk assessment and adaptation planning can occur at multiple levels of governance: central, devolved and local. Local level enabling is regarded as the current priority. However, there are potential tensions between the localism agenda and the formulation of a coherent, national adaptation plan. For example, it remains to be seen how localised partnership funding arrangements will play out for flood risk and coastal management. As one respondent observed, *local authorities have such a crucial role to play in climate change adaptation action that they should be subject to the Reporting Requirement*<sup>54</sup>.

One interviewee called for a much clearer strategy/statement from Government on *how* they will practically assist adaptation, along with the implied costs to Government and the private sector of business as usual *versus* improving resilience to climate change. The expected costs and benefits of building adaptive capacity will depend on the level of diversification or specialization of the UK economy. Another wanted a palette of adaptation measures that Devolved Administrations could then use in their own economic analysis.

Some interviewees called for greater clarity on the relative roles and authorities of ASC, Defra and the Environment Agency, and their fitness for managing evolving/transient climate risks. This involves establishing the extent to which the ASC has the remit to comment on or shape adaptation work being led by the Agency. The latter covers the extent to which all three bodies regularly review and modify their technical capabilities to meet changing needs. This includes knowledge of most vulnerable sectors and macro-scale risks, as well as competencies in handling international dimensions to risks that could have significant local consequences (e.g., for health, food or energy security).

## ***Evidence base***

As noted in the previous two sections, the first CCRA flushed out many gaps in the evidence base that will need to be picked up in a coherent research strategy led by Defra. This is already reflected in forthcoming Defra research themes which will address different risk methodologies; scope for customizing CCRA products for other countries (with DFID and the Met Office); more thorough analysis of risk interactions; valuation of impacts; organisational uptake of climate risk information; existing resilience over the 5-20 year time horizon; household level decisions and adaptation (such as water, energy, insurance); and improved understanding of the public acceptance of different types of risk.

In some cases, the evidence may already exist but has not been fully exploited. Defra's work on national soil erosion was cited as an area of under-exploited research. More specific evidence needs were identified by some respondents. The first CCRA benefited from access to established national modelling tools used in, for example, the National Flood Risk Assessment. Aside from flood, water and some bioclimatic modelling such capabilities or up-scaling methods are not yet sufficiently advanced in many other sectors.

One interviewee felt that there needed to be more collaborative research between global change community and those working on UK impacts. Another felt that further scoping was needed of *the alternatives to response functions given climate model uncertainties*. In other words, by acknowledging the very large range in regional climate change projections the outcome of any scenario-led assessment is bound to deliver very general findings, bringing into question the value-added by this form of risk assessment to local adaptation.

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<sup>54</sup> See comments on Adaptation Reporting Power: <http://engage.defra.gov.uk/nap/home/reporting/>



### **Monitoring and reporting**

Observational data are the single most important asset for adaptation planning. This mainly refers to routine monitoring of physical, hydrological and socio-economic drivers of risk (and associated impacts). Even so, the respondents made few references to monitoring and reporting requirements for risk assessment and adaptation planning. This could imply that the work of the Marine Climate Change Impacts Partnership (MCCIP) and forthcoming Environment Agency climate impacts report card are addressing these basic needs. However, there could be a greater role for the Met Office in routinely producing and disseminating standard biophysical indicators such as heating and growing degree days (that can be directly related to equivalent outputs from climate model projections).

It was also suggested that a distributed centre (like the NERC National Centre for Atmospheric Science) could build capabilities in national modelling and hold the observational data for successive CCRAAs. Ideally this virtual centre would interface between funders, researchers, stakeholders and the Government. Existing data archives and research facilities such as the Centre for Ecology and Hydrology (CEH) might be well-placed to lead such an initiative. There is a widely held view that such data are a public good and should be made freely available to all.

### **Research councils**

Suggestions were offered on how the UK research establishment might better meet the evidence and data needs for adapting to climate change. This presupposes that government clearly articulates the policy questions that need to be tackled by the research community – something that has already begun via the five ‘challenge’ themes identified in the draft LWEC strategy<sup>34</sup>. However, others believe that a much broader and more strategic research framework is needed for adaptation, backed by Chief Scientists, with delivery devolved to the departments that own the climate risks. The Met Office would also be expected to take an important role in shaping the programme of work as the lead ‘climate service provider’ to the private and public sector.

Research councils have been working hard to increase knowledge exchange and the societal relevance of their work. However, there is still room for improvement in procedures. For example, there could be much greater stakeholder representation (and weight attached to their views) on funding panels to ensure that resources are dispersed to applied research that leads to actionable adaptation. This includes more effort on translating the science into adaptation guidance or field trials and pilots to test effectiveness of measures<sup>55</sup>. There is also a case for allocating more resources for the opportunistic study of the causes and consequences of extreme weather events.

### **Technical capacity**

The 2004 *Foresight Flood and Coastal Defence Project* recognised a potential shortfall in civil engineering graduates relative to the expected increase in flood risk, associated demand for new build and maintenance of existing assets<sup>56</sup>. This is just one example of how schools, higher education and business will need to ensure that the UK develops sufficient disciplinary expertise to meet adaptation challenges. One respondent felt that more risk management and adaptation thinking could be incorporated within undergraduate *curricula*. Likewise, government departments and agencies would benefit from in-house training programmes and regular technical briefings in order to fully exploit research developments and to operate as an intelligent client when devising terms of

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<sup>55</sup> Wilby et al. (2010)

<sup>56</sup> <http://www.bis.gov.uk/assets/foresight/docs/flood-and-coastal-defence/appendixc.pdf>

reference, or commissioning work. Specialised technical skills and innovation are also needed to devise new technologies that support adaptation. For example, industry could be incentivised to develop adaptation technologies such as drought resistant crops.

### ***Bridging organisations***

Bridging agencies such as UKCIP facilitate cross-sectoral cooperation and vertical integration through different levels of governance. They also help to raise awareness of risks and to mainstream 'climate smart' approaches within institutional decision-making. Furthermore, UKCIP has stimulated much participative knowledge and two-way information exchange between stakeholder and scientific communities<sup>57</sup>. These kinds of activity can be particularly important for small organisations with limited in-house capacities for climate risk screening and analysis.

Under the new arrangements for UKCIP, it will be necessary for the Environment Agency to continue the process of engagement with the most important bodies involved in adaptation delivery. At this point in time it is unclear how these objectives will be reconciled with the Agencies regulatory role for the same sectors, within the context of the NAP.

One respondent suggested that bridging is also needed at the international level to ensure that good practice on climate risk assessment and adaptation planning is shared between nations. The recent *ASC Workshop on Monitoring and Evaluating Progress in Adaptation* was a good example of this type of activity. The academic community can also help by publishing syntheses of national strategies<sup>8</sup> and lessons learnt<sup>19</sup>.

### ***Communication and dissemination***

Effective communication and dissemination of the CCRA findings is closely linked to the bridging activities discussed above. Information technologies could assist in a number of ways. For example, spatial models linked to visualization can enable stakeholders explore longer-term outcomes of adaptation options within a virtual gaming environment (e.g., FloodRanger and CoastRanger). Likewise, E-learning packages could be developed to assist Local Authorities better understand their existing and potential climate risk exposure. As noted previously, there is an over-arching need to help organisations retrieve the information that is most relevant to them from the range of CCRA products.

Role-play exercises such as Operation Trident (2004) and Exercise Watermark (2011) are periodically used to test contingency planning and systems set up by the UK government to deal with flooding and infrastructure emergencies<sup>58</sup>. Key sectors under scrutiny include food, energy, water, transport, energy, communications, emergency services, health care, financial services and government. However, some believe that there is also a need to improve the capability of communities and households to self-help. The CCRA could be used as a vehicle for raising awareness of appropriate actions to take before, during and after extreme events, including evacuation routes.

With all these measures it is important to strike the right balance between over-selling the climate risk versus understating the true extent of climate uncertainty. Entrenched and simplistic narratives such as "warmer wetter winters" may also appear contradictory to recent experience and must be carefully explained to non-expert audiences.

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<sup>57</sup> Hedger et al. (2006)

<sup>58</sup> Cabinet Office: <http://www.cabinetoffice.gov.uk/sites/default/files/resources/sector-resilience-plan.pdf>

## 6. Conclusions and recommendations

This report is an independent evaluation of the first UK Climate Change Risk Assessment (CCRA) including the broader context, underlining objectives and outputs of the study. The review draws on several sources of evidence: literature addressing aspects of climate risk assessment, including work by other countries; semi-structured interviews and consultations with key actors who were directly involved in the first CCRA or are potential end-users; documentation related to the management and advice surrounding the first CCRA; and the range of outputs published from the first CCRA.

Like most other countries surveyed the UK has adopted a science-first approach. Other national assessments vary in terms of the risk framework, sector coverage and level of integration but the outcomes are broadly the same. Uncertainties are seen to propagate through the analysis, resulting in wide ranging (monetized) risks, and rather generic messages for adaptation. Furthermore, the prioritization of risks depends ultimately on the framing of climate change and the treatment of other non-climatic drivers, such as socio-economic change and assumed levels of adaptation.

From a much narrower perspective it was possible to judge the extent to which the Terms of Reference for the first CCRA (Annex 1) were met. The consultants were charged with three main tasks: i) develop a risk framework that can be applied at different scales and across sectors; ii) identify priorities for action; and iii) determine the costs and benefits of adaptation to climate change. The customer for the work was Government at UK, national and regional levels.

The first CCRA was successful if measured against these Terms of Reference. The contractors devised an analytical framework for assessing risks to those things that have social, environmental and economic value in the UK. The risks were monetized for the UK using the UKCP09 projections as requested by Defra. The greatest legacies of the work will probably be the preliminary collection and sifting of sector risks by stakeholders, and subsequent exposure of major knowledge and data gaps. These outputs provide a firm basis for a more focused and deeper risk assessment next time.

The methodology used in the first CCRA has undoubtedly attracted a lot of attention but other elements of the enabling environment for risk assessment (as part of adaptation planning) are just as important. Greater attention could have been given to the fitness of institutional structures and governance, monitoring and reporting systems, freedom of access to data, technical capacities in public and private sectors, resources for strategic research programmes and bridging organisations, communications, and so forth. Even the way in which the project was procured mattered since this affected the potential for building institutional memory and knowledge transfer between successive CCRA/NAP cycles.

Recognised shortcomings of an approach based on response functions and sectors are that 'macro' inter-dependent risks and those originating from outside the UK are difficult to quantify. These risks should be the focus for the second CCRA, accepting that the present evidence base is limited. Further work is also needed to establish which parts of government own these risks. For example, Local Authorities currently fall outside of the Reporting Powers but have an important role to play in managing local climate risks.

The first CCRA monetized around 100 individual climate change risks to give an initial assessment of the economic risks and scale of adaptation required. Again, given the mandated focus of the first CCRA on direct UK impacts, total economic costs including indirect and overseas impacts were not presented. The physical realm could also be expanded to the UK overseas territories but this is outside the scope of the Climate Change Act.

In summary six main recommendations are made:

- 1. The terms of reference for the second CCRA should be drawn up by a working group including Defra, the ASC, the Environment Agency (in their new capacity as lead agency on adaption),**

**and technical experts.** Thorough policy appraisal and engagement with stakeholders is needed from outset, with project deliverables tied more explicitly to policy objectives on adaptation. A policy-first approach requires clarity about who the end users are and their needs beyond simply knowing that the *customer for this work is Government at UK, national and regional levels*. This further implies prior appreciation of which elements of Government ‘own’ which nationally significant climate change risks (including those originating from outside the UK).

2. **The scope of the second CCRA should take forward a much narrower and deeper analysis of priority risks identified in the first CCRA and by related studies.** The programme should begin with work on international and imported climate risks, major inter-sectoral risks, convergent processes of change (involving climate, population, food, energy and water security), and future socio-economic scenarios.
3. **As required by the Act, the ASC will provide advice to inform preparations for the second CCRA (to be published in 2017). This advice should explore, amongst other things:**
  - How climate risk ownership varies across horizontal and vertical levels of governance;
  - The fitness of the UK’s enabling environment for climate risk assessment and adaptation, for example, barriers to action;
  - Different ways of assessing and framing the risks and opportunities of climate change beyond monetization.
4. **Work on the second CCRA should begin in 2013 and follow a Foresight approach.** There was widespread support amongst interviewees for a Foresight-style project managed by Defra. In this way, technical experts, panels and contributory studies could be procured as required. Experience from the *Foresight Future Flooding Project* suggests that this approach leads to consensus building and high quality outputs but the process can be slower and require more administrative resource. Time pressure was a major concern in the first CCRA and should be avoided in the second by commencing work as soon as the National Adaptation Plan (NAP) has been completed.
5. **The UK Government should take steps to improve the fitness of the wider enabling environment for regular climate risk assessment in the UK.** For example, measures for strengthening institutional memory and governance, sustaining long-term monitoring and reporting systems, promoting freedom of access to data and analytical tools, growing technical capacities in public and private sectors, allocating resources for strategic research programmes and bridging organisations, disseminating findings and advice at all levels of governance, and piloting different adaptation measures.
6. **The ASC should continue to be proactive when dealing with research councils and other agencies to shape programmes that promote good adaptation practice.** For example, the Living With Environmental Change (LWEC) challenge areas provide scope for mutual advancement of work on climate risk assessment and evidence collection for adaptation. Discussion is needed about the extent to which the ASC has a remit to comment on or shape adaptation work being led by the Environment Agency. The ASC should also continue to promulgate good practice on climate risk assessment and adaptation planning between nations.

Finally, in reviewing the detailed anatomy of the first CCRA there is a danger of missing the broader contextual forces that are shaping the approach to climate risk assessment and adaptation planning in the UK. There is widespread support for a policy-first approach, yet this presupposes explicit objectives for adaptation from which an appropriately designed risk assessment and options appraisal can flow. Such a clearly articulated strategy for climate-proofing the UK has yet to emerge.

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## Other Resources

Adapting to Climate Change (ACC) Programme <http://www.ukcip.org.uk/government/central-government/acc/>

Association of British Insurers (ABI), 2009. *The financial risks of climate change*. ABI Research Paper No 19, London <http://www.abi.org.uk/Publications/54940.pdf>

Australian Government Department of Climate Change <http://www.climatechange.gov.au/climate-change.aspx>

BBC News on the Climate Change Risk Assessment <http://www.bbc.co.uk/news/science-environment-16730834>

Danish Climate Change Adaptation Portal <http://www.klimatilpasning.dk/en-us/Sider/ClimateChangeAdaptation.aspx>

Delta Programme (Netherlands) <http://www.deltacommissaris.nl/english/topics/>

European Commission – Maritime Affairs  
[http://ec.europa.eu/maritimeaffairs/documentation/studies/climate\\_change\\_en.htm](http://ec.europa.eu/maritimeaffairs/documentation/studies/climate_change_en.htm)

European Environment Agency (EEA) National Adaptation Strategies  
<http://www.eea.europa.eu/themes/climate/national-adaptation-strategies>

Marine Climate Change Impacts Partnership (MCCIP) <http://www.mccip.org.uk/>

Natural Resources Canada (Climate Change Impacts and Adaptation Division)  
<http://www.nrcan.gc.ca/earth-sciences/climate-change/11610>

NERC EQUIP (End-to-end quantification of uncertainty for impacts prediction)  
<http://www.equip.leeds.ac.uk/>

Partnership for European Environmental Research (PEER)  
[http://www.peer.eu/fileadmin/user\\_upload/publications/PEER\\_Report1.pdf](http://www.peer.eu/fileadmin/user_upload/publications/PEER_Report1.pdf)

UK National Ecosystem Assessment <http://uknea.unep-wcmc.org/>

UK National Risk Register (Cabinet Office) <http://www.cabinetoffice.gov.uk/resource-library/national-risk-register>

UNFCCC Submitted Fifth National Communications (Annex I)  
[http://unfccc.int/national\\_reports/annex\\_i\\_natcom/submitted\\_natcom/items/4903.php](http://unfccc.int/national_reports/annex_i_natcom/submitted_natcom/items/4903.php)

US Climate Change Science Program (CCSP) <http://www.climatescience.gov/default.php>

US Department of Transportation Federal Highway Administration  
<http://www.fhwa.dot.gov/hep/climate/ccvaraaa.htm>

US National Climate Predictions and Projections Platform (NCPP)  
<http://www.esrl.noaa.gov/cog/ncpp/>

US National Fish, Wildlife and Plants Climate Adaptation Strategy  
<http://www.wildlifeadaptationstrategy.gov/>

Water Research Foundation Climate Change Clearinghouse  
<http://www.theclimatechangeclearinghouse.org/ClimateChangeClearinghouse/ForTheWaterCommunity.aspx>

## **Annex 1** Terms of Reference for the first CCRA<sup>59</sup> with author highlights in **bold**.

### Introduction and background

*The purpose of this “Climate Change Risk Assessment” (CCRA) contract is **to undertake an assessment of the risks (including opportunities) to the those things which have social, environmental and economic value in the UK, from current and future economic, social, and environmental climate change, in order to help Government create an enabling environment for the UK to adapt and identify priorities for action**. The Government views this as a requirement to identify, assess, and where possible monetise the key climate change risks and opportunities at UK, national, and regional level.*

*The CCRA should be accompanied with an Economic Analysis that informs the Government about the costs and benefits of adaptation to climate change. This has two purposes: to provide an overall indication of the scale of the challenge and potential benefits from acting; and, given the wide-ranging nature of possible interventions to identify priority areas for action on a consistent basis.*

*The Climate Change Act requires that a CCRA is undertaken and laid in parliament every 5 years. This is the first of such assessments, and as such not only provides evidence and analysis to support current planning and prioritisation at UK, national, and regional levels, but also sets out frameworks, approaches, evidence, and direction as a platform for subsequent cycles to build on. **This CCRA will need to deliver an assessment with sufficient breadth, depth and credibility to be readily adopted for policy prioritisation**. Given that it is the first one however, trade-offs will need to be made between research and analysis that is required for the first cycle, that which needs to be started now for consideration in later CCRA cycles, and that which can be left prioritised for later CCRA cycles. Clearly to achieve this compromise it will be essential to build on the best of the existing evidence and approaches using a high level of analytical expertise and a close process of engagement with Government customers that takes account of their existing approaches and needs and empowers them to make best use of the CCRA.*

***The customer for this work is Government at UK, national, and regional levels**, however the risk assessment needs to build on the best available approaches in all sectors, and be usable and accessible by others who need this information to develop effective plans to address the risks of climate change, particularly those whose actions can contribute to reducing the UK’s vulnerabilities, building adaptive capacity, and implementing and evaluating adaptive strategies and measures.*

*A scoping study for the CCRA and Economic Analysis has been recently completed. The outputs from this study, which include both the scoping report and a literature review are included within the competition pack (Annexes A and B), along with a commentary on these from the CCRA project steering group.*

*The CCRA and Economic Analysis will be key inputs to a later statutory adaptation policy programme (which will be developed subsequently by Government and laid in parliament after the CCRA). As such, it is expected that they will provide sufficient information to inform the Government’s priorities for action on adaptation.*

*The CCRA is also linked with the legal power that the Secretary of State has to ask for reports from statutory undertakers (organisations that provide an element of a public service) about their action on adapting to climate change. The links between the CCRA and this reporting power are summarised at Annex C.*

*The Adaptation Sub-Committee (ASC – currently being appointed) to the Committee on Climate Change has an important role in scrutinising the CCRA. The ASC will need to complete its review*

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<sup>59</sup> Defra CEOSA 0901

activities by July 2011. They will need to be engaged at regular intervals, but the final CCRA needs to be with them by April 2011. The Economic Analysis of adaptation options is not bound by this statutory deadline, but should be completed within 6 months of the CCRA being laid in Parliament, and will also be scrutinised by the ASC. Please note the Q&A event set for 4<sup>th</sup> June. See the 'Further Information' section for details and how to express an interest in attending, or confirm an interest you have already expressed.

## Key Deliverables Overview

### Summary of Key deliverables

**The context for the CCRA and Economic Analysis is the high level Government policy objective of enabling the UK to adapt to the impacts of climate change** through:

- Mainstreaming adaptation in decision making in the public, private and third sectors
- Building UK adaptive capacity
- Enabling UK adaptive actions

For this first cycle, the contractor will need to deliver through both original research and synthesis and use of existing analytical tools and evidence. The CCRA will include the following key components:

1. **CCRA – Analytical Frameworks and Approaches; Using UKCP09 projections** and other analytical tools, and building on the best of existing evidence and approaches;
  - a. An assessment of the range of types of climate impacts that will create risks (both threats and opportunities) for the UK to 2100, and subsequently a framework that can be applied at national and regional level to identify their specific risks.
  - b. An assessment of range of issues/areas/sectors affected by climate impacts, their adaptive capacity and vulnerability and an approach to assessing which sectors become priorities for application to the required national and regional breakdowns
  - c. A systems analysis of drivers of change and causality in the climate/UK socio-economic system, that discovers, describes, and prioritises for attention important potential cross sectoral, secondary and indirect impacts.
  - d. A short synthesis of other work (some of which is ongoing) that prioritises international climate change issues for attention in the CCRA
  - e. Using a framework derived from a, b, c and d, that can be consistently applied at UK, national, and regional levels, an assessment of risk (including opportunities<sup>60</sup>), including economic, social, and environmental impacts and their likelihood. This will need to include an assessment of vulnerability and adaptive capacity as key determinants of level of impacts.
  - f. Methods for dealing with uncertainty, both in assessing climate impacts, and in assessing risks (which may be dependent on uncertainty in non-climate factors)
2. **Economic Analysis - Analytical Frameworks and Approaches;** building on the analysis of the CCRA, and using existing analysis where appropriate:

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<sup>60</sup> Throughout, 'risks' should be taken to include both threats and opportunities.

- a. *A monetary estimate of the total impacts of climate change on the UK, broken down by sector and the 9 regions where possible*
    - b. *An identification of the broad types of options for reducing the potential damages from the risks identified in 1, both for sectoral and cross-sectoral risks, and their expected costs and benefits*
    - c. *Development of a methodology for prioritising Government action on adaptation given uncertainty and incomplete information*
    - d. *An overall estimate of the scale and resources required for adaptation, and the likely benefits from this in reducing the impacts identified in part a.*
  3. **Primary Research and Evidence gaps;** *In parallel with 1 and 2, from a synthesis of existing sources, an assessment of primary research that needs to be fast tracked to deliver 1 and 2, and recommendations on research priorities needed to inform future CCRA cycles, including relative timing. Deliver this research, working with UKCIP (see further discussion).*
  4. **Applications;** *Using the approaches and frameworks developed in 1 and 2, assessment of risks from current and future climate impacts to -*
    - i. *The UK as a whole (including territorial waters)*
    - ii. *England (including each of the 9 English regions)*
    - iii. *Wales*
    - iv. *Northern Ireland*
    - v. *Scotland*
  5. **Learning for the future;** *recommendations on research priorities and approaches needed to inform subsequent CCRA cycles to build on this first CCRA.*
- For the outputs that will be used and should influence government customers for the work, a communications strategy will also have to be implemented.*

## Annex 2 Log of activities in the first CCRA process

Date	Agents and activities
February 2009	Defra scoping study for CCRA and Adaptation Economic Assessment (AEA)
July 2009	Defra scoping study on common metrics for adaptation
August 2009	Defra scoping study on the international impacts of climate change on the UK Contractors submit final tender documents to Defra
September 2009	ASC and CCRA contractors meet for the first time
October 2009	ASC relays list of issues concerning CCRA methodology to Defra
November 2009	ASC raises concerns and recommendations about methodology with Secretary of State
December 2009	Contractors present revised methodology to ASC
January 2010	ASC updates Secretary of State about revised methodology
March 2010	Contractors provide progress report on methodology and pilot study
April 2010	Expert workshop for the pilot water sector study
May 2010	Stakeholder workshop for the pilot water sector study Defra and contractors present lessons from pilot study ASC requests method overview
June 2010	ASC recommends external experts to review CCRA sector reports on behalf of Defra Contractors provide draft CCRA method document ASC workshop to address remaining methodological issues
July 2010	ASC advises Defra of outstanding high priority issues
September 2010	Defra advises ASC of changes to CCRA method ASC workshop to resolve methodological issues and review water pilot study ASC receives independent report on decision-making processes Contractors deliver report on risk assessment methodology ASC signs off CCRA methodology
October 2010	ASC workshop on AEA ASC advises Secretary of State on the AEA methodology
November 2010	Independent peer review of 11 sector-specific reports on behalf of Defra
March 2011	Contractors deliver report on UK's adaptive capacity to climate change
May 2011	Defra provides ASC with high-level overview of the draft Synthesis Report
September 2011	Independent peer review comments received on final draft sector reports Academic peer review of CCRA Synthesis Report on behalf of Defra Academic peer reviewers discuss Synthesis Report with contractors Chair of academic peer review provides feedback to Defra Chief Scientist
October 2011	Defra and contractors revise Synthesis Report
November 2011	Defra circulates revised Synthesis Report for final peer review
January 2012	CCRA laid before Parliament and launched at the Royal Society

**Annex 3** Example plot summarising potential agriculture and forestry risks with an indication of direction, magnitude and confidence<sup>15</sup>



#### Annex 4 Example score card for the natural environment.

Metric code	Potential risks for the natural environment	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	u
AG1b	Changes in wheat yield (due to warmer conditions)	M	1	2	2	2	2	3	2	3	3
AG1a	Changes in sugar beet yield (due to warmer conditions)	M	1	1	2	1	2	3	2	3	3
MA4b	Changes in fish catch latitude/centre of gravity (plaice, sole)	M	~	1	~	~	2	~	~	3	~
AG10	Changes in grassland productivity	M	1	1	1	1	2	2	1	2	2
FO4b	Increase of potential yield of Sitka spruce in Scotland	M	1	1	1	1	1	1	3	3	3
AG1c	Changes in potato yield (due to combined climate effects and CO <sub>2</sub> )	L	1	1	2	1	1	2	1	1	2
FO1a	Forest extent affected by red band needle blight	M	1	2	3	2	3	3	2	3	3
WA7	Insufficient summer river flows to meet environmental targets	L	1	2	3	2	3	3	3	3	3
BD7	Risks to coastal habitats due to flooding	M	1	2	3	2	2	3	2	3	3
BD14	Ecosystem risks due to low flows and increased water demand	M	1	2	2	2	2	3	2	3	3
MA2a	Decline in marine water quality due to sewer overflows	M	1	2	2	1	2	3	2	3	3
FL4b	Agricultural land at risk of regular flooding	H	2	2	2	2	2	3	2	3	3
BD11	Generalist species more able to adapt than specialists	L	1	2	3	2	2	3	2	3	3
BD3	Risk of pests to biodiversity	L	1	2	2	2	2	3	2	3	3
BD4	Risk of diseases to biodiversity	L	1	2	2	2	2	3	2	3	3
MA6	Northward spread of invasive non-native species	M	1	2	3	2	2	3	2	3	3
BD5	Species unable to track changing 'climate space'	H	1	2	3	2	2	3	2	3	3
BD9	Changes in species migration patterns	H	1	2	3	2	2	3	2	3	3
BD10	Biodiversity risks due to warmer rivers and lakes	M	1	2	3	2	2	3	2	3	3
BD2	Risks to species and habitats due to coastal evolution	M	1	2	2	2	2	2	2	3	3
BD8	Changes in soil organic carbon	L	1	2	2	1	2	3	1	3	3
WA9a	Potential decline in summer water quality (point source pollution)	L	1	1	3	1	3	3	1	3	3
WA9b	Potential decline in water quality due to diffuse pollution	L	1	1	3	1	3	3	1	3	3
BU2	Monetary losses due to tourist assets at risk from flooding	M	1	1	2	2	2	3	2	3	3
MA4a	Changes in fish catch latitude/centre of gravity (cod, haddock)	M	~	1	~	~	2	~	~	3	~
BE5	Effectiveness of green space for cooling	M	1	1	2	1	2	3	2	3	3
BD1	Risks to species and habitats due to drier soils	M	1	1	1	2	2	2	2	3	3
MA3	Increased ocean acidification	M	1	1	1	2	2	2	2	3	3
FO4a	Decline in potential yield of beech trees in England	M	1	1	1	2	2	2	3	3	3
FO1b	Forest extent affected by green spruce aphid	M	1	1	2	1	2	2	1	2	3
BD12	Wildfires due to warmer and drier conditions	M	1	1	2	1	2	3	2	2	3
BD13	Water quality and pollution risks	M	1	1	2	1	2	3	1	2	3
MA10	Disruption to marine ecosystems due to warmer waters	M	~	1	~	~	2	~	~	2	~
FL14b	Priority habitats lost due to coastal erosion	H	1	1	1	2	2	2	2	2	3
MA8	Potential disruption to breeding of seabirds and intertidal invertebrates	M	~	1	~	~	1	~	~	2	~
BD6	Environmental effects of climate mitigation measures	L	Too uncertain								
MA1	Risk of Harmful Algal Blooms due to changes in ocean stratification	L	Too uncertain								
MA2b	Risks of human illness due to marine pathogens	L	Too uncertain								

M	Confidence assessment from low to high
3	High consequences (positive)
2	Medium consequences (positive)
1	Low consequences (positive)
1	Low consequences (negative)
2	Medium consequences (negative)
3	High consequences (negative)
~	No data



## Annex 5 Interviewees

Name	Affiliation
Campbell, Darius	Deputy Director, Climate Change Mitigation and Adaptation to Climate Change, Defra
Challinor, Andy	Principal Investigator of NERC EQUIP (End-to-end Quantification of Uncertainty for Impacts Prediction), University of Leeds
Christie, Mary	Policy and Advice Manager, Scottish Natural Heritage
Donovan, Bill	Strategy and Engagement Flood and Coastal Erosion Risk Management Directorate, Environment Agency
Hall, Jim	Director of the Environmental Change Institute, Oxford University (ASC member)
Humphrey, Kathryn	Senior Analyst, ASC Secretariat (formerly Defra)
Lewis, Rupert	Deputy Chief Scientific Advisor, Department for Business Innovation and Skills
Lovell, Joseph	Scientific Advisor, Department for Environment, Food and Rural Affairs
Meadowcroft, Ian	Technical Manager, Environment Agency
Street, Roger	Technical Director, UK Climate Impacts Programme
Tompkins, Emma	Reader in Environment and Development, University of Southampton
Wade, Steven	Group Manager (Water), HR Wallingford (lead contractor for the first CCRA)
Watkinson, Andrew	Director of Living With Environmental Change (LWEC) Programme, University of East Anglia
Watkiss, Paul	Consultant, Paul Watkiss Associates
Watts, Glenn	Climate Science Manager, Environment Agency
Young, Barbara	Chief Executive, Diabetes UK (former member of the ASC)