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Climate Change Risk Assessment Recommendations Report

July 2012

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- AMEC Environment & Infrastructure UK
Ltd (formerly Entec UK Ltd)
- The Met Office
- Collingwood Environmental Planning
- Alexander Ballard Ltd
- Paul Watkiss Associates
- Metroeconomica



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Statement of use

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Statement of Use

This report provides a guide for those that may contribute to or be commissioned to undertake the next Climate Change Risk Assessment that is due in 2017. It is also intended to provide recommendations regarding where efforts should be focused in enhancing the science behind the risk assessment.

This is an independent report produced by HR Wallingford on behalf of the contractors, and represents the views of the consortium and not those of the client or any other Government Department or their agencies.

Although an overview of how the first CCRA was undertaken is provided, this report is not a critique of how successfully the project was managed, nor does it discuss in detail the commissioning process for the next CCRA.

Summary

Preamble

The lessons learned from completing the first Climate Change Risk Assessment are arguably as important as the main findings of the assessment. This report provides a review of the CCRA and recommendations for the next assessment. It has been prepared by the project team for Government and to assist research scientists and consultants that will contribute to or be contractors involved in 'CCRA2.'

Although the main authors of this report are from HR Wallingford, the lead contractor for the CCRA, it aims to provide a very open and self critical review. The preparation of this report has benefited from feedback since the CCRA was published in January 2012, a workshop that involved key consortium team members and additional time to reflect on the work completed. We have considered how the project was received and how it is being applied in different contexts and how we would improve the approach for future assessments.

The Adaptation Sub-Committee has completed its own independent review of the CCRA method and outputs (Wilby, 2012). It also commissioned a second review looking at the coverage of economic impacts in the CCRA (Paul Watkiss Associates, 2012). In addition, a number of UK and European research projects have already started to take a detailed look at the research needs for future CCRA's (LWEC Research Fellow/Roger Street) and the process of completing the first national assessment (ERC project ICAD/Prof. Suraj Dessai).

The focus of this report is on the UK CCRA, but the findings are of broader relevance to other countries that are interested in completing their own risk assessments (or similar studies) to inform national decision-making. For example, as part of the UNFCCC process a large number of countries are required to complete assessments of the risk of loss and damage associated with the adverse effects of climate change. There is considerable international interest in the CCRA and how the process and aspects of the methodology may be relevant in different country contexts.

The main aspects of the CCRA discussed in this report are:

- Project structure, processes and management
- Methodology
- Research needs
- Stakeholder engagement.

Appraisal of the methodology

In appraising the methodology for the CCRA we have identified strengths and weaknesses of specific aspects of the project. Some issues are related to the original methodology, others are related to data availability or implementation of the method.

Our view on the performance and relative importance of different steps in the methodology are summarised in the following table. The scores relate to how well these steps performed within the context of the methodology as a whole, rather than as individual activities. Where the score is 'limited' this was for a number of reasons including lack of time and lack of evidence; these issues are discussed in more detail in the report.

Summary of performance of different parts of the methodology

	Performance			Importance	
	Method	Data	Implementation	CCRA1	CCRA2
1. Literature review & Tier 1 analysis	Good	Good	Good	High	Low
2. Identification of cross-sectoral & indirect consequences	Fair	Limited	Limited	Medium	High
3. Review of policy	Limited	Limited	Limited	Low	Medium
4. Social vulnerability	Fair	Limited	Limited	Medium	High
5. Adaptive capacity	Good	Fair	Fair	Medium	High
6. Selection of Tier 2 impacts	Good	Fair	Fair	High	Medium
7. Identify risk metrics	Good	Fair	Fair	High	High
8. Response functions	Good	Fair	Fair	High	Medium
9. Estimates of change in selected climate change scenarios	Good	Fair	Fair	High	High
10. Socio-economic change	Fair	Limited	Fair	Medium	High
11. Economic impacts	Good	Fair	Fair	Medium	High
12. Report outputs	Fair	N/A	Good	High	High

The method that was developed for the CCRA suited a rapid assessment over one to two years. It was regarded as a good technical approach, although it was weaker in some areas (see items 2, 3, 4 and 10 above) and was better suited to sectors characterised by well developed quantitative impacts or risk assessment methods.

The availability of data was a project constraint, particularly given the tight timescales, and there are both research gaps and data ownership and licensing issues that need to be resolved for CCRA2 and subsequent assessments. The implementation of the methodology was good in some sectors and more difficult in others; some steps were implemented poorly (items 2, 3 and 4), although this was sometimes due to time and resource constraints and other factors outside of the project's control.

Overall, the method could be improved and used again for CCRA2. Improvements or refinements need to be made to several high priority areas (items 2, 4, 5, 7 and 9 to 12). However, the findings of the CCRA could also be used to focus CCRA2 more sharply on high risks and possibly take a different methodological approach in these areas.

Research needs

The research needs for CCRA2 broadly reflect the data gaps and methodological areas that worked less well. However, two additional research needs are:

- Improved projections of potential changes in extremes including droughts, heat waves and intense rainfall. This research should include a robust set of 'H++' scenarios that describe a range of 'low probability-high

consequence' changes in climate that could have serious implications for UK society.

- Better evidence on how international impacts affect UK society, including an understanding of current and future risks. While the International Dimensions of Climate Change study made good progress (Foresight, 2011), more research is needed to bring international risks into the CCRA methodology.

Stakeholder engagement

The stakeholder engagement undertaken during the CCRA has been evaluated and the results of the evaluation can be found in Annex A. The main recommendations regarding future stakeholder engagement are:

- Be very clear at the outset about the scope of the stakeholder engagement, i.e. who to involve and how.
- Plan a continuous process of engagement with a logical progression through a series of events.
- Find smarter ways of working and communicating with stakeholders, especially with groups that traditionally are hard to engage.
- Provide regular feedback to stakeholders to encourage ownership of the process and aim to make the next CCRA as open as possible throughout to retain that ownership.

Recommendations

The headline recommendations related to managing CCRA2 are:

- Read this report and build on the foundations put in place by this first CCRA, learning from what worked well and tackling head on problems that we faced.
- Make sure that the right technical expertise is available within the delivery team at the right time and that they are able to take ownership of their technical area.
- Make sure that the contractor and client work together to understand fully the client's needs and those of the intended audience.
- Make sure that full use is made of stakeholders throughout the project to stay focused on the intended audience and as a source of valuable information.

At the end of Chapter 3 we make eight recommendations with respect to the method, but the following five recommendations are regarded as the highest priority for CCRA2:

- Review existing Environment Agency and UK National Ecosystem Assessment (UK NEA, 2011) **socio-economic scenarios** and select an appropriate framework for using socio-economic scenarios in CCRA2.
- Review scope of Met Office climate change projections research to check that it meets requirements of CCRA2; develop a **package of relevant**

biophysical indicators, which will be made available at the start of CCRA2¹.

- Scope changes to the methodology with key stakeholders², focusing on development of a **practical integrating framework** that can combine evidence on risks, social vulnerability and adaptive capacity.
- **Work on the ‘decision matrix’ and thresholds first** to understand clearly what outputs are needed to inform decisions. The assessment in Chapter 9 of the Evidence Report provides a preliminary framework that needs further work.
- Ensure that **data licensing and access** are agreed between Government Departments and agencies at the start of CCRA2.

¹ This may need to involve research institutes, such as CEH, POL and Cefas as well as the Met Office UKCP team.

² The scoping work could involve CCRA team members, ASC, Defra and invited researchers; however this work may already be underway but has not involved HRW team members

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1 Introduction

1.1 Background

The Climate Change Act 2008 makes the UK the first country in the world to have a legally-binding long-term framework to cut greenhouse gas emissions and a framework for building the UK's ability to adapt to a changing climate. As part of this, the Act requires:

- A UK-wide climate change risk assessment that must take place every five years, with the first one having to be laid before parliament by January 2012; and
- A national adaptation programme (NAP) which must be put in place and reviewed every five years, setting out the Government's objectives, proposals and policies for responding to the risks identified in the CCRA.

The UK Climate Change Risk Assessment (CCRA) 2012 is the first of the risk assessments and it was successfully laid before parliament in January 2012.

A consortium led by HR Wallingford was commissioned to undertake the CCRA on behalf of the UK Government, funded by the Department for Environment, Food and Rural Affairs (Defra), the Devolved Governments of Scotland, Wales and Northern Ireland and, in the first year, the Regional Development Agencies.

The CCRA has assessed the main risks and opportunities in the UK from climate change. This independent analysis provides a good starting point, providing an overview and assessment of risks in and across sectors, and enables comparison between different sectors. It provides underpinning evidence that can be used by the UK Governments to help inform priorities for action and appropriate adaptation measures. It also highlights where more work is needed to understand better the scale and nature of the risks, and to help Government to consider what action (if any) needs to be taken.

The CCRA is being followed by national adaptation programmes in England, Wales, Scotland and Northern Ireland. Further economic analysis is currently underway to supplement the findings from the CCRA to inform Government about the case for further action and the costs and benefits of a number of options for adaptation to climate change.

1.2 Purpose of this report

The purpose of this report is to provide a guide for those that may contribute to or be commissioned to undertake the next CCRA (CCRA2), which will be due in 2017. It is also intended to provide recommendations regarding where efforts should be focused in enhancing the science behind the risk assessment.

The discussion focuses on the following issues:

- Project structure, processes and management
- Methodology
- Research needs

- Stakeholder engagement.

Although an overview of how the first CCRA was undertaken is provided, this report is not a critique of how successfully the project was managed, nor does it discuss in detail the commissioning process for the next CCRA. Communication activities are also touched upon, as these relate closely to the stakeholder engagement activities.

This is an independent report produced by HR Wallingford on behalf of the contractors, and represents the views of the consortium and not those of the client or any other Government Department or their agencies.

The contractor team has provided input into this report in the following ways:

- Key members of the contractor team³ participated in a full-day workshop to discuss lessons learnt from this first CCRA and recommendations for CCRA2 (details are provided in Appendix 1).
- Collingwood Environmental Planning (CEP), who led the stakeholder engagement activities for the CCRA, has undertaken an evaluation exercise looking at the effectiveness of the stakeholder engagement (details are provided in Annex A).

1.3 Structure of this report

Chapter 2 – Project structure, processes and management

This chapter gives an overview of how the CCRA project was undertaken, including the involvement of the Steering Group, the In-House Experts, other Government Departments (OGDs), the Adaptation Sub-Committee (ASC) and academic peer reviewers. It includes details of how input from third parties was sought, at what stages and how these steps were managed and how this input was incorporated into the final outputs. Details specifically related to the stakeholder engagement process are described in Chapter 5.

Chapter 3 – Methodology

This chapter discusses the methodology followed for the CCRA. This includes:

- A summary of the method
- The rationale behind the method (including the review of risk assessments previously undertaken by other countries)
- How successfully the method was followed
- How successfully the method delivered the aims of the CCRA
- How the method should/could be modified for the next CCRA.

The main technical issues are then discussed individually.

This chapter takes into consideration the comments already received from the ASC, academic peer reviewers and OGDs with regards to the limitations of the analysis undertaken and the scope of this first CCRA.

³ This included Sector Analysts, Sector Champions and other key experts, plus the project management and stakeholder engagement teams.

Chapter 4 – Research needs

This chapter builds on the previous chapter and identifies where further research is needed to:

- Develop the existing method or alternatives
- Improve confidence in the findings for specific risk metrics that were analysed as part of the first CCRA
- Enable development of other high priority risk metrics
- Fill in geographical gaps, e.g. where suitable data was missing for Scotland, Wales or Northern Ireland
- Understand the distribution of impacts and how this relates to social vulnerability.

This chapter refers to the information provided in the CCRA Research Gaps Report (HR Wallingford, 2010a) issued in March 2010 and details given in the final Sector Reports and Evidence Report (see Section 2.3 for details of these reports).

Suggestions are provided regarding how these research needs might be addressed in either the near-term (i.e. next 2 years) or longer-term, based on the expertise of the authors.

This chapter refers to research that is known to be already underway or planned, but does not attempt to be an authoritative review of all potentially relevant research.

Chapter 5 – Stakeholder engagement

This chapter describes the objectives of the stakeholder engagement and how it was undertaken for the CCRA. It also discusses the success of the engagement undertaken and includes the findings of a post-project evaluation process, as described in Annex A.

Chapter 6 – Key recommendations

This chapter provides conclusions from the discussions in the earlier chapters.

1.4 Other supporting information

As well as the main deliverables from the project (see Section 2.3), it is recommended that reference is also made to the following documents produced during the course of the project:

- Scoping Report (Watkiss *et al.*, 2009)
- Inception Report (HR Wallingford, 2009)
- Pilot Study Report (HR Wallingford, 2010b)
- Method Reports (Defra, 2010a, b)
- Systematic Mapping Report (CCRA, 2011)
- Social Vulnerability to Climate Impacts (Twigger-Ross and Orr, 2011)
- Adaptive Capacity Report (Ballard *et al.*, unpublished)
- Research Gaps Report (HR Wallingford, 2010a).

2 Project structure, processes and management

2.1 Project phases

There were six phases to the delivery of the CCRA:

- Phase 1 – Project planning, sector scoping and method development
- Phase 2 – Sector analysis
- Phase 3 – Assessments for Scotland, Wales and Northern Ireland
- Phase 4 – Synthesis of findings
- Phase 5 – Final reporting
- Post-publication phase – Recommendations, technical support and website tools.

It should be noted that these represent what was actually carried out and differ slightly from the original programme at the start of the project.

Figure 2.1 provides a summary of the timing of the main activities of the project (again as completed, not as originally planned) and the level of staffing required to implement these.

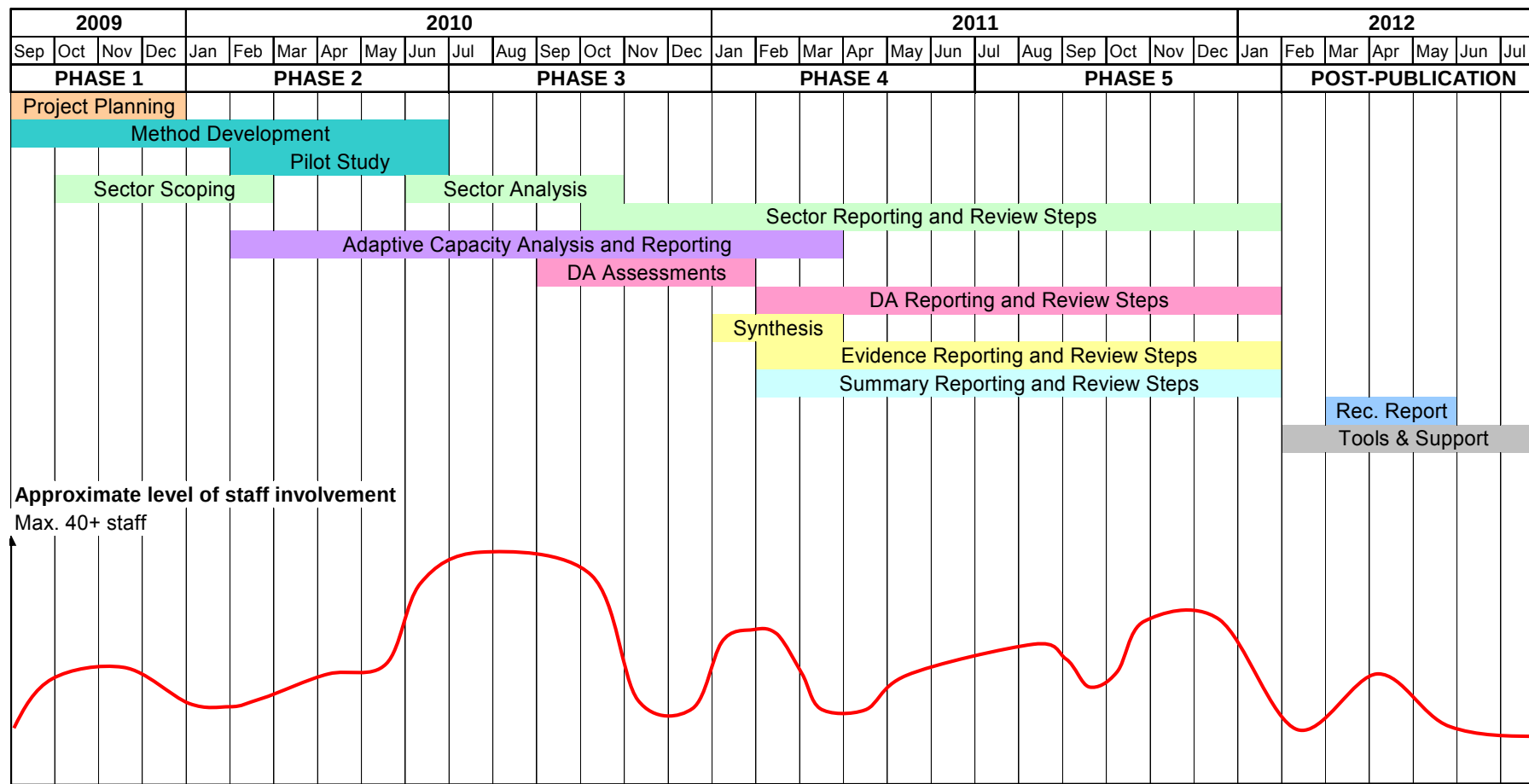


Figure 2.1 CCRA project timeline

2.2 Team structure

Figure 2.2 gives a summary of the different organisations and individuals involved in the delivery of the CCRA. These are made up of four main groups:

- ‘Client and Funders’ team responsible for governance and decision-making
- Contractor team responsible for implementation of the contract
- Independent reviewers engaged by the ‘Client and Funders’ team ⁴
- External stakeholders and technical advisors engaged by the Contractor team.

These are discussed in more detail in the following sections.

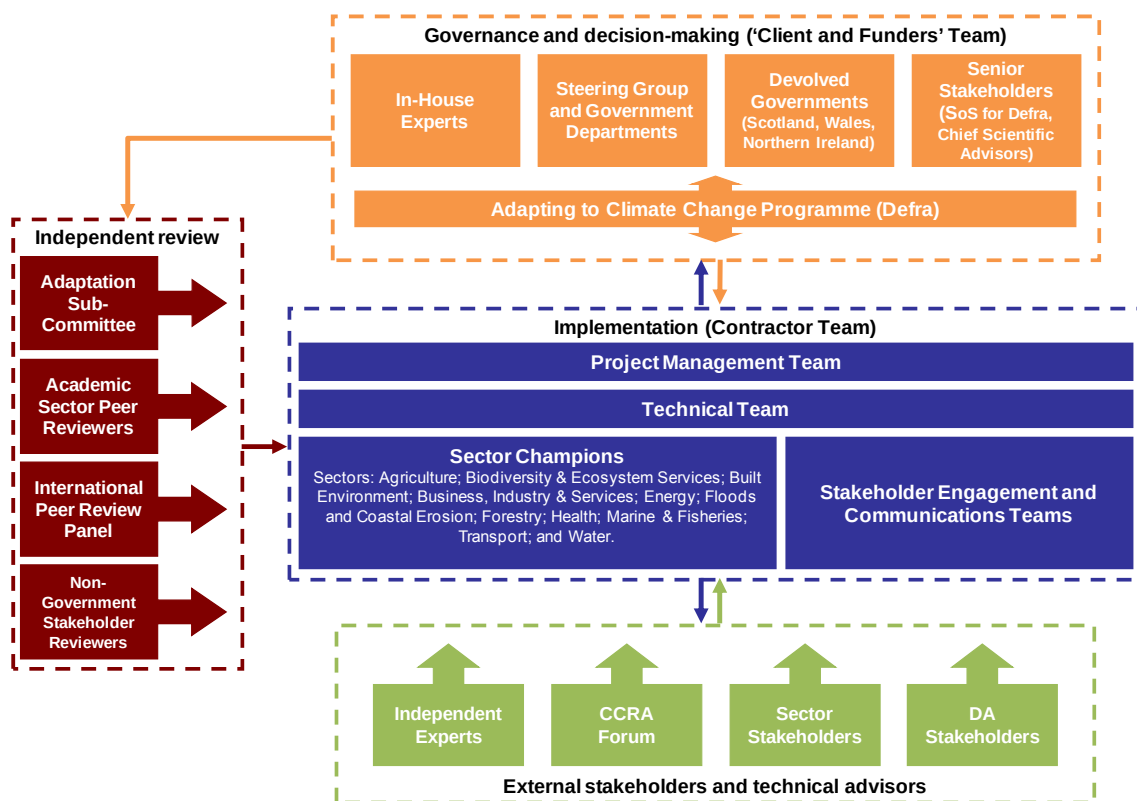


Figure 2.2 CCRA project delivery structure

2.2.1 Contractor team

The Contractor team comprised a consortium led by HR Wallingford. Contractors within the consortium in addition to HR Wallingford were:

- AMEC Environment & Infrastructure UK Ltd (formerly Entec UK Ltd)
- The Met Office

⁴ With the exception of the ASC, who had their own statutory requirement to act as independent reviewers of the CCRA.

- Collingwood Environmental Planning (CEP)
- Alexander Ballard Ltd (ABL)
- Paul Watkiss Associates (PWA)
- Metroeconomica.

Overall project management was provided by HR Wallingford. To help facilitate this, a HR Wallingford team member was seconded into the ACC team at Defra. Initially a member of the project management team was seconded for 2 to 3 days a week from October 2009 until around March 2010. She was replaced by a Project Administrator, who was seconded for 9 out of 10 days to Defra from February 2010 until around May 2011, when this was reduced to 1 day a week.

The consortium was supported by a group of sub-contractors, including:

- Sector Champions (see below)
- Dialogue by Design, providing specialist services related to stakeholder engagement activities
- Phil Sivell Consulting, providing specialist services in support of the work for the English areas
- Yippee Design, providing graphic design services
- Smith School, providing an international review of previous risk assessments.

The Sector Champions were as follows:

- Agriculture – Jerry Knox, Cranfield University
- Biodiversity & Ecosystem Services – Iain Brown, Hutton Institute
- Built Environment – Rachel Capon, Independent Consultant
- Business, Industry & Services – Alastair Baglee, Acclimatise
- Energy – Richard Betts and Lynsey McColl, The Met Office
- Floods & Coastal Erosion – David Ramsbottom, HR Wallingford
- Forestry – Andy Moffat and James Morison, Forestry Research
- Health – Sotiris Vardoulakis, formerly Health Protection Agency
- Marine & Fisheries – Katherine Kennedy and John Pinnegar, CEFAS
- Transport – John Thornes, formerly Birmingham University
- Water – Nick Reynard, CEH and Steven Wade, HR Wallingford.

The Sector Champions during the early stages of the project had the role of providing expert advice and review of the sector analysis work. This included preparation of scoping reports for their sectors, which fed into the detailed sector analysis work (see below). In the latter stages of the project, they had a more direct role in undertaking additional analytical work for their sectors and finalising the Sector Reports.

Management and implementation of the detailed sector analysis work was initially shared between HR Wallingford and AMEC Environment & Infrastructure UK Ltd. During the later stages of the project all sectors were managed by HR Wallingford and the analysis work was shared between HR Wallingford and the Sector Champions.

Additional contributors to the sector analysis included:

- The Met Office, providing climate science expertise
- PWA and Metroeconomica, undertaking the monetisation of risks
- ABL, undertaking adaptive capacity assessments for the sectors
- CEP, providing expertise in social vulnerability.

The DA assessments, DA reporting, synthesis and Evidence reporting were carried out by HR Wallingford, with some support from other members of the Contractor team as required.

Stakeholder engagement was led by CEP, with support from Dialogue by Design and HR Wallingford.

ABL provided expertise and guidance on communications activities throughout the project, which were then implemented by HR Wallingford and CEP.

2.2.2 Client and Funders team

The Adapting to Climate Change (ACC) cross-Government programme, based at Defra, acted as the 'Client' project managers.

The Funders (Defra, the Devolved Governments of Wales, Scotland and Northern Ireland) and the other central Government departments (OGDs) made up the Project Steering Group (PSG) that was the decision-making body on the project.

On general project matters the Devolved Governments were represented via the PSG; for the DA assessments each Government worked more directly with the Contractors to enable the project to meet their requirements.

The In-House Experts (IHE), a multi-disciplinary and cross-sectoral group, provided technical support to the ACC and Steering Group with regard to the development and review of the project. They were particularly involved with the method development. The IHE comprised individuals from Defra, the OGDs, Devolved Governments and non-departmental government bodies.

Towards the end of the project views were also sought from the Chief Scientific Advisor at Defra, particularly regarding the Evidence Report and CCRA Summary. The draft findings were also presented to the Chief Scientific Advisors at the OGDs and for Wales and Scotland.

2.2.3 Independent reviewers

The Adaptation Sub-Committee (ASC) has a statutory obligation under the Climate Change Act 2008 to scrutinise the CCRA. The CCRA methodology was developed in consultation with the ASC during the first half of 2010. Final sign-off of the method by the ASC following the pilot was not until August 2010. The ASC was also given early access to the sector reports and specifically reviewed the Evidence Report.

All other review groups were engaged directly by the ACC team.

The Sector Reports were reviewed by 22 independent sector experts plus 2 economists at the end of 2010. Towards the end of 2011, the Sector Reports were reviewed once more by the same independent sector experts and a selected body of key non-government stakeholders.

Martin Parry, from the ASC chaired the independent and international panel of experts (given below) that reviewed the Evidence Report in early Autumn 2011:

- Nigel Arnell, Walker Institute
- Jean Palutikof, Griffith University
- Tom Wilbanks, Oak Ridge National Laboratory
- Juan-Carlos Ciscar, Joint Research Centre, European Commission
- Rob Wilby, Loughborough University
- Nicola Ranger, Grantham Institute
- Emma Tompkins, Southampton University.

Government stakeholders were extensively engaged and reviewed all published documents throughout their development during 2010 and 2011. Further details of these reviews are provided in Section 2.3.

2.2.4 External stakeholders and independent experts

Engagement with external stakeholders was undertaken directly by the Contractor team. Further details of the stakeholder engagement activities can be found in Chapter 5.

At various stages during the project, the Contractor team also contacted other experts to provide advice and data for either the sector analysis or the DA assessments. For several sectors, the Sector Champions chose to contact colleagues and peers for assistance with elements of the sector analysis work.

2.3 Deliverables

A full list of CCRA reports, including interim reports, and other outputs is provided in Appendix 2.

The final reports that were published in January 2012 are shown in Figure 2.3.

The Act Report, which is made up of the Evidence Report and Government Report, was laid before Parliament in January 2012. The other reports were published online, but not laid before Parliament. These reports are described in more detail in the sections below.

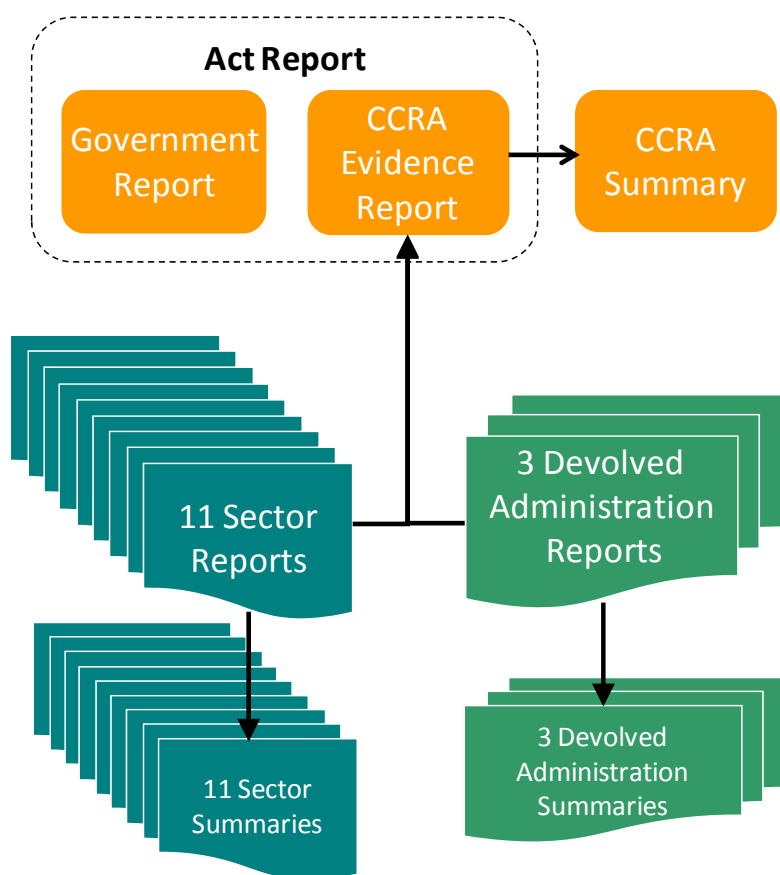


Figure 2.3 CCRA end of project publications

2.3.1 Evidence Report

The Evidence Report (CCRA, 2012a) provides an overview of the risk assessment, including a synthesis of the key findings. The report uses evidence from the Sector Reports (see below), CCRA workshops (see Chapter 5), other Government reports and wider peer reviewed literature to present the best information currently available on the vulnerability of the UK to climate change, based on currently available climate change projections. It identifies the main threats (and opportunities), based on current understanding, but also highlights the gaps in that understanding.

The Evidence Report was academically peer reviewed once alongside reviews by the Adaptation Sub-Committee and Government Departments, where there were two formal review rounds for each.

This was a very large document (480+ pages) and was accompanied by two separate annexes:

Annex A: Scenarios of climate variability and change

Annex B: Social Vulnerability to Climate change Impacts

This report's primary audience was intended to be senior policy-makers within Government and the senior international climate science and risk community (including the ASC). The Sector Reports (see below) are intended to be used by the climate science and risk research community.

2.3.2 Government Report

The Government Report is a short document, which outlines the UK Government's views on the main issues raised in the Evidence Report, to highlight actions already in place to manage the risks identified in the CCRA, and to outline UK Government plans for the future.

Together with the Evidence Report these form the 'Act Report' that was laid before Parliament in January 2012.

This report was written by Defra, the DAs and OGDs and was aimed at central Government and large organisations within both the public and private sectors.

2.3.3 CCRA Summary

The CCRA Summary is a separate document from the Evidence Report that presents a summary of the key findings from the CCRA in non-technical language.

This is a short document of around 16 pages and its main audience was intended to be Government Ministers and high-level policy-makers, but it also provides an accessible summary for all interested parties including the general public.

Feedback was sought specifically from Defra's Chief Scientific Advisor (Professor Sir Bob Watson) regarding how best to convey the findings and other key messages in this document. His feedback informed the development of the summary format and communication style.

2.3.4 Devolved Administration Reports

The Evidence Report presents an overview of the findings from the CCRA project for the UK. The DA Reports (CCRA, 2012c, 2012d, 2012e) present the findings from the CCRA project for Scotland, Wales and Northern Ireland, based on the threats and opportunities most relevant for each country and taking into consideration the specific vulnerabilities of each country.

The Devolved Governments are using these reports as part of their evidence base as they develop their own National Adaptation Programmes.

The DA Reports went through 5 rounds of reviews. The extent of these varied depending on the country, but in all cases they included sector stakeholders, Devolved Government departments and their agencies and non-government sector experts.

Each DA Report is accompanied by a 4-page DA Summary, which presents an overview of the findings in an accessible way, suitable for high-level policy-makers, Ministers and the general public.

2.3.5 Sector Reports

The eleven Sector Reports (see Appendix 2 for full references) provide the underpinning evidence used in the Evidence Report, CCRA Summary and DA Reports. Each Sector Report includes the main threats and opportunities identified as affecting the sector, drawing in relevant information from other Sector Reports. Details of the analysis undertaken to quantify these threats and opportunities are also provided, along with the results.

The Sector Reports have benefitted from two rounds of academic peer review and four rounds of policy review by Government Departments and at the latter stages selected non-government stakeholders were also invited to review these.

Each Sector Report is accompanied by a 4-page Sector Summary, which presents an overview of the findings for the sector in an accessible way, suitable for high-level policy-makers, Ministers and the general public.

2.4 Summary of key issues

The project was successfully delivered on time and to the required standard. However, there were some hurdles to overcome during the course of the project that may be avoidable next time round.

2.4.1 Project timetable

The timeline provided in Figure 2.1 helps to highlight a number of important issues with the project implementation:

- Method development - this took 10 months in total, which meant that the sector analysis had to start later than originally planned.
- Sector analysis work - which forms the main evidence base for the CCRA, was carried out over the summer of 2010. This required a particularly large staff input over an intensive 5 week period when the bulk of the analysis was undertaken. If more time had been available to undertake this stage of the work, more detailed/sophisticated analysis could have been undertaken for a significant number of the risks. This would have provided greater confidence in the projections and the outputs may have been closer to meeting the expectations of the Client and their reviewers. The monetisation task within this work was particularly 'squeezed' due to the tight timescale, which allowed little time for iteration and refinement. Difficulties with obtaining data in this tight timescale were also an issue.
- Sector Reports - it then took a further 16 months to review, refine/update and finalise the Sector Reports most notably to meet the requirements of Defra and the OGDs (see Section 2.4.3).
- The Devolved Administration (DA) assessments, which were based on the analysis for the sectors, had to commence before completion of that analysis and DA reporting had to be completed whilst the Sector Reports were also being modified. This meant that several updates were required to the DA Reports in addition to having their own reviews.
- The DA assessments became much longer and more detailed than originally planned, partly due to the expectations of the Devolved Governments being greater than originally recognised by both the Contractors and the Client, but this was also a reflection of the under-representation of DA issues within the main sector analysis work. Difficulties were experienced engaging DA stakeholders as part of the sector analysis work, although the extent of this varied depending on the sector.

- The synthesis of the results from all 11 sectors was carried out over a relatively short three month period, again, before the Sector Reports had been finalised.
- The Evidence Report, which draws together and interprets the findings from the sector analysis, took 12 months to be written and finalised. Early sight of the Evidence Report was provided to the Client after only one month of synthesis work, which gave the Client team a lot of time to provide input into the shaping of the report, but gave the Contractors little time to think about how to best synthesise and present the findings before the redrafting steps started.
- The summary reporting also took 12 months to complete. Again, this had to be carried out whilst the main reports were still undergoing changes, which meant that several updates were required in addition to having their own reviews.
- Due to the heavy workload to deliver all of the final publications by January 2012, this recommendations report was delayed until after publication. This has allowed additional time to reflect on the work carried out and to be responsive to the feedback received post-publication.

2.4.2 Having the right team

The success of the project was, to a great extent, due to having a strong team that was able to work effectively within the constraints of the contract, but also flexible enough to modify the way they worked to ensure the outputs met the evolving requirements of the Client and its customers.

During the course of the project the following became apparent:

- Sector Champions - Technical work was undertaken more efficiently once the Sector Champions were more closely involved in the delivery of the sector analysis, rather than acting only in an advisory role.
- As sectors were technically quite broad, the Sector Champion was rarely able to cover all aspects of the sector. This resulted in the Sector Champions calling upon the expertise of others to cover areas beyond their specialisation and for a few sectors (e.g. Business, Industry & Services and Transport) this restricted which risks that could be looked at in detail.
- The level of project management required by the Contractor was significant and greater than expected, with 2 people working full-time plus a Project Administrator for the majority of the contract. This was due to a number of factors including:
 - The large project team (including subcontractors)
 - The large number of deliverables (and their evolution)
 - Parallel work streams
 - Changes in contract (related to changes to Contractors in the consortium, programme, budget, technical specification and deliverables)
 - Close liaison with the Client team

- Communication between the Contractors and the ACC (on behalf of the Client team) was necessary on a daily basis for most phases of the project.
- Despite this regular communication, monthly progress reports and face to face meetings remained essential to ensure rapid progress on the wide range of tasks being carried out at any one time.
- The role of the Contractor's Project Administrator (seconded into Defra) was of paramount importance in maintaining the strong working relationship between the Contractors and Client team at the ACC.
- As well as acting as the Client project management team, ACC team members were also able to contribute their technical knowledge, in particular regarding UKCP09, socio-economic scenarios and social vulnerability as part of the method development and technical review steps. This input meant that the Contractor was able to have meaningful technical discussions with the ACC team, which proved very important in a ground-breaking project.
- The stakeholder engagement process was very important to help the Contractors and Client to draw upon a large and diverse group of specialists and practitioners covering many sectors. Further discussion regarding this is provided in Chapter 5.

2.4.3 Reporting

The reports produced for this first CCRA are numerous and serve a number of different purposes, as discussed in Section 2.3. The time and effort required to deliver these to an acceptably high standard was significant, as already discussed in Section 2.4.1.

During the course of the project the following became apparent:

- There were too many internal reports required during Phase 1 of the project that dealt with different aspects of project delivery and the method. Although these were intended to demonstrate to the Client team that progress was being made, these actually impeded genuine progress.
- The report structure for the Sector Reports that was originally based on the method steps needed reshaping to meet the needs of the relevant Government Departments. In summary, the technically orientated reports needed changing to be more policy facing.
- Thousands of comments were received for the various reports to be published, which first required collation by the ACC and Devolved Governments and then individual responses from the Contractors. The quality of these comments varied widely, ranging from the highly technical and thoughtful to the ill-informed or irrelevant. A significant number of the comments and corrections requested by reviewers were trivial, but, as they all required a response, they were very time consuming. However, amongst all of these comments was some very useful feedback that enabled the Contractors to deliver a much more thorough and accurate account of the work undertaken and robust discussion of the findings.
- A compromise had to be found, particularly with the Sector Summaries, whereby the language used was relatively easily understood by non-specialists, whilst remaining unambiguous and accurate and reflecting the levels of uncertainty in the results. In some instances, due to restrictions in space, terminology that was more technical than desired had to be used.

- Consistency checking of reports became a very time consuming part of the latter stages of the project, due to the large number of final reports, a lot of duplication across reports, and in some cases the programme requiring delivery of reports whilst analysis was still underway. This meant there was a high chance of error.

2.5 Recommendations

In our view, an early start on CCRA2 to allow a full sequential programme of studies over three to four years is needed.

The practicalities regarding how to successfully deliver the project next time round will depend heavily on how the project is commissioned and what the objectives are for CCRA2. However, the following recommendations would apply in all cases:

Project Scoping (pre-project)

1. Decide on the audience – in particular be very clear on whether the deliverables will be for one or more of the following:
 - a. UK Government
 - b. Devolved Governments
 - c. English areas
 - d. research community (international as well as domestic)
 - e. business and industry
 - f. general public
2. Decide on the scope – in particular be very clear on whether the assessment will include the international dimensions of climate change and how these may affect the UK. Also consider whether analysis work should be organised differently, e.g. around sectors, themes or some other kind of breakdown (see Section 3.3.2).
3. Work across Government – work with other central Government Departments to review the analysis undertaken for this first CCRA and identify priorities for CCRA2.
4. Get specialist advice – work with researchers and consultants to determine:
 - a. What research has progressed since the first CCRA
 - b. What could be modelled or analysed for CCRA2, taking into account ongoing research and modelling activities
5. Work with the ASC – to review the priorities identified for CCRA2 and to agree how and when the ASC will be involved (including how it will fulfil its statutory obligations).
6. Review the method – taking on board the recommendations regarding the method presented in this report and the specialist advice mentioned above (item 4), draw up a plan of the proposed analysis and modelling work and how this will implement the updated method.
7. Identify gaps in research – and look to have these gaps filled in advance of project implementation where possible (see Chapter 4).

8. Identify data and model needs – including sources of suitable data and models and negotiate licence agreements well in advance of the planned analysis work (see also Section 3.3.1). Start collating data as early as possible.
9. Identify stakeholder needs – and respond to those needs with an effective stakeholder engagement strategy that runs for the full duration of the project (see Chapter 5). This should include a review of follow-on initiatives stimulated by this first CCRA⁵, in order to understand how stakeholders responded to the project findings and how they can remain engaged.
10. Decide on the publications – emphasis should be given to fewer, high quality publications that meet the needs of the chosen audience(s), with an eye to using more innovative methods of dissemination (such as online). A review of the use of the results and different publications from this first CCRA (such as extent of readership, usability, how the NAP was able to build on this, etc.) could help identify how these could be improved for next time. This could also inform the development of the method and help shape future stakeholder communication or engagement processes.
11. Identify review steps – linking closely with the agreed publications, identify which deliverables need to have:
 - a. An independent academic peer review
 - b. A review by the ASC and/or Chief Scientific Advisors
 - c. A policy review by Government Departments
 - d. A stakeholder review
12. Set a realistic programme – that allows for all of the above to be completed in advance of project implementation.

Project Implementation (during project)

1. Have the right technical team – make sure that the right technical expertise is available within the delivery team at the right time and that they are able to take genuine ownership of their technical area. This expertise needs to be within the Client team as well as the Contractor team. As well as sector experts, climate scientists along with experts in social vulnerability, socio-economic scenarios and adaptive capacity need to be included within this team.
2. Have the right project management team – this team needs to include a Project Administrator and Project Managers that have experience and competency in managing large, multi-disciplinary teams working on both research and consultancy projects. Again, this expertise needs to be within the Client team as well as the Contractor team.
3. Have a strong working relationship with the Client – make sure that the Contractor and Client work closely together to explore fully the Client's needs and those of their customers, including potential policy sensitivities. This may include developing closer and more direct working relationships between the Contractor and other Government Departments.
4. Have a very clear contract, scope of work and programme – as much information and knowledge as possible should be brought into the project scoping process, so that a realistic scope of work and programme are specified.

⁵ Examples include: the recent workshop in Scotland for Emergency & Rescue Services; and LWEC climate change report cards currently being piloted for Biodiversity and Water.

Depending on how the work is commissioned (e.g. as a single contract, in project phases or across a number of contracts) the actual programme of work may differ significantly from this first CCRA. In all cases, it is important that project phases work sequentially, building upon one another and limiting revisions in results and reporting as much as possible. It is also important to ensure sufficient time in the programme for technical work to be completed to the satisfaction of the Contractors before the work is to be reviewed, as this should be more time efficient in the long-run.

5. Have a robust method – building on the method developed for this first CCRA and incorporating pilot testing of untried aspects of any new methods. Guidelines should be provided regarding best practice across technical teams, covering issues such as how to use climate data, applying baselines, reporting writing, etc. Flexibility in approach is also needed to accommodate the challenges of different sectors, whilst retaining overall consistency of approach (see Chapter 3).

Project Completion (post-project)

1. Produce recommendations – provide a review similar to this report that will provide a degree of ‘institutional memory’ for the Client team.

3 Methodology

3.1 Method development

One of the most challenging aspects of the CCRA was the development of a suitable methodology that would meet the project objectives within the constraints of time available to complete the first assessment. The main CCRA study started in September 2009 with a fixed delivery date of January 2012 and just over 2 years to complete. In other statutory planning processes with 5 year cycles, timescales broadly involve one year for commissioning/decommissioning of project teams, one year for the development of new methods, two years for implementing studies and one year for consultation. The first CCRA proceeded with a compressed time scale and this influenced method development and placed a sharp focus on 'delivery on time' (in 2 years) rather than development of an ideal methodology for the a study with a longer (3-4 year) timeframe.

Within this context the method was developed building on the Scoping Study (Watkiss *et al.*, 2009) with an Inception Report (HR Wallingford, 2009), which was based on an expert workshop and literature review, then a methods report, which was delivered in two stages (Defra, 2010a, 2010b) and informed by a pilot study in the Water sector. As well as aiming to combine different methodological perspectives the method aimed to make good use of the UK Climate Projections, UKCP09 (Murphy *et al.*, 2009) and was informed by the views of the In-House Experts Group, Project Steering Group and independent Adaptation Sub-Committee (ASC).

3.1.1 The scoping study

The scoping study was commissioned by Defra in 2009. It considered nine previous national-scale studies, variously for the UK, USA, Australia, Finland and Sweden (Evans *et al.*, 2004; Metroeconomica, 2006; US NAS, 2001; Morgan *et al.*, 2005; Australian Greenhouse Office, 2003; Garnaut, 2008; IPCC, 2007a; IPCC, 2007b; SCCV, 2007).

Following the classification in the IPCC AR4 (IPCC, 2007a), the scoping study identified six broad methodological approaches as options for the CCRA: synthesis, impact assessment, integrated assessment, risk assessment, vulnerability assessment and stakeholder and participatory reviews (Watkiss *et al.*, 2009). It concluded that all the approaches considered had strengths and weaknesses and favoured a composite approach combining a scenario-based assessment of the potential impacts of climate change (i.e. an 'impact assessment' with a vulnerability assessment that was focused on current climate and other drivers). It did not, however, provide an agreed conceptual framework for how to do this and this task was therefore an immediate requirement for the early stages of the CCRA.

3.1.2 Inception Report

The Inception Report was developed in the first few weeks of the project in 2009. It provided some further scoping of what was needed, reviewed existing methods and the issues related to their implementation and made some further proposals for the CCRA method development as well as covering various project management activities. The inception work achieved two important steps:

1. It decided to follow the sector definitions in the Scoping Study as a means to collect evidence for the CCRA, which enabled the process of data collection and stakeholder engagement to start.
2. It introduced concepts on how to include information on different types of uncertainties (Defra, 2005; Shaxson, 2005) including the NUSAP methodology (Funtowicz and Ravetz, 1990) that was eventually simplified for incorporation into the study.

The inception work built on the existing EA and UKCIP decision making framework (Willows and Connell, 2003) and explored ideas on how to factor in autonomous adaptation and how to integrate impacts and vulnerability and adaptive capacity assessments (Figure 3.1 below). Although some of the ideas presented were not supported by the ASC and other stakeholders, it exposed some of the difficulties of the integration proposed in the Scoping Study and communicating potential methods to different groups without tangible case studies.

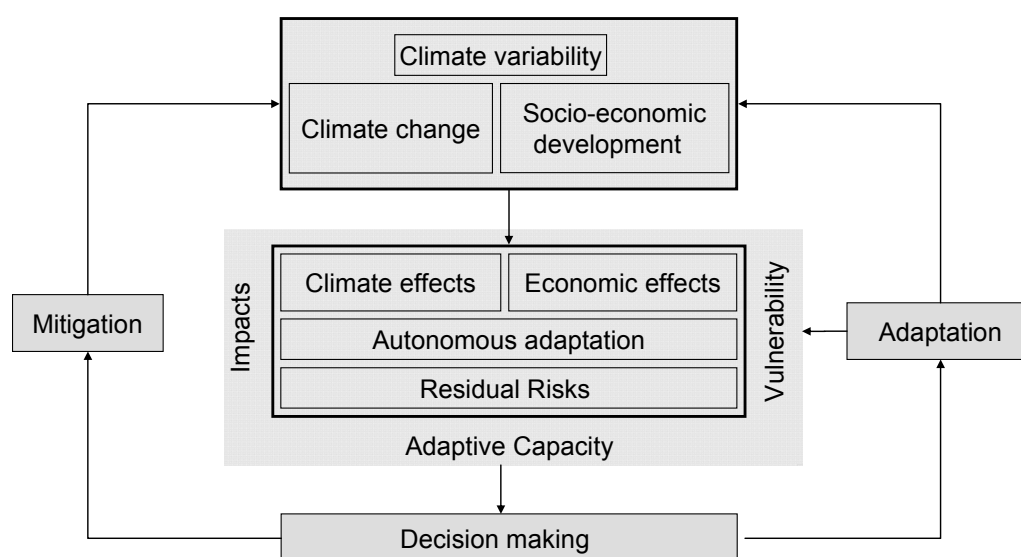


Figure 3.1 Potential high-level framework for CCRA proposed in the Inception Report (HR Wallingford, 2009)

The 'sectors' used for collecting evidence were as follows:

- Agriculture
- Biodiversity & Ecosystem Services
- Built Environment
- Business, Industry & Services⁶
- Energy
- Floods & Coastal Erosion
- Forestry
- Health
- Marine & Fisheries
- Transport
- Water

It was recognised from the start that the sector classification was imperfect; that many risks were cross-cutting; and that it was important to draw out the inter-dependencies between sectors. In particular, Biodiversity & Ecosystem Services cannot be treated as

⁶ Specifically tourism, financial services, food & beverages, primary extractive industries & chemical manufacturing

a 'sector' in the same way as, for example, Energy or Transport. Natural ecosystems are considered as the foundation of all products and services for all sectors (Watson and Albon, 2010). Similarly, the Marine sector included aspects of biodiversity, fisheries and shipping. Flooding affects all sectors and is one of the main risks for the Built Environment, Transport and critical infrastructure in the Water and Energy sectors.

A Sector Champion was assigned to each sector to provide technical guidance with support from analysts and the stakeholder engagement team (see Section 2.2.1). Later, during the implementation of the project the sectors were brought together as five broader themes (See Section 3.3.2).

3.1.3 Methods Report Part I

The Methods Report Part I was completed in draft for the ASC in December 2009 with the final report produced in February 2010 (Defra, 2010a). It provided a more detailed review of Climate Change Impacts, Adaptation and Vulnerability (CCIAV) assessment methods, compared impacts assessment to risks assessment and chose to adopt the UKCIP Risk and Uncertainty Framework (Willows and Connell, 2003).

Over subsequent cycles of IPCC assessments, methods have moved towards a risk assessment approach and most recently, resilience approaches (Table 3.1). This change has been driven by the demand for policy relevant information and the desire to 'mainstream' climate change adaptation into government and institutional decision-making processes. The latest assessments are generally characterised by a risk based approach and an emphasis on understanding the uncertainties related to climate model projections and impacts. The probabilistic UKCP09 projections (Murphy *et al.*, 2009) were aimed primarily towards risk assessment and provided a means of estimating the probabilities of changes in climate exceeding specific thresholds, at least for individual emissions scenarios.

Table 3.1 Evolution of IPCC approaches (Source: Lu, 2007; adapted to include more recent interests in robust decision making)

CCIAV Assessments	Focus of investigation	Assessment frameworks	Climate scenarios needed
1 st generation	Does climate change matter?	Sensitivity analysis	Synthetic scenarios
2 nd generation	What are the likely impacts of climate change?	Impact assessment	Analogue or climate model based scenarios
3 rd generation	How to manage climate change induced risks?	Risk management frameworks	Model based projections with uncertainties quantified
4 th generation	How to make choices that are resilient to climate change? How to reduce risks of losses and damage.	Robust decision making Hybrid frameworks (incorporating concepts from DRR and CC studies)	Wide range of possible futures Climate variability (inc. extremes)

Due to the 'deep uncertainties' related to future climate and socio-economic changes a further development has been the promotion of robust decision-making, which aims to promote choices that produce satisfactory outcomes under a wide range of possible future scenarios. The CCRA was concerned with identifying potential risks and stopped short of considering adaptation actions (which are being considered in the ongoing Economics of Climate Resilience (ECR) study). As such it was primarily conceived as a risk assessment that explored the potential risks under a wide range of scenarios.

Although this report moved the methodology forward, there were still difficulties with aspects of the method. Therefore, the decision was taken to implement the

methodology on one pilot sector, learn from this pilot study and then finalise the method for the remaining eleven sectors.

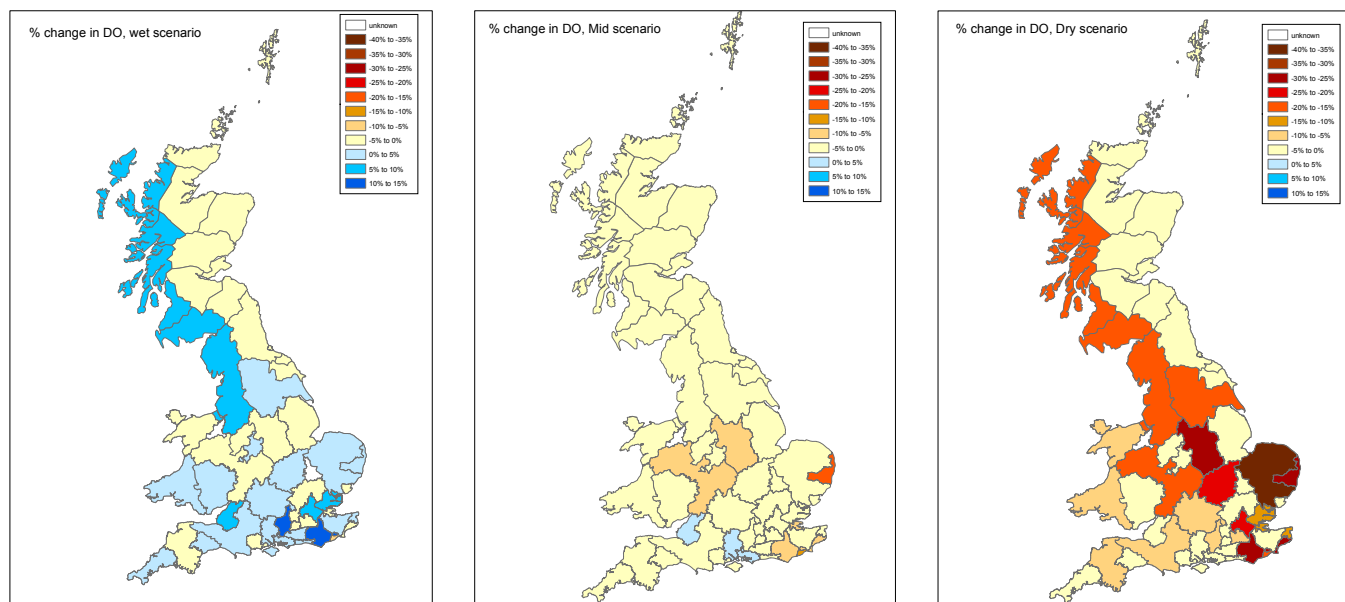
3.1.4 Pilot study on the Water Sector

The pilot study was developed to provide tangible examples of how specific aspects of the methodology could be applied to understand future climate risks. It was completed in spring 2010 and fed directly into the Method Report Part II (see Section 3.1.4). The Pilot Study Report was published as an internal project document in July 2010, but was not released in public as it included some confidential data and preliminary results (HR Wallingford, 2010b).

The pilot study allowed testing and refinement of key aspects of the methodology including:

- Stakeholder engagement methods and how the outcomes of the workshops could be used to scope and prioritise risks
- Scoring of impacts and consequences based on perceived magnitude, likelihood of risks and urgency of adaptation action
- Response functions and how these could bring together available evidence on the sensitivity of specific risks to climate variability and change using UKCP09
- Adaptive capacity assessment based on structured questionnaires and how the outputs might inform assumptions in the risk analysis
- Social vulnerability checklists and how these could be used to record any evidence of vulnerable people or places related to broad risk themes
- Policy risk mapping, which was subsequently not taken forward in to the full methodology
- Systematic mapping methods to link direct biophysical impacts of climate change to secondary and tertiary consequences
- Presentation of results using maps at different scales (e.g. Figure 3.2).

While the pilot study was successful, with hindsight other sectors with less data available may have provided a better test of the draft methodology. The Water sector turned out to be one of the sectors with the most quantification of future risks. This was due to the large amount of regulatory reporting required from water companies, which include a statutory requirement to make an assessment of the impacts of climate change for water resources planning.



Note: Raw data from draft Water Resources Management Plans – presented on UKCP09 basin basis only.

Figure 3.2 Impact on Deployable Output in the 2020s, for the wet, mid and dry scenarios

3.1.5 Methods Report Part II

The second Methods Report was completed in draft for the ASC in June 2010 (some 5-6 months after Part I) with the final report produced in August 2010 (almost one year into the study) (Defra, 2010b). The time elapsed reflected the difficulties of developing a new approach for assessing risks across many diverse sectors and agreeing an integrated approach that brings together different aspects of risk assessment, vulnerability and adaptive capacity assessment. This report focused on the risk assessment step, illustrating the work needed by using the results of the water pilot study. It provided a basis for 'signing off' the methodology with the ASC and a consistent approach that could be implemented across all eleven sectors.

The agreed method presented in Part I and Part II of the Method Reports is summarised in Section 3.2. The method was implemented across eleven different sectors and in some cases subtle, and in others significant, changes were made for individual risk metrics.

3.1.6 The role of Project Steering Group and In-House Experts

As evident from the time line of method development (10+ months), the process was not straightforward. The PSG and IHE both played important roles in the improvement of the methodology between the Part I and Part II reports. The PSG and broader CCRA Forum engagement identified a number of issues related to the method as well as evidence gaps that needed to be filled as part of the future programme. The IHE provided a useful initial test of the methodology that helped to identify strengths and weaknesses and to ensure that methods were appropriately framed and caveated prior to presentation to the ASC.

3.1.7 The role of informal review processes

More informal reviews with both the ASC members and other external experts were very valuable for resolving some of the most difficult issues related to using UKCP09, communicating risks and understanding some of the most complex sector risk models (e.g. in Floods & Coastal Erosion and Health). For example, a guidance note on communicating risk and uncertainty in the CCRA reports was produced after discussions with the Met Office and representatives of Oxford University and the London School of Economics. This discussion meant that the consequences of climate change were presented as fairly wide ranges without the use of probabilities. While this did not entirely prevent some later criticism, it ensured that the project was very clear on caveats and limitations and that it did not overstate the utility of UKCP09.

3.1.8 Summary of method development

The development of an agreed methodology for assessing risks across eleven diverse sectors was a challenging task, which took longer than expected to complete. The involvement of different groups and experts with different perspectives was very useful for developing a suitable method. The process of piloting the method was essential in order to show tangible results that helped the team understand the approach and refined it further. The method developed suited delivering this project within a timescale of two years and was effective in how it brought together different types of evidence. However, it is not necessarily the right method for CCRA2 or the right method in other

country contexts; a detailed appraisal of the method is provided in Section 3.3 and recommendations for CCRA2 in Section 3.5.

An overview of the methodology is provided in the following section. Full details of the method can be found in Defra (2010a, 2010b) and updated post project in CCRA (2012b). The Evidence Report includes more information including a number of 'study boxes' that shows: how climate projections were used; how uncertainties were considered and communicated; and how climate and socio-economic projections were combined to develop results.

3.2 Overview of technical approach

The method developed can be considered at a high level as a series of studies that contributed to the overall evidence base or as a more detailed series of methodological steps, akin to the early impacts assessment methods. At a high level, the CCRA completed studies in five discrete stages, with each applied systematically across each sector:

1. To identify and characterise the impacts of climate change
2. To assess the vulnerability of the UK, including adaptive capacity
3. To identify the main risks for closer analysis
4. To assess the risks up to the year 2100, using a combination of climate and socio-economic projections
5. To report on the findings to inform government action.

The first stage was based primarily on desk studies and a large amount of stakeholder engagement in each sector. The second stage involved more specialist reviews, questionnaires and in-depth discussion with key informants. Stages three and four involved a large amount of analytical work, including the use of UKCP09 and the final stage moved back into a process of engagement with Government policy-makers.

In summary, the process involved:

- Stage 1: Scoping studies, extensive stakeholder engagement and technical reviews that contributed to the development of a wide ranging list with more than 700 potential climate change impacts (known as the Tier 1 list).
- Stage 2: Building on the scoping studies, a review of social vulnerability related to groups (or clusters) of risks identified in Stage 1. This stage also included the initiation of specialist studies on adaptive capacity.
- Stage 3: Selection of approximately 100 impacts for consideration in more detail for the UK assessment (known as the Tier 2 list). This list was based on our preliminary understanding of the scale or severity of consequences and confidence related to climate risks and 'urgency' for adaptation action.
- Stage 4. Sector by sector analysis of 'risk metrics' that estimated how risks may change in the 2020s, 2050s and 2080s for different climate change scenarios, population projections and, in some cases, levels of anticipated adaptation.
- Stage 5: Peer review of sector analysis by academics and industry experts; policy reviews by OGDs and DAs; and ongoing liaison with the ASC. Further review and refinements of the analysis, including responding to ASC advice, discussion with OGDs and incorporation of findings from other

reports, most notably Foresight studies, some comparison with the Adaptation Reporting Power (ARP) reports and finally the latest Departmental Adaptation Plans (DAPs).

The relationship between these stages and more detailed steps is shown in Figure A3.2 in Appendix 3. A more detailed walk through of these steps is also provided in Appendix 3.

3.2.1 Social vulnerability

Equity considerations are an important part of the Government's rationale for intervention. However, the distributional effects of climate impacts within the UK are a relatively new topic and the incorporation of social vulnerability into climate risk assessment is still an emerging field in research. Recent studies aim to fill this gap in knowledge (in particular the climate impacts programme of the Joseph Rowntree Foundation and studies funded by the Economic and Social Research Council). In the CCRA, a simple social vulnerability checklist was used, which supported the later identification of risk metrics that reflect equity.

The following factors, based on CAG (2009), were considered in the social vulnerability checklist, which included a qualitative assessment on how these factors may influence specific groups of risks on a sector by sector basis:

- i. Location and place
- ii. Poor mental and physical health
- iii. Fewer financial resources
- iv. Living and working in poor quality homes or workplaces
- v. Limited access to public transport
- vi. Limited or lack of awareness of potential risks
- vii. Lack of social networks
- viii. Little access to systems and support services (e.g. health services).

The checklist was completed by sector analysts based on desk studies and expert opinion. It was a rapid review added on to the end of the sector analysis work and key vulnerabilities could not be followed up with more detailed assessment. However, in the floods sector it was possible to make use of detailed mapping of the Index of Multiple Deprivation (IMD) as a "good enough" indicator of a broad range of factors contributing to deprivation (e.g. Walker *et al.*, 2006). Therefore it was possible to highlight areas with high current or future risks of flooding for the more vulnerable groups due to combination of factors related to location (i), fewer financial resources (iii) and other factors listed above.

Early work on the CCRA Evidence Report attempted to link climate change risks to the well-being agenda (New Economics Foundation, 2011) because the development of sustainable local communities that take positive environment action may support local resilience, risk reduction and climate change adaptation. This would have broadened the Health sector assessment and incorporated much of the social vulnerability work. This was difficult because the project had not started by adopting this framework and this approach was dropped. However, this may be a valid approach and should be considered as part of the scoping work for CCRA2 based on more recent policy research (e.g. New Economics Foundation, 2012).

3.2.2 Adaptive Capacity

The methods used for the adaptive capacity assessment were based on the application and further development of the PACT framework⁷ (Ballard, Black and Lonsdale, 2011). The analysis included a preliminary assessment of all sectors. This was followed by structural analysis and many in-depth stakeholder discussions, plus detailed analysis of 26 organisations involved in adaptation decision-making, for the following sectors:

- Business (focusing on the finance sector)
- Transport (focusing on road and rail)
- Built Environment (focusing on house building)
- Health
- Biodiversity
- Water.

This assessment distinguished between two aspects of adaptive capacity:

- **“Structural adaptive capacity”** - The extent to which a system is free of structural barriers to change that make it hard to devise and implement effective adaptation strategies to prepare for future impacts. This covers issues such as the duration of decision outcomes (those with long-lasting outcomes are more challenging) and sector complexity (high complexity is more challenging).
- **“Organisational adaptive capacity”** - The extent to which human capacity has developed to enable organisations to devise and implement effective adaptation strategies. The analysis used the PACT multi-level framework of adaptive capacity to assess this. It recognises different levels of adaptation, from entry level (‘Engaging’) to advanced levels (‘Pioneering’ and ‘Leading’), all of which may be needed for effective adaptation.

Adaptive capacity is relevant to the risk assessment because the future level of risk will be affected by the amount and quality of adaptation (i.e. of ‘autonomous adaptation’) that can be expected.

The method’s inclusion of an explicit adaptive capacity review was a particularly innovative aspect, potentially allowing consideration of the relative capacity between sectors, for different priorities or decisions. However, due to timescales this work could not be completed sufficiently in advance of the risk assessment stage and there were only weak linkages⁸, therefore, between adaptive capacity and future risks. Instead the final outcomes of this work were taken forward in the ECR study to inform the development of adaptation options.

3.2.3 Selecting risks for more detailed assessment

A simple multi-criteria assessment and a scoring system were used to select an initial list, which was then reviewed and revised via discussions with key informants and further stakeholder workshops. The criteria used, and agreed by the CCRA IHE group, were:

⁷ PACT was developed in the UK as one of the outcomes of the ESPACE Project (European Spatial Planning: Adapting to Climate Events) <http://www.pact.co/home>.

⁸ For example, some the adaptive questionnaire outputs influenced or reinforced assumptions in the risk assessment.

- Magnitude of the consequences, including:
 - Economic consequences
 - Social consequences
 - Environmental consequences
- Perceived likelihood of the impact occurring
- Urgency with which a decision needs to be made.

These criteria were equally weighted and scored following pre-defined guidelines (the selection scoring criteria). This led to a subset of just under 100 risks for the more detailed Tier 2 analysis.

3.2.4 Risk metrics and response functions

A key step involved the use of risk metrics and a scenario based impact assessment approach with quantitative, semi-quantitative or qualitative “response functions” that related consequences (such as changes in the number of houses flooded) to measured or projected changes in climate variables (such as changes in monthly rainfall). The rationale involved keeping the assessment relatively simple, the ability to assimilate different types of evidence from detailed modelling studies to expert elicitation methods and the potential for scaling the results for previous studies for use with UKCP09. In this way a consistent approach and consistent set of climate scenarios could be applied to a wide range of risks.

Examples of the risk metrics derived included:

- Expected annual damage to residential property from river flooding (£)
- Expected rates of morbidity and mortality due to cold winters
- Average number of people flooded per year
- Number of ‘vulnerable’ people living in the 1 in 100 year floodplain
- Crop water demand (mm depth or m³/ha)
- Average crop yield (t/ha)
- Water availability for public water supply (Ml/d)
- Ecological status (number of sites in a class)
- Habitat loss (hectares).

The response functions helped to understand the sensitivity of risk metrics to changing climate conditions. Their development, led by the Sector Champions, was based on either qualitative assessment by experts and practitioners or quantitative analysis based on existing research studies or small pieces of original research. Key assumptions and uncertainties were elicited and recorded. The response functions were based on historical observations, modelling and/or expert opinion. As such, these were not intended to be ‘best-fit’ mathematical regressions or empirical models that predicted consequences based on climate variables, but rather aimed to provide a simple way to present the available evidence, to enable some form of interpolation and scaling of the consequences of the UKCP09 projections and the socio-economic scenarios.

The response functions were then combined with the baseline and future climatology from the UKCP09 datasets (Murphy *et al.*, 2009) to examine consequences under different emission scenarios and different timescales. The UKCP09 datasets provide 30-year time periods for the baseline climate (1961 to 1990) and for three future climate projections: the 2020s (2010 to 2039), the 2050s (2040 to 2069) and the 2080s (2070 to 2099) for three emission scenarios based on IPCC Special Report on Emissions Scenarios (SRES) for a low (B1), medium (A1B) and high (A1FI) scenario (Nakićenović *et al.*, 2000). These UKCP09 datasets are based on a methodology which allows a measure of the modelling uncertainty in future climate projections to be included and presented as probabilistic functions. The CCRA mainly considered the near term (2020s) and longer term (2050s and 2080s) climate projections while noting the statutory requirement to consider risks up to 2100. The choice of emissions scenario (low, medium or high) does not produce significantly different projected climate variables until after the 2040s, so for the near-term (2020s) the medium emission scenario (SRES A1B) was used. For longer-term time horizons, the low, medium and high emissions scenarios were all used (SRES B1, A1B and A1FI); no judgements were made on their relative likelihood.

The use of response functions allowed the disaggregation of climate and non-climate drivers of risk, which was an important part of this assessment. For example, the numbers of people affected by river flooding in future was estimated in two steps, first considering the sensitivity of the current population to increased river flows and then making assumptions about future socio-economic changes on population growth and structure⁹.

Considering future socio-economic scenarios and assumptions is important as the UK may be very different in future time periods, particularly projecting through to 2100. The expected costs from flooding, for example, depend not only upon the climate but also the number and value of assets at risk and investments in flood risk management (Evans *et al.*, 2004), each of which will be greatly affected by non-climate factors. Similarly, in the Agriculture sector many of the future near-term risks are sensitive to non-climate factors including CAP reform, environmental regulation and compliance (Knox *et al.*, 2010). The future socio-economic framework also influences the vulnerability of social and economic systems to projected climate change, and may also determine the nature of adaptation response. The standard approach for accounting for non-climate drivers in risk analysis is to use forecasts of the key variables for the relevant period of time, for example, population growth rates. This can be extended to capture uncertainty through the use of sensitivity testing – for example, to explore the consequences of higher, or lower than expected growth rates. However, by 2100, the levels of uncertainty around central forecasts are extremely wide. For the short-term assessment (2020s), the CCRA used existing government datasets and assumptions regarding population and economic growth, which link closely to current government policy. For the medium and longer term, a qualitative description of what may happen under different socioeconomic scenarios was completed for all sectors except Agriculture.

3.3 Appraisal of the method

The main CCRA reports were published in January 2012. The project team received general feedback on the CCRA reports, which were very positive, a series of more technical queries on specific risk metrics from other UK scientists and some enquiries

⁹ The logic of considering climate change then socio-economic change suited the CCRA partly because there were no agreed socio-economic scenarios at the starting point. However other studies have done the converse and the pros and cons of each approach need to be considered for the CCRA2.

on the methodology, with the greatest interest being from international scientists (e.g. from Australia, Japan, Singapore) rather than from the UK.

The project team held an internal workshop to discuss the strengths and weaknesses of the methodology. A number of issues were discussed ranging from: the availability of data and information; specific methodological steps and their suitability in different sectors; and the presentation and communication of the project findings. These are discussed in detail in this section. Under each heading, the issues raised are introduced, elaborated with examples from the CCRA (or other sources) and, where possible, recommendations are made for CCRA2.

3.3.1 Data availability and usage

Implementation of the methodology required the use of a wide range of data, from historical climate observations and future climate projections through to population projections, health questionnaires and industry turnover by sector. The availability of data for some aspects of the research and in some sectors enabled detailed quantitative assessment of future risks but a number of data problems and barriers in other sectors limited the amount or detail of the work that could be done.

Some examples of data “successes” (Table 3.2) and “failures” (Table 3.3) are useful to highlight some of the issues related to data availability and use. Across the final project reports we identified more than one hundred examples of problems related to the lack of monitoring, data availability and public access to Government data sets (see Appendix 4).

Table 3.2 Examples of data sets that were available and used successfully in the CCRA

UKCP09 data (including outputs of the underlying Regional Climate Models) were used for a significant proportion of the biophysical impacts assessment and for most risk metrics. Headline UKCP09 outputs were used to scale many of the simpler risk metrics that were dependent on a single climate variable.
Agroclimatic data and modelling results of changes in Potential Soil Moisture Deficits (Knox <i>et al.</i> , 2010b) based on UKCP09 were a useful building block for other agricultural risk metrics.
Potential changes in average monthly river flows at the catchment scale based on UK Water Industry Research (UKWIR) research (Vidal <i>et al.</i> , 2011) made it possible to use UKCP09 successfully in the Water sector.
Potential changes in peak river flows for estimating flood risk was based on research completed by CEH and funded by both NERC and Defra/EA research programmes (Kay <i>et al.</i> , 2010).
The Environment Agency National Flood Risk Assessment (NaFRA) was used for many of the flood risk metrics. Prior research and operational use of this tool meant that it could be easily incorporated into the CCRA.
Water company draft Water Resources Management Plans (dWRMP) and June Returns to Ofwat provided data that were incorporated into the Water sector assessment.
Research completed by the London School of Hygiene and Tropical Medicine (LSTHM) on heat mortality provided data that could be used directly in the Health sector assessment (Armstrong <i>et al.</i> , 2010).
Forest Research's Ecological Site Classification (ESC) (Pyatt <i>et al.</i> , 2001) was used to estimate potential changes in the growth of specific tree species for sites across England, Wales and Scotland.

Table 3.3 Examples of barriers and problems related to data

Difficultly gaining access to existing comprehensive Met Office climate observation data sets for original research during the CCRA. The UK has excellent data sets but license conditions and potential costs made it difficult for Sector Champions to gain timely access to up to date data.
The lack of socio-economic scenarios at the beginning of the CCRA was a significant problem for several sectors. Research completed by the Foresight Land Use Futures projects provided lots of background information on drivers and pressures but no scenarios. The National Ecosystem Assessment subsequently developed appropriate scenarios, but these were developed too late for use in the CCRA.
Lack of data of forest fires across the UK to quantify current risks (in terms of frequency, area affected, economic impacts).
Lack of data on specific building types to support assessment of overheating and indoor thermal comfort. Hence within the CCRA, external temperature was used as a proxy for indoor thermal comfort.
Lack of comprehensive data on the impacts of flooding on business continuity. Some data exist but the sample size was too small to provide robust results.
Lack of data on the disruption to businesses caused by heat-waves and drought conditions (Business theme).
Large data gaps related to the epidemiology, and biology of marine-associated <i>Vibrio</i> pathogens in the UK and Europe.
National soils data to support subsidence and soil erosion risk assessments are available but the costs in England and Wales were prohibitive.
Existing Defra funded studies on climate change on soil erosion in England and Wales were not made available to the project team (because they were in final draft form only) so original calculations on rainfall erosivity were completed.
The most recent coastal erosion data for England and Wales was not available due to licensing problems (internal Defra/EA) and there were no suitable data available in Scotland and Northern Ireland.

The problems related to data availability and access can be characterised as a series of project constraints:

- **Data constraint:** A priority risk was identified but no or insufficient data were available to develop a quantitative response function, e.g. due to lack of monitoring or storage/archiving of data.
- **Data licensing constraint:** Data on priority risks existed but were not made available to the project due to restrictive licensing conditions (e.g. Met Office and NERC) or confidentiality concerns (e.g. abstraction license data sets).
- **Knowledge (or methodological) constraint:** Data were available but a decision was made that it would be inappropriate to attempt to develop a quantitative response function (QRF). This was the case for some risks in the natural environment theme where synthesis of the available evidence was favoured instead of developing response functions.

- **Capacity constraint:** Data sets were available but the project team did not have sufficient time to negotiate licensing terms or complete the original research needed to make use of large data sets.

As the CCRA is part of a statutory process, data licensing across Government Departments or between Government agencies and contractors working in the CCRA should not be a constraint. It is recommended that data licensing issues are addressed in 2012, prior to the start of CCRA2 (Section 2.5).

Knowledge and capacity constraints could be addressed in a number of ways but require stronger links between policy-makers, UK Research Councils and the private sector to develop evidence that is relevant at the national and regional scales for informing risk assessments and adaptation policy. The Environment Agency's National Flood Risk Assessment (NaFRA) and underpinning tools provided data and the ability to query these data that was ideal for the CCRA. National risk assessment tools were not available in any other sector, although the building blocks for similar systems exists for water resources and parts of the Health sector.

Finally, although the need for better data sets is clear there are a number of other considerations required for scoping future CCRA2s that will affect the data needed. For example:

- **What is the value of quantifying impacts versus qualitative or categorical information?** The case for adaptation action may be easier to make when impacts are quantified and monetised in terms of economic damage but policy-makers can (and often do) develop policy based on a wide range of evidence and full quantification may not be needed or desirable when uncertainties are so 'deep'.
- **Are similar levels of quantification needed to compare risks or can different types of information be brought into a comparative framework?** The CCRA outputs included simple 'onset plots' that categorised risks into 'High', Medium' and 'Low' classes. If different types of information can be successfully compared in this way, then full quantification is not needed in all sectors.
- **What kind of decision-making frameworks will be used to inform adaptation planning and what are their data monitoring and analysis needs?** The choice of decision-making framework, e.g. optimisation of investment decisions versus robust decision-making affects the kind of data needed. If an adaptive framework is being promoted then continuous monitoring of key risks is essential to inform adaptation decisions as part of regular review process.

3.3.2 Sectors, themes and interdependencies

In the CCRA an early decision was made to collect evidence from eleven 'sectors', although these were later generalised in to five overlapping themes:

- Agriculture and Forestry
- Business
- Health and Wellbeing
- Buildings and Infrastructure
- The Natural Environment.

These broader themes were able to describe some of the important cross-cutting issues. For example risks related to both flooding and extreme heat were covered in every theme.

The scope of the CCRA was always to examine ‘domestic’ risks arising due to climate impacts on activities in the UK, rather than international impacts that may have indirect impacts, which were reviewed in the Foresight International Dimensions of Climate Change (IDCC) study (Foresight, 2011). The CCRA made use of some of the outputs of the IDCC study but it was difficult to assess the relative importance of international versus national risks as the IDCC did not monetise all risks or categorise them in a similar way to the CCRA.

The acknowledged interdependencies between sectors were the main driver for developing a systematic mapping tool. This aimed to link direct and indirect impacts in one sector to impacts in other sectors through a web-based tool that allowed each Sector Champion to make entries and review entries in a large impacts database. The database included more than one thousand entries describing links between direct, secondary or tertiary impacts and consequences within and across sectors. Figure 3.3 summarises the process of data entry that was completed in up to five “passes” to build up cross-sector links.

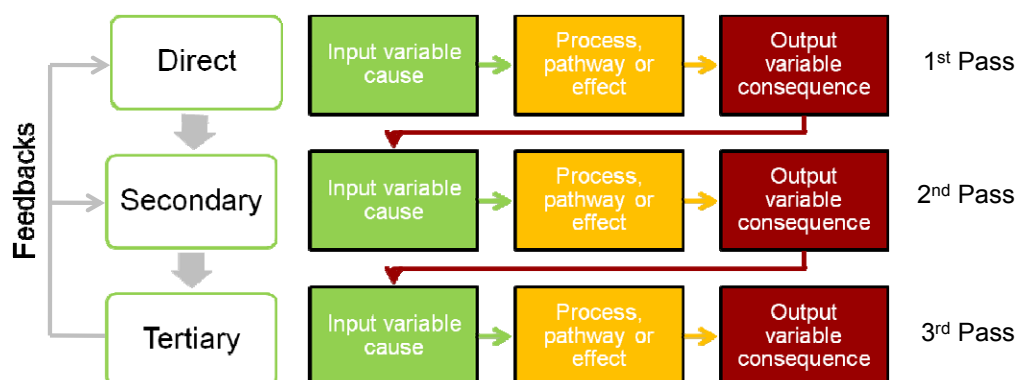


Figure 3.3 Illustration of forward chaining process in the systematic mapping tool

Despite these efforts, feedback from the project team was that the study fell short in terms of capturing the links between UK and international risks and the complex interdependencies between sectors. The systematic mapping was regarded as over-elaborate for the time allocated to this task. The project team members suggested a number of ways the cross-sector analysis could have been completed:

- Use of simple cross-sector matrices of impacts and consequences rather than attempting complex systems maps; although this was done behind the scenes as part of the risk selection and prioritisation process and as part of the development of reporting themes.
- The use of more detailed local case studies or geographical types (urban areas, coasts, uplands, etc.) to understand cross-sector risks, although it was recognised that scaling results to the national scale may be difficult. Other studies designed to inform policy do use case study approaches but scaling impacts to a national scale is then often problematic.
- A greater focus on how to identify key thresholds and feedbacks, rather than trying to identify comprehensive lists of all inter-linkages. Some kind of

early prioritisation of the most important feedbacks may have helped, although this may narrow the analysis and mean that important links are not 'discovered' as part of the systematic mapping process.

However, there were also simple practical reasons that made capturing cross-sector issues difficult:

- The UKCP09 projections provided large volumes of data of changes in future climate. Extending the analysis to the development of sets of simple biophysical indicators, such as cooling and heating degree days, soil moisture deficits and rainfall erosivity (and making these more easily available to contractors working on the statutory CCRA) would have promoted consistency between sectors and the building blocks for the 'first pass' of the systematic mapping.
- Due to the timescales of the study each sector was completed in parallel and as such outputs from key sectors such as Floods & Coastal Erosion were not available as early inputs to sectors like the Built Environment or Business. Therefore Sector Champions in 'downstream' sectors were working without full knowledge of the project outputs of flood, drought and heat wave risks. A longer study period of 3-4 years would assist in developing a cross-sector analysis.
- The general lack of integrated assessment tools meant that the cross-sector tools used in the CCRA were developed "on the job". Ongoing UK Research Council projects may provide more suitable frameworks for future CCRAs. For example, the EPSRC Arcadia project was applying a standard Source Pathway Receptor framework for assessing climate risks in London (Tranos, 2010) and the Infrastructure and Transport Research Consortium (ITRC) may also develop relevant tools.

Overall feedback suggests that this is an area of research where improvements could be made for future assessments. The systematic mapping tool and background database developed in the CCRA may provide a useful database for follow on research studies.

3.3.3 Climate change and socio-economic projections

The CCRA made extensive use of UKCP09 and other climate change scenarios but did not use a comprehensive set of socio-economic projections.

The climate change projections were simplified for use in the CCRA by focusing on only three time periods, the 2020s, 2050s and 2080s, using only the Medium Emissions in the 2020s and summarising the outputs as ranges, for example from the lower end of the Low Emissions scenario to upper end of the High Emissions scenario for the 2050s and 2080s.

The main issues raised by the project team on climate projections and their use in CCRA2 were as follows:

- Developing suitable baselines for risks, consistent with the UKCP09 baseline of 1961-1990 and our understanding of present day risks, which include some climate change was challenging. In practice, some assessments made small adjustments to future projections to take account of the warming between 1990 and 2010 and others used UKCP09 absolute data rather than 'change' data. Future climate projections are expected to provide more information on how to derive suitable baselines as we are now within the thirty year period defined as the 2020s (2011 to 2040).

- The UKCP09 projections provide information on changes in thirty year means, but many response functions were based on shorter term and often annual data. Therefore there was an assumption that changes in thirty year means would translate to similar changes in annual average climate. While this is a reasonable assumption, risks may be more sensitive to changes in the variability from year to year or occurrence of extreme conditions, which may not be well represented by this approach.
- UKCP09 did not provide enough information on extreme floods, heat waves and droughts, although follow up research using UKCP09 did provide the required information on changes in peak river flow (Kay *et al.*, 2010). For extremes, Sector Champions needed information on changes in the frequency of occurrence as well as changes in magnitude to build up an understanding of future risks. In order to develop a true risk assessment, sectors need to consider changes affecting average climate and a range of more extreme events that take account of long-term climate change and natural variability.
- UKCP09 does not cover the full range of possible changes in future climate. For sea level rise and coastal surge there is a H++ scenario, but this was only used qualitatively in the Floods & Coastal Erosion sector work. For heat waves and drought there is no equivalent H++ scenario that can be used to test the consequences of these more extreme scenarios. Some reviewers argued that the CCRA was too focused on the central Medium Emissions results and, as a risk assessment, should have focused more on High Emissions and H++ scenarios to highlight the potential risks to the UK.
- The lack of spatial coherence in UKCP09 outputs was problematic for some sector analyses. This technical issue, which means that the UKCP09 outputs for one grid square, administrative area or river basin cannot be easily combined or presented on maps (without appropriate caveats) meant that some Sector Champions preferred to use regional climate model data or even older UKCIP02 data for their assessments. In the case of the Floods sector, detailed research had already been completed and the CCRA had access to research based on both spatially coherent RCM data and UKCP09.
- Informal reviews by climate scientists from outside of the project team as well as close involvement of the UK Met Office were important to make appropriate use of UKCP09, i.e. not to overstate the robustness of the probabilities presented, while still making good use of the UKCP09 outputs. The CCRA 'navigated' an approach, which had broad acceptance and was very clear on the limits and caveats related to the study (although these were sometimes lost/compromised in the communication of headline results).

The lack of socio-economic projections was recognised as an issue in the scoping study. However the CCRA made successful use of the Office of National Statistics (ONS) population projections and provided qualitative discussion of other key drivers.

Lessons learned for CCRA2 include:

- The ONS population projections were very useful and provided a key data set that ensured consistency across the sectors. A data set on the same geographical basis should be provided with the climate projections for use on climate change studies. Further work with ONS on population based indicators and how these could be brought together with climate projections would be good preparation for CCRA2.

- Within the project there was considerable discussion on the development of bespoke socio-economic scenarios (SEs) for the project. However, we found that different drivers were important for different sectors and the utility of generic scenarios was questioned. The development of new SEs was regarded as a major task that would need to be completed prior to or in the first stage of CCRA2. However, further development of the National Ecosystem Assessment (NEA) scenarios or similar scenarios developed by the Environment Agency provide a possible practical way forward.
- Finally, a number of methodological issues were raised with respect to how climate and SEs were combined to assess risks and, more broadly, how social vulnerability and adaptive capacity were taken into account. In the CCRA, headline results were presented as a range with low population growth and low rates of climate change at one end of the spectrum and high population growth and higher rates of climate change at the other. However more detailed combinations or sensitivity tests and clearer presentation of the influence of climate versus socio-economic drivers may have provided a richer picture for policy-makers.

3.3.4 Response functions

The response function approach was borne out of the necessity to develop a workable method in the specific context of the first CCRA. Relevant factors included project timescales, the recent delivery of UKCP09 so that few detailed research studies using UKCP09 were available and the need for national scale assessments. Overall the response function approach had a number of advantages and disadvantages.

- Advantages
 - The response function methodology was flexible so that the relationship between a risk metric and climate variables could be developed based on the results of detailed modelling studies, observed relationships or expert opinion.
 - The presentation of evidence in the format of a response function was a useful simplification to show the sensitivities to climate, particularly to stakeholders who were not experts in the specific risks.
 - The use of response functions enabled modelling results based on UKCIP02 to be scaled for UKCP09 and therefore promoted consistency between sectors.
- Disadvantages
 - The use of functions was an over simplification in many cases where they were developed based on observed data, e.g. agricultural yields, but caveats were always clearly stated in each case.
 - While the use of the functions to interpolate between modelled results was valid, extrapolation to cover greater rates of warming or hydrological changes was difficult, required the use of expert opinion and reduced confidence in the results.
 - Sector analysts tried to develop quantitative functions when in many cases the evidence was too weak and expert elicitation or qualitative synthesis may have been more appropriate.

The response function approach may be useful for CCRA2 or for some sectors only. Project team discussions suggest that the approach may evolve in two directions. First, in sectors with detailed impacts or risk assessment models these will be used for CCRA2 but presenting sensitivity in a similar framework would be a useful output for comparing different risks. Secondly, where evidence is weak there should be greater use of expert elicitation and less detailed quantification using response functions.

3.3.5 Social vulnerability

In the workshop it was agreed there was a need to include social vulnerability earlier and more comprehensively in the CCRA. There were no clear conclusions with respect to the best approach for doing this but there are likely to be two parts to this:

- Development and use of indicator data from the national census, such as the Multiple Deprivation Indicator, which was used in the flood risk analysis.
- The use of more detailed and in-depth case studies of vulnerability to specific risks to inform the national assessments.

Work on social vulnerability needs to be completed early on in CCRA2 so that it informs that risk assessment rather than being a 'side line' activity.

3.3.6 Scoring systems and thresholds

Scoring systems were used for risk selection (Tier 1 to Tier 2) and describing the findings (magnitude, confidence and urgency) as a means of comparing risks across different sectors. These systems were needed because it is not possible to reduce potential impacts to a simple common metric, such as annual damages, there are multiple criteria that need to be considered when comparing risks and simplifying the outputs is useful for communicating results to a wide range of audiences.

The scoring system to select risks from Tier 1 to Tier 2 involved considering the perceived magnitude of consequences, likelihood and urgency for decision-makers. It covered social, environmental and economic consequences and retained the highest score from these criteria rather than averaging results. This approach was regarded as practical and logical by the project team. In some cases bias in the scoring may have been introduced through the selection/availability of stakeholders and the areas of expertise of the Sector Champions, although efforts were made to make the scoring as consistent and balanced as possible within the time available.

The final results of the CCRA were presented in terms of magnitude (low, medium, high), confidence (low, medium, high) and urgency (low, medium, high), which provide a useful simplification of the outputs for more than 100 risk metrics. However the class thresholds were clearly very important and, in some cases, classification required a lot of judgement, particularly when risks were not monetised or when the monetisation was partial and did not include the 'knock-on' effects of a particular risk. The approach also presented the problem of 'salami-slicing' risks into small components that were classified individually as having 'low' or 'medium' consequence when collectively they may present a 'high' consequence.

Overall, the approach to characterising risks using different criteria worked well and helped to make sense of complex results and communicate project findings. For CCRA2, more up front work on the choice of categories, thresholds and how these will be used to inform decision-making would help to guide the risk assessment methodology. For example, if this kind of categorisation is sufficient there would be less

incentive to develop fully quantified and precise results and the method could be tailored to provide these kinds of outputs instead.

3.3.7 Regional analysis

The CCRA aimed to produce national assessments for the UK and Devolved Administrations but it was recognised that the vulnerability and exposure to risks varies across the country due to a range of factors. Regional variations were partially captured in a number of ways:

- Many risk response functions and risk assessments were developed for UKCP09 administrative regions or river basin areas rather than at the national scale. Therefore broad variations in population growth and differences in the climate projections were reflected in regional maps.
- Indicators of Multiple Deprivation at a detailed spatial resolution were used in the flood risk analysis to take account of more deprived communities in inner cities and some UK coastal areas at risk of flooding.
- Risks that were related to particular landscapes, e.g. uplands, lowlands and coastlines were highlighted in the DA reports. The project team argued that this was a more helpful approach than using UKCP09 administrative regions. Local case studies were also used in the DA assessments but were not incorporated in the Evidence Report.

Overall, the geography of the risks could have been assessed in more detail and this is an area for potential improvement in CCRA2. For example, particular landscapes or geographical settings may provide a way of organising the work, which is more appropriate than sectors or themes. This approach has been taken in the past in regional scoping studies developed in the late 1990s (e.g. see West and Gawith, 2005 for a review).

Finally, the DA Reports were part of a parallel but separate process from the Evidence Report. This led to some differences in the scoring of risks and the focus and emphasis of these reports. On the one hand this provides a fair reflection of what is important from a policy perspective for Scotland, Wales and Northern Ireland, but on the other hand, some team members have highlighted the differences as discrepancies between the UK and DA reports.

3.3.8 Autonomous or planned adaptation

The methodology originally planned to specifically include autonomous adaptation and planned adaptation, but a number of factors meant that this was not implemented.

- Timescales meant that the work needed on adaptive capacity was not available to inform assumptions on autonomous adaptation for the risk assessment.
- The change of Government in May 2010 meant that the CCRA was out of step with the policy development process and unable to make assumptions on policy direction and Government adaptation action.
- The evaluation of options and their effectiveness fell within the scope of the subsequent Economic of Climate Resilience study.

For CCRA2 careful consideration should be given to joining the CCRA with ECR methods to allow iterative evaluation of adaptation options. For example, in sectors

with impact assessment models, a wide range of adaptation options could be tested in the models and then existing or new policy options could be refined to reduce residual risks.

Alternatively CCRA2 may be able to make some much simpler assumptions on anticipated adaptation based on the first National Adaptation Programme (NAP) and then the NAP2 may subsequently be refined in light of the CCRA2 outcomes.

3.3.9 Adaptive capacity

The adaptive capacity work was an innovative part of the project, which produced some useful findings that influenced the CCRA but are now being fed into the subsequent Economics of Climate Resilience study. The adaptive capacity findings were not as fully integrated into the risk assessment as originally proposed in the Methods Reports. This was due to timescales, difficulties of generalising and integrating findings in some sectors and programme level decisions on how to take account of government policy. This was primarily a problem of implementation rather than methodology.

The project team found that some aspects of the adaptive capacity worked well, for example:

- The process of completing a PACT assessment and more in depth interviews was received well by users involved, who saw the value of taking stock of their organisation's capacity and understanding how they could improve.
- The project contributed to conceptual developments of the PACT tool that led to the clearer distinction between organisational and structural adaptive capacity.
- The early CCRA work to select key risks provided a focal point and allowed the adaptive capacity work to investigate the decisions that affect those risks. The adaptive capacity work was the only place where there was a real focus on decision-making and this was important and contributed to the development of the "urgency" criteria applied to the CCRA results.

Other aspects were particularly challenging for this first CCRA:

- Early discussion within the team on the most appropriate 'integrating framework' for incorporating adaptive capacity was not completed as other aspects of method development, such as risk selection and the monetisation, became higher priority.
- While the organisational adaptive capacity approach was very well developed (and proven), the structural capacity approach was new and there was insufficient time to fully develop the concepts, explain to key stakeholders (e.g. ASC) and implement.
- Adaptive capacity work requires significant time and resources to cover all the relevant organisations and key decisions related to adaptation; the CCRA partially covered five sectors and therefore the evidence could not be used consistently across eleven sectors.

An important early consideration for scoping CCRA 2 is the 'integrating framework' that will bring together evidence on risks, vulnerability, adaptive capacity and consider the contents of the National Adaptation Plan.

3.4 Summary of key issues

In appraising the methodology for the CCRA we have identified strengths and weaknesses of specific aspects of the project. Some issues are related to the original methodology, others are related to data availability or implementation of the method. The key issues are summarised in Figure 3.4. The scores relate to how well these steps performed within the context of the methodology as a whole, rather than as individual activities.

	Performance			Importance	
	Method	Data	Implementation	CCRA1	CCRA2
1. Literature review & Tier 1 analysis	Good	Good	Good	High	Low
2. Identification of cross-sectoral & indirect consequences	Fair	Limited	Limited	Medium	High
3. Review of policy	Limited	Limited	Limited	Low	Medium
4. Social vulnerability	Fair	Limited	Limited	Medium	High
5. Adaptive capacity	Good	Fair	Fair	Medium	High
6. Selection of Tier 2 impacts	Good	Fair	Fair	High	Medium
7. Identify risk metrics	Good	Fair	Fair	High	High
8. Response functions	Good	Fair	Fair	High	Medium
9. Estimates of change in selected climate change scenarios	Good	Fair	Fair	High	High
10. Socio-economic change	Fair	Limited	Fair	Medium	High
11. Economic impacts	Good	Fair	Fair	Medium	High
12. Report outputs	Fair	N/A	Good	High	High

Figure 3.4 Summary of performance of different parts of the methodology

The weakest part of the methodology was the policy mapping. Whilst not surprising as the method is mostly a top-down (science led) risk assessment, this aspect also suffered from the change of Government and stage of the policy development cycle. For CCRA2 the methods could be more sharply focused on the kinds of adaption decisions that need to be made and this should be helped by the publication of the National Adaptation Plan.

There were lots of issues related to data availability, which are relevant for the methodology and may be filled by more targeted research. For example, projects such as ARCADIA and the ITRC may fill important gaps related to understanding cross-sectoral risks. The lack of new socio-economic scenarios was a known gap at the beginning of the project that needs to be filled for CCRA2.

Finally, there were many issues related to implementation, in part due to timescales, which reinforces the need for a clear integrating framework, better guidelines for sector leads and other team members and clearer definition of outputs, review processes and how CCRA findings are integrated into the National Adaptation Programme.

3.5 Recommendations

The following recommendations are made with respect to the methodology, although some touch on issues related to research and project process (which are also discussed in other chapters of this report):

- Review existing EA and NEA socio-economic scenarios and select an appropriate framework for using SESs in CCRA2.
- Review scope of Met Office climate change projections research to check that it meets requirements of CCRA2; develop a package of relevant biophysical indicators, which will be made available at the start of CCRA2¹⁰.
- Ensure that data licensing and access are agreed between Government departments and agencies at the start of CCRA2.
- Scope changes to the methodology with key stakeholders¹¹, focusing on development of a practical integrating framework that can combine evidence on risks, social vulnerability and adaptive capacity. In particular:
 - Keep an open mind to completely new approaches for CCRA2.
 - Consider whether the findings of the CCRA can be used to narrow the scope of CCRA2, e.g. so it provides an in depth update of some risks/sectors/regions only.
 - Review Research Councils UK studies that will complete in 2012 or early 2013 to determine whether they can inform CCRA2 (EPSRC have funded an LWECC research fellow to do this).
 - Complete this scoping work prior to starting CCRA2.
- Maintain the list of risk metrics developed in the CCRA as a baseline set and select sub-sets that may provide useful indicators of current and future risks; set up data licensing arrangements so that annual or periodic monitoring is possible.
- Maintain the concept of a response function as a means to show the sensitivity of a risk metric to climate variability and/or change but apply it more carefully, e.g. avoid developing quantitative risk response functions if these are not robust and use expert elicitation, categorical matrices and/or synthesis of evidence instead to inform decision-makers.
- Work on the 'decision matrix' and thresholds first to understand clearly what outputs are needed to inform decisions. The assessment in Chapter 9 of the Evidence Report provides a preliminary framework that needs further work.
- Ask users what information they want and how it is best organised, e.g. by sector, region, landscape type, etc.; develop a mechanism possibly with UKCIP for managing and collating regional and local evidence for CCRA2.

¹⁰ This may need to involve research institutes, such as CEH, POL and Cefas as well as the Met Office UKCP team.

¹¹ The scoping work could involve CCRA team members, ASC, Defra and invited researchers; however this work may already be underway but has not involved HRW team members.

4 Research needs

4.1 Summary of key issues

A full list of identified research gaps is provided in Appendix 4. Research gaps were identified at an early stage in the CCRA project and are discussed at length in the Sector Reports and Evidence Report. Many of the issues discussed in Chapter 3 also make reference to the need for better data and information in a number of sectors.

Rather than repeating this material, this Chapter takes a step back and focuses on the relatively 'quick wins' where ongoing research or new applied research projects that can be delivered in the short-term can help to deliver CCRA2.

Five key gaps have come up repeatedly throughout the assessment:

1. Improved projections of potential changes in extremes including droughts, heat waves and intense rainfall.
 - a. Research on flood risks related to sea level rise and increases in longer duration rainfall were relatively well covered in the CCRA due to research completed as part of UKCP09 and subsequent research projects by CEH (Kay *et al.*, 2010).
 - b. Work on droughts, heat waves and intense shorter duration rainfall was less well developed; even though climate models have good skill at projecting high temperatures the impacts research seemed less well developed than in floods.
 - c. This research should include a robust set of 'H++' scenarios that describe a range of 'low probability-high consequence' changes in climate that could have serious implications for UK society.
2. A standard set of biophysical indicators to inform the risk assessment.
 - a. Even though UKCP09 made some progress in this regard, a fuller suite of biophysical indicators needs to be made available at the beginning of CCRA2.
 - b. Many indicators could be developed by the Met Office Hadley Centre and other climate scientists as part of ongoing work programmes but some will require specialist input from impacts experts. Some indicators used in the CCRA, like the fire hazard indicator, were based on international research rather than specifically on UK conditions.
 - c. National agricultural and forestry growth models that consider temperature, soil moisture and CO₂ may be a useful addition to a standard suite of biophysical indicators. However impacts models will also need to consider a range of other land suitability and socio-economic factors.

3. An agreed set of socio-economic scenarios for climate change risk assessment, including baseline information on social vulnerability and adaptive capacity.
 - a. The lack of socio-economic scenarios was highlighted before the main CCRA project started and it remained an issue throughout the project. Review work to make best use of existing UK NEA and EA scenarios would provide a quick win for CCRA2.
4. Better evidence on how international impacts affect UK society, including an understanding of current and future risks.
 - a. The IDCC report provided a useful review for the CCRA, but some review work, perhaps as part of the socio-economic scenarios development, is needed to develop a clearer review on the relative importance of international versus domestic risks on UK society.
5. A robust and practical integrating framework is needed to combine evidence on risks, social vulnerability and adaptive capacity as well as evidence from national assessments and more detailed case studies and both quantitative and qualitative data.
 - a. Rather than a theoretical model or advanced research approach, this needs to be a practical method, understood by stakeholders and focused on the kinds of adaptation decisions that need to be made as part of the NAP process.

5 Stakeholder engagement

5.1 Purpose

Stakeholder engagement was an essential element of the CCRA. It helped the team to obtain information that was not necessarily available in written reports. At the same time, involving people with an interest in the risk assessment was a good way of raising awareness of the work being carried out and developing a sense of ownership of the outcomes.

5.2 How stakeholders have been involved

The CCRA team tried to involve stakeholders in ways that were relevant to their interests and expertise. This covered a range of different engagement activities over the course of the risk assessment:

CCRA Forum - The CCRA Forum was set up in January 2010. The Forum involves a cross-section of stakeholders, from different parts of the UK, different types of organisation and different areas of interest. As a group, Forum members provide an overview of issues, across sectors and across geographical and administrative boundaries. There were four Forum workshops as part of the project.

Sector Workshops - Early on during the risk assessment (May 2010) workshops were held with stakeholders from nine different sectors; telephone interviews with stakeholders were undertaken for the remaining two sectors. 155 people participated in the workshops. They were able to comment on an initial list of impacts for their sector, identify any important omissions to the list, give their views on the reliability of the data being used and discuss other potential data sources. They also discussed the criteria for prioritising impacts and suggested potential 'risk metrics' for the impacts.

DA Workshops - Stakeholders from Scotland, Wales and Northern Ireland participated in meetings in March¹² and workshops in September 2010. They also had the opportunity to provide online feedback after the September workshops, on the relevance of the climate change impacts identified. This input has helped the team to tailor the CCRA outputs to be of value to each country.

Online Feedback – For stakeholders unable to attend the sector or DA workshops, there were opportunities between August and October 2010 to provide online feedback on sector and DA impacts and to identify missing impacts.

English Workshops - Between November 2010 and January 2011 almost 150 stakeholders participated in workshops in the English areas. By this stage the risk assessment had identified the important climate change impacts for the UK as a whole. During the workshops participants had the opportunity to say which of these impacts are particularly important for their areas and to provide real-place evidence of these impacts. They also told us about studies specific to the area.

¹² Northern Ireland and Scotland only

Policy Reviews - From November 2010 onwards, central UK Government Departments, the Devolved Governments and selected non-government stakeholders reviewed the Sector Reports relevant to their area of activity and Evidence Report, once available.

DA Reviews - From February 2011 onwards, the Devolved Governments and their selected stakeholders reviewed the DA Reports.

Peer Reviews - Alongside the policy reviews described above, the Sector Reports and Evidence Report were also reviewed by academic experts that had not been involved in the project, in order to ensure that the reports were as technically robust as possible.

Figure 5.1 provides an overview of the timings for these activities. Further information on the stakeholder engagement activities can be found in Annex A.

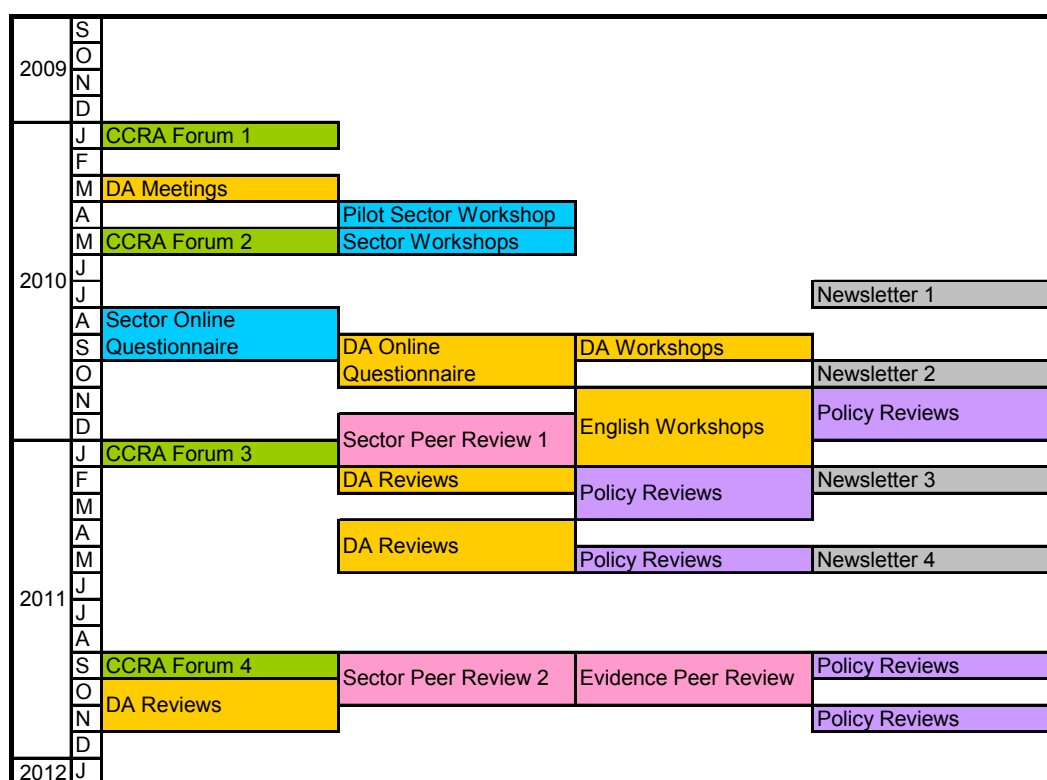


Figure 5.1 CCRA stakeholder engagement timeline

5.3 Summary of key issues

The CCRA stakeholders made a significant difference to the focus, content and shape of the CCRA by:

- Highlighting the impacts that were most important to assess
- Identifying the relevance of particular impacts to different parts of the UK
- Providing data and evidence
- Helping to shape how the findings from the CCRA were communicated.

The involvement of such a large number of different types of stakeholders lays the foundations for broad based involvement in the National Adaptation Programme.

As part of the CCRA project, CEP carried out an evaluation of the stakeholder engagement activities, which is detailed in Annex A. This identified the following key issues:

- Changes to the planned engagement process leading to less involvement of some stakeholders during the latter stages of the project may have reduced their buy-in to the final results of the risk assessment. For example:
 - While the voting approach to prioritising risks during the sector workshops was seen as democratic and transparent, some stakeholders expressed concern that such an approach led, in some cases, to risks being prioritised based on group perceptions of importance, rather than specific expertise or evidence. As follow-up workshops were cancelled, stakeholders were not given the opportunity to discuss how the results from the workshops were interpreted by the technical team and, hence, where further expert views were applied to increase confidence in the selection of the priority impacts.
 - Some stakeholders involved in the sector workshops felt 'disconnected' from the final CCRA outputs as they could not see how the workshops influenced the final reports. Again, this may have been partly the result of the follow-up workshops being cancelled and may also relate to the limited use of newsletters. This may have led to a lack of transparency in the process for the wider stakeholder group.
- Levels of ownership and buy-in are much higher among stakeholders with more involvement in the CCRA development, such as those attending multiple sector workshops and/or the CCRA Forum and, in particular, those involved in the review of the Sector and Evidence Reports during the latter stages of the project.
- The Business, Industry & Services sector was relatively unrepresented, and did not input as much information and data to the CCRA as other sectors. For the second CCRA it will be important to engage with this sector early in the process, and perhaps in different ways.
- Many issues may have been more appropriately addressed as cross-sectoral as they were considered by sector stakeholders to fall into more than one, and sometimes many, of the sector categories as defined in the CCRA process.

Further discussion of these issues is provided in the Stakeholder Engagement Evaluation Report in Annex A.

5.4 Recommendations

Stakeholder engagement should remain an important element of future CCRA with the purpose of:

- a. Ensuring the project remains focused on what is important for stakeholders
- b. Providing additional information and data for analysis
- c. Exploring ways to communicate risks effectively
- d. Building greater adaptive capacity within stakeholder organisations
- e. Encouraging stakeholder buy-in to the project findings.

The following recommendations are made for maximising the benefits of future stakeholder engagement:

- Be realistic and pragmatic about the scale of the stakeholder engagement that will be undertaken. Although it is important to aspire for as wide a stakeholder group as possible, be clear at the start about the reasons for involving different types of stakeholder, the resources and time required and what they will be able to contribute, as managing stakeholder expectations can become difficult.
- Generally, the second CCRA process should aim to be more open, especially during the latter stages of the project. One specific suggestion is to make documents more widely and easily available to stakeholders during the project. However, measures would have to be put in place to manage the review and provide clarity about how documents have been updated in response.
- Ensure that engagement is, as far as possible, a continuous process, with a logical progression through a series of events, providing stakeholders with opportunities to input throughout. Specifically more than one workshop is recommended in each sector¹³, with additional workshops perhaps adding value by exploring specific themes.
- There is a need to develop 'smarter' ways of working and communicating with stakeholders, encouraging their input across sectors rather than in specific 'silos'; this is particularly the case for certain areas, such as the Business, Industry & Services and Biodiversity & Ecosystem Services sectors.
- Better and more consistent feedback from the project team should be provided to stakeholders. This may be a key factor in encouraging ownership and buy-in and will demonstrate to stakeholders that their views and knowledge are valued. Greater involvement in workshops on the part of the client could also be one relatively simple way to indicate to stakeholders that their views are valued.

Further discussion of these issues is provided in the Stakeholder Engagement Evaluation Report in Annex A.

¹³ Assuming sectors are used next time.

6 Key recommendations

The following provides a brief summary of the key recommendations from this report. Further, more detailed, recommendations are provided in the preceding chapters.

6.1 Headline messages

- Read this report and build on the foundations put in place by this first CCRA, learning from what worked well and tackling head on problems that were faced.
- Make sure that the right technical expertise is available within the delivery team at the right time and that they are able to take ownership of their technical area.
- Make sure that the contractor and client work together to understand fully the client's needs and those of the intended audience.
- Make sure that full use is made of stakeholders throughout the project to stay focused on the intended audience and as a source of valuable information.

6.2 Project delivery

- Work with other Government Departments and the Adaptation Sub-Committee to review the analysis undertaken for this first CCRA and identify priorities for CCRA2.
- Scope the project in detail as early as possible, taking into consideration issues such as the intended audience; publications and their review; revisions to the method; latest research and remaining gaps in knowledge; data and modelling needs; and how to involve stakeholders.
- Set a realistic programme that allows for detailed scoping in advance of commissioning the project and then allows sufficient time to carry out technical work prior to the review stages.

6.3 Method development

- Review existing Environment Agency and UK National Ecosystem Assessment (UK NEA, 2011) socio-economic scenarios and select an appropriate framework for using socio-economic scenarios in CCRA2.
- Review scope of Met Office climate change projections research to check that it meets requirements of CCRA2; develop a package of relevant biophysical indicators, which will be made available at the start of CCRA2¹⁴.

¹⁴ This may need to involve research institutes, such as CEH, POL and Cefas as well as the Met Office UKCP team.

- Scope changes to the methodology with key stakeholders¹⁵, focusing on development of a practical integrating framework that can combine evidence on risks, social vulnerability and adaptive capacity.
- Work on the 'decision matrix' and thresholds first to understand clearly what outputs are needed to inform decisions. The assessment in Chapter 9 of the Evidence Report provides a preliminary framework that needs further work.
- Ensure that data licensing and access are agreed between Government Departments and agencies at the start of CCRA2.

6.4 Research

The research needs for CCRA2 broadly reflect the data gaps and methodological areas that worked less well. However, two additional research needs are:

- Improved projections of potential changes in extremes including droughts, heat waves and intense rainfall. This research should include a robust set of 'H++' scenarios that describe a range of 'low probability-high consequence' changes in climate that could have serious implications for UK society.
- Better evidence on how international impacts affect UK society, including an understanding of current and future risks. While the International Dimensions of Climate Change study made good progress (Foresight, 2011), more research is needed to bring international risks into the CCRA methodology.

6.5 Stakeholder engagement

- Be very clear at the outset about the scope of the stakeholder engagement, i.e. who to involve and how.
- Plan a continuous process of engagement with a logical progression through a series of events.
- Find smarter ways of working and communicating with stakeholders, especially with groups that traditionally are hard to engage.
- Provide regular feedback to stakeholders to encourage ownership of the process and aim to make the next CCRA as open as possible throughout to retain that ownership.

¹⁵ The scoping work could involve CCRA team members, ASC, Defra and invited researchers; however this work may already be underway but has not involved HRW team members.

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Appendices

Appendix 1 – Review Workshop

Aims

The overall aim of the workshop was to contribute information and suggestions for the CCRA2 Recommendations Report.

Specifically, the workshop aimed to:

- Identify the aspects of the CCRA methodology that worked well and those that worked less well and the reasons for this.
- Make recommendations about how the weaknesses identified could be overcome.
- Review research currently being undertaken or planned that could help to address some of the weaknesses of the CCRA.
- Identify research gaps that, if filled, could contribute to the improvement of the overall methodology or specific topics (taking account of known existing and future research programmes).
- Identify the main ways that stakeholder engagement contributed to the CCRA, assess the effectiveness of the engagement methods used and make suggestions about how the stakeholder engagement process could be improved.

Agenda

10:30 – 11:00	Arrival and refreshments
11:00 – 11:30	Welcome, introduction and scene-setting
11:30 – 13:00	Session 1: Methodology [Break-out groups and plenary sessions] • Understanding what worked well or not so well and why. • How to address challenges.
13:00 – 13:45	Lunch break with buffet
13:45 – 14:50	Session 2: Research Needs [Break-out groups and plenary session] • What are main gaps in current or planned research that, if filled, would benefit the next CCRA? • How and when can these research gaps be filled? • What would need to happen to enable this research to be undertaken?
14:50 – 15:10	Afternoon break with refreshments
15:10 – 16:15	Session 3: Stakeholder Engagement [Break-out groups and plenary session] • What did the stakeholder engagement contribute to the CCRA? • What elements of the stakeholder engagement / engagement methods did not work so well? • What should we do differently next time in terms of stakeholder engagement?
16:15 – 17:00	Session 4: Reality check and wrap-up
17:00 – 18:00	Informal chat and refreshments

Summary of findings

The following provides a brief overview of the main messages that came from the workshop. A more detailed record of the workshop outputs has not been reproduced here as, in general, these are reflected in the main body of this report.

Methodology

Headline messages:

- Scoring System – most concerned about areas that had little data e.g. ecosystem services
- Regional aspects – there is a lot that can be said about this e.g. how could we frame a ‘region’ for next time?
- Response functions – due to time constraints we couldn’t really test these and we should start now to get more data.
- Method development – integration (conceptually and practically) and considering adaptation up front.
- Key areas for investment –
 - Cross-sectoral issues and interdependencies.
 - Process and governance issues – lack of institutional memory within Government (given constant change over of personnel).

Group discussions:

1. Scoring system and thresholds

- Feedback focused on the Tier 2 selection process rather than later scoring system used for presenting the findings.
- In general the Tier 2 selection process was conceptually considered good, but there was a lack of confidence in some of impacts selected. There was concern that some impacts may have been underscored and that impacts may have not been chosen because they could not be scored economically with any confidence.
- Concerns were raised regarding the ‘normalisation’ process and this step may have benefitted from greater involvement by the Sector Champions.

2. Method development, social vulnerability and use of data

- One of the headline messages is the need for greater ‘integration’, but how this should actually manifest itself is less clear beyond the recognition that we need to develop a ‘conceptual framework’.
- Although the need to include social vulnerability earlier and more comprehensively is clear, there is no suggestion how. [But see ‘Outputs at the regional scale’ below.]
- What is clearer is that more work on building more appropriate response functions would be beneficial.

- It was also recognised that we need to be mindful of the purpose of the assessment and consider how adaptation could be taken into consideration. This links to the conceptual framework mentioned above.

3. Sectors, themes and interdependencies

- The usefulness of the systematic mapping was questioned in the brainstorming session, but this is not discussed much by the breakout group.
- The main conclusion appears to be that we needed something in addition to the systematic mapping to look at cross-sectoral issues. Some form of specialist group would have been a good idea to discuss these issues more fully.
- Inclusion of international risks is clearly an issue and also highlighted by other groups.

4. UKCP09 projections and socio-economic scenarios

- When to consider SES and how to build up an understanding of present and future risks is important and could have been tackled differently.

5. Outputs at a regional scale

- Constraining the assessment to the political regions was not particularly helpful and a more useful assessment could be based on agri-climatic zones, which would enable focus to be given to, for example, fenland agriculture in the east of England or industrial towns and cities in the Midlands, etc.
- There is also value to be gained from looking at local case-studies, which had been done for the DAs and English Areas, but did not make it through to the Evidence Report.
- The high-level UK assessment could be enhanced by looking at the geographical variation in receptors, e.g. regional GDP, population, deprived areas, people in education, types of agricultural production, etc. This seems like a potential means of bringing social vulnerability more fully into the assessment.

Research Gaps

A large amount of information on research gaps is already provided in the Sector Reports and the earlier Research Gaps Report. However, the main messages from discussions were as follows:

1. Conceptual framework and method refinement

- We need a more sophisticated framework that encompasses adaptation and social vulnerability, as well as socio-economic and climate change.
- Tweaks are also needed to a number of elements of the existing method that would benefit from early research (rather than development on the job) including the scoring processes, response functions, SES, etc.
- We need to look at whether we can move away from sectors, as previously used, yet still find a way to ensure delivery of findings in a useable way (this links to systems analysis and interdependencies).

2. Understanding extremes

- We need better projections of future change in climate extremes.
- We need to understand better the effects of these climate extremes, not just mean climate conditions.

3. Data and information

- There are some fundamental issues regarding data availability, quality and usage.
- We need to better understand what data is available and how this could be improved.

4. Bio-physical effects of climate change on natural systems

- There is still a lot learn about effects on UK habitats and ecosystem services (in particular soils), which requires basic data collection and analysis

5. Economics of natural systems

- A much better understanding is needed of economics of all natural systems. The economics of marine impacts was particularly highlighted.

6. Systems analysis and interdependencies

- Other approaches need to be looked at alongside further development of the systematic mapping, such as supply chains and value chains in complex systems.

7. Risk communication and public awareness

- It may be useful to find out how the outputs from this first CCRA have been used and how they could be put to better use.
- Coupled with this would be analysis of alternative ways of presenting risk and how to influence decision-making as a result.

Stakeholder Engagement

Information on the findings from the workshop is included in Annex A. However, the headline messages from discussions were as follows:

1. There is a large community of stakeholders resulting from the first CCRA that should be built upon next time round rather than starting from scratch.
2. Stakeholders contributed a great deal to the project and we learnt a lot from them.
3. The change in the client's view on engagement part way through the project made things difficult.

Reality Check

The purpose of this session was to check back over the earlier discussions and highlight the most important message for future CCRA teams:

1. Employ the right people to do the job.
2. Make sure you make full use of stakeholders throughout the project.

3. Work as a team with the Client team to help them understand what they need, recognising that the client is cross-governmental.
4. Build on this first CCRA, learning from what worked well and tackling head on the problems that we faced this time.

Appendix 2 – List of CCRA Reports and Other Outputs

Method Reports

Defra (2010a) Method for undertaking the CCRA, UK 2012 Climate Change Risk Assessment, Defra, London, Report No: D.1.3.3 by HR Wallingford, The Met Office, Alexander Ballard Ltd, Collingwood Environmental Planning, Entec Ltd UK, Paul Watkiss Associates, Metroeconomica.

Defra (2010b) Method for undertaking the CCRA Part II - Detailed Method for Stage 3: Assess Risk, UK 2012 Climate Change Risk Assessment, Defra, London, Report No: D.2.1.1 by HR Wallingford, The Met Office, Alexander Ballard Ltd, Collingwood Environmental Planning, Entec Ltd UK, Paul Watkiss Associates, Metroeconomica.

Both of these reports were published and further discussion of these reports is provided in Sections 3.1.3 and 1.1.1.

CCRA (2012b) Climate Change Risk Assessment Methodology Report, UK 2012 Climate Change Risk Assessment, Defra, London, by HR Wallingford, The Met Office, Alexander Ballard Ltd, Collingwood Environmental Planning, Entec Ltd UK, Paul Watkiss Associates, Metroeconomica.

At the time of writing, this report is still be drafted, but will be available soon.

CCRA Evidence Report

CCRA (2012a) The UK Climate Change Risk Assessment 2012: Evidence Report, Defra, London.

Details of the content and purpose of this report is provided in Chapter 2.

Devolved Administration Reports

CCRA (2012c) A climate change risk assessment for Northern Ireland, Defra, London.

CCRA (2012d) A climate change risk assessment for Scotland, Defra, London.

CCRA (2012e) A climate change risk assessment for Wales, Defra, London.

Details of the content and purpose of these reports are provided in Chapter 2.

CCRA Sector Reports

Baglee, A., Haworth, A. and Anastasi, S. (2012) CCRA Risk Assessment for the Business, Industry and Services Sector. UK 2012 Climate Change Risk Assessment, Defra, London.

McColl, L., Betts, R. and Angelini, T. (2012) CCRA Risk Assessment for the Energy Sector. UK 2012 Climate Change Risk Assessment, Defra, London.

Moffat, A.J., Morison, J.I.L., Nicoll, B., and Bain, V. (2012) CCRA Risk Assessment for the Forestry Sector. UK 2012 Climate Change Risk Assessment, Defra, London.

Brown, I., Ridder, B., Alumbaugh, P., Barnett, C., Brooks, A., Duffy, L., Webbon, C., Nash, E., Townend, I., Black, H. and Hough, R. (2012) CCRA Risk Assessment for the Biodiversity and Ecosystem Services Sector. UK 2012 Climate Change Risk Assessment, Defra, London.

Hames, D. and Vardoulakis, S. (2012) CCRA Risk Assessment for the Health Sector. UK 2012 Climate Change Risk Assessment, Defra, London.

Knox, J.W., Hurford, A., Hargreaves, L. and Wall, E. (2012) CCRA Risk Assessment for the Agriculture Sector. UK 2012 Climate Change Risk Assessment, Defra, London.

Capon, R. and Oakley, G. (2012) CCRA Risk Assessment for the Built Environment Sector. UK 2012 Climate Change Risk Assessment, Defra, London.

Ramsbottom, D., Sayers, P. and Panzeri, M. (2012) CCRA Risk Assessment for the Floods and Coastal Erosion Sector. UK 2012 Climate Change Risk Assessment, Defra, London.

Rance, J., Wade, S.D., Hurford, A.P., Bottius, E. and Reynard, N.S. (2012) CCRA Risk Assessment for the Water Sector. UK 2012 Climate Change Risk Assessment, Defra, London.

Thornes, J., Rennie, M., Marsden, H. and Chapman, L. (2012) CCRA Risk Assessment for the Transport Sector. UK 2012 Climate Change Risk Assessment, Defra, London.

Pinnegar, J., Watt, T., and Kennedy, K. (2012) CCRA Risk Assessment for the Marine and Fisheries Sector. UK 2012 Climate Change Risk Assessment, Defra, London.

Details of the content and purpose of these reports are provided in Chapter 2.

Sector Scoping Reports

Baglee, A. (2010) The UK's First Climate Change Risk Assessment: Business Industry and Services Phase 1 Report, Acclimatise, 26 March 2010.

Brown, I. and Black, H. (2010) The UK's First Climate Change Risk Assessment: The Natural Environment – Key issues for biodiversity and ecosystem services, Macaulay Institute, January 2010.

Capon, R. (2010) The UK's First Climate Change Risk Assessment: Built Environment Sector Early Report, February 2010.

Knox, J., Weatherhead, E., Hess, T., Daccache, A. and Morris J. (2010) Climate Change Risk Assessment: Agriculture Sector Scoping Study, Cranfield University, February 2010.

Mathison, C. and Palin, E. (2010) The UK's First Climate Change Risk Assessment: Energy sector early issues report, Met Office, March 2010.

Moffat, A. and Morison, J. (2009) The UK Forestry Sector – Report to Climate Change Risk Assessment Consortium, Forest Research, December 2009.

Pinnegar, J., Kennedy, K., Pilling, G., Feist, S., Dye, S. and Rangdale, R. (2009) The UK's First Climate Change Risk Assessment: Marine Sectoral Early Issues Report, Cefas, December 2009.

Reynard, N. (2010) The Water Resources Sector – Phase 1 report to the Climate Change Risk Assessment, Centre for Ecology & Hydrology, March 2010.

Sayers, P. (2010) The UK's First Climate Change Risk Assessment: Floods and Coastal Erosion, HR Wallingford, February 2010.

Thornes, J. (2010) The UK's First Climate Change Risk Assessment: Transport Phase 1 Report, University of Birmingham, January 2010.

Vardoulakis, S. (2010) The UK's First Climate Change Risk Assessment: Health Sector Scoping Study, London School of Hygiene & Tropical Medicine, March 2010.

During the early stages of the project, the Sector Champions provided a review of existing evidence on climate impacts for their sector. These Sector Scoping Reports provided background information on what was known at the time for each sector and informed the development of the remaining phases of the project. They acted as the starting point for developing the Tier 1 list of impacts for each sector, which is discussed in more detail in Section 3.2.

Inception Report

HR Wallingford (2009) Inception Report. Project Deliverable number D.1.1.2, October 2009. CCRA internal project report for Defra.

An initial Inception Report was produced after 1 month of the project contract, which contained details of the agreed project tasks, programme and initial ideas on the method. This report was unpublished and is discussed further in Section 3.1.2.

Pilot Study Report

HR Wallingford (2010b) Climate Change Risk Assessment 2012: Pilot study on the water resources sector. Project Deliverable number D.2.3.1, July 2010. CCRA internal project report for Defra.

A pilot study was undertaken for the water resources sector to test the risk assessment method proposed for the CCRA. This highlighted both strengths and weaknesses of the methodology and lessons learnt from the pilot resulted in refinements to the method. This is discussed in more detail in Section 3.1.4.

The report did not present the full results for the water sector and further work was undertaken in order to produce the Water Sector Report to the same specification as the other sectors. Therefore, this report has not been published.

Systematic Mapping Report (Published)

CCRA (2011) Systematic mapping report. UK 2012 Climate Change Risk Assessment, Defra, London, Report No: D.2.7.3 by HR Wallingford, The Met Office, Alexander Ballard Ltd, Collingwood Environmental Planning, Entec Ltd UK, Paul Watkiss Associates, Metroeconomica.

This report describes the tool used during the project to identify links between causes of change and their consequences and the processes that lead to that change.

Research Gaps Report

HR Wallingford (2010a) Research Gaps. Project Deliverable number D.1.6.1, March 2010. CCRA internal project report for Defra.

This report provides an assessment of research gaps based on a review of current research and the scoping studies carried out for the 11 sectors. It was issued to Defra in early 2010, but has not been published.

Adaptive Capacity Report

Ballard, D.I., Black, D.G. and Lonsdale, K. (2011) Assessment of the UK's Adaptive Capacity for responding to the impacts of climate change. UK 2012 Climate Change Risk Assessment, Defra, London.

As part of the CCRA project, an assessment was carried out of the UK's adaptive capacity for responding to the impacts of climate change.

The original plan had been that the main findings from the adaptive capacity assessment would be incorporated into the Evidence Report and Sector Reports. However, it was decided to separate this work from the main CCRA findings, as further work was required to develop sufficiently robust findings for publication.

Work is still ongoing with the stand-alone Adaptive Capacity Report following a peer review process in February/March 2012.

English Areas Report

CCRA (2011) A climate change risk assessment for English Areas. Project Deliverable number D.3.2.1, April 2011. Draft only.

At the outset of the project, the intention had been to produce a single report covering Scotland, Wales, Northern Ireland and the nine England areas. It then became apparent that, due to the scale of information available, separate reports were required in order to provide 'standalone' assessments for Scotland, Wales and Northern Ireland that would form the main evidence base for the adaptation programmes for devolved matters to be carried out in these countries.

In parallel to this, it was decided to produce a separate report for England that presented the findings of the CCRA for the nine English areas, along with case studies provided by local stakeholders.

This report got as far as release 2, but following the dismantling of the Regional Development Authorities there was no longer a 'client' for this work and the report was shelved.

This work has been superseded by 'information packs' produced by the Climate Change Partnerships (CCPs) across England highlighting key risks and opportunities from climate change within each English area. These are available on the CCPs' web pages, also accessible through the Defra CCRA web page or Climate UK.

Miscellaneous Interim Deliverables

Alexander Ballard Ltd (2010) Climate Change Risk Assessment 2012: Communications plan. Project Deliverable number D.1.9.2, February 2010. CCRA internal project report for Defra.

Collingwood Environmental Planning (2010) Climate Change Risk Assessment 2012: Detailed stakeholder engagement plan. Project Deliverable number D.1.7.4, February 2010. CCRA internal project report for Defra.

Entec (2010) UK Climate Change Risk Assessment: Policy Risk Mapping Project Deliverable number D.2.5.1, July 2010. CCRA internal project report for Defra (draft only).

HR Wallingford (2009b) Interim report on the development of the CCRA method. Project Deliverable number D1.3.1, October 2009. CCRA internal project report for Defra.

HR Wallingford (2010c) Tier 2 Interim Report. Project Deliverable number D.2.5.2, September 2010. CCRA internal project report for Defra.

HR Wallingford and Met Office (2010) Synthesis Report – International climate change issues. Project Deliverable number D.1.2.1, March 2010. CCRA internal project report for Defra.

Twigger-ross, C. and Orr, P. (2011) Social vulnerability to climate impacts. UK 2012 Climate Change Risk Assessment, Defra, London. Report No: D.3.3.4 by HR Wallingford, The Met Office, Alexander Ballard Ltd, Collingwood Environmental Planning, Entec Ltd UK, Paul Watkiss Associates, Metroeconomica.

Workshop Records

Detailed records were produced for all stakeholder workshops and were made available to workshop delegates as well as the Client team a few weeks after each workshop.

Newsletters

Newsletters for stakeholders were originally intended to be issued every 3 months throughout the project to keep them up to date with project progress and stakeholder engagement activities. Four newsletters were issued: July and October 2010 and February and May 2011. The reason for the limited number of issues is discussed in Annex A.

Website tools

At the time of writing this draft report the following website tools are being developed to accompany the reports online:

- Catalogue of risk metrics and metadata, which provides:
 - A list of risk metrics that were assessed for each of the 11 sectors
 - A summary of how each risk metric was assessed and what sources of information were used, including key references and datasets
 - For each dataset that was used, metadata is provided to explain where the data comes from, who owns it and whether it is publicly available or available under licence.
- Systematic mapping tool - A read only version of the tool used during the project to identify links between causes of change and their consequences and the processes that lead to that change.
- Risk matrix tool – A tool that generates summary tables showing the projected magnitude of risks against confidence and urgency, to support

adaptation planning by identifying important risks that may require early action.

At the time of writing, html versions of the following reports are also being produced for the website to enable easier navigation:

- Evidence Report
- Sector Reports
- Devolved Administration Reports

Stakeholder database

A stakeholder database was developed to support the stakeholder engagement activities. This was populated with the names of organisations and individuals who were potentially relevant to or interested in the CCRA. The database was used to identify groups of stakeholders to be contacted for different aspects of the study. It was then also populated with information regarding how and when stakeholders were involved in engagement activities.

Presentation slide packs

To support activities being undertaken by the ACC with respect to the National Adaptation Plan, two sets of presentation slides were produced by HR Wallingford:

- CCRA Overview Slide Pack – providing a summary of the purpose, scope and approach to the CCRA, as well as the key findings.
- CCRA Theme Slide Pack – providing additional slides to supplement the overview slides presenting CCRA findings for the 5 themes (see Section 3.3.2).

Appendix 3 – Summary of Risk Assessment Method

Introduction: CCRA Framework

The overall aim of the CCRA is to inform UK adaptation policy, by assessing the main current and future risks (threats and opportunities) posed by the current climate and future climate change for the UK to the year 2100. The overall approach to the risk assessment and subsequent adaptation plan is based on the UK Climate Impacts Programme (UKCIP) Risk and Uncertainty Framework (UKCIP, 2003). The framework comprises eight stages as shown in Figure A4.1. The CCRA has undertaken Stages 1, 2 and 3 as outlined below. Stages 4 and 5 will be addressed as part of a separate economic assessment, entitled the 'Economics of Climate Resilience', and the remaining stages will be implemented by the UK and Devolved Governments. The framework presents a continual process that can adapt as new evidence and policy emerges; in the case of the CCRA the process will be revisited every five years.

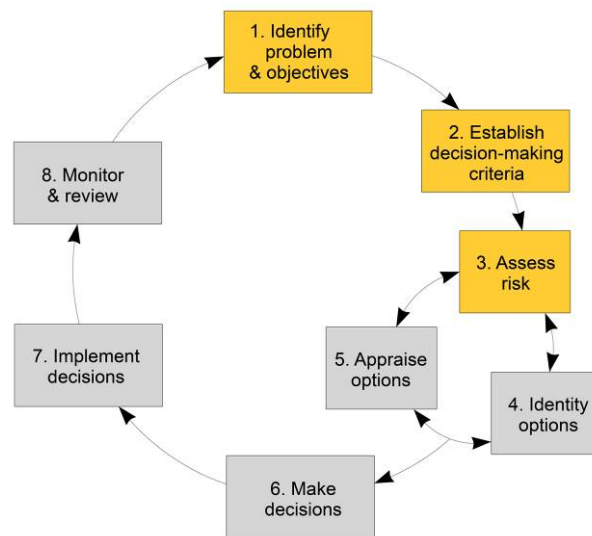


Figure A3.1 Stages of the CCRA (yellow) and other actions for Government (grey)

(Adapted from UKCIP, 2003)

- Stage 1 is defined by the aim of the CCRA project, to undertake an assessment of the main risks (both threats and opportunities) posed by climate change that will have social, environmental or economic consequences for the UK.
- Stage 2 established decision-making criteria for the study, which were used to inform the selection of impacts for analysis in Stage 3. These criteria are the social, environmental and economic magnitude of consequences, the likelihood that they will happen and the urgency of taking adaptation action for UK society as a whole.
- Stage 3 covers the risk assessment process. This involved a tiered assessment of risks with Tier 1 (broad level) identifying potential impacts and Tier 2 (detailed level) providing a more detailed analysis including quantification and monetisation of some impacts. A list of climate change impacts was developed based on eleven sectors with further impacts

added to cover cross-cutting issues and impacts which fell between sectors. This list of climate change impacts is referred to as the '**Tier 1' list of impacts**'. This list contained approximately 700 impacts – too many to analyse in detail as part of this first CCRA. A consolidated list of the highest priority climate change impacts for analysis was developed and referred to as the '**Tier 2 list of impacts**'.

The background to the framework and the approach used for each of the first three stages is set out in more detail in the CCRA Method Report (Defra, 2010b). This appendix aims to summarise the CCRA method for the risk assessment stage (Stage 3 in the framework above).

Outline of the method used to assess impacts, consequences and risks

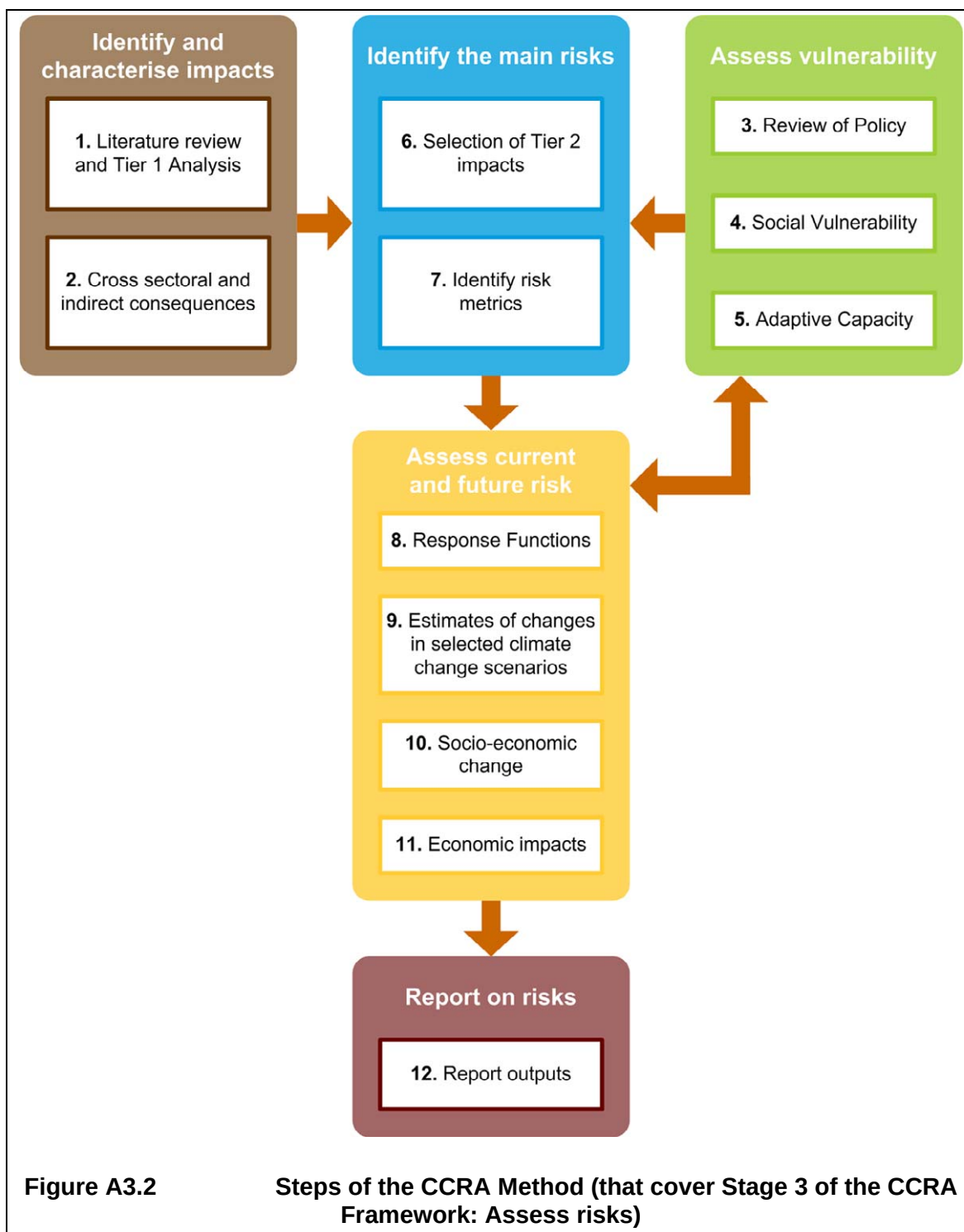
The risk assessment presented in this report is the focus of Stage 3 in the CCRA Framework (see Figure A4.1). This was done through a series of steps as set out in Figure A4.2. These steps are explained in the sections below and are discussed in more detail in the CCRA Method report (Defra, 2010b).

The components of the assessment sought to:

- **Identify and characterise the impacts** of climate change
This was achieved by developing the Tier 1 list of impacts, which included impacts across eleven sectors as well as impacts not covered by the sectors and arising from cross sector links.
- **Identify the main risks** for closer analysis
This involved the selection of Tier 2 impacts for detailed analysis from the long list of impacts in Tier 1. Higher priority impacts were selected by stakeholder groups based on the social, environmental and economic magnitude of impacts and the urgency of taking action (see below).
- **Assess current and future risk**, using climate projections and considering socio-economic factors
The risk assessment was done by developing 'response functions' that provide a relationship between changes in climate with specific consequences based on analysis of historic data, the use of models or expert elicitation. In some cases this was not possible, and a narrative approach was taken instead. The UKCP09 climate projections and other climate models were then applied to assess future risks. The potential impact of changes in future society and the economy was also considered to understand the combined effects for future scenarios (see below.)
- **Assess vulnerability** of the UK as a whole
This involved:
 - A high level review of Government policy on climate change in the eleven sectors
 - A high level assessment of the social vulnerability to the climate change impacts
 - A high level assessment of the adaptive capacity of the sectors (see below).

- **Report on risks** to inform action

The results for the eleven sectors are presented in detail in the Sector Reports and this report draws together the main findings from the whole project, including consideration of cross-linkages, and outlines the risks to the UK as a whole.



Identify and characterise the impacts

Step 1 – Literature review and Tier 1 analysis

This step scoped the potential impacts of climate change on the UK based on existing evidence and collating the findings from literature reviews, stakeholder participation through workshops, correspondence with wider stakeholders and soliciting expert opinion. This work developed the Tier 1 list of impacts. The Tier 1 impacts have not been analysed in detail; high level discussion of these impacts is provided in the sector reports.

Step 2 – Cross sectoral and indirect consequences

The Tier 1 lists for the eleven sectors in CCRA were compared and developed further to include cross-sectoral and indirect impacts. This was done by ‘Systematic Mapping’, which sets out a flow chart to link causes and effects in a logical process. The impacts that were identified in this step were added to the Tier 1 list of impacts.

Assess vulnerability

Step 3 – Review of Policy

Government policy on climate change develops and changes rapidly to keep pace with emerging science and understanding of how to respond through mitigation and adaptation. The sector reports include an overview of selected relevant policy as this provides important context for understanding how risks that are influenced by climate relate to existing policies.

Step 4 – Social Vulnerability

The vulnerability of different groups in society to the climate change risks for each sector was considered at a high level through a check list of questions. This information is provided for context; it is not a detailed assessment of social vulnerability to specific risks. Note that this step is different from Step 10, which considers how changes in society may affect the risks.

Step 5 – Adaptive Capacity

The adaptive capacity of a sector is the ability of the sector as a whole, including the organisations involved in working in the sector, to devise and implement effective adaptation strategies in response to information about potential future climate impacts. An introduction into adaptive capacity is given in the sector reports however; work on this is currently ongoing.

Identify the main risks

Step 6 – Selection of Tier 2 impacts

The Tier 1 list of impacts for each sector that resulted from Step 2 (see above) was consolidated to select the higher priority impacts for analysis in Tier 2. Firstly, similar or overlapping impacts were grouped where possible in a simple cluster analysis. Secondly, the Tier 2 impacts were selected using a simple multi-criteria assessment based on the following criteria:

- the social, economic and environmental magnitude of impacts
- overall confidence in the available evidence
- the urgency with which adaptation decisions needs to be taken.

Each of these criteria were allocated a score of 1 (low), 2 (medium) or 3 (high) and the impacts with highest scores over all criteria were selected for Tier 2 analysis. The scoring for each sector was carried out based on expert judgement and feedback from expert consultation workshops (or telephone interviews). Checks were carried out to ensure that a consistent approach was taken across all the sectors. The results of the scoring process are provided in the sector reports.

Step 7 – Identifying risk metrics

For each impact in the Tier 2 list, one or more risk metrics were identified. Risk metrics provide a measure of the consequences of climate change, related to specific climate variables or biophysical impacts. For example, in the Water Sector Report one of the impacts identified is ‘major drought’ due to reduced precipitation. The risk metrics that were identified to measure the consequences of this impact included reductions in summer river flow (Q95), change in water available for public water supply and the population in areas with future deficits. The risk metrics were developed to provide a spread of information about economic, environmental and social consequences. The metrics have been referenced using the sector acronym and a number; for example the Water sector metrics are referenced as WA1 to WA10.

Assess current and future risk

Step 8 – Response functions

This step established how each risk metric varied with one or more climate variables using available data or previous modelling work. This step was only possible where evidence existed to relate metrics to specific climate drivers, and has not been possible for all of the Tier 2 impacts. This step was carried out by developing a ‘response function’, which is a relationship to show how the risk metric varies with change in climate variables. Some of the response functions were qualitative, based on expert elicitation, whereas others were quantitative.

Step 9 – Estimates of changes in selected climate change scenarios

The response functions were used to assess the magnitude of consequences the UK could face due to climate change by making use of the UKCP09 climate projections. This step used the response functions to provide estimates of future risk under three different emissions scenarios (High emissions, A1FI; Medium emissions, A1B; Low emissions, B1; see <http://ukclimateprojections.defra.gov.uk/content/view/1367/687/> for further details), three future 30-year time periods (centred on the 2020s, 2050s and 2080s) and for three probability levels (10, 50 and 90 percent, see <http://ukclimateprojections.defra.gov.uk/content/view/1277/500/> for further details). The probability levels are cumulative and denote the degree of confidence in the change given; for example 90% suggests that it is thought very unlikely that the change will be higher than this; 50% suggests that it is thought equally likely that the change will be higher or lower than this; and 10% suggests that it is thought very unlikely that the change will be lower than this. For example, 90% does not mean that the change is 90% likely to occur.

All of the changes given in the UKCP09 projections are from a 1961-1990 baseline.

The purpose of this step is to provide the estimates for the level of future risk (threat or opportunity), as measured by each risk metric.

Step 10 – Socio-economic change

It is recognised that many of the risk metrics in the CCRA are influenced by a wide range of drivers, not just by climate change. The way in which the social and economic future of the UK develops will influence the risk metrics. Growth in population is one of the major drivers in influencing risk metrics and may result in much larger changes than if the present day population is assumed. For some of the sectors where this driver is particularly important, future projections for change in population have been considered to adjust the magnitude of the estimated risks derived in Step 9.

For all of the sectors, a broad consideration has been made of how different changes in our society and economy may influence future risks and opportunities. The dimensions of socio-economic change that were considered are:

- Population needs/demands (high/low)
- Global stability (high/low)
- Distribution of wealth (even/uneven)
- Consumer driver values and wealth (sustainable/unsustainable)
- Level of Government decision making (local/national)
- Land use change/management (high/low Government input).

The full details of these dimensions and the assessment of the influence they have on the sector is provided in the sector reports. Note that this step is different from Step 4, which considers how the risks may affect society; whereas this step considers how changes in society may affect the risks.

Step 11 – Economic impacts

Based on standard investment appraisal approaches (HM Treasury, 2003) and existing evidence, some of the risks were expressed as monetary values. This provides a broad estimate of the costs associated with the risks and is presented in detail in the sector reports. A more detailed analysis of the costs of climate change will be carried out in a study on the Economics of Climate Resilience.

Appendix 4 – List of Research Gaps

This is also available as an Excel spreadsheet.

Data gap definitions

Data gap type	Definition
Geographical	Data is not available in a consistent manner across the UK as a whole. Most usually, data is not available for Scotland and Northern Ireland. This may also relate to where there is detailed site-level data that needs scaling to the UK level.
Socio-economics	Population changes; changes in markets and demands for products; changes driven by government policy; changes driven by social preferences;
Land-use change modelling	Sub-section of socio-economics. Understanding of future changes in land-use required to understand the risk
Data collection/Public availability	Fundamental lack of data suitable for a national risk assessment or the datasets required are not easily available.
Climate sensitivity	The sensitivity of the metric to climate is unknown or uncertain;
Seasonal sensitivity	Seasonal sensitivity uncertain but suspected
Extremes sensitivity	Sensitivity to extremes in climate uncertain but suspected
Experimentation/Investigate baseline	Little is known, experimental tests (laboratory etc.) required. The baseline is difficult to determine.
Combined climate drivers	Suspect single climate variables are particularly unsuitable in determining the risk
Management effects	Management (of land or planning) and climate may interact. The level and type of management may greatly effect the risk and we are not entirely sure how.
Ecosystems and Ecosystem Goods and Services	Ecosystem dynamics, interactions and goods and services
Systems modelling	Cause - effect and pathways unknown or uncertain and quite possibly non-linear. A catch-all where understanding of the risk is patchy, but thought to be complex
Flood/erosion modelling	Separate from systems modelling as more developed
Economics	Economic consequences unknown
Natural adaptive capacity	Of plants, animals, ecosystems. Needs to be understood in order to understand the levels of vulnerability and risk.
Adaptive responses and feedbacks (natural or non-natural)	Autonomous adaptation likely to affect the level of risk. Feedbacks from human actions thought to lead to a significant change in the level of risk
UKCP09 (extremes)	Sensitivity to extremes known, but UKCP09 prevents projection being made.
Combined climate and non-climate drivers	Where human actions directly interact with climate to produce the resulting risk, i.e. tourism increasing or atmospheric pollution.
Demographical	When the effects of the risk are heavily associated with demographic and therefore to any associated changes in UK demography
Integrated assessments	Assessment of the risk cannot be made with any confidence without inclusion of multi-disciplinary information.
Adaptive capacity (non-natural)	Adaptive capacity of organisations/institutions
UKCP09	UKCP09 prevents projections of risk being made.

Sector	Risk Metric Code	Risk metric	Gaps in information and data (raw info)	Geographical	Socio-economics	Land-use change modelling	Data collection/Public availability	Climate sensitivity	Seasonal sensitivity	Extremes sensitivity	Experimentation/Investigate baseline	Combined climate drivers	Management effects	Ecosystems and Ecosystem Goods and Services	Systems modelling	Flood/erosion modelling	Economics	Natural adaptive capacity	Adaptive responses and feedbacks (natural or non-UKCP09 (extremes)	Combined climate and non-climate drivers	Demographical	Integrated assessments	Adaptive capacity (non-natural)	UKCP09
Agriculture	General	n/a	Not all of the metrics developed for agriculture cover the whole of the UK, with several (including AG2, AG5, AG6, and AG10) covering only England and Wales. This is partly due to the level of information available at the time of the analysis, but for others, such as (irrigation water demand AG5) there was simply no data for Scotland. Conversely, some metrics were relevant for the whole of the UK with a consistent level of detail (e.g. AG4). There are also some areas where there is a noticeable of climate impacts research (e.g. AG9 new crops) and hence the current levels of understanding on climate risks are limited.	1																				
Agriculture	General	n/a	Knowledge gaps within the sector are related to the potential combined impacts of a range of different climate factors on agricultural performance (productivity), the importance of local geography on the sustainability of specific agricultural systems, uncertainty in future socio and agro economic policies, and changes in market demands for agricultural services and products driven by changing population demographics and societal preferences. Given the multifunctional nature of agriculture, there is also uncertainty about the risks to many of the other 'non food' services of this sector including landscape and amenity, environmental enhancement and ecosystems services. In addition, the forthcoming Government report on biofuels may provide an opportunity for the agricultural sector to diversify, altering the magnitude and extent of the risks and impacts.	1	1							1		1	1		1	1	1		1	1		
Agriculture	General	n/a	Patterns of food consumption and dietary preferences may also shift as a consequence of a changing climate. For example, with warmer summers, there may be greater demand for salads and pasta and conversely a reduction in demand for certain winter foods as the seasonal distinctions change and become more blurred (with Autumn arriving earlier and Spring later). Similarly, changes in markets and trade opportunities, as foreign production alters, may also have a large effect on cropping patterns and livestock. There are also complex interactions with natural resources, social and political systems, economics, trade and policy and potential conflicts with the drive to boost crop production without undue depletion of the natural resource base. However, in reality, it will be the more arid parts of the world from where we import most of our food that will suffer most from a changing climate – here increasing aridity and competition for food, energy and water are all likely to exert a much greater impact on the reliability and cost of future food supplies in the UK (Beddington, 2010).		1				1								1	1			1			
Agriculture	General	n/a	Knowledge gaps within the sector are related to the potential combined impacts of a range of different climate factors on agricultural performance (productivity), the importance of local geography on the sustainability of specific agricultural systems, uncertainty in future socio and agro economic policies, and changes in market demands for agricultural services and products driven by changing population demographics and societal preferences. Given the multifunctional nature of agriculture, there is also uncertainty about the risks to many of the other 'non food' services of this sector including landscape and amenity, environmental enhancement and ecosystems services. In addition, the forthcoming Government report on biofuels may provide an opportunity for the agricultural sector to diversify, altering the magnitude and extent of the risks and impacts.		1									1										
Agriculture	AG1a	Changes in sugar beet yield (due to warmer conditions)	Rainfed crop yields are susceptible to changes in land suitability. Daccache et al (2011b) showed how sensitive rainfed potato yields were to changes in land suitability with increased droughtiness significantly reducing the area in England and Wales well suited to rainfed production. Similar analyses would be beneficial for extrapolating into Scotland for potatoes (and other important rainfed field vegetable crops) particularly where quality assurance is an important market determinant.	1																				
Agriculture	AG1b	Changes in wheat yield (due to warmer conditions)	Rainfed crop yields are susceptible to changes in land suitability. Daccache et al (2011b) showed how sensitive rainfed potato yields were to changes in land suitability with increased droughtiness significantly reducing the area in England and Wales well suited to rainfed production. Similar analyses would be beneficial for extrapolating into Scotland for potatoes (and other important rainfed field vegetable crops) particularly where quality assurance is an important market determinant.	1		1																		
Agriculture	AG1c	Changes in potato yield (due to combined climate effects and CO ₂)	Rainfed crop yields are susceptible to changes in land suitability. Daccache et al (2011b) showed how sensitive rainfed potato yields were to changes in land suitability with increased droughtiness significantly reducing the area in England and Wales well suited to rainfed production. Similar analyses would be beneficial for extrapolating into Scotland for potatoes (and other important rainfed field vegetable crops) particularly where quality assurance is an important market determinant.	1		1																		

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Agriculture	AG2a	Flood risk to high quality agricultural land	Risk metric only considers flooding in England and Wales. Scotland and Northern Ireland have yet to produce flood maps to allow for analysis. Northern Ireland has produced a preliminary flood risk assessment, although this only considers climate change up to the 2030s. Costing to include direct and indirect costs of flood events.	1												1	1								
Agriculture	AG2b	Flood risk to horticultural land	Risk metric only considers flooding in England and Wales. Scotland and Northern Ireland have yet to produce flood maps to allow for analysis. Northern Ireland has produced a preliminary flood risk assessment, although this only considers climate change up to the 2030s. Costing to include direct and indirect costs of flood events.	1												1	1								
Agriculture	AG2c	Flood risk to grassland	Risk metric only considers flooding in England and Wales. Scotland and Northern Ireland have yet to produce flood maps to allow for analysis. Northern Ireland has produced a preliminary flood risk assessment, although this only considers climate change up to the 2030s. Costing to include direct and indirect costs of flood events.	1												1	1								
Agriculture	AG3a	Risk of crop pests and diseases	Further specific research is needed into the impact of climatic drivers on crop and livestock pest and disease vectors. Current research provides conflicting evidence on the degree of control climate exerts on pests and diseases (e.g. Bluetongue virus) and a further understanding of pest and disease pathology and responses would allow for their impact to be assessed with a greater confidence.					1	1		1		1												
Agriculture	AG3b	Risk of crop pests and diseases	Further specific research is needed into the impact of climatic drivers on crop and livestock pest and disease vectors. Current research provides conflicting evidence on the degree of control climate exerts on pests and diseases (e.g. Bluetongue virus) and a further understanding of pest and disease pathology and responses would allow for their impact to be assessed with a greater confidence.					1	1		1		1												
Agriculture	AG3c	Risk of crop pests and diseases	Further specific research is needed into the impact of climatic drivers on crop and livestock pest and disease vectors. Current research provides conflicting evidence on the degree of control climate exerts on pests and diseases (e.g. Bluetongue virus) and a further understanding of pest and disease pathology and responses would allow for their impact to be assessed with a greater confidence.					1	1		1		1												
Agriculture	AG4	Drier soils (due to warmer and drier summer conditions)	Impact of combined climate factors									1													
Agriculture	AG5	Increases in water demand for irrigation of crops	No water abstraction figures for agriculture exist for Scotland or Northern Ireland, therefore an assessment of the risks due to climate change on abstraction patterns cannot be made. The development of the Abstraction and Impound Regulation licences in Northern Ireland provide an opportunity monitor the volume of abstraction which may allow for future projections to be made. An investigation to whether the earlier onset of Spring may allow for greater early year production, reducing the need for irrigation during drought years could provide useful additional information to assess future abstraction risks. Conversely drought events may occur earlier causing a greater loss in farm production. These seasonal sensitivities need to be considered, in the context of water demand for agriculture, but also set against the latest projections in river flow (available water supplies).	1					1																
Agriculture	AG6	Increases in water demand for livestock	Current and changes in future water demand for livestock could not be assessed at the UK-wide scale due to limitations in data availability. However, current Defra research (WU0310) is investigating the future sustainable use of water for livestock.				1				1														
Agriculture	AG7a	Reduction in milk production due to heat stress	Further analysis on a range of livestock systems and consideration of indoor and outdoor farming. Further research on husbandry systems would allow for a more robust assessment of the impacts.				1				1														
Agriculture	AG7b	Reduction in dairy herd fertility due to heat stress	Further analysis on a range of livestock systems and consideration of indoor and outdoor farming. Further research on husbandry systems would allow for a more robust assessment of the impacts.				1				1														
Agriculture	AG8a	Increased duration of heat stress in dairy cows	Further analysis on a range of livestock systems and consideration of indoor and outdoor farming. Further research on husbandry systems would allow for a more robust assessment of the impacts.				1				1														
Agriculture	AG8b	Dairy livestock deaths due to heat stress	Further analysis on a range of livestock systems and consideration of indoor and outdoor farming. Further research on husbandry systems would allow for a more robust assessment of the impacts.				1				1														

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Agriculture	AG10	Changes in grassland productivity	Grassland productivity was only assessed for England and Wales. There is a significant knowledge gap on how productivity may change for grassland productivity in Scotland and Northern Ireland. Improved knowledge of the effects of CO2 fertilisation on crop growth and yield would inform future grassland yield projections. Changes in land-use patterns and crop rotations due to socio economic factors (e.g. a switch to biofuel and/or changes in dietary habits) might reduce the extent of grassland cultivation with impacts on rural livelihoods	1	1	1		1	1			1												
Agriculture	AG11	Increased soil erosion due to heavy rainfall	Impact of climate and land-use management factors			1		1					1											
Agriculture	AG9	Opportunities to grow new crops	General lack of research on a UK wide scale	1							1													
Biodiversity & Ecosystem Services	General	n/a	Much of the climate change research conducted to date has, of necessity, been focused either upon individual species or on specific locations or habitat types. Development of systems-based approaches that can improve understanding of the multitude of interactions within the natural environment, and their links to the human environment, remain in the early stages. Continuous data records that are comparable across years or standardized across the UK are also limited, although some very good examples do exist. Use of UKCP09 data has been restricted until very recently by the lack of spatially-coherent data in the future projections; this remains a major challenge for the further development of probabilistic data in climate change risk assessments.		1	1					1				1									
Biodiversity & Ecosystem Services	General	n/a	The basic knowledge gap is our understanding of change and ecosystem dynamics, including the interaction of people within ecosystems. This is essentially due to the complexity of responses and feedbacks involved, but also because this has often been a neglected topic in research. As a consequence, key functions and services provided by ecosystems have fundamental uncertainty in terms of how they will respond to change.		1	1					1			1	1									
Biodiversity & Ecosystem Services	General	n/a	More systematic UK-level collation and interpretation of site monitoring and other available data (e.g. phenology), against inter-annual patterns of climate variability and trends of long-term change.	1			1	1	1															
Biodiversity & Ecosystem Services	General	n/a	Improved understanding of the combined impact of climate change and atmospheric pollution on ecosystems. This would facilitate further measures to limit pollution below critical levels to improve ecosystem resilience.											1						1				
Biodiversity & Ecosystem Services	General	n/a	Critical thresholds ('tipping points') in the interactions between climate and ecosystem responses beyond which the system may undergo a major non-linear change or shift to a new ecological regime (e.g. coastal systems in response to a major storm surge event). Some recent advances have been made with regard to identifying key thresholds for animal population declines (e.g. Drake and Griffin, 2010).					1			1			1	1			1	1					
Biodiversity & Ecosystem Services	General	n/a	Improved understanding of the implications of the rate of climate change for natural adaptive responses in different ecosystems (including across different species), including the role of extreme events, and hence the limits to and thresholds for maintaining adaptive capacity.					1			1			1	1			1						
Biodiversity & Ecosystem Services	General	n/a	Evaluation of the effectiveness of landscape-scale initiatives, including measures to improve landscape permeability, in both short-term and long-term. This would act as a bridge between broad-scale modelling studies and site-specific monitoring/modelling to identify strategic maps of habitat creation opportunities that are robust against climate change.	1									1	1	1			1						
Biodiversity & Ecosystem Services	General	n/a	Evaluation of options for further development of protected areas. How will existing areas cope with change and how might they be further strengthened and better integrated into the wider landscape for maximum ecological benefits?	1									1	1	1			1						
Biodiversity & Ecosystem Services	General	n/a	Detailed analysis of the scope for increasing the resilience of species and communities within their existing range, including measures to increase heterogeneity of habitat patches and increase population size of vulnerable species (e.g. based upon variation of microclimate with aspect and vegetation structure). This should include area issues: larger sites are generally considered less vulnerable to edge effects such as desiccation during droughts, but can general rules be derived for minimum site extent.	1									1					1						

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Biodiversity & Ecosystem Services	General	n/a	Further information on the role of genetic diversity within species. This is mainly based on cultivated crops and domesticated animals at present. Although this is time-consuming and expensive to gather, it would help to identify and monitor genetic constraints on adaptation and may be used to evaluate the viability of translocation as an option for some threatened species.	1									1					1						
Biodiversity & Ecosystem Services	General	n/a	Improved valuation techniques for biodiversity (both qualitative and quantitative) that can incorporate dynamic system processes and interactions. Existing work has shown that results can vary across scales (relative to the level of generalization) therefore multi-level assessments would be particularly instructive in understanding trade-offs for decision-making. The prevailing approach to quantifying ecosystem services is still based on static analyses and single services, typically interactions between ecological and social systems.		1									1	1									
Biodiversity & Ecosystem Services	General	n/a	Better understanding of the role of culture and social capital (i.e. non-monetary benefits) in ecosystem-based management and the wider benefits of ecosystem services for human well-being.		1									1	1									
Biodiversity & Ecosystem Services	General	n/a	Development and implementation of a cross-sectoral approach to assess trade-offs in adaptive capacity between different sectors, with particular emphasis on reducing conflicts and enhancing complementarities between biodiversity and other sectors.												1			1						
Biodiversity & Ecosystem Services	BD1	Risks to species and habitats due to drier soils	Further work is required on ecosystem response to increased CO2 and associated feedbacks in conjunction with changing climate variables (e.g. temperature, soil moisture), based upon both modelling and experimental evidence. This has not been incorporated into most climate change impact assessments.					1	1	1	1	1		1	1			1	1	1	1			
Biodiversity & Ecosystem Services	BD2	Risks to species and habitats due to coastal evolution	Improved information on coastal impacts. Integration of ecological and geomorphological assessments for evaluation of habitat change in highly dynamic environments, particularly the coastal zone and river floodplains. This would also inform adaptation management based upon improved knowledge of the interaction of current biological and physical processes.										1		1			1				1		
Biodiversity & Ecosystem Services	BD3	Risk of pests to biodiversity	Increase in UK scale data sets and research into pest/INNS climate sensitivity in situ (in addition to ex situ i.e. laboratories) and economic effects	1			1	1	1	1		1	1											
Biodiversity & Ecosystem Services	BD4	Risk of diseases to biodiversity	Increase in UK scale data sets and research into disease/INNS climate sensitivity in situ (in addition to ex situ i.e. laboratories) and economic effects	1			1	1	1	1		1	1											
Biodiversity & Ecosystem Services	BD5	Species unable to track changing 'climate space'	Integrated modelling of species distributions and interactions, habitat shifts and landscape structure based upon a linked framework that combines bioclimate and ecological factors. This would provide a more robust evidence base than the current reliance on bioclimate envelope models to project future changes.					1	1	1					1							1		
Biodiversity & Ecosystem Services	BD6	Environmental effects of climate mitigation measures	Exploration of biodiversity strategies that better integrate adaptation with opportunities from climate mitigation schemes. For example, the development of biomass energy (including short rotation coppice and short rotation forestry) could add to landscape and habitat diversity. Initiatives to enhance carbon storage in soils and biomass could also have significant benefits for biodiversity.										1		1			1				1		
Biodiversity & Ecosystem Services	BD7	Risks to coastal habitats due to flooding	Integration of ecological and geomorphological assessments for evaluation of habitat change in highly dynamic environments, particularly the coastal zone and river floodplains. This would also inform adaptation management based upon improved knowledge of the interaction of current biological and physical processes.					1							1							1		
Biodiversity & Ecosystem Services	BD8	Changes in soil organic carbon	Improved assessments of climate impacts on ecosystem functions. For example, this is particularly necessary for understanding the key role of soil biodiversity in changing ecosystem processes (such as nutrient cycling) and the implications for habitats and species biodiversity, soil organic matter and carbon storage, with implications for flood risk, water quality, soil erosion risk, habitat conservation and crop production capacities.					1	1	1	1		1	1	1									
Biodiversity & Ecosystem Services	BD9	Changes in species migration patterns	Vulnerability assessment of key locations and pathways for migratory routes (e.g. using space-for-time substitutes based upon current climate variability).					1	1		1													
Biodiversity & Ecosystem Services	BD10	Biodiversity risks due to warmer rivers and lakes	Upscaling of sensitivity data from freshwater ecosystems for regional and national-scale assessments to understand the interactions between water temperature, water quality and water quantity on priority habitats and species. Most information is currently only available at site level.	1				1	1	1					1									

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Biodiversity & Ecosystem Services	BD11	Generalist species more able to adapt than specialists	Integrated modelling of species distributions and interactions, habitat shifts and landscape structure based upon a linked framework that combines bioclimate and ecological factors. This would provide a more robust evidence base than the current reliance on bioclimate envelope models to project future changes.					1							1							1		
Biodiversity & Ecosystem Services	BD12	Wildfires due to warmer and drier conditions	A new look at forest fire risk assessment for the UK is required, building on relevant international experience, but developed for UK forests and climate conditions, evaluated with existing UK data, using detailed UKCP09 climate projections, forest area data from the National Forest Inventory, and soil data.				1	1	1	1			1		1									
Biodiversity & Ecosystem Services	BD13	Water quality and pollution risks	Little is know about how climate change will affect diffuse pollution. Data is variable across the UK.	1				1	1	1	1			1	1									
Biodiversity & Ecosystem Services	BD14	Ecosystem risks due to low flows and increased water demand	Scotland and Northern Ireland. Ecosystem responses to low flows and water demand changes and recovery times/thresholds.	1				1	1	1			1	1	1			1						
Biodiversity & Ecosystem Services	BD15	Ecosystem risks due to low flows and increased water demand	Scotland and Northern Ireland. Ecosystem responses to low flows and water demand changes and recovery times/thresholds.	1				1	1	1			1	1	1			1						
Biodiversity & Ecosystem Services	BD16	Ecosystem risks due to low flows and increased water demand	Scotland and Northern Ireland. Ecosystem responses to low flows and water demand changes and recovery times/thresholds.	1				1	1	1			1	1	1			1						
Built Environment	BE1	Urban Heat Island effect	It is unclear from UKCP09 projections how extremes are likely to change relative to mean temperatures, yet it is during heat-waves that heat-related impacts and consequences may be most keenly felt.																1					
Built Environment	BE2	Increased subsidence risk due to rainfall changes	Detailed soil inventory data exists but only under expensive licensing. The association between climate and subsidence is less certain.				1		1															
Built Environment	BE3	Overheating of buildings	Thermal performance varies widely from building to building. Thus, ideally, this risk metric would be broken down by building type/construction/age. Such data is not however readily available. There is also very limited research data to relate specific building types to indoor thermal comfort. Hence within the CCRA, external temperature has been used as a proxy for indoor thermal comfort. This analysis does not take into account possible physiological or behavioural adaptation, for which there is considerable scope. Examples include relaxing dress codes and changing working or school hours to an earlier cooler part of the day. The lack of knowledge as to what constitutes overheating and the need for further research in this area has already been identified by DCLG and is highlighted here. Furthermore, it is important to note that an absolute comfort threshold temperature has been used to derive these results. As already stated, overheating criteria are the subject of ongoing research. An alternative adaptive approach to thermal comfort has been proposed (Nicol et al., 2009), in which the 'comfort temperature' in a naturally ventilated				1	1											1				1	
Built Environment	BE5	Effectiveness of green space for cooling	The BE5 risk metric presented here should be considered as purely indicative. Recent research for Defra and DCLG has identified several knowledge gaps in the field of green space (Forest Research, 2010). More detailed, statistically valid experimentation is necessary to improve understanding of the mechanisms by which vegetation cools the surrounding environment (Bowler et al., 2010). More information is also needed on suitable species for use in climate change adapted green infrastructure and their physiological characteristics, such as heat and drought tolerance and resistance to frost damage. This will enable a more robust correlation to be made between the climate drivers (relative aridity in this case) and the effectiveness of green space. This in turn could inform decisions about the effectiveness of mitigation strategies, for example replacing built areas with green space.					1			1							1						
Built Environment	BE9	Reduction in energy demand for heating	No available information on Northern Ireland. Socio-economic and demographic changes are important in assessing this risk as well as any changes to domestic building stock. These factors have not been measured this time around.	1	1		1														1			
Business, Industry & Services	BU1	Climate risks to investment funds	The performance of financial institutions is dependent on many socio-economic drivers and discerning the effect of climate change is particularly challenging. This is made even more difficult due to the fact that information on credit scores and revenue is deemed commercially sensitive and therefore not widely available in the public domain. This naturally leads to information gaps when undertaking an assessment of climate-related risks and financial performance. Data that would enable such assessments to take place include internal rate of return and tangible and intangible asset value.		1		1	1																

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Business, Industry & Services	BU2	Monetary losses due to tourist assets at risk from flooding	Risk to tourist assets.... The impact of sea level rise on beach area· For all the beaches considered, it was assumed that the beach high water mark is unable to move landwards.· Beaches on most of the 291 inhabited islands around the UK, including the beaches of the Outer Hebrides, were excluded from this analysis.· The accuracy of the analysis is constrained by the resolution of the beach dataset. It is known that the Environment Agency is in the process of compiling a detailed dataset, which would enable a more detailed estimate to be made, but that this dataset is unfortunately not yet available.· Coastal geomorphology, oceanography and sediment transport processes are very complex and difficult to model. This analysis takes a very simplistic view; it is important to stress that localised responses will depend on the regional geomorphological setting.Number of tourist visitor attractions and facilities at risk from fluvial flooding· Whilst the data show how the risk to tourism assets currently located in the English Flood Zone 3 zone may change, it is limited in that there is no expansion of the geographical area	1			1								1									
Business, Industry & Services	BU3	Risk of restrictions in water abstraction for industry	Total industrial abstraction per RBD is only provided for England and Wales. For assessment WA8b, the method of extrapolation of the original modelling to larger flow reductions has the potential to produce significant inaccuracies and the exact figures produced by this assessment should be treated with some caution. Whilst the SIC data provides a UK-wide coverage, the water abstraction data are limited to England and parts of Wales. Coverage is therefore limited to that of the abstraction data. The estimates of loss of abstraction equivalent turnover do not represent the real cost to business resulting from reduced access to water. However, it does provide a surrogate measure and allows the relative change to be evaluated in relation to individual industries. A more detailed investigation of water dependency for individual groups of industries would be needed to develop more realistic estimates.	1													1							
Business, Industry & Services	BU4	Risks of business disruption due to flooding	It is assumed that business continuity losses are proportional to changes in Expected Annual Damages (EAD) associated with Non-Residential Properties (NRP). Proportion of flood losses out of all weather related claims are the same for business and domestic customers. The 8-year average business continuity figure could be overestimated, given the small sample size, which includes the 2007 event. The 8-year average business continuity figure does not include uninsured / unclaimed losses. It is likely therefore that the true baseline cost of business disruption caused by flooding is greater than the £20 million per year used in the above estimate. The loss figures are likely to underestimate business continuity risk as they do not include uninsured losses and disruption to business activity, supply chains, etc. There is a mismatch in terms of UK-wide EAD for NRP data and the other data used in this section, which only relates to England and Wales. This is explained in the text above. Figures are purely indicative and should be treated with caution.	1			1																	
Business, Industry & Services	BU5	Loss of productivity due to ICT disruption	No relevant information currently available. Although historical case studies provide information of weather-related disruptions to IT, these tend to be isolated and robust data is currently not available to provide meaningful estimates of potential climate change impacts.				1																	
Business, Industry & Services	BU6	Mortgage provision threatened due to increased flood risk	Scotland and Northern Ireland. Surface water flooding. More data is needed to accurately discern the distribution and value of at risk mortgage assets now and in the future across the UK. Data used only covers England and Wales. The management of flood risk is clearly not a new issue for primarily financial institutions and insurance companies. As such this forecast serves to underline the process of adaptation already occurring, however, the magnitude of the numbers involved, should provide added impetus to making such changes take place. More generally, there is a great deal of uncertainty in relation to future Government policy, its agreements with insurers on covering flood risk, and the likely levels of Government investment on flood management. The figures presented in this analysis underline the importance of this risk to the UK economy.	1	1		1									1								

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Business, Industry & Services	BU7	Insurance industry exposure to UK flood risks	Given the short time-series sampled, it is difficult to robustly link the impacts of climate change to any recorded increase in insurance payout costs. It is stressed that these figures only provide an approximate estimate of average annual claims made and are uncertain. Regional variations are neglected in this methodology, due to a lack of flood data for Scotland and Northern Ireland. Assumptions were made that the average exposure to flood risk across England and Wales is a reasonable approximation for Scotland and Northern Ireland. This methodology assumes that provision of flood damage insurance cover will remain on the same basis as currently provided. The estimation that payout costs increase in the future and have increased in the past cannot necessarily be viewed as a risk to insurance companies associated with climate change, if this is matched by higher and adjusted premiums. This would therefore only be problem if this was not anticipated and accommodated for by insurance companies. If premiums are adjusted accordingly by the industry, a change in risk can be managed. However, the rise in premiums may	1	1			1																
Business, Industry & Services	BU8	An expansion of tourist destinations in the UK	It has been considered too coarse an indicator, as it is insensitive to the large variety of weather requirements that are posed by tourist activities. A lack of consideration of additional climate variables that are important to tourism-related activities. Empirical validation of the index is relatively weak, with the index based heavily on expert judgement (Moreno and Amelung, 2009). Progress has been made in addressing these issues and improving the climate indices for tourism. De Freitas et al., (2008) proposed a new index that accounts for the overriding properties of some weather aspects and acknowledges the existence of intercultural differences in climate preferences. Morgan et al., (2000) also developed a tailor-made climate index for beach tourism, based on Mieczkowski's TCI, but fine-tuned with empirical information (the stated preferences of actual beach users, through survey data).		1															1				
Business, Industry & Services	BU10	Loss of staff hours due to high internal building temperatures	The metric response function needs is based on US studies and therefore needs to be validated for UK conditions. It is likely that productivity is not simply a function of temperature, with other factors such as humidity, ventilation and building solar gain also important. Some researchers have suggested that temperatures can be much closer to the physiological tolerance curve before there is any significant impairment of mental capacity (Hancock, 1981); this would suggest that the curve in Figure 4.6 may be overly pessimistic. The range of results generated by the two temperature thresholds (26°C and 28°C) provide an indication of the uncertainty associated with this methodology. A better understanding of the impact of high temperatures on worker efficiency would provide more accurate estimates of potential impacts for business turnover and profitability. Worker acclimatisation has been excluded from the analysis. It is suggested that after 7-10 days of sustained exposure, workers start to develop some degree of acclimatisation, although they still do not work as efficiently as in cooler environments (NIOSH, 1986). As a conseq	1			1					1					1		1					
Business, Industry & Services	BU9	A decrease in output for businesses due to supply chain disruption	Because supply chains are complex and dependent on a network of interconnected, yet independent, elements, it is not possible to develop a clear and direct causal link between climate change and supply chain disruption. Many climatic factors (e.g. heat, precipitation, melting, flooding) can break supply chains, making a single response function too simplistic. Import intensity could be considered as a proxy for climate change risk, as businesses which are heavily dependent on foreign imports are exposed to climate impacts in other parts of the world. However, this is a narrow view which ignores the fact that even domestic suppliers can be affected by extreme weather events or changes in climatic thresholds. Moreover, it is the ability of retailers and manufacturer to shift suppliers that is more important than the level of international imports, as it is entirely possible that a UK retailer with no imports may be highly vulnerable to climate change if the retailer has limited or no alternative suppliers.	1				1				1			1								1	
Energy	EN1	Energy infrastructure at significant risk of flooding	The analysis is based on information for England and Wales. Suitable information for analysis was not available for Scotland and Northern Ireland. The analysis is based on tidal and river flooding. There is much less information available for surface water flooding which meant that it could not be covered by the analysis. Information on water pumping stations and treatment works was not available for the analysis. The quality of coastal erosion data used in the analysis was relatively poor and better information should become available from the National Coastal Erosion Risk Map (NCERM).	1	1		1									1								

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Energy	EN1b	Power stations at significant risk of flooding	The analysis is based on information for England and Wales. Suitable information for analysis was not available for Scotland and Northern Ireland. The analysis is based on tidal and river flooding. There is much less information available for surface water flooding which meant that it could not be covered by the analysis. Information on water pumping stations and treatment works was not available for the analysis. The quality of coastal erosion data used in the analysis was relatively poor and better information should become available from the National Coastal Erosion Risk Map (NCERM).	1	1		1									1								
Energy	EN2	Energy demand for cooling	This metric was based on UKCP09 CDD projections and on cooling energy demand projections from previous studies (Day et al., 2009 and DECC, 2010d). For this metric confidence could be improved by calculating cooling energy demand projections using the UKCP09 CDD projections. This would only be possible if future forecasts of energy demand for cooling in the domestic, service and industrial sectors were available.		1																			
Energy	EN3	Heat related damage/disruption to energy infrastructure	For this metric confidence could be improved by carrying out a quantitative analysis on future risk. One approach would be to use the design standards set by the industry (for example power transformers must sustain peak ambient air temperature not greater than 30°C average in one day or more than 20°C average in any one year) and to investigate how the frequency of these temperature thresholds may change in the future. This would quantitatively indicate whether the current standards are sufficient to sustain future climate change.				1																	
Energy	EN4	Risk of restrictions in water abstraction for energy generation	The analysis is based on information for England and Wales. Suitable information for analysis was not available for Scotland and Northern Ireland. This metric was calculated using data from Entec (2010) which links changes in Q95 with changes in water availability classes or CAMS colours for England and Wales. As Q95 is a poor indicator of ecological stress on river ecosystems on its own, the analysis for this metric provides only a partial view and further information on understanding hydro-ecological stress from modifications of the flow regime as a whole is needed. This metric would be further enhanced if similar data were available for Scotland and Northern Ireland. The WFD river basin management planning process should provide a mechanism for improving our understanding of the impacts of climate on ecological status.	1			1				1				1									
Energy	EN10	Energy transmission efficiency capacity losses due to heat - over ground	This metric is based on up-to-date research published by ENA (2011) and UKCP09 climate projections. As a result the confidence in this metric is assumed to be high.																	1				
Floods & Coastal Erosion	General	n/a	The gaps in evidence outlined above do not cover impacts on the Tier 1 list that were not taken forward to Tier 2. It is recommended that this list is reviewed and further work undertaken on those impacts that may be underestimated at present. For example the possibility of flooding as a result of joint extremes (including high sea levels combined with high fluvial flows, or high sea levels combined with extreme wave conditions) is relatively poorly understood at present.													1				1				
Floods & Coastal Erosion	General	n/a	Another potential gap is the need for additional monitoring and interpretation of data so that it can be used in future cycles of the CCRA.				1																	
Floods & Coastal Erosion	FL1	Number of people at significant risk of flooding	Scotland and Northern Ireland. Surface water flooding.	1												1								
Floods & Coastal Erosion	FL2	Vulnerable people at significant risk of flooding	Scotland and Northern Ireland. Surface water flooding.	1												1								
Floods & Coastal Erosion	FL4a	Agricultural land at risk of flooding	Scotland and Northern Ireland. Surface water flooding. Waterlogging	1												1								
Floods & Coastal Erosion	FL4b	Agricultural land at risk of regular flooding	Scotland and Northern Ireland. Surface water flooding. Waterlogging	1												1								

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Floods & Coastal Erosion	FL6a	Residential properties at significant risk of flooding	Scotland and Northern Ireland. Surface water flooding.	1												1								
Floods & Coastal Erosion	FL6b	Expected Annual Damage (EAD) to residential property due to flooding	Scotland and Northern Ireland. Surface water flooding.	1												1								
Floods & Coastal Erosion	FL7a	Non-residential properties at significant risk of flooding	Scotland and Northern Ireland. Surface water flooding.	1												1								
Floods & Coastal Erosion	FL7b	Expected Annual Damage (EAD) to non-residential property due to flooding	Scotland and Northern Ireland. Surface water flooding.	1												1								
Floods & Coastal Erosion	FL8a	Roads at significant risk of flooding	Scotland and Northern Ireland. Surface water flooding.	1												1								
Floods & Coastal Erosion	FL8b	Railways at significant risk of flooding	Scotland and Northern Ireland. Surface water flooding.	1												1								
Floods & Coastal Erosion	FL10	Water infrastructure at risk of flooding	Lack of data re. water infrastructure at risk of flooding				1																	
Floods & Coastal Erosion	FL11a	Power stations at significant risk of flooding	Scotland and Northern Ireland. Surface water flooding.	1												1								
Floods & Coastal Erosion	FL11b	Sub-stations at significant risk of flooding	Scotland and Northern Ireland. Surface water flooding.	1												1								
Floods & Coastal Erosion	FL12a	Hospitals and schools at significant risk of flooding	Scotland and Northern Ireland. Surface water flooding.	1												1								
Floods & Coastal Erosion	FL12b	Hospitals and schools at significant risk of flooding	Scotland and Northern Ireland. Surface water flooding.	1												1								
Floods & Coastal Erosion	FL13	Ability to obtain flood insurance for residential properties	Scotland and Northern Ireland. Surface water flooding.	1												1								
Floods & Coastal Erosion	FL14b	Priority habitats lost due to coastal erosion	Scotland and Northern Ireland. Improved coastal erosion data including towns on coasts and estuaries.	1			1									1								
Floods & Coastal Erosion	FL14a	Agricultural land lost due to coastal erosion	Scotland and Northern Ireland. Improved coastal erosion data including towns on coasts and estuaries.	1			1									1								
Floods & Coastal Erosion	FL15	Flood risk for Scheduled Ancient Monument sites	Scotland and Northern Ireland. Surface water flooding. Locations of cultural heritage sites	1			1									1								
Forestry	General	n/a	Better knowledge of how different tree species and provenances will respond to climate change, and information on how their populations and distributions are already changing.	1										1				1						
Forestry	General	n/a	Information on how forest disturbance regimes will change (e.g. wind throw, fires).							1										1				
Forestry	General	n/a	More understanding of how to improve resilience at landscape scale (including the woodland component), and its economic benefits.											1			1	1						
Forestry	General	n/a	Quantifying/understanding the spatial and dynamic nature of ecosystem goods and services, and their responses to climate change.											1										

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Forestry	General	n/a	The development of scientifically robust tools for identification and optimisation of land types and areas suitable for expansion of particular woodland types in the face of climate change.			1												1	1					
Forestry	General	n/a	Better understanding of societal and stakeholder motives and incentives likely to help overcome barriers to adaptation.		1																			
Forestry	General	n/a	The need to pilot operational scale adaptive forest management, with scientifically rigorous monitoring and evaluation linked to planning and decision making.										1					1	1					
Forestry	General	n/a	Progress in assessing the likely impacts of extreme climatic effects on woodland function and ecosystem service provision.							1				1										
Forestry	General	n/a	Modelling of impacts of climate change and possible adaptation measures on forest and carbon inventory and production forecasting.										1					1	1					
Forestry	General	n/a	Improved woodland surveillance and enhanced early detection of possible impacts of climate change, at a range of scales.				1																	
Forestry	FO1a	Forest extent affected by red band needle blight	Better understanding of risks posed by current and possible future insect pests and pathogens to British forests, woodlands and trees, including modelling of future outbreaks under a changing climate. Modelling for a wider range of damaging pests and pathogens, using more complex models (such as CLIMEX) where these exist, or developing them where this is possible. Targeting examples from a range of types of organisms, with different climate driver sensitivity. Coupling these models with actual or modelled location of forest tree species in future decades, and with relationships between pest and pathogen prevalence and effect on tree growth.					1							1									
Forestry	FO1b	Forest extent affected by green spruce aphid	Better understanding of risks posed by current and possible future insect pests and pathogens to British forests, woodlands and trees, including modelling of future outbreaks under a changing climate					1							1									
Forestry	FO2	Loss of forest productivity due to drought	Evaluating risk using process models which describe more precisely reductions in tree growth and yield response to modelled soil moisture deficit, using climate projections and soil information. Using separate analyses to evaluate damage from severe drought (timber quality, pest and pathogen risk etc). Coupling these models with actual or modelled location of forest tree species in future decades.								1				1									
Forestry	FO4a	Decline in potential yield of beech trees in England	Extending ESC approach to all of UK forest area using information from the National Forest Inventory. More evidence on productivity of new species, and productivity of semi-natural mixed woodlands. Building the likely effects of changing climate, (including increased atmospheric CO2 concentrations) into forest production forecasting. Combining productivity change modelling with analysis of extreme event probability (e.g. wind throw, frost, fire, pest attack).							1					1					1				
Forestry	FO4b	Increase of potential yield of Sitka spruce in Scotland	Extending ESC approach to all of UK forest area using information from the National Forest Inventory. More evidence on productivity of new species, and productivity of semi-natural mixed woodlands. Building the likely effects of changing climate, (including increased atmospheric CO2 concentrations) into forest production forecasting. Combining productivity change modelling with analysis of extreme event probability (e.g. wind throw, frost, fire, pest attack).							1					1					1				
Health	General	n/a	Most of the research outlined in this report has been carried out for England and Wales. Where applicable, the research should be extended to include Scotland and Northern Ireland.	1																				
Health	General	n/a	Most risks in the health sector are strongly correlated to social demographics. The elderly for example are typically more vulnerable to most health impacts, and a projected ageing population is likely to increase these risks. Further social demographic specific research, in particular related to age should therefore be considered for many of the impacts identified in this sector.																		1			
Health	General	n/a	A number of health impacts are very uncertain as they are to a greater or lesser degree driven by human behaviour or actions. Where applicable, the effect of human actions such as links between periods spent outside and levels of UV exposure should be explored, and how these are likely to change in the future.		1																			
Health	General	n/a	In many cases it is difficult to break health impacts down to a regional basis. However, this mainly relates to a general lack of research in these areas rather than any lack of region specific research. Where possible, health impacts should be looked at regionally.	1																				
Health	General	n/a	Food borne diseases: More research is required linking changes in temperatures to changes in cases of food borne diseases, and the effect on hospital admissions.					1			1													

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Health	General	n/a	Vector borne diseases: Monitoring of malaria transmission and other risks related to climate sensitive vector borne diseases is required so as to consider it for assessment in the next CCRA.								1													
Health	General	n/a	Water quality and water borne diseases: There is limited evidence linking pathogen survival to projected temperature increases, and whether this is the driving factor. As this metric is likely to affect those on a private water supply, and is also regionally dependant, regional projections are required on how the public to private water supply balance is likely to change over the rest of this century.					1	1	1	1													
Health	General	n/a	Agricultural contaminants: The link between climate change and agricultural contaminants and the consequent human health impacts is inconclusive.					1			1													
Health	General	n/a	Emergency medicine: Emergency medicine is very likely to experience a significant change in demand for its services over and above current annual levels as a result of climate change. This is likely to result in an increase in levels and variety of demand during extreme weather events, such as floods and heatwaves.		1					1														
Health	General	n/a	Medicine efficacy: Manufactured drugs are in general licensed for storage at temperatures up to 25°C, and these medicines can be exposed to temperatures greater than this either on the storage premises (e.g. GP surgeries), or in bags during home visits. Additional research is therefore required (on a regional basis) to investigate the efficacy of different medicines both on site and during home visits during future heatwaves.		1					1														
Health	General	n/a	Algal/fungal growth in buildings and respiratory diseases: Research undertaken since the mid 1990s has limited evidence and data available to analyse the impact of improved housing standards on damp and mould occurrences, and thus the impact on respiratory conditions. There seems to be limited data on the link between damp homes and respiratory conditions which needs to be investigated.				1				1													
Health	General	n/a	Hospitals at risk from flooding: The current and future risk to hospitals due to flooding in Scotland and Northern Ireland is currently unknown. Future and ongoing research into flood risk for Scotland and Northern Ireland should start to address this issue, and this should be considered in time for the next CCRA.	1																				
Health	General	n/a	Transport and communications network failure: There is little known research into the human health effects due to disruption of transport systems and communications network failure.					1			1													
Health	General	n/a	Traffic accidents: A future changing climate is likely to have an effect on the number of traffic accidents. The different climate factors and exposure-response relationships need to be investigated, as well as how these are likely to change under a different climate.					1			1													
Health	General	n/a	Social disruption: Although some research has been carried out into how social behaviour changes under different climate effects, further research is required in this area.		1						1													
Health	HE1	Summer mortality due to higher temperatures	The additional impact of heatwaves on mortality (and morbidity) requires estimates of the intensity, frequency and duration of heatwaves in the future which is currently uncertain. Additional analysis of existing data sets should enable this to be done for the next CCRA. It is likely that a future population would be more acclimatised to heat, and less acclimatised to cold. Limited research has been carried out in this area, and this was not considered in this assessment. There are no known published temperature-mortality relationships for Scotland or Northern Ireland. As a result, the results presented are likely to be under-estimated for heat (although not significantly), yet over-estimated for cold related mortality.	1			1				1													
Health	HE2	Summer morbidity due to higher temperatures	Although there is certain evidence that very high and very cold temperatures have an impact on a range of morbidity outcomes, with an increase in patient-days per year due to heat and cold related illnesses, the rate of change is highly uncertain. In addition, as for cold mortality noted above, winter hospitalisations are confounded by infectious diseases more common in the winter which means that it is difficult to attribute individual hospitalisations to a cold related disease. Existing NHS data sets should enable this to be assessed in more detail for the next CCRA, although ethical clearance, as noted above, would probably be required before these data sets could be released.	1			1				1													

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Health	HE3	Extreme weather event (flooding and storms) mortality	Very little research has been carried out into the relationship between extreme weather events and their impacts, and the consequent increased deaths and injuries as a result of these events. This is particularly the case for countries such as the UK that are not exposed to weather events such as hurricanes, and/or the large scale deep flood events experienced in recent decades in places such as the USA, India and Bangladesh. Baseline data sets are poor, with no central record of deaths or injuries related to individual floods or storms kept. There is also no clear accepted definition of what is a flood or storm related injury. With relatively few deaths and injuries due to extreme weather event flooding and storms, as well as the highly clustered nature of these events, it is currently difficult to establish baseline estimates. A national surveillance system set in place to officially record all flood related deaths and injuries would remove this gap, although limited data would be in place in time for the next CCRA. As with all flood related risk metrics, research in Scotland and Northern Ireland lags behind England and Wales. It is likely that				1			1	1									1				
Health	HE4a	Mortality due to summer air pollution (ozone)	The research for ozone presented in this report is based on a linear non-threshold effect on human health. The effect of different threshold models for ozone needs to be considered, and further research should enable this to be done for the next CCRA. Projections of future ground-level ozone concentrations depend on emission scenarios, atmospheric transport, chemical reactions and removal processes which are currently not fully understood. Further modelling of these processes is therefore required. There is lack of concrete evidence of the health impacts of potentially prolonged exposure to allergens such as pollen, and future exposure levels in the UK are uncertain. Modelling is required to investigate the effect of climate change on winter air pollution (nitrogen dioxide and PM10). Levels of the different types of air pollution will show noticeable variations across the UK, which will need to be investigated, and will disproportionately affect certain population groups. There is a large amount of research therefore required to better understand these impacts and how they are likely to change.					1			1										1			
Health	HE4b	Morbidity due to summer air pollution (ozone)	The research for ozone presented in this report is based on a linear non-threshold effect on human health. The effect of different threshold models for ozone needs to be considered, and further research should enable this to be done for the next CCRA. Projections of future ground-level ozone concentrations depend on emission scenarios, atmospheric transport, chemical reactions and removal processes which are currently not fully understood. Further modelling of these processes is therefore required. There is lack of concrete evidence of the health impacts of potentially prolonged exposure to allergens such as pollen, and future exposure levels in the UK are uncertain. Modelling is required to investigate the effect of climate change on winter air pollution (nitrogen dioxide and PM10). Levels of the different types of air pollution will show noticeable variations across the UK, which will need to be investigated, and will disproportionately affect certain population groups. There is a large amount of research therefore required to better understand these impacts and how they are likely to change.					1			1										1			
Health	HE5	Decline in winter mortality due to higher temperatures	Limited information is available on thresholds and exposure response functions for cold-related mortality. In addition, many winter deaths are as a result of infectious diseases such as influenza and pneumonia which means that it is difficult to attribute individual deaths to a cold related disease. Based on current published evidence, this means that any estimate of cold related deaths would be unreliable, although still significant. Additional analysis of existing data sets should enable this to be done for the next CCRA. There are no known published temperature-mortality relationships for Scotland or Northern Ireland. As a result, the results presented are likely to be under-estimated for heat (although not significantly), yet over-estimated for cold related mortality. Although these relationships would be relatively easy to establish, the data sets required for the analysis cannot be released without ethical clearance, which typically takes six months. It is likely that a future population would be more acclimatised to heat, and less acclimatised to cold. Limited research has been carried out in this area, and this was not consider	1			1				1													
Health	HE6	Decline in winter morbidity due to higher temperatures	Although there is certain evidence that very high and very cold temperatures have an impact on a range of morbidity outcomes, with an increase in patient-days per year due to heat and cold related illnesses, the rate of change is highly uncertain. In addition, as for cold mortality noted above, winter hospitalisations are confounded by infectious diseases more common in the winter which means that it is difficult to attribute individual hospitalisations to a cold related disease. Existing NHS data sets should enable this to be assessed in more detail for the next CCRA, although ethical clearance, as noted above, would probably be required before these data sets could be released.	1			1				1													

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Health	HE9	Sunlight/UV exposure	The relationship between UV exposure and melanoma incidence and mortality is unclear. Little if any evidence exists linking UV exposure and non melanoma incidence, particularly for the more aggressive forms, squamous and merkel cell carcinoma. Although there would be expected to be public health benefits of increased UV exposure, such as increased vitamin D levels and improved physical and mental health due to people spending more time outdoors, these levels are not currently fully documented.				1				1													
Health	HE10	Effects of floods/storms on mental health	Although significant progress has been made in recent years researching the mental health effects due to extreme weather events, little is known about the effects long term. The methodology commonly used in flood studies uses the GHQ-12 to assess mental health effects. Although this methodology indicates that a mental health effect has occurred, it is unspecified and gives no indication of the nature or severity of the effect. Current estimates do not cover Scotland and Northern Ireland. Research into the change in flood risk in these countries would enable these estimates to be updated for the next CCRA.	1			1												1					
Health	HE7	Extreme weather event (flooding and storms) injuries	Knowledge of flood related injuries				1												1					
Marine & Fisheries	MA1	Risk of Harmful Algal Blooms due to changes in ocean stratification	Section 4.3.1 clearly indicates that the level of understanding regarding how the incidence of harmful algal blooms will be impacted by future climate change remains rudimentary, with limited knowledge of the processes that result in bloom formation (which vary from species to species) and how these could or should be modelled in the future. Significantly more research is required in this field, and this should be targeted at those species or strains that pose the greatest threat to citizens and ecosystems around the UK.					1	1	1	1													
Marine & Fisheries	MA2a	Decline in marine water quality due to sewer overflows	In the assessment contained in Section 4.3.2 it was only possible to provide a very localised case-study of the climate change impact on sewage overflows and harmful pathogens in the River Dart catchment and estuary (Devon). A recommendation for future iterations of the CCRA would be to build on this analysis and apply similar techniques to multiple river catchments throughout the United Kingdom, some of which are expected to experience greater flows in the future and others lower flows (e.g. Arnell and Reynard, 1996). In winter, all of the UK with the exception of north-west Scotland will experience an increase in the magnitude of the 'two-year event' (flash flooding). In some areas, notably the south of England and southern Scotland, the increase might be as much as 20 per cent under Medium-High Emission scenarios. The probability that on any given winter day heavy rainfall will occur also increases throughout the whole of the UK. In Central-south England for example, the probability that any given winter day by the 2080s will have precipitation in excess of 20 mm is about 2.5%, compared to 1% at present.	1			1	1	1	1														
Marine & Fisheries	MA2b	Risks of human illness due to marine pathogens	There are currently large data gaps in the understanding of the epidemiology, and biology of marine-associated Vibrio pathogens in the UK and Europe. This presents serious limitations in the ability to provide accurate and reliable risk assessments and advice in this area. An important future step in increasing our understanding of risk is the collection of accurate monitoring data which should encompass at the very least, components related to climate change, pathogen biology and economic/epidemiological factors. Designation of V. vulnificus and V. parahaemolyticus as notifiable pathogens for inclusion in the European Network for Epidemiologic Surveillance and Control of Communicable Diseases would aid this.				1				1													
Marine & Fisheries	MA3	Increased ocean acidification	A number of research initiatives are currently underway to improve understanding of the physiochemical, biological, ecological and socio-economic impacts of ocean acidification. This includes international research programmes such as the EU funded EPOCA and MedSeA programmes, national programmes such as the UK Ocean Acidification Research Programme and the German BIOACID programme, and extensive work in US and elsewhere. Developing precise and specific projections of the potential impacts of ocean acidification on marine processes underpinning the societal "goods and services" derived from the seas is a challenging interdisciplinary task. Whilst the aforementioned research initiatives are expected to enhance understanding of potential ocean acidification impacts and reduce the range of projected outcomes, significant uncertainty is likely to remain for the foreseeable future. Work that seeks to scale up to projections of potential population, community and ecosystem level responses is required. This work needs to be brou A key requirement that has been highlighted is the need for observational data to provide accurate baseline measurements against which future changes in pH					1				1		1	1					1				

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Marine & Fisheries	MA4a	Changes in fish catch latitude/centre of gravity (cod, haddock)	Given time and resources available, it has only been possible to develop a relatively crude 'response function' to reflect the shifting distribution of fish species, and consequently fisheries in Europe. Modelling strategies for projecting the potential impact of climate change on the natural distribution of species have been developing quickly in recent years and have often focused on the characterisation of a species' 'bioclimate envelope' (Pearson and Dawson, 2003). Effort should also be directed in the future, toward projecting the distribution patterns of a greater number of species that are of conservation and fisheries importance. There are several recommendations with regard to work that is needed if we are to adequately understand the economic consequences of climate change on the UK fishing sector:· UKCP09 outputs for the marine environment are inadequate in comparison with those available for the terrestrial environment. In the longer-term UKCIP should work towards more-detailed model outputs for multiple scenarios that are comparable in detail with those available on land.· Application of mo				1								1	1								
Marine & Fisheries	MA4b	Changes in fish catch latitude/centre of gravity (plaice, sole)	Given time and resources available, it has only been possible to develop a relatively crude 'response function' to reflect the shifting distribution of fish species, and consequently fisheries in Europe. Modelling strategies for projecting the potential impact of climate change on the natural distribution of species have been developing quickly in recent years and have often focused on the characterisation of a species' 'bioclimate envelope' (Pearson and Dawson, 2003). Effort should also be directed in the future, toward projecting the distribution patterns of a greater number of species that are of conservation and fisheries importance. There are several recommendations with regard to work that is needed if we are to adequately understand the economic consequences of climate change on the UK fishing sector:· UKCP09 outputs for the marine environment are inadequate in comparison with those available for the terrestrial environment. In the longer-term UKCIP should work towards more-detailed model outputs for multiple scenarios that are comparable in detail with those available on land.· Application of mo				1								1	1								
Marine & Fisheries	MA5b	Opening of Arctic shipping routes due to ice melt	With regard to the melting of arctic sea ice, the above assessment has been carried out using projections from the Met Office's HadCM3 model. The Met Office is currently developing a new generation of climate models known as the HadGEM series (Hadley Global Environment Model). HadGEM1 was the first iteration of these models developed in 2006. The key difference between these models and the CM3 model are in the level of detail and resolution provided. The HadGEM model series (1, 2 and 3) of climate configurations is currently under development and therefore for the purposes of this assessment the established HadCM3 was used particularly because of its relevance to the UKCP09 projections. For future iterations of the CCRA it is suggested that the potential to use the HadGEM model series should be considered due to the greater spatial resolution afforded.	1																				
Marine & Fisheries	MA5a	Arctic ice melt due to higher temperatures	With regard to the melting of arctic sea ice, the above assessment has been carried out using projections from the Met Office's HadCM3 model. The Met Office is currently developing a new generation of climate models known as the HadGEM series (Hadley Global Environment Model). HadGEM1 was the first iteration of these models developed in 2006. The key difference between these models and the CM3 model are in the level of detail and resolution provided. The HadGEM model series (1, 2 and 3) of climate configurations is currently under development and therefore for the purposes of this assessment the established HadCM3 was used particularly because of its relevance to the UKCP09 projections. For future iterations of the CCRA it is suggested that the potential to use the HadGEM model series should be considered due to the greater spatial resolution afforded.	1																				
Marine & Fisheries	MA6	Northward spread of invasive non-native species	As previously suggested there are various 'bioclimate envelope' modelling techniques available to project the extent of 'suitable' habitat for incoming species and some of these have been used to model the potential spread of non-native marine species (e.g. Herborg, et al., 2007). The application of such techniques in the maritime environment is at an early stage and existing efforts have tended to focus on defining the potential 'suitable' habitat now, and not potential habitat in the future as a consequent of long-term climate change. Numerous methodologies used to predict the occurrence and potential range of non native species focus on life history attributes (e.g. Kolar and Lodge, 2002) or on vectors that link invaded sources with un-invaded destinations. Another methodology, ecological niche modelling, seeks to assess the potential range of non native species based on distribution data in the native range and a range of environmental variables in both areas (reviewed in Peterson, 2003). It is suggested that for future iterations of the CCRA these types of modelling assessment need to be employed to better understand the ran					1								1								

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Marine & Fisheries	MA7	Potential disruption to shipping due to rough seas	With regard to projections of disruption to ferry services and shipping, at present, confidence in the wind projections from Global Climate Models (GCMs) and down-scaled Regional Climate Models (RCMs) is low, with some models suggesting that the UK might experience fewer storms and others suggesting an increase in the future. Thus the confidence in projections of wind and storms from the models underlying UKCP09 were also considered very unreliable and uncertain. Added to this, UKCIP did not provide wind field changes within its package of model outputs for the marine environment, although wind projections have subsequently been made available (Sexton et al., 2010). For important applications that depend on wind, such as the offshore renewable sector but also shipping, the uncertainty surrounding this parameter is a major limitation when attempting to estimate future risks. Wave heights around the UK depend on winds and storms both locally and in the wider Atlantic.							1									1					
Marine & Fisheries	MA8	Potential disruption to breeding of seabirds and intertidal invertebrates	With regard to projections of future breeding distribution of seabirds Huntley et al. (2007) provides a detailed discussion of limitations concerning the 'bioclimate envelope approach' that was adopted here. It is extremely important to be aware, when examining the maps of potential future breeding distribution that in some cases the simulated potential future range may be realised only after considerable delay, and in other cases not at all. For many bird species the ability to realise their future potential ranges will be dependent upon the extent to which suitable habitat is available to them (which is not guaranteed) in the areas that are newly climatically suitable. Species that are habitat specialists, or that have specialist interactions with other species, may find their ability to occupy newly climatically suitable areas limited. Habitat generalists with generalist interspecific interactions (feeding preferences) are likely to be more successful in occupying new areas and consequently spreading in response to climate change. Most of the work conducted in relation to seabirds has pointed out the lack of understanding of interactions be					1							1									
Marine & Fisheries	MA9	Decline in productivity of 'cold water' fish and shellfish stocks	In the assessment of fish year class strength (metric MA9), we used relatively simplistic models with strong assumptions about how this index might respond to future temperature rises. It is apparent that different species respond to climate in different ways and many respond more to ocean-wide climatic indices such as the NAO (which is difficult to project for the future), rather than sea temperature itself. Better understanding of biological processes is needed and in particular concerning the various sources of mortality to fish eggs and larvae that determine 'recruitment' success, and are sensitive to climatic conditions. Sometimes recruitment success can be related to changes in the plankton and/or abundance of potential predators; however such 'match-mismatch' issues are poorly understood. Furthermore, it is often very difficult to differentiate the effects of fishing from those of climate change. Fishing can make stocks more vulnerable to climatic variability, i.e. occasional poor year classes. Ottersen et al. (2006) pointed out for arctic cod, that higher dependency nowadays of recruitment on climate, relates to changes					1					1		1									
Marine & Fisheries	MA10	Disruption to marine ecosystems due to warmer waters	Complex models have been used for projections of the potential impact of climate change on nutrient cycling and ecosystem function in the North Sea, although these have thus far only been applied in 1D mode for three discrete sites and using one climate scenario. Clearly a major recommendation would be to repeat the work in the future using a fully 3D version of the model, and where possible to use an 'ensemble' of different model formulations and scenarios in order to characterise uncertainty.												1									
Transport	General	n/a	Analyses are difficult for many impacts in the sector as there is a gap in knowledge with respect to trigger mechanisms and thresholds. Whilst some thresholds are clear, for example, 0°C for ice formation, 36°C for blanket speed restrictions on the railway (Dobney et al., 2010), such simple thresholds cannot be applied universally across all impacts and modes. Impacts such as flooding and bridge scour are location specific and the trigger mechanism will vary from location to location. A detailed inventory of all hard infrastructure and past climate events is required to complete a detailed analysis of such impacts.				1	1			1													
Transport	General	n/a	Throughout this assessment, there is a general lack of quantitative data sufficient to produce robust metrics. Examples of this are evident for many of the Tier 2 impacts. For example, no qualitative landslip information in TR2; no data available for Northern Ireland in TR5; no national bridge register and no data on bridge foundations in TR6. The result of a lack of data is ultimately the reason behind the low-medium confidence rating in the results of this report.	1			1																	

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Transport	General	n/a	Data availability is the key issue leading to reduced confidence in analyses. However, further uncertainty in the response functions reflects the uncertainties in climate change drivers. The majority of analyses in this report have used the UKCP09 temperature and precipitation data. Other impacts would need additional datasets and these are not readily available (e.g. wind and visibility projections).							1									1					
Transport	General	n/a	Similarly, analysis of some impacts (e.g. landslides) needs to consider antecedence, which can be achieved in UKCP09 by using a weather generator, but is ultimately a difficult exercise. Indeed, the majority of the analysis conducted on the Tier 2 impacts in this report is completely dependent on the accuracy of UKCP09 scenarios and therefore its limitations (for example, non-inclusion of urban areas which are major hubs of the UK transport network).																					1
Transport	General	n/a	Many of the impacts of climate on the transport sector are caused by extreme short lived events. In this analysis seasonal mean changes in mean temperature and rainfall from UKCP09 have been used as the basis for assessing future climate change projections. Consideration should be given to developing better projections of daily and extreme climate variables and using these for future CCRA's.																1					
Transport	General	n/a	Finally, there are uncertainties surrounding the application of socio-economic scenarios in the analysis. It is accepted that the application of these is challenging and an attempt has been made to incorporate these based on the assumption of increasing population and travel demand. Whilst this is a useful first attempt, more work is needed to fully test this assumption and fully integrate potential scenarios into the analysis.		1																			
Transport	TR1	Disruption to road traffic due to flooding	Scotland and Northern Ireland. Surface water flooding. Costs required	1			1									1	1							
Transport	TR2	Landslide risks on the road network	No causal link between winter rainfall and landslides has been confirmed. No data is available for Wales	1						1	1													
Transport	TR4	Cost of carriageway repairs due to high summer temperatures	No data available for Scotland and Wales. It was not possible to do this analysis for extremes in temperature	1						1						1			1					
Transport	TR5	Rail buckling risk	No data available for Northern Ireland.	1																				
Transport	TR6	Scouring of road and rail bridges	This is no national register for bridges				1																	
Water	WA1	Warmer and drier conditions in the South East of England	Further research is needed to improve understanding of the changing frequency and magnitude of major drought events. The UK Research Councils have started this work with the NERC Changing Water Cycle and proposed UK Drought programmes.																1					
Water	WA10	Combined Sewer Overflow spill frequency	Confidence in this metric could be improved by using observed data on CSO spill frequency and rainfall event characteristics. This requires a detailed understanding of how drainage systems work and water companies are best placed to quantify future impacts as part of the business planning process.												1									
Water	WA2	Lower summer river flows (Q95)	For this metric, confidence could be improved by using the new assessment of 'Future Flows', to be published by the Natural Environment Research Council (NERC), Environment Agency, UKWIR and Defra in 2012.	1									1	1	1									
Water	WA3	Reduction in water available for public supply	For this metric, confidence could be improved by using data from the next round of WRMPs, in which most companies are expected to use UKCP09 data to estimate the impact of climate change on DO. Water companies will complete this analysis before 2014, so it should be possible to include it in the next CCRA.					1																
Water	WA4	Change in household water demand	Using data for the whole of the UK rather than for England and Wales only would have greatly improved understanding of how the demand for water might change in the entire country. Data for Scotland and Northern Ireland were unavailable for the current CCRA. Further work is needed on climate change and demands. Preliminary work using UKCP09 indicates that the impacts on peak demands may be greater than previously assumed (HR Wallingford, forthcoming).	1																				

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Water	WA5	Public water supply-demand deficits	Confidence in this metric would be improved by including broader consideration of the factors influencing the supply-demand balance. This includes leakage, of which further UKWIR studies into the impacts of climate are planned in 2011/12. The water resources planning process provides data and information that can be used for national assessments. However further work is needed to reconcile and streamline abstraction licensing data and water company information. A further consideration would be the influence of the potential withdrawal of abstraction licences due to environmental pressures, because the analysis did not fully take account of this.		1								1								1	1		
Water	WA6	Population affected by water supply-demand pressures	As with WA5, confidence in this metric would be improved by including broader consideration of the factors influencing the supply-demand balance, including leakage. The development of simple indicators, like deficits per head or water scarcity indicators may help to communicate the magnitude of climate change risks.		1								1								1	1		
Water	WA7	Insufficient summer river flows to meet environmental targets	As Q95 is a poor indicator of ecological stress on river ecosystems on its own, the analysis for this metric provides only a partial view and further information on understanding hydro-ecological stress from modifications of the flow regime as a whole is needed. This metric would be further enhanced if similar data were available for Scotland and Northern Ireland. The WFD river basin management planning process should provide a mechanism for improving our understanding of the impacts of climate on ecological status.	1									1	1	1									
Water	WA8	Number of unsustainable water abstractions (total)	As with WA7, improved understanding of hydro-ecological stress from modifications of the flow regime as a whole is needed to improve confidence in this metric. In addition there is scope to capture the impacts on groundwater dependent wetlands impacted by unsustainable abstraction. This is of importance because the 'Quantitative Status' of groundwater under the WFD is determined in part by the condition of wetlands designated as Groundwater Dependent Terrestrial Ecosystems (GWDTEs). Metric WA8 could therefore be expanded beyond consideration of lakes, rivers and estuaries to also include GWDTEs and the quantitative status of groundwater.	1									1	1	1									
Water	WA8a	Number of unsustainable water abstractions (agriculture)	As with WA7, improved understanding of hydro-ecological stress from modifications of the flow regime as a whole is needed to improve confidence in this metric. In addition there is scope to capture the impacts on groundwater dependent wetlands impacted by unsustainable abstraction. This is of importance because the 'Quantitative Status' of groundwater under the WFD is determined in part by the condition of wetlands designated as Groundwater Dependent Terrestrial Ecosystems (GWDTEs). Metric WA8 could therefore be expanded beyond consideration of lakes, rivers and estuaries to also include GWDTEs and the quantitative status of groundwater.	1									1	1	1									
Water	WA8b	Number of unsustainable water abstractions (industry)	As with WA7, improved understanding of hydro-ecological stress from modifications of the flow regime as a whole is needed to improve confidence in this metric. In addition there is scope to capture the impacts on groundwater dependent wetlands impacted by unsustainable abstraction. This is of importance because the 'Quantitative Status' of groundwater under the WFD is determined in part by the condition of wetlands designated as Groundwater Dependent Terrestrial Ecosystems (GWDTEs). Metric WA8 could therefore be expanded beyond consideration of lakes, rivers and estuaries to also include GWDTEs and the quantitative status of groundwater.	1									1	1	1									
Water	WA9a	Potential decline in summer water quality (point source pollution)	Confidence in this metric could be improved by using outputs from quantified modelling which properly incorporates algal growth in rivers, and links this back to Biochemical Oxygen Demand (BOD) and dissolved oxygen.					1	1	1				1	1									
Water	WA9b	Potential decline in water quality due to diffuse pollution	Little is know about how climate change will affect diffuse pollution. Data is variable across the UK.	1				1	1	1	1													
Northern Ireland	NE theme	n/a	Much of the climate change research conducted to date has, of necessity, been focused either upon individual species or on specific locations or habitat types. Development of systems-based approaches that can improve understanding of the multitude of interactions within the natural environment, and their links to the human environment, remain in the early stages.		1	1					1				1									

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Northern Ireland	NE theme	n/a	The basic knowledge gap is our understanding of change and ecosystem dynamics, including the interaction of people within ecosystems (and the role that biodiversity plays in driving functions and underpinning ecosystem services). This is essentially due to the complexity of responses and feedbacks involved, but also because this has often been a neglected topic in research. As a consequence, key functions and services provided by ecosystems have fundamental uncertainty in terms of how they will respond to change. A coherent baseline is required on the current state of ecosystems, the impacts that can be expected and how they relate to both the rest of the UK and to the Republic of Ireland.		1	1					1			1	1									
Northern Ireland	NE theme	n/a	Continuous data records that are comparable across years or standardized across the UK are also limited, although some very good examples do exist. In Northern Ireland specifically, data and research issues often centre on whether data exist, their accessibility and their comparability and compatibility (NEA, 2011).				1																	
Northern Ireland	NE theme	n/a	· Integrated modelling of species distributions and interactions, habitat shifts and landscape structure based upon models that combine biological, ecological and climate factors. This would provide a more robust evidence base than the current reliance on bioclimate envelope models to project future changes in range shifts.					1							1							1		
Northern Ireland	NE theme	n/a	· Better understanding of the implications to ecosystem function and services from climate change. For example, what will be the net effect of phenological mismatches (mismatches or asynchrony in the timing of species life-cycle events); what will be the costs to humans?						1		1			1										
Northern Ireland	NE theme	n/a	· Detailed epidemiological knowledge of different pests and diseases (and their vectors) and their relationship with climate and climate change.					1			1													
Northern Ireland	NE theme	n/a	· Detailed knowledge of different non-native species with the potential to become invasive; their associated economic costs and their relationship with climate and climate change.					1			1			1			1							
Northern Ireland	NE theme	n/a	· Exploration of the role of biodiversity in ecosystem function and services. Of particular to Northern Ireland is the role of soil biodiversity in the production and maintenance of soil organic matter, nutrient and water cycling and carbon sequestration (NEA, 2011).								1			1										
Northern Ireland	NE theme	n/a	· Climate change mitigation:										1		1			1				1		
Northern Ireland	NE theme	n/a	- Opportunities for the natural environment. For example, how efforts to increase carbon storage in soils may benefit soil biodiversity and flora.					1			1			1										
Northern Ireland	NE theme	n/a	- Threats for the natural environment: For example, exploration of where future wind farms will be located and the impact that will have on bird and bat strikes.										1	1				1	1	1				
Northern Ireland	NE theme	n/a	· Improving the effectiveness of the protected area network. Evaluation of current protected areas, how they might change (e.g. change in species use due to changes to migration paths) and how they might be strengthened and better integrated into the wider landscape.	1										1	1									
Northern Ireland	NE theme	n/a	· Develop a baseline understanding of the incidence and consequences of wildfire currently.			1	1					1		1										
Northern Ireland	NE theme	n/a	· Improved understanding of the combined impact of climate change and pollution on ecosystems.																	1				
Northern Ireland	NE theme	n/a	- Exploration of the role that the environment plays, in addition to climate, in determining raw water quality; how these things may change under future climate and environmental conditions and how water quality changes may be monitored is required. The associated consequences for water provision and on priority habitats and species need to be better understood.				1	1	1	1	1										1			
Northern Ireland	NE theme	n/a	- Exploration into the combined effects of climate change and the point or diffuse sources of pollutants that may lead to eutrophication and unwanted algal growth.								1									1				
Northern Ireland	NE theme	n/a	- Exploration into the relationship between current abstraction rates and implications for biodiversity under drought conditions and future climate change.							1	1													
Northern Ireland	NE theme	n/a	· Exploration into the national-level impacts (not just local studies) of increasing water temperatures on biodiversity and the regulation of water quality for the natural environment and human use.	1				1	1	1														

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Northern Ireland	NE theme	n/a	· An understanding of the impact of climate mitigation measures on biodiversity is required. The information needed to improve this understanding is: The spatial strategy for future renewable energy expansion. Distribution of important habitats and species in the future.	1									1	1					1	1		1		
Northern Ireland	NE theme	n/a	- Baseline maps of habitats are required. Coupled with quality and biodiversity assessments and investigation of the impacts on ecosystem services.				1									1								
Northern Ireland	NE theme	n/a	- Maps of past erosion, current state and future erosion conditions are required.													1								
Northern Ireland	NE theme	n/a	- Need an understanding of what and where cultural heritage is at risk.				1																	
Northern Ireland	NE theme	n/a	- More complete monitoring of potential bathing waters				1																	
Northern Ireland	NE theme	n/a	- Exploration of the potential for Harmful Algal Blooms, specific to the seas around Northern Ireland. Consideration of stratification as well as average temperature increases is important.					1	1	1	1													
Northern Ireland	NE theme	n/a	· Exploration into the drivers of eutrophication of sea loughs to ascertain the level of impact climate change may have.					1			1									1				
Northern Ireland	NE theme	n/a	· Fish and shellfish stocks. Understanding the future implications of climate change for fishing fleets, fishermen, economies and society with regard to changes in fish ranges, recruitment and the impacts of ocean acidification on shellfish stocks.								1			1			1							
Northern Ireland	NE theme	n/a	· The impacts of climate change on plankton blooms, and the interaction any changes may have on marine life, carbon and nutrient cycling and invasive species should be further investigated. There is an associated risk to the shell-fish industry which may require further exploration.					1			1			1										
Northern Ireland	NE theme	n/a	The impact of climate mitigation measures. This has been analysed in the Biodiversity and Ecosystem Sector report regarding terrestrial bird strikes, but it does not include sea birds. An improved understanding the impacts of marine renewable energy sites, including wave power and wind turbines, is needed to fully understand the risks to biodiversity and the marine environment. With Northern Ireland expected to increase the number of offshore wind farms, and potentially also use wave and tidal generation (such as SeaGen), there is a requirement for further research into how these may affect the marine and coastal environments.										1	1				1	1	1				
Northern Ireland	A&F theme (AG)	n/a	Future projections of river and tidal flood risk to arable, horticultural and grassland are not provided for Northern Ireland due to a lack of suitable data at the time of the assessment. Additionally, data was unavailable to analyse the risk of saline intrusion on agricultural land despite this being highlighted as a potential problem by stakeholders. Whilst it is now possible to have a strategic overview of future risk using the Strategic Flood Map (SFM) and output from the recent preliminary flood risk assessment. However due to the inherent uncertainties in the flood modelling techniques and data used to produce this national snapshot of flood prone areas, the SFM is not sufficiently accurate to determine the flood risk to individual properties or specific point locations. The second generation flood hazard and risk maps that will be produced for the Areas of Potential Significant Flood Risk shall be much improved with less uncertainty as these will be derived from predictive models, developed in accordance with best practice.				1									1								
Northern Ireland	A&F theme (AG)	n/a	· UK wide assessments indicate that greater evidence is needed on specific social vulnerability issues for the climate change risks analysed, as these currently focus on agricultural and forestry production rather than the broader issue of the rural economy. The vulnerabilities of rural communities to cope and the impact on their lives and livelihoods could be explored further. The overall impacts on farming systems need a greater insight into how Northern Ireland's farmers adapt to climate change.		1																1			
Northern Ireland	A&F theme (AG)	n/a	· To fully quantify climate change risks, further investigation into the impact of extreme events on livestock welfare and production is needed for Northern Ireland. An assessment of heatwaves and drought impacts on livestock is also required.							1														
Northern Ireland	A&F theme (AG)	n/a	· Additionally, an assessment of livestock water use could be undertaken to include the impacts of climate change, and the effect on local hydrology.								1													

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Northern Ireland	A&F theme (AG)	n/a	· Analysis of the impacts of climate change on potato yield currently excludes the effects of CO2. The adaption of this model to include CO2, or the development of a similar model to also include Northern Ireland, would help quantify the risk for Northern Irish potato farming for future climate change.					1	1	1	1				1		1								
Northern Ireland	A&F theme (AG)	n/a	· Currently climate change evidence impacts on crop pests and disease is qualitative and provides a weak assessment of the risks. A quantitative assessment of crops, pests and pathogens and their relationship to climate change would increase the risk analysis.					1	1		1				1										
Northern Ireland	A&F theme (AG)	n/a	· Further analysis into grassland productivity and the influence of CO2 fertilisation is needed for Northern Ireland. There is an indication that the increases projected as part of the CCRA may be too high, but there is a lack of robust research to confirm this.					1	1		1														
Northern Ireland	A&F theme (AG)	n/a	· GHG emission may increase with a change in land use, brought about by climate change and agricultural development. Little data is available on the potential carbon release as a result of the drying-out of wetlands.			1	1	1	1												1				
Northern Ireland	A&F theme (AG)	n/a	· A more detailed study into the impacts of waterlogging would enable a more regionally representative assessment of the future risk. This would allow for adaptation measures to be suggested for Northern Ireland's important agricultural sector.	1														1	1					1	
Northern Ireland	A&F theme (FO)	n/a	· The impact on frost and snow damage would benefit from further evidence and analysis.				1		1		1														
Northern Ireland	A&F theme (FO)	n/a	· Further developments in the modelling of storms would allow more confident projections regarding windthrow and storm damage.				1			1	1									1					
Northern Ireland	A&F theme (FO)	n/a	· Tree productivity, biodiversity and tree suitability modelling excludes Northern Ireland. Impacts on forest biodiversity and ecosystem services could be better understood with the aid of national datasets and an understanding of rising temperature on vegetation growth and reproduction. The development of a tool similar to the Ecological Site Classification System, used for the rest of the UK, for Northern Ireland would help analysis of tree productivity metrics.	1			1																		
Northern Ireland	A&F theme (FO)	n/a	Further research into the link between tree pests and diseases and their interaction with climate drivers would aid forestry planning and development. Greater insight to pest and disease physiology would help understand their spread and response and allow for a more robust assessment of future risks. Additionally, the development of tree productivity modelling to include the effects of pests and diseases would aid future projections.			1		1	1		1												1		
Northern Ireland	BU theme	n/a	The potentially most significant gaps in knowledge regarding the consequences for businesses and services in Northern Ireland relate to flooding (see Section 6.1).													1									
Northern Ireland	BU theme	n/a	· At the moment, there is limited substantive evidence of the consequences of changes in climate on UK financial institutions, including the impact on investment funds. The confidential nature of the underlying data and the fact that there are many other socio-economic drivers operating, mean that disentangling the impacts of climate change is challenging.		1		1	1																	
Northern Ireland	BU theme	n/a	· The complexity of supply chains is similarly, difficult to analyse because it involves the interaction of a number of networks that are themselves complex. Nonetheless, there may be scope to develop a better understanding of network interactions as modelling improves.												1						1		1		
Northern Ireland	BU theme	n/a	· The information on the disruption caused to business by extreme events, such as floods and heatwaves is limited and largely reliant on insurance industry reporting. More systematic data collection would enable a more complete assessment to be developed.				1			1															
Northern Ireland	BU theme	n/a	· Two risks were highlighted as potentially becoming increasingly important towards the middle of the century, namely water abstraction for industry and a loss of productivity due to over-heating. Both of these assessments have been made with very limited information on the likely response and the potential of adaptation measures to reduce the extent of the impact. More detailed assessments would be helpful better to understand the likely significance of these impacts, although over-heating may be less of an issue for Northern Ireland than for other parts of the UK.																1					1	

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Northern Ireland	BU theme	n/a	· Creation of data regarding water abstraction for energy supply. The development of the Abstraction and Impound Regulation licences provide an opportunity monitor the volume of abstraction.				1														1				
Northern Ireland	BU theme	n/a	Further assessment of the risk posed by key workers being unable to get to work due to severe weather. Research into this risk would allow for management and action plans to be implemented for future extreme events.				1			1															
Northern Ireland	B&I theme	n/a	The potentially most significant gaps in knowledge regarding the consequences for buildings and infrastructure in Northern Ireland relate to flooding (see Section 6.1).													1									
Northern Ireland	B&I theme	n/a	· Reliance on imported fossil fuels																		1				
Northern Ireland	B&I theme	n/a	· Energy demand by water suppliers				1														1				
Northern Ireland	B&I theme	n/a	· Failure of water impoundment structures				1				1														
Northern Ireland	B&I theme	n/a	· Algal growth in raw water supply sources				1				1														
Northern Ireland	B&I theme	n/a	· Changes in reservoir yields for public water supply				1				1										1				
Northern Ireland	B&I theme	n/a	· The disaggregation of projected supply-demand deficits for the river basins shared with the Republic of Ireland				1				1										1				
Northern Ireland	B&I theme	n/a	· Pest infestations				1				1														
Northern Ireland	B&I theme	n/a	· Waste management				1				1														
Northern Ireland	B&I theme	n/a	· Rainwater penetration and damage to buildings				1				1														
Northern Ireland	B&I theme	n/a	Condensation, damp, mould, algal/fungal growth in buildings				1				1														
Northern Ireland	B&I theme	n/a	· Development of a better understanding of the complex cause-and-effect interactions of climate change impacts.																		1		1		
Northern Ireland	B&I theme	n/a	· Development of a clearer understanding of technical solutions, their costs and their financial viability.														1						1		
Northern Ireland	B&I theme	n/a	· Development of an improved appreciation of the economic impacts of climate change.					1		1							1								
Northern Ireland	B&I theme	n/a	· Development of low-carbon solutions that are also robust to the effects of climate change.																1					1	
Northern Ireland	B&I theme	n/a	· Research into potential impacts (e.g. increased pest infestations) on historic buildings and the heritage sector in general.				1				1														
Northern Ireland	B&I theme	n/a	· The effects of an Urban Heat Island, with greater consideration to impacts on human health.	1																	1		1		
Northern Ireland	B&I theme	n/a	· Site-specific flood risks to individual locations where energy infrastructure is located.	1	1		1									1									
Northern Ireland	B&I theme	n/a	· Relating CDD to energy demand taking into consideration non-climate factors (such as building stock and uptake of air-conditioning).		1																1				
Northern Ireland	B&I theme	n/a	· Positive and negative impacts of warmer temperatures on electricity demand and supply and the interdependence between these impacts.		1			1	1										1		1				
Northern Ireland	B&I theme	n/a	· Climate projections for other parts of the world relevant to the UK energy sector (e.g. the Middle East).	1				1																	
Northern Ireland	B&I theme	n/a	· The particular vulnerability of cities to climate change.	1				1	1																
Northern Ireland	B&I theme	n/a	· The impact of climate change on the UK's wind energy resource.				1	1	1	1										1					1
Northern Ireland	B&I theme	n/a	· Timescales within which different adaptation approaches need to be implemented in order to be successful.										1						1					1	

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Northern Ireland	B&I theme	n/a	More broadly, future climate change risk assessments should aim to look more closely at alternative future pathways for delivering a low carbon economy (in particular regarding the future energy mix) and how these may be affected by climate change.																		1				
Northern Ireland	B&I theme	n/a	The underlying issue for this sector (Transport) is a lack of coherent data across the UK, resulting in a predominantly qualitative assessment with a significant amount of uncertainty in the outcomes.				1																		
Northern Ireland	B&I theme	n/a	The transport sector is integral to the smooth running of society and the economy and further work is required to help meet the challenge of establishing reliable and relevant climate change impact projections and adaptation strategies. Technological innovation should be considered alongside other socio-economic factors.		1														1				1	1	
Northern Ireland	B&I theme	n/a	Ongoing research, such as the TRACCA project (Tomorrow's Railways and Climate Change Adaptation), will be a first step to providing more knowledge in some areas.					1			1														
Northern Ireland	B&I theme	n/a	· The potential impact of climate change on water quality and the knock-on effects to the public water supply.					1	1	1	1														
Northern Ireland	B&I theme	n/a	· The environmental impacts of drought (and climate modelling of droughts lasting more than one season).							1	1				1	1									
Northern Ireland	B&I theme	n/a	· The impacts of changes in water demand on river flows.																1						
Northern Ireland	B&I theme	n/a	· Techniques enabling early detection/attribution of manmade climate-related impacts on the water sector.					1	1																
Northern Ireland	B&I theme	n/a	· Development of tools and techniques for scaling up local case studies to UK level.	1																					
Northern Ireland	B&I theme	n/a	There is a limited evidence base regarding climate change impacts for the telecommunications sector. This makes forward planning difficult and is compounded by the short-term business models applied by industry.				1	1			1										1				
Northern Ireland	B&I theme	n/a	Telecommunications within the context of our future climate are important due to the interdependencies described in earlier sections of this chapter. Further research and awareness-raising is needed regarding the resilience of ICT systems. It is particularly important that the role of ICT systems in potential cascade failures is understood more fully, especially in light of the growing usage of ICT systems and the sharing of ICT infrastructure within the UK and abroad.																		1		1		
Northern Ireland	H&W theme	n/a	Although a significant amount of research has been carried out into the Health effects of climate change for the UK, much of this work has been carried out for England and Wales only, and as such in certain areas there are specific gaps in knowledge pertinent to Northern Ireland.	1																					
Northern Ireland	H&W theme	n/a	The CCRA analysis focused on England and Wales as the data was in the public domain and the relationships had already been established. For Northern Ireland (and Scotland), the data is not yet in the public domain and would require an ethical clearance order to release it, which can take a long time. If this data were obtained, it would be possible to carry out similar analysis for Northern Ireland, but the project timescale prevented this.	1			1																		
Northern Ireland	H&W theme	n/a	Some future health impacts are very uncertain, as they are an accumulation of several climate variables, and/or mainly driven by human behaviour or actions rather than climate.		1			1											1		1				
Northern Ireland	H&W theme	n/a	Temperature mortality (heat and cold): There are no known published temperature-mortality relationships for Northern Ireland. As a result, the results presented are likely to be overestimated for heat (although not significant), yet under-estimated for cold related mortality. Although these relationships would be relatively easy to establish, the data sets required for the analysis cannot be released without ethical clearance, which typically takes six months. In addition, many winter deaths are as a result of infectious diseases such as influenza and pneumonia which means that it is difficult to attribute individual deaths to a cold related disease. Based on current published evidence, this means that any estimate of cold related deaths would be unreliable, although still significant.				1	1			1														

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Northern Ireland	H&W theme	n/a	Temperature morbidity (heat and cold): Although there is certain evidence that very high and very cold temperatures have an impact on a range of morbidity outcomes, with an increase in patient-days per year due to heat and cold related illnesses, the rate of change is highly uncertain. In addition, as for cold mortality noted above, winter hospitalisations are clouded by infectious diseases more common in the winter which means that it is difficult to attribute individual hospitalisations to a cold related disease. Similar to above, this impact is likely to provide a significant opportunity for Northern Ireland due to cold, yet a relatively small impact compared to the rest of the UK due to heat.	1			1				1													
Northern Ireland	H&W theme	n/a	Extreme weather event (flooding and storms) mortality and morbidity – analysis: Very little research has been carried out into the relationship between extreme weather events and their impacts, and the consequent increased deaths and injuries as a result of these events. This is particularly the case for countries such as the UK that are not exposed to weather events such as hurricanes, and/or the large scale deep flood events experienced in recent decades in places such as the USA, India and Bangladesh. Northern Ireland is also not exposed to the levels of wave activity from the Atlantic Ocean and North Sea experienced on many parts of the British mainland, and the risk due to coastal activity would therefore be expected to be less significant here than for the rest of the UK.				1			1	1								1					
Northern Ireland	H&W theme	n/a	Extreme weather event (flooding and storms) mortality and morbidity – data sets: Baseline data sets are poor, with no central record of deaths or injuries related to individual floods or storms kept in Northern Ireland. There is also no clear accepted definition of what is a flood or storm related injury. With relatively few deaths and injuries due to extreme weather event flooding and storms, as well as the highly clustered nature of these events, it is currently difficult to establish baseline estimates for Northern Ireland. Current and future flood risk is also unknown, although ongoing research due to deliver later this year should address this issue. However, the lack of long-term reliable tidal data sets particularly along the fast moving waters of the North Channel means that estimates due to coastal flood events would currently remain unreliable.				1			1	1								1					
Northern Ireland	H&W theme	n/a	Summer air pollution (ozone): Little research has been done on future ground-level ozone concentrations and how climate may affect them, and research that has been carried out has only considered plausible climates in the 2070s and 2080s, and no research specific to Northern Ireland. More research is required for time periods specific to Northern Ireland in both rural and urban environments and different thresholds below which ozone concentrations do not cause harm to human health.					1			1									1				
Northern Ireland	H&W theme	n/a	Sunlight/UV exposure – skin cancer: The future change in the numbers of skin cancers per year is related to the change in risk of skin cancer due to the change in the mean annual flux. However, this variance is linked to a number of factors, including the main variable time spent outdoors, as well as a number of socio-economic factors including the future age structure of the population and the changing ethnic mix. Although current projections indicate little change to UVB radiation for Northern Ireland, future research is required into how the various socio-economic factors may change skin cancer risk, and whether this may change the current rate for Northern Ireland, which currently shows little variation from the UK average.		1			1											1				1	
Northern Ireland	H&W theme	n/a	Sunlight/UV exposure – health benefits: UV exposure can have a number of health benefits, including the synthesis of vitamin D as well as some therapeutic effects. There is also some evidence for vitamin D protecting against some cancers, although evidence is currently weak. More research is therefore required into the health benefits of increased UV exposure and how these may weigh against the negative effects of increased cases of skin cancers.		1			1											1				1	
Northern Ireland	H&W theme	n/a	Sunlight/UV exposure – registration of non melanoma skin cancers: Registration of non melanoma skin cancer cases is currently incomplete across the whole of the UK, particularly in relation to basal cell carcinomas. This needs to be corrected to enable a more robust analysis of this metric to be made.				1				1													
Northern Ireland	H&W theme	n/a	Effects of floods/storms on mental health: Although significant progress has been made in recent years researching the mental health effects due to extreme weather events, little is known about the effects long term. The methodology commonly used in Northern Ireland flood studies uses the GHQ-12 to assess mental health effects. Although this methodology indicates that a mental health effect has occurred, it is unspecified and gives no indication of the nature or severity of the effect.	1			1												1					

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Northern Ireland	H&W theme	n/a	Hospitals at risk from flooding: There is a risk that hospitals in Northern Ireland may not be resilient to flooding, particularly during extreme events. It is not currently known how many hospitals are at flood risk in Northern Ireland, or how this is likely to change in the future. A strategic overview of the flood risk to hospitals and medical centres can now be undertaken using the Strategic Flood Map (SFM) and output from the recent PFRA (see Appendix D). However, due to the inherent uncertainties in the flood modelling techniques and data used to produce this national snapshot of flood prone areas, the SFM is not sufficiently accurate to determine the flood risk to individual properties or specific point locations. The second generation flood hazard and risk maps that will be produced for the Areas of Potential Significant Flood Risk shall be much improved with less uncertainty as these will be derived from predictive models, developed in accordance with best practice.							1						1								
Northern Ireland	H&W theme	n/a	Insurance and mortgage availability: The more vulnerable members of society are more likely to live in flood risk areas, and are at significantly greater risk due to likely levels of increased flood levels and occurrence under a changing climate. With the potential reduced availability and increased cost of insurance, this could have not only consequential economic costs, but also mental health effects as more people do not have the financial resources to cope. More research is required in this area, however, this could only be considered after the future flood risks for Northern Ireland are better understood (see comments under extreme weather event flooding/storms above).	1	1						1					1				1	1		1	
Northern Ireland	H&W theme	n/a	Fuel poverty: Projected increases in mean temperatures are likely to be an opportunity for Northern Ireland, with lower heating requirements in the winter and reduced probability of people unable to heat their homes adequately. This would have consequential reduced levels of morbidity and mortality. There is little research that has been carried out in this area.					1			1													
Northern Ireland	H&W theme	n/a	Winter air pollution: Although winter air pollution episodes are likely to decline in frequency and intensity mainly as a result of warmer temperatures, more research is required into how these are likely to change, and the consequent changes in levels of mortality and morbidity. This would include the effects of the changes in wind speeds projected for Northern Ireland.					1		1	1								1					1
Northern Ireland	H&W theme	n/a	Increased immigration: Although future outbreaks of certain vector borne diseases such as malaria are expected to be rare and limited in number in Northern Ireland, there will be a currently unknown increased risk of new diseases as a result of immigration, as well as international travel. How this risk may change therefore needs to be investigated, including the robustness of local populations.								1									1				
Northern Ireland	H&W theme	n/a	Transport and communications network failure: There is little known research into the human health effects due to changes in levels and durations of transport and communications network failure.				1				1													
Northern Ireland	H&W theme	n/a	Pollen and allergens: There is currently insufficient quantitative evidence for establishing the impact of climate change on aeroallergens including pollen and the associated risks for public health.				1	1		1					1									
Northern Ireland	H&W theme	n/a	Emergency medicine: Emergency medicine will very likely experience a significant change in demand for its services over and above current annual levels as a result of climate change. This is likely to result in an increase in levels and variety of demand during extreme weather events, such as floods and heatwaves, as well as the prevalence and severity of allergic and respiratory illness through increases in the frequency, spatial distribution and concentrations of airborne allergens. These effects will show noticeable variations across the UK, which will need to be investigated for Northern Ireland, and will disproportionately affect certain population groups. There is a significant amount of research therefore required to better understand these impacts and how they are likely to change under the climate projected for Northern Ireland with the consequential impacts on emergency medicine.		1					1														
Northern Ireland	H&W theme	n/a	Medicine efficacy: Manufactured drugs are in general licensed for storage at temperatures up to 25°C, and these medicines can be exposed to temperatures greater than this either on the premises, or in bags during home visits. However, as temperatures projected for Northern Ireland are typically lower than the rest of the UK, this is not anticipated to be a significant impact, although additional research would still be required to investigate the efficacy of different medicines both on site and during home visits during future heatwaves.		1					1														

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Northern Ireland	H&W theme	n/a	Cold weather working/travelling: This would be seen as an opportunity for Northern Ireland, with increased winter temperatures and consequential reduced levels of cold weather working and travelling. However, there is currently little known research in this area and how it would impact on working conditions and general morbidity levels.				1			1	1													
Northern Ireland	H&W theme	n/a	Algal/fungal growth in buildings and respiratory diseases: A lack of research undertaken since the mid 1990s has limited evidence and data available to analyse the impact of improved housing standards on damp and mould occurrences, and thus the impact on respiratory conditions. There seems to be limited data on the link between damp homes and respiratory conditions in Northern Ireland.				1				1													
Wales	X-cutting	n/a	· Consideration of climate extremes and associated uncertainty. This particularly applies to the effects of droughts on water availability and biodiversity.							1				1						1				
Wales	X-cutting	n/a	· Changes in storminess and wind speed. Current guidance from the Met Office indicates that changes are projected to be small, but further research is in progress.							1										1				
Wales	X-cutting	n/a	· Consequences of surface water and groundwater flooding.													1								
Wales	X-cutting	n/a	· Overall impacts of climate change on vulnerable people and communities. Vulnerable locations include flood risk areas, remote locations and coastal locations which are threatened by erosion.		1											1					1			
Wales	X-cutting	n/a	· Understanding the effects of climate change on biodiversity and ecosystems. This reflects the complexity of natural systems and limitations in current knowledge.								1			1										
Wales	X-cutting	n/a	· Knowledge of potential changes in pests and diseases and consequences for livestock, crops, forests and ecosystems.								1													
Wales	X-cutting	n/a	· Overall impacts of climate change on land use and spatial planning.			1					1		1											
Wales	NE theme	n/a	Much of the climate change research conducted to date has, of necessity, been focused either upon individual species or on specific locations or habitat types. Development of systems-based approaches that can improve understanding of the multitude of interactions within the natural environment, and their links to the human environment, remain in the early stages.								1		1	1	1			1		1				
Wales	NE theme	n/a	The basic knowledge gap is the understanding of ecosystems including the interaction with people. This is mainly due to the complexity of dependencies within ecosystems and the way in which they are affected by external factors. A coherent baseline is required on the current state of ecosystems in Wales and how they relate to the rest of the UK.										1	1				1	1	1			1	
Wales	NE theme	n/a	· Knowledge of potential changes in the organic content of soils including the storage of organic matter and carbon.					1			1		1	1	1									
Wales	NE theme	n/a	- Changes in the water environment including a potential reduction in water availability, increases in water temperatures and increases in pollution and eutrophication;					1						1						1				
Wales	NE theme	n/a	- Increases in temperature and aridity during the summer; and						1					1										
Wales	NE theme	n/a	- The consequences of extreme conditions, particularly individual droughts and successive years of drought.							1				1										
Wales	NE theme	n/a	· Knowledge of the consequences for ecosystems of an increase in fire risk.											1										
Wales	NE theme	n/a	· Detailed epidemiological knowledge of different pests and diseases (and their vectors) and their relationship with climate and climate change.					1			1													
Wales	NE theme	n/a	· Knowledge of the potential impacts of climate change on species migration patterns. This is a complex issue as migration patterns are world-wide.					1			1													
Wales	NE theme	n/a	· Understanding of the implications of asynchrony in the timing of species life-cycle events.					1			1													
Wales	NE theme	n/a	· Projections of future changes in agriculture and implications for ecosystems.			1		1						1							1		1	
Wales	NE theme	n/a	· Assessment of the effects of climate change on protected habitats and species.					1			1													
Wales	NE theme	n/a	· Analysis of the potential impacts of coastal erosion based on the National Coastal Erosion Risk Map (NCERM).													1								
Wales	NE theme	n/a	· Knowledge of the potential for Harmful Algal Blooms. Consideration of stratification as well as average temperature increases is important.					1	1	1	1													
Wales	NE theme	n/a	· Understanding of the effects of ocean acidification on species and ecosystems.					1			1			1										
Wales	NE theme	n/a	· Knowledge of the potential impacts of non-native invasive species on ecosystems and ecosystem services (including fisheries).								1			1										
Wales	NE theme	n/a	· Potential impacts of increased tourism. This could be addressed by case studies for selected areas.											1										

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Wales	A&F theme	n/a	· Understanding of the combined effects on crop yield of temperature increases, changes in precipitation and changes in soils. Grassland yield is of particular importance in Wales.					1	1			1												
Wales	A&F theme	n/a	· Assessment of the consequences of droughts for agriculture.							1														
Wales	A&F theme	n/a	· Potential future allocation of water for agriculture.																	1				
Wales	A&F theme	n/a	· Current and future extent of surface water flooding and waterlogging of agricultural land, and associated impacts on land use and crops.			1										1								
Wales	A&F theme	n/a	· Knowledge of the impacts of climate change on pollination.					1	1		1													
Wales	A&F theme	n/a	· Knowledge of the effects of climate change on the occurrence of cryptosporidium.					1	1		1													
Wales	A&F theme	n/a	· The estimate of coastal erosion of agricultural land should be updated using the NCERM.													1								
Wales	A&F theme	n/a	· Knowledge of the potential climate change effects of pests and diseases on livestock.								1													
Wales	A&F theme	n/a	· Assessment of the potential effects of climate change on meat production including livestock stress factors, yield and product quality.					1	1											1				
Wales	A&F theme	n/a	· Assessment of the impact of fire risk on forest production.				1	1	1	1			1		1									
Wales	A&F theme	n/a	· Understanding of the implications of phenological changes on tree growth and forest management.						1		1			1										
Wales	A&F theme	n/a	· Current and future extent of waterlogging and landslips in forests and associated impacts on forest yield.								1			1	1	1								
Wales	BU theme	n/a	One of the main gaps in evidence is a general lack of information that can be used to assess climate change impacts for Business.				1	1			1													
Wales	BU theme	n/a	· Impacts of surface water flooding on business premises.													1	1							
Wales	BU theme	n/a	· Information on the effects of supply chain disruption on business caused by extreme weather events. This is a complex issue as many supply chains are international and are affected by disruption in other countries.							1														
Wales	BU theme	n/a	· The assessment of flood and coastal erosion impacts on mortgages and insurance is very high level and requires refinement.													1								
Wales	BU theme	n/a	· Potential future allocation of water for business.																	1				
Wales	BU theme	n/a	· Understanding of the potential impacts of climate change on the disposal of solid and liquid wastes.					1			1									1				
Wales	BU theme	n/a	· Detailed knowledge of the impacts of climate change on ICT systems and quantification of the consequences. Whilst the probability of failure is considered to be low, the consequences could be very serious.								1													
Wales	BU theme	n/a	· Knowledge of coastal tourist assets potentially at risk from flooding and coastal erosion.								1					1	1							
Wales	BU theme	n/a	· Understanding of the potential impacts of climate change on the financial sector.					1									1							
Wales	B&I theme	n/a	Much of the analysis has been concerned with specific impacts of climate change on either buildings or types of infrastructure. However one of the main gaps related to buildings and infrastructure is assessing the magnitude of the consequences of disruption to infrastructure caused by extreme weather events.							1														
Wales	B&I theme	n/a	· Impacts of surface water and groundwater flooding on buildings. The potential for flash floods is also a concern: this can occur from rivers or surface water flooding.							1						1								
Wales	B&I theme	n/a	· Location of all relevant heritage sites by category (SAMs, listed buildings, etc) and analysis of the flood and erosion risk.				1									1								
Wales	B&I theme	n/a	· Consideration of the potential magnitude of combination flooding (including tide-locking of drainage outfalls) in addition to the flood risk already covered in the CCRA analysis.													1								
Wales	B&I theme	n/a	· Evidence on damage to buildings from heat/drying.				1	1	1		1													
Wales	B&I theme	n/a	· Knowledge of the potential for soil erosion and landslips that could affect buildings.				1				1													

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Wales	B&I theme	n/a	· Potential erosion of land in coastal communities.				1									1								
Wales	B&I theme	n/a	· Impacts of surface water and groundwater flooding on infrastructure.				1									1								
Wales	B&I theme	n/a	· Knowledge of the potential for soil erosion and landslips that could affect transport links.				1				1					1								
Wales	B&I theme	n/a	· Potential for coastal erosion on transport links including roads and railways. This could be assessed using the NCERM data.				1									1								
Wales	B&I theme	n/a	· Assessment of the impacts of climate change on cold weather working and travelling. Whilst there will be benefits, there could also be adverse effects including, for example, a possible increase in damage caused by the freeze/thaw cycle.				1			1	1													
Wales	B&I theme	n/a	· Potential future allocation of water between different uses including domestic, business, agriculture and the environment.																	1				
Wales	B&I theme	n/a	· Assessment of the impacts of droughts on water supply and the potential consequences for people and businesses.		1					1	1						1							
Wales	B&I theme	n/a	· Assessment of the consequences of climate change on private water supplies.																	1				
Wales	B&I theme	n/a	· Knowledge of the location of water supply infrastructure in order to assess the consequences of an increase in flood risk.				1									1								
Wales	B&I theme	n/a	· Assessment of the number of people who could be affected by failure of water supply and sewerage infrastructure as a result of extreme weather events.				1			1	1													
Wales	B&I theme	n/a	· Assessment of the number of people who could be affected by failure of energy supply infrastructure as a result of extreme weather events.				1			1	1													
Wales	B&I theme	n/a	· Assessment of the impacts of climate change on water supply for energy generation. This may require site specific assessments as local circumstances are very variable.				1			1	1													
Wales	B&I theme	n/a	· Combined assessment of heating and cooling requirements to provide an overall view of changes in energy requirements.																		1			
Wales	B&I theme	n/a	· Assessment of the impacts of climate change on power station turbine efficiency and cooling processes. This may affect the generation capacity and identify the need for power station modifications.					1			1													
Wales	H&W theme	n/a	· Impacts of climate change on social inequalities, particularly vulnerable people in flood risk areas and isolated rural areas.		1											1					1			
Wales	H&W theme	n/a	· Knowledge of the potential effects of increased sunlight and UV exposure.					1			1									1				
Wales	H&W theme	n/a	· Assessment of potential changes in outdoor leisure, sport and tourism. This could be based on equivalent metric to the 'Tourist Comfort Index' used to assess changes in tourism.		1															1				
Wales	H&W theme	n/a	· Projections of the number of people at risk from surface and groundwater flooding.		1											1								
Wales	H&W theme	n/a	· Improved knowledge of the number of vulnerable people, taking account of deprivation and social vulnerability indices.		1																1			
Wales	H&W theme	n/a	· Improved projections of the number of vulnerable people at risk from flooding.		1											1					1			
Wales	H&W theme	n/a	· Knowledge of the long-term effects of extreme weather events on mental health.							1	1													
Wales	H&W theme	n/a	· Flood risk to health centres.				1									1								
Wales	H&W theme	n/a	· Potential impacts of future droughts on water supply and public health.							1														
Wales	H&W theme	n/a	· Review of potential changes in water quality and water-borne diseases. It is assumed in the CCRA that adaptation will take place to ensure safe water supplies, but the potential risks in this assumption should be considered.					1	1	1	1													
Wales	H&W theme	n/a	· Assessment of potential resources needed for emergency response to more frequent and more severe extreme weather events (including flood, heat wave and fire).							1	1													
Wales	X-cutting	n/a	There are gaps in knowledge related to wider impacts that cut across the five themes covered above, for example the combined consequences of climate change on different parts of Wales. Areas of particular concern include isolated rural communities, small coastal communities, upland farming, and environmentally sensitive locations (for example, the estuaries of west Wales).		1			1			1							1			1	1		

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Scotland	X-cutting	n/a	The most significant gaps in evidence for Scotland relate to future flooding due to climate change, which may have significant consequences for coastal environments, agriculture, residential and non-residential properties, infrastructure (including transport, energy, water and ICT) and the health and wellbeing of people affected. An assessment of future flood risks due to climate change could not be undertaken for Scotland as part of this first CCRA, as suitable data are not currently available. However, an assessment of present day and future flood risk in Scotland is currently underway. Therefore, this gap could be addressed in time for the next CCRA.													1									
Scotland	NE theme	n/a	Much of the climate change research conducted to date has, of necessity, been focused either upon individual species or on specific locations or habitat types. Development of systems-based approaches that can improve understanding of the multitude of interactions within the natural environment, and their links to the human environment, remain in the early stages.											1	1						1				
Scotland	NE theme	n/a	The basic knowledge gap is our understanding of change and ecosystem dynamics, including the interaction of people within ecosystems (and the role that biodiversity plays in driving functions and underpinning ecosystem services). This is essentially due to the complexity of responses and feedbacks involved, but also because this has often been a neglected topic in research. As a consequence, key functions and services provided by ecosystems have fundamental uncertainty in terms of how they will respond to change. A coherent baseline is required on the current state of ecosystems, the impacts that can be expected and how they relate to the rest of the UK.											1					1		1				
Scotland	NE theme	n/a	Continuous data records that are comparable across years, or standardized across the UK, are also limited although some very good examples do exist. In Scotland specifically, data and research issues often centre on whether data exist, their accessibility and their comparability and compatibility (NEA, 2011).				1																		
Scotland	NE theme	n/a	· Integrated modelling of species distributions and interactions, habitat shifts and landscape structure based upon models that combine biological, ecological and climate factors. This would provide a more robust evidence base than the current reliance on bioclimate envelope models to project future changes in range shifts.					1						1	1				1	1		1		1	
Scotland	NE theme	n/a	· Better understanding of the ecosystem implications of phenological mismatches (mismatches or asynchrony in the timing of species life-cycle events).						1		1			1											
Scotland	NE theme	n/a	· Detailed epidemiological knowledge of different pests and diseases (and their vectors) and their relationship with climate and climate change.					1			1														
Scotland	NE theme	n/a	· Detailed knowledge of different non-native species with the potential to become invasive; their associated economic costs and benefits and their relationship with climate and climate change.					1			1			1			1								
Scotland	NE theme	n/a	· Improved understanding of the implications of the rate of climate change for natural adaptive responses in different ecosystems (including across different species), including the role of extreme events, and hence the limits to and thresholds for maintaining adaptive capacity.							1				1				1	1						
Scotland	NE theme	n/a	· Exploration of the role of biodiversity in ecosystem function and services. Of particular concern to Scotland is the role of soil biodiversity in the production and maintenance of soil organic matter, nutrient and water cycling and carbon sequestration (NEA, 2011).								1			1											
Scotland	NE theme	n/a	· Opportunities for the natural environment. For example, how efforts to increase carbon storage in soils may benefit soil biodiversity and flora, and how the soil carbon content may be impacted by climate change.					1			1			1											
Scotland	NE theme	n/a	· Threats for the natural environment: For example, exploration of where future wind farms will be located and the impact that will have on bird and bat strikes.										1	1				1	1		1				
Scotland	NE theme	n/a	· Improving the effectiveness of the protected area network. Evaluation of current protected areas, how they might change (e.g. change in species use due to changes to migration paths) and how they might be strengthened and better integrated into the wider landscape.	1										1	1										
Scotland	NE theme	n/a	· Develop a baseline understanding of the incidence and consequences of wildfire currently.			1	1					1		1											
Scotland	NE theme	n/a	· Suggested uncertainty over Scotland's isostatic rebound rates may impact on the projected increases in sea level rise. Lower rebound rates would increase relative sea-level rise in areas of Scotland having a larger impact than predicted.								1														

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Scotland	NE theme	n/a	· Improved assessments of climate impacts on ecosystem functions. For example, this is particularly necessary for understanding the key role of soil biodiversity in changing ecosystem processes (such as nutrient cycling) and the implications for habitats and species biodiversity, soil organic matter and carbon storage, with implications for flood risk, water quality, soil erosion risk, habitat conservation and crop production capacities					1	1	1				1										
Scotland	NE theme	n/a	· Further work is required on ecosystem response to increased CO2 and associated feedbacks in conjunction with changing climate variables (e.g. temperature, soil moisture), based upon both modelling and experimental evidence. This has not been incorporated into most climate change impact assessments.					1			1			1	1				1					
Scotland	NE theme	n/a	· Critical thresholds ('tipping points') in the interactions between climate and ecosystem responses beyond which the system may undergo a major non-linear change or shift to a new ecological regime (e.g. coastal systems in response to a major storm surge event). Some recent advances have been made with regard to identifying key thresholds for animal population declines (e.g. Drake and Griffin, 2010).					1			1			1	1			1		1				1
Scotland	NE theme	n/a	· Vulnerability assessment of key locations and pathways for migratory routes (e.g. using space-for-time substitutes based upon current climate variability).					1			1													
Scotland	NE theme	n/a	· Evaluation of the effectiveness of landscape-scale initiatives, including measures to improve landscape permeability, in both short-term and long-term. This would act as a bridge between broad-scale modelling studies and site-specific monitoring/modelling to identify strategic maps of habitat creation opportunities that are robust against climate change.	1									1	1	1			1						
Scotland	NE theme	n/a	· An understanding of the impact of climate mitigation measures on biodiversity is required. The information needed to improve this understanding is: - The spatial strategy for future renewable energy expansion - Distribution of important habitats and species in the future. · Exploration of biodiversity strategies that better integrate adaptation with opportunities from climate mitigation schemes. For example, the development of biomass energy (including short rotation coppice and short rotation forestry) could add to landscape and habitat diversity. Initiatives to enhance carbon storage in soils and biomass could also have significant benefits for biodiversity. · Further information on the role of genetic diversity within species · Better understanding of the role of culture and social capital (i.e. non-monetary benefits) in ecosystem-based management and the wider benefits of ecosystem services for human wellbeing.	1										1	1				1		1			
Scotland	NE theme	n/a	Improved understanding of the combined impact of climate change and pollution on ecosystems.																	1				
Scotland	NE theme	n/a	Upscaling of sensitivity data from freshwater ecosystems for regional and national-scale assessments to understand the interactions between water temperature, water quality and water quantity on priority habitats and species and the regulation of water quality for the natural environment and human use. Most information is currently only available at site level.	1				1	1	1					1									
Scotland	NE theme	n/a	- Exploration of the role that the environment plays, in addition to climate, in determining raw water quality; how these things may change under future climate and environmental conditions and how water quality changes may be monitored is required. The associated consequences for water provision and on priority habitats and species need to be better understood.				1	1	1	1	1									1				
Scotland	NE theme	n/a	- Exploration into the combined effects of climate change and the point or diffuse sources of pollutants that may lead to eutrophication and unwanted algal growth.								1									1				
Scotland	NE theme	n/a	- Exploration into the relationship between current abstraction rates and implications for biodiversity under drought conditions and future climate change.							1	1													
Scotland	NE theme	n/a	· Snowmelt has not been considered for UKCP09 due to a lack of data. However, it plays an important part in winter flooding, magnifying rainfall impacts. Additionally snowmelt can act to trigger the emergence of insects in spring. Projections suggest a decrease in snowfall, but up to date data would allow for more robust projections.				1																	
Scotland	NE theme	n/a	· Exploration into the national-level impacts (not just local studies) of increasing water temperatures on biodiversity and the regulation of water quality for the natural environment and human use.	1				1	1	1														

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Scotland	NE theme	n/a	· Future analysis should focus more broadly on the climate change impacts of CSO discharges and harmful pathogens. Additionally, the ability to apply similar techniques to multiple river catchments throughout Scotland, some of which are expected to experience greater flows in the future and others lower flows. This would aid the analysis.												1									
Scotland	NE theme	n/a	· Further research is required into peak flow occurrences to enable a measure of this impact to be assessed.												1									
Scotland	NE theme	n/a	· Coastal flooding and coastal erosion:													1								
Scotland	NE theme	n/a	- Baseline maps of habitats are required. Coupled with quality and biodiversity assessments and investigation of the impacts on ecosystem services.				1																	
Scotland	NE theme	n/a	- Maps of past erosion, current state and future erosion conditions are required.				1									1								
Scotland	NE theme	n/a	- Habitat loss and gain, and opportunities for new species need to be quantified.				1				1				1									
Scotland	NE theme	n/a	- Salinity ingress on freshwater coastal habitats is an area of concern however analysis was not able to be undertaken for Scotland as no known data exist. The Defra report in developing risk analysis tools for coastal habitats evaluates the consequences for coastal biodiversity due to climate change, and a similar report for Scotland would help calculate the risks.				1																	
Scotland	NE theme	n/a	- More complete monitoring of potential bathing waters				1																	
Scotland	NE theme	n/a	- Exploration of the potential for Harmful Algal Blooms, specific to the seas around Scotland. Consideration of stratification as well as average temperature increases is important.					1	1	1	1													
Scotland	NE theme	n/a	- Impact of CSO spill volume and frequency as a result of flood and high flow events.								1					1								
Scotland	NE theme	n/a	· Fish and shellfish stocks. Understanding the future implications of climate change for fishing fleets, fishermen, economies and society with regard to changes in fish ranges, recruitment and the impacts of ocean acidification on shellfish stocks.								1			1			1							
Scotland	NE theme	n/a	· Ocean acidification is a poorly understood topic. The impact of acidification on marine species has not yet been discussed in significant detail and therefore has not been analysed for Scotland. It is thought that a range of species and processes may be affected by acidification, but further evidence is required to analyse the risk.								1													
Scotland	NE theme	n/a	· Specific research into the risks of alien and invasive species, and species migration as climate space changes in Scotland is required. Similarly a clearer insight into the expected changes in disease and pest occurrences is needed.								1													
Scotland	NE theme	n/a	· Projected changes in the open ocean (especially the circulation) are particularly uncertain due to the limitations of the ocean model used. These changes are likely to have a marked impact on the Scottish marine environment.								1													
Scotland	A&F theme	n/a	· A greater understanding on how climate change is likely to affect food demand and trade for Scotland would allow a more robust assessment of expected changes to agricultural intensification, and the impact of this on biodiversity.																	1				
Scotland	A&F theme	n/a	· Currently climate change evidence for impacts on crop pests and disease is qualitative and provides a weak assessment of the risks. A quantitative assessment of new crops, pests and pathogens strains and their relationship to climate change would improve the risk analysis.								1													
Scotland	A&F theme	n/a	· An assessment of climate change effects on livestock is needed. Livestock pests and diseases, stress, yield and productivity metrics currently have little quantification (see for example Moran et al., 2009). The importance of the Scotland agriculture sector means that further research and/or quantification would be desirable.								1													
Scotland	A&F theme	n/a	· Land use classification was not undertaken for the CCRA. Discussion in the report is based on UKCIP02 projections. To be able to provide an updated land capability assessment, UKCP09 results are required.								1													1
Scotland	A&F theme	n/a	· An assessment is needed into projected crop suitability and GHG emissions. Changes in CO2 and nitrogen may have direct effects on plant growth rate and temperature and rainfall changes may alter plant suitability positively or negatively. These alterations could have a large affect on carbon emissions and storage.								1				1									

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Scotland	A&F theme	n/a	· Surface water flooding and waterlogging are serious problems for agriculture, with land stability, crop production and access affected. An indicative analysis has been carried out specifically for Scotland for waterlogging using the workability of land as a proxy, but the other issues have not been analysed because of a lack of suitable information on present day and future risk. Forest soils are more susceptible to winter waterlogging, primarily due to a higher prevalence of peat layers, but existing forest policy and practice pays careful consideration to management practices that mitigate such risk. Forestry has a role to play in alleviating flooding through acting as a hydrological 'brake' in designed floodplains.								1				1	1									
Scotland	A&F theme	n/a	· Further understanding of the risk to diffuse pollution from agricultural land and the role of climate change. This is also relevant for the forestry sector.																		1				
Scotland	A&F theme	n/a	· There has been a limited amount of research into the impact of frost and snow damage on tree growth and biodiversity.						1					1											
Scotland	A&F theme	n/a	· The impacts of climate change and higher CO2 concentrations on soils including development, quality, carbon content, soil erosion and oxidation of peatland are poorly understood. Further analysis into climate change effects on carbon flux and storage would allow for a greater understanding.					1	1		1			1	1				1						
Scotland	A&F theme	n/a	· Pests and disease impacts through detailed epidemiological information, country-wide data and climate relationships for current and prospective pests and diseases. Additionally the relationships between the host, including forest structure and management, and the impact of potential 'climatic release' of existing pests, as well as potential new ones, should be assessed and, if possible, quantified.					1	1		1														
Scotland	BU theme	n/a	The potentially most significant gaps in knowledge regarding the consequences for business and services in Scotland relate to flooding (see Section 6.1).													1									
Scotland	BU theme	n/a	· At the moment, there is limited substantive evidence of the consequences of changes in climate on Scotland's important financial institutions. The confidential nature of the underlying data and the fact that there are many other socio-economic drivers operating, mean that disentangling the impacts of climate change is challenging. Further research is needed into the connection between climate change and financial performance.		1		1	1																	
Scotland	BU theme	n/a	· The information on the disruption caused to business by extreme events, such as floods and heatwaves is limited and largely reliant on insurance industry reporting. More systematic data collection would enable a more complete assessment to be developed.				1			1															
Scotland	BU theme	n/a	· Two risks were highlighted as potentially becoming increasingly important towards the middle of the century, namely water abstraction for industry and a loss of productivity due to overheating. Both of these assessments have been made with very limited information on the likely response and the potential of adaptation measures to reduce the extent of the impact. More detailed assessments would be helpful to better understand the likely significance of these impacts, although overheating may be less of an issue for Scotland than for other parts of the UK.																1					1	
Scotland	BU theme	n/a	· Seasonal interruptions to construction activities due to rainfall and temperature could be quantified with appropriate data and investigation.				1		1																
Scotland	BU theme	n/a	· Currently there are no available statistics regarding the emergency services response to flooding. Clearer data on the response and role of the fire, police and ambulance services would provide a better understanding and allow for a higher confidence when projecting future trends.				1	1																	
Scotland	BU theme	n/a	· Similarly, greater data is needed to accurately assess the FRS response to wildfires. Currently recent data on wildfires is inclusive of all outdoor fires, including those in rubbish tips or derelict rural buildings. Data on the fire extent, the number of fire fighters needed to control the fire and the cost of damage would enable a more qualitative assessment of future wildfire projections.				1	1									1								
Scotland	BU theme	n/a	· The number of those affected due to heatwaves requires greater and more complete data, especially in relation to hospital admissions. Greater research is needed into heatwave occurrences and ambulance service pressure to establish the strength of the link.				1	1																	

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Scotland	BU theme	n/a	· The effects of climate change could modify Scotland's tourism industry significantly. Favourable summer weather may increase outdoor activities, but this may be countered by a reduction in biodiversity and natural resources. Coastal erosion, fishing and ecotourism may be badly affected. The link between recreation and climate change needs to be explored further.											1						1				
Scotland	BU theme	n/a	· Key workers unable to get to work due to extreme events. More data is needed on work missed due to weather and consequential financial impacts on the companies affected.				1			1														
Scotland	BU theme	n/a	· Further understanding of how climate change may affect Scotland's transport network. Impact of transport disruption to small and remote businesses is essential as the reliance upon transport vital for their continued operation.							1														
Scotland	BU theme	n/a	· There is currently a lack of data to assess decommissioning liabilities and end of life costs of large fixed assets.				1																	
Scotland	B&I theme	n/a	Potentially the most significant gaps in knowledge regarding the consequences for infrastructure and buildings in Scotland relate to flooding, with this having a significant impact on transport infrastructure and bridge scour and stability. The following gaps in knowledge for Scotland were identified as part of the UK-wide assessment:													1								
Scotland	B&I theme	n/a	· Development of a better understanding of the complex cause-and-effect interactions of climate change impacts.								1									1				
Scotland	B&I theme	n/a	· Development of an improved appreciation of the economic impacts of climate change.													1								
Scotland	B&I theme	n/a	· Rainwater penetration/damage. Little qualitative information is available for rainwater penetration and the performance of building fabrics during wind driven rain episodes (see Appendix C4).				1			1	1								1					
Scotland	B&I theme	n/a	· Condensation, damp, mould, algal/fungal growth in buildings. Research interest reduced after the mid 1990s, therefore there is limited information into the impact of improved housing standards and the occurrences of damp and mould.				1				1													
Scotland	B&I theme	n/a	· Effect of changes in rainfall patterns on waterlogging of construction sites and activities.				1				1													
Scotland	B&I theme	n/a	· Site-specific flood risks to individual locations where energy infrastructure is located. Whilst the impact on substations at risk from flooding has been considered for Scottish Power, there was no information available on this risk from Scottish and Southern Energy. To consider the risk to Scotland's power infrastructure as a whole, data would need to be available from all owners of the electricity infrastructure.				1									1								
Scotland	B&I theme	n/a	· There is a lack of evidence on the positive and negative impacts of warmer temperatures on electricity demand and supply and the interdependence between these impacts. This also applies to the impact of warmer temperatures on electric turbine efficiency and gas pipeline compressor ratings.				1				1													
Scotland	B&I theme	n/a	· There is a lack of knowledge on future river flows and their effect on station cooling processes and power generation. The impacts of changing precipitation should be investigated regarding current and future reservoirs.				1	1	1		1													
Scotland	B&I theme	n/a	· Future projections of wind speeds, in particular over Scotland are uncertain. The consequent impact on the wind energy resource is therefore uncertain.				1	1	1	1										1				1
Scotland	B&I theme	n/a	More broadly, future climate change risk assessments should aim to look more closely at alternative future pathways for delivering a low carbon economy (in particular regarding the future energy mix) and how these may be affected by climate change.																	1				
Scotland	B&I theme	n/a	The underlying issue for this sector is a lack of coherent data across the UK, resulting in a predominantly qualitative assessment with a significant amount of uncertainty in the outcomes.				1																	
Scotland	B&I theme	n/a	Climate change impacts on transport require a more detailed understanding. For example, there is no qualitative landslip information for non trunk roads[1], no thermal loading data for Scotland, no national bridge register as well as missing data on the number of bridge failures due to scour[2]. The result of a lack of data is ultimately the reason behind the low-medium confidence rating.				1																	
Scotland	B&I theme	n/a	Due to the currently ongoing Scottish flood risk assessment, projections are not available for future river and coastal flood risk. Additionally, there is limited information on the current risk of coastal erosion on road networks.				1									1								

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Scotland	B&I theme	n/a	The transport sector is integral to the smooth running of society and the economy and transport needs will develop as a result of decisions in other sectors, notably planning. An assessment of where transport is needed or demanded, and how much the network might be at risk, and how this might be managed needs to be considered. Further work is required to help meet the challenge of establishing reliable and relevant climate change impact projections and adaptation strategies. Technological innovation should be considered alongside other socio-economic factors.		1												1		1		1				
Scotland	B&I theme	n/a	· The potential impact of climate change on water quality.					1	1	1															
Scotland	B&I theme	n/a	· The environmental impacts of drought, and the potential changes in the frequency and severity (and climate modelling of droughts lasting more than one season).							1															
Scotland	B&I theme	n/a	· Mechanisms for encouraging increased efficiency in water use. Impact of low flows on businesses relying on water abstraction.		1								1									1			
Scotland	B&I theme	n/a	· The impacts of changes in water demand on river flows.		1																	1			
Scotland	B&I theme	n/a	· Techniques enabling early detection/attribution of manmade climate-related impacts on the water sector.					1																	
Scotland	B&I theme	n/a	· Development of tools and techniques for scaling up local case studies to UK level.	1																					
Scotland	B&I theme	n/a	There is a limited evidence base regarding climate change impacts for the telecommunications sector. This makes forward planning difficult and is compounded by the short-term business models applied by industry.				1	1			1										1				
Scotland	B&I theme	n/a	Telecommunications within the context of our future climate are important due to the interdependencies described in earlier sections of this chapter. Further research and awareness-raising is needed regarding the resilience of ICT systems. It is particularly important that the role of ICT systems in potential cascade failures is understood more fully, especially in light of the growing usage of ICT systems and the sharing of ICT infrastructure within the UK and abroad.																		1		1		
Scotland	H&W theme	n/a	Although a significant amount of research has been carried out into the health effects of climate change for the UK, much of this work has been carried out for England and Wales only, and as such in certain areas there are specific gaps in knowledge pertinent to Scotland. In addition, some future health impacts are very uncertain, as they are an accumulation of several climate variables, and/or mainly driven by human behaviour or actions rather than climate.	1																					
Scotland	H&W theme	n/a	· There are no known published temperature-mortality relationships for Scotland. As a result, the results presented are likely to be under-estimated for heat (although not significantly), yet over-estimated for cold related mortality. Although these relationships would be relatively easy to establish, the data sets required for the analysis cannot be released without ethical clearance, which typically takes six months. In addition, many winter deaths are as a result of infectious diseases such as influenza and pneumonia which means that it is difficult to attribute individual deaths to a cold related disease. Based on current published evidence, this means that any estimate of cold related deaths would be unreliable, although still significant.				1	1			1														
Scotland	H&W theme	n/a	· Although there is certain evidence that very high and very cold temperatures have an impact on a range of morbidity outcomes, with an increase in patient-days per year due to heat and cold related illnesses, the rate of change is highly uncertain. In addition, as for cold mortality noted above, winter hospitalisations are clouded by infectious diseases more common in the winter which means that it is difficult to attribute individual hospitalisations (data which is already available) to a cold related disease. Similar to above, this impact is likely to provide a significant opportunity for Scotland due to a reduction in cold, yet a relatively small impact compared to the rest of the UK due to heat.	1			1				1														
Scotland	H&W theme	n/a	· Very little research has been carried out into the relationship between extreme weather events and their impacts, and the consequent increased deaths and injuries as a result of these events. This is particularly the case for countries such as the UK that are not exposed to weather events such as hurricanes, and/or the large scale deep flood events experienced in recent decades in places such as the USA, India and Bangladesh.				1			1	1														

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Scotland	H&W theme	n/a	· Mortality and morbidity data sets for extreme weather event flooding and storms are poor, with no central record of deaths or injuries related to individual floods or storms kept in Scotland. There is also no clear accepted definition of what is a flood or storm related injury. With relatively few deaths and injuries due to extreme weather event flooding and storms, as well as the highly clustered nature of these events, it is currently difficult to establish baseline estimates for Scotland. Current and future flood risk is also unknown, although research recently released by SEPA should address this issue. However, the lack of long-term reliable tidal data sets, particularly along the fast moving waters of the North Channel, means that estimates due to coastal flood events would currently remain unreliable.				1			1	1								1					
Scotland	H&W theme	n/a	· Although significant progress has been made in recent years researching the mental health effects due to extreme weather events, little is known about the effects long term. The methodology commonly used in Scotland flood studies uses the GHQ-12 (see Health report) to assess mental health effects. Although this methodology indicates that a mental health effect has occurred, it is unspecified and gives no indication of the nature or severity of the effect.	1			1																	
Scotland	H&W theme	n/a	· There is a risk that hospitals in Scotland may not be resilient to flooding, particularly during extreme events. It is not currently known how many hospitals are at flood risk in Scotland, or how this is likely to change in the future. However, the research into flood risk for Scotland noted above should start to address this issue.							1						1								
Scotland	H&W theme	n/a	· The more vulnerable members of society are more likely to live in flood risk areas, and are at significantly greater risk due to likely levels of increased flood levels and occurrence under a changing climate. With the potential reduced availability and increased cost of insurance (see Section 4.4), this could have not only consequential economic costs, but also mental health effects as more people do not have the financial resources to cope. More research is required in this area, however, this could only be considered after the future flood risks for Scotland are better understood (see comments under extreme weather event flooding/storms above).	1	1						1					1			1		1		1	
Scotland	H&W theme	n/a	· Projected increases in mean temperatures are likely to be an opportunity for Scotland, with lower heating requirements in the winter and reduced probability of people unable to heat their homes adequately. This would have consequential reduced levels of morbidity and mortality. There is little research that has been carried out in this area.					1			1													
Scotland	H&W theme	n/a	· There is little known research into the human health effects due to changes in levels and durations of transport and communications network failure.				1				1													
Scotland	H&W theme	n/a	· Emergency medicine could experience a significant change in demand for its services over and above current annual levels as a result of climate change (Hess et al., 2009). This is likely to result in an increase in levels and variety of demand during extreme weather events, such as floods and heatwaves, as well as the prevalence and severity of allergic and respiratory illness through increases in the frequency, spatial distribution and concentrations of airborne allergens. These effects will show noticeable variations across the UK, which will need to be investigated for Scotland, and will disproportionately affect certain population groups. There is a significant amount of research therefore required to better understand these impacts and how they are likely to change under the climate projected for Scotland with the consequential impacts on emergency medicine.	1	1					1											1		1	
Scotland	H&W theme	n/a	· Manufactured drugs are in general licensed for storage at temperatures up to 25°C, and these medicines may be exposed to temperatures greater than this either on the premises, or in bags during home visits. However, as temperatures projected for Scotland are typically lower than the rest of the UK, this is not anticipated to be a significant impact. However, additional research at a UK level would still be required to investigate the efficacy of different medicines both on site and during home visits during future heatwaves.					1			1													
Scotland	H&W theme	n/a	· Cold weather working/travelling would be seen as an opportunity for Scotland, as for warmer winters there would be less frequent and reduced levels of disruption. However, there is currently little known research in this area and how it would impact on working conditions and general morbidity levels.							1	1													
Scotland	H&W theme	n/a	· There is a lack of research on the impact of improved housing standards on damp and mould occurrences, and thus the impact on respiratory conditions. There seems to be limited data on the link between damp homes and respiratory conditions in Scotland.								1													

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Scotland	H&W theme	n/a	· Little quantified research has been carried out into climate change effects on water-borne diseases, in particular cryptosporidium.								1													
Scotland	H&W theme	n/a	· Climate change impacts are likely to have a greater impact on the health and wellbeing status on rural island communities, and these need to be investigated across a range of impacts.								1			1										
Scotland	H&W theme	n/a	The UKCP09 regional climate models do not have sufficient resolution to include an explicit representation of urban areas and their effects. Therefore specific projections of the UHI under climate change are not available within UKCP09.	1																1				1
Evidence Report	A&F theme	n/a	· Studies have not yet made full use of the UKCP09 projections and more work is required using the projections or RCMs to understand the potential impacts of warmer and drier conditions and particularly drought.					1	1	1					1									
Evidence Report	A&F theme	n/a	· The impacts on forest biodiversity and other non-provisioning ecosystem services are poorly understood; this requires national level datasets, information on the direct impacts of rising temperatures on vegetation growth and reproduction.	1			1	1	1			1		1										
Evidence Report	A&F theme	n/a	· The impacts of climate change and higher CO2 concentrations on soils including development, quality, carbon content, soil erosion and oxidation of peatlands.					1	1		1			1	1				1					
Evidence Report	A&F theme	n/a	· An accurate response function for plant and tree productivity due to CO2 fertilisation and a quantitative analysis of the projected increases in yield. This may have a substantial impact on potato yield.					1	1	1	1				1		1							
Evidence Report	A&F theme	n/a	· Pests and disease impacts through detailed epidemiological information, country-wide data and climate relationships for current and prospective pests and diseases. Much further research is needed into the physiology and epidemiology of tree and crop diseases and a greater analysis in the role of climate variable in the spreading and extent.					1	1		1				1									
Evidence Report	A&F theme	n/a	· The links between biodiversity and timber production in the face of climate change; guidance on which species are most suitable and how adaptation measures can be implemented sustainably (integrated with the ESC system).					1	1					1				1	1					1
Evidence Report	A&F theme	n/a	· The scale and direction of the risk of wildfire given not only climatic but also vegetation changes and socio-economic changes, such as visitor numbers.		1			1	1	1											1			
Evidence Report	A&F theme	n/a	· Development of a framework for monitoring and evaluating changes in forest growth on an annual basis, nationwide.	1			1																	
Evidence Report	A&F theme	n/a	· The impacts of saline incursion and intrusion on agricultural abstractions in important agricultural areas.										1		1					1				
Evidence Report	A&F theme	n/a	· A better understanding of the impacts on animal health and welfare, particularly the impacts of heatwaves, droughts and extremes on livestock rather than the influence of average climate that was considered in this assessment.							1										1				
Evidence Report	A&F theme	n/a	· Exploration of the ecological, production and treatment consequences of weed species that may increase with climate change.																	1				
Evidence Report	A&F theme	n/a	· The impacts of climate change on the broader food and drinks supply chain including the changing demand for products in the UK and internationally.		1			1	1	1							1			1	1			
Evidence Report	A&F theme	n/a	· Vulnerabilities and adaptive capacity of rural communities to cope with climate change and its impacts on their lives and livelihoods. Research to test the effectiveness of both methods for understanding climate-related risks to these communities and their adaptation responses.					1	1	1									1				1	
Evidence Report	B&I theme	n/a	Limited data, coupled with the level of system complexity have constrained the analysis in this assessment. Greater pooling of information, without compromising commercial interests, will be needed to make progress on representing and understanding the vast array of interactions that take place and upon which climate change is superimposed.				1								1					1		1		
Evidence Report	B&I theme	n/a	Key areas where further work could increase understanding of the impacts of climate change, help remove uncertainties regarding their scale and nature, and aid climate change adaptation in relation to the Business sector include:					1	1	1														

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Evidence Report	B&I theme	n/a	· At the moment, there is limited substantive evidence of the consequences of changes in climate on UK financial institutions. The confidential nature of the underlying data and the fact that there are many other socio-economic drivers operating, mean that disentangling the impacts of climate change is challenging. Some recent attempts to model this type of system may provide a way forward (Haldane and May, 2011), although the idealisations necessary may mean that such models are best suited to developing an understanding of system behaviour, rather than making detailed predictions.				1								1								1		
Evidence Report	B&I theme	n/a	· The complexity of supply chains is similarly, difficult to analyse because it involves the interaction of a number of networks that are themselves complex. Nonetheless, there may be scope to develop a better understanding of network interactions as modelling improves (e.g. the modelling of container traffic; Sinha-Ray et al., 2003).												1						1		1		
Evidence Report	B&I theme	n/a	· The information on the disruption caused to business by extreme events, such as floods and heatwaves is limited and largely reliant on insurance industry reporting. More systematic data collection would enable a more complete assessment to be developed.				1																		
Evidence Report	B&I theme	n/a	Two risks were highlighted as potentially becoming increasingly important towards the middle of the century, namely water abstraction for industry and a loss of productivity due to over-heating. Both of these assessments have been made with very limited information on the likely response and the potential of adaptation measures to reduce the extent of the impact. More detailed assessments would be helpful better to understand the likely significance of these impacts.							1					1				1					1	
Evidence Report	H&W theme	n/a	To improve the characterisation of the risks due to climate change there is a need for a better understanding of the physiological response to temperature and the implications for human activity and mental health, as well as mortality. Improved understanding of ozone concentrations and UV exposure are also needed.					1			1														
Evidence Report	H&W theme	n/a	· Although significant progress has been made in recent years researching the mental health effects of flooding, little is known about the effects long term. The methodology commonly used in flood studies uses the GHQ-12 to assess mental health effects. Although this methodology indicates that a mental health effect has occurred, it is unspecified and gives no indication of the nature or severity of the effect.								1														
Evidence Report	H&W theme	n/a	· Important knowledge gaps exist in relation to long-term anxiety and depression, as well as the indirect effects on mortality and the use of health care services following a severe weather event (Kovats and Hajat, 2008).								1								1						
Evidence Report	H&W theme	n/a	· The relationship between temperature related mortality, deprivation and social capital is very complex and not possible to characterise within this assessment. It is also believed that there is limited published research in this area (Wolf et al., 2010, Hajat et al., 2007, Wilkinson et al., 2004).		1			1			1											1			
Evidence Report	H&W theme	n/a	· There is limited published evidence on cold mortality thresholds in the UK. This means that estimates are unreliable and can vary significantly between different studies.						1		1														
Evidence Report	H&W theme	n/a	· No known research has been carried out on temperature mortality response relationships for Scotland and Northern Ireland.	1																					
Evidence Report	H&W theme	n/a	· There is limited published evidence on hospital patient days related to either temperature or temperature related deaths.				1																		
Evidence Report	H&W theme	n/a	· A surveillance system is required for the rapid monitoring of temperature and mortality.				1																		
Evidence Report	H&W theme	n/a	· Little work has been carried out on the effects (including mental stress) of extremes of temperature on vulnerable groups such as older people and the most effective ways of reducing these effects.		1					1			1						1		1	1		1	
Evidence Report	H&W theme	n/a	· There is no known quantifiable research on how people's behaviour would change as a result of projected warmer temperatures, and how the consequent risk in terms of UV exposure would change as indicated by Autier et al., (1994) and Elwood and Jopson (1997).		1			1											1					1	
Evidence Report	H&W theme	n/a	· Little research has been carried out on the relationship between extreme event flooding and storms and the link to deaths and injuries.				1			1	1									1					

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Evidence Report	H&W theme	n/a	· More research is required on future ground-level ozone concentrations and how climate change might affect them.					1		1															
Evidence Report	H&W theme	n/a	· There is a lack of concrete evidence on potential prolonged exposure to aeroallergens such as pollen. The effect of climate change on winter air pollution (nitrogen dioxide and PM10) has not been investigated, as this would require extensive modelling work and large input datasets.				1		1	1					1										
Evidence Report	H&W theme	n/a	· More research is required on the disruption to maintenance work as a result of heatwaves and algal growth in buildings.		1					1	1														
Evidence Report	H&W theme	n/a	· A surveillance network to ascertain the potential risks of Vibrio pathogens in UK waters needs to be established.				1				1														
Evidence Report	H&W theme	n/a	· More research is required to better understand the cause-effect pathways that determine bloom formation in HABs.					1			1				1										
Evidence Report	H&W theme	n/a	· A more thorough assessment is required for all catchments of the risks associated with releases from CSOs and the consequential changes in associated illnesses (Norovirus) at the coast.	1											1						1				
Evidence Report	H&W theme	n/a	· More research is required on the types of hospitals (as well as other buildings) that are more safe under different climatic conditions.					1			1								1						
Evidence Report	H&W theme	n/a	· The cost-effectiveness of different adaptation options for the National Health Service needs to be investigated.														1							1	
Evidence Report	H&W theme	n/a	Little research has been done on the joint occurrence of extreme events, such as a heatwave occurring at the same time as poor air quality.							1					1										
Evidence Report	B&I theme	n/a	A common theme across buildings and infrastructure is the evidence gaps associated with extreme events. Many of the weather and climate related threats facing buildings and infrastructure in the UK relate to extreme events. Providing projections of future changes to extreme events is a developing area of science that is particularly challenging due to the limitations in the current generation of climate models. This is discussed further in Chapter 9.							1															
Evidence Report	B&I theme	n/a	· It is unclear from the UKCP09 projections how extremes are likely to change relative to mean temperatures, yet it is during heatwaves that heat related impacts and consequences may be most significant.					1		1									1						
Evidence Report	B&I theme	n/a	· Further research to relate specific building types to indoor thermal comfort would provide a much better understanding of the thermal performance of buildings. Coupled with this, further research into what constitutes overheating would also be beneficial.					1		1											1				
Evidence Report	B&I theme	n/a	· More research is needed to improve understanding of the mechanisms by which vegetation cools the surrounding environment.								1				1				1						
Evidence Report	B&I theme	n/a	· Improved understanding of the effectiveness of water efficiency and technology and behavioural change due to water scarcity.		1								1						1			1	1		
Evidence Report	B&I theme	n/a	· The analysis for this first CCRA focuses on river and tidal flooding in England and Wales, as comparable data are not yet available for surface water flooding. There is an urgent need to further develop projections of future surface water flood risk in England and Wales and for all types of flooding in Scotland and Northern Ireland for the next CCRA.	1												1									
Evidence Report	B&I theme	n/a	· Further analysis is needed to understand the correlation between estimated annual damages to properties from flooding compared to insurance claims and how this may change in the future.														1						1		
Evidence Report	B&I theme	n/a	· Access to high-resolution soil data was a significant limitation of the analysis undertaken.				1																		
Evidence Report	B&I theme	n/a	· It would also be beneficial to explore the correlation between stock replacement rates and soil types.										1										1		
Evidence Report	B&I theme	n/a	· Understanding the influences of population growth and increasing numbers of properties in the future and how these may offset the projected reduction in heating demand, would lead to a better understanding of future winter energy demands.																				1		
Evidence Report	B&I theme	n/a	· Data on energy demand for cooling for both domestic and non-domestic properties would increase confidence in the projections of cooling energy demand.				1																		
Evidence Report	B&I theme	n/a	· Site-specific flood risks to individual locations where energy infrastructure is located.				1	1		1						1									

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Evidence Report	B&I theme	n/a	· Relating CDD to energy demand taking into consideration non-climate factors (such as building stock and uptake of air-conditioning).																	1				
Evidence Report	B&I theme	n/a	· Positive and negative impacts of warmer temperatures on electricity demand and supply and the interdependence between these impacts.		1			1	1						1						1			
Evidence Report	B&I theme	n/a	· Climate projections for other parts of the world relevant to the UK energy sector (e.g. the Middle East).	1																				
Evidence Report	B&I theme	n/a	· The particular vulnerability of cities to climate change.					1	1	1														
Evidence Report	B&I theme	n/a	· The impact of climate change on the UK's wind energy resource.					1		1									1					1
Evidence Report	B&I theme	n/a	· Timescales within which different adaptation approaches need to be implemented in order to be successful.																1				1	
Evidence Report	B&I theme	n/a	More broadly, future climate change risk assessments should aim to look more closely at alternative future pathways for delivering a low carbon economy (in particular regarding the future energy mix) and how these may be affected by climate change.					1					1						1	1		1	1	
Evidence Report	B&I theme	n/a	There are also areas where gaps in data could also be filled. For example, data are not available to assess the vulnerability of gas infrastructure to permanent inundation by sea level rise.				1																	
Evidence Report	B&I theme	n/a	The underlying issue for this sector is a lack of coherent data across the UK, resulting in a predominantly qualitative assessment with a significant amount of uncertainty in the outcomes. Improved record keeping is required across all modes of transport, for example delay times, if the analysis that has been undertaken as part of this CCRA is to be built upon for future assessments.	1																				
Evidence Report	B&I theme	n/a	Many impacts on the transport sector could not be analysed due to lack of knowledge regarding trigger mechanisms and thresholds. For example, impacts such as flooding and bridge scour are location specific and the trigger mechanism will vary from location to location. A detailed inventory of all hard infrastructure and past climate events is required to complete a detailed analysis of such impacts.	1				1		1														
Evidence Report	B&I theme	n/a	A specific gap in knowledge relates to railway embankment stability. Work is in progress to evaluate the potential risks to railway embankments from climate change, which may be suitable for use in the next CCRA (Loveridge et al., 2010). Academic research is also ongoing in this area, including the CLIFFS[2] and BIONICS[3] projects.					1			1													
Evidence Report	B&I theme	n/a	Further uncertainties relate to the climate change drivers; the majority of analysis for this CCRA has focused on UKCP09 temperature and precipitation data. Other impacts would need projections for climate variables that are not available yet, such as wind and visibility projections. As stated earlier, projections for extreme events would also be an important step forward. The uncertainty surrounding offshore wind and storm projections is a major limitation with attempting to assess future risks for shipping and offshore renewable energy.					1		1									1					1
Evidence Report	B&I theme	n/a	The transport sector is integral to the smooth running of society and the economy and further work is required to help meet the challenge of establishing reliable and relevant climate change impact projections and adaptation strategies. Technological innovation should be considered alongside other socio-economic factors and Government policy, such as a low carbon future (see Section 7.4.5). Ongoing research, such as the TRACCA project (Tomorrow's Railways and Climate Change Adaptation), will be a first step to providing more knowledge in some areas.		1								1				1		1		1	1		
Evidence Report	B&I theme	n/a	· The potential impact of climate change on water quality.					1	1	1														
Evidence Report	B&I theme	n/a	· The environmental impacts of drought (and climate modelling of droughts lasting more than one season).							1														
Evidence Report	B&I theme	n/a	· Incentives and mechanisms that could encourage water trading between water companies.										1						1					
Evidence Report	B&I theme	n/a	· Mechanisms for encouraging increased efficiency in water use.		1								1								1			
Evidence Report	B&I theme	n/a	· Methods for increasing energy efficiency/decrease energy use in water and wastewater treatment.		1								1								1			

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Evidence Report	B&I theme	n/a	· The impacts of changes in water demand on river flows.		1																1			
Evidence Report	B&I theme	n/a	· Techniques enabling early detection/attribution of manmade climate-related impacts on the water sector.					1																
Evidence Report	B&I theme	n/a	· Development of tools and techniques for scaling up local case studies to UK level.	1																				
Evidence Report	B&I theme	n/a	Any future changes in drought magnitude and frequency are likely to have the greatest impact on water resources, and therefore a key area where more research is required. At present this is an area where different views exist. For example, some recent papers have suggested an increase in rainfall droughts (Vidal and Wade, 2009) but others, including recent Met Office Hadley Centre research, have concluded that while there is a tendency for increased drought, it is not yet possible to robustly project changes in UK meteorological droughts arising from increased greenhouse gases (Burke et al., 2010). Therefore, new research on future droughts is likely to improve evidence in this area prior to the next CCRA.							1														
Evidence Report	B&I theme	n/a	There is a limited evidence base regarding climate change impacts for the ICT sector. This makes forward planning difficult and is compounded by the short-term business models applied by industry.				1	1			1										1			
Evidence Report	B&I theme	n/a	ICT within the context of our future climate are important due to the interdependencies described in earlier sections of this chapter. Further research and awareness-raising is needed regarding the resilience of ICT systems. It is particularly important that the role of ICT systems in potential cascade failures is understood more fully, especially in light of the growing usage of ICT systems and the sharing of ICT infrastructure within the UK and abroad.																		1		1	
Evidence Report	NE theme	n/a	Understanding the interaction of climate and other drivers of change on the natural environment is an area of large uncertainty. Scaling up local, species or habitat specific studies to a more integrated understanding of the relative influence of different drivers at a regional or national scale will require a sustained research effort over the next decade.	1		1															1		1	
Evidence Report	NE theme	n/a	· Development of systems-based approaches that can improve understanding of the multitude of interactions within the natural environment, between species, habitat shifts and landscape structure and geomorphological changes, to provide a more robust evidence base that bioclimatic envelope models alone.											1	1			1			1			
Evidence Report	NE theme	n/a	· Development of a greater understanding of the drivers of changes in the natural environment, for example, the cause-effect pathways that lead to harmful algal blooms and the contribution of human-led drivers, such as pollution versus climate change.					1	1	1	1										1			
Evidence Report	NE theme	n/a	· Evaluation of the effectiveness of long-term landscape-scale initiatives, such as measures to improve landscape upland water retention and water quality (freshwater and marine).	1				1	1	1			1	1										
Evidence Report	NE theme	n/a	· Develop and increase understanding of the 'protected areas' approach, e.g. development of mechanisms to improve and integrate protected areas into the wider landscape and so deliver more ecological benefits. For example:	1									1	1										
Evidence Report	NE theme	n/a	- Modification of marine and terrestrial protected site management and quality, to increase the ability for species to adapt;	1									1					1	1				1	
Evidence Report	NE theme	n/a	- Development and use of UK wide priority habitat projections for different geographical areas; and	1																				
Evidence Report	NE theme	n/a	- More detailed biogeographical information is needed to increase resolution of knowledge, especially in Northern Ireland.	1																				
Evidence Report	NE theme	n/a	· More systematic UK-level collation and interpretation of site monitoring and other available data (e.g. phenology), against inter-annual patterns of climate variability and trends of long-term change.	1			1	1	1	1	1													
Evidence Report	NE theme	n/a	· Exploration of land use methods that better integrate biodiversity adaptation with climate change mitigation, e.g. the potential contribution of biomass energy plantations to habitat diversity.			1					1		1	1				1	1					1
Evidence Report	NE theme	n/a	· Development of regional/national-level assessments of the climate sensitivity of freshwater and marine ecosystems.	1			1	1	1	1	1													
Evidence Report	NE theme	n/a	· Generation of more information on genetic diversity within species, to help identify and monitor genetic constraints and manage genetic diversity to allow species to adapt successfully.								1							1	1					

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Evidence Report	NE theme	n/a	· Detailed epidemiological knowledge of different invasive non-native species, pests and diseases (and their vectors) and their relationship with climate and climate change, in the terrestrial, marine and freshwater environments.					1	1	1	1													
Evidence Report	NE theme	n/a	· Further information on understanding hydro-ecological stress from modifications of the flow regime as a whole is needed. In addition, there is a need to capture the impacts on groundwater dependent wetlands impacted by unsustainable abstraction and the relative importance of point versus diffuse pollution sources under climate change for the natural environment and for the ecosystem services obtained e.g. drinking water.											1				1	1		1			
Evidence Report	NE theme	n/a	· Development of better assessments of medium- to long-term climate impacts on ecosystem functions (e.g. marine CO2 absorption, nutrient cycling, soil functions, effects of CO2, pollution, impact of wildfires and measures being introduced in response to the low carbon agenda) and the knock-on consequences of these.					1			1			1	1			1	1		1			
Evidence Report	NE theme	n/a	Understanding, assessing the drivers and valuing ecosystem services, including specific gaps, for example: Understanding the future implications of climate change for fishing fleets, fishermen, economies and society; A better understanding of the likely socio-economic benefits of increased arctic ship-passage balanced against environmental risks; and Better understanding of the role of culture and social capital (i.e. non-monetary benefits) in ecosystem-based management and the wider benefits of ecosystem services for human wellbeing.		1									1			1							
Evidence Report	NE theme	n/a	Trade-offs in adaptation capacity between different sectors. One of the key principles of sustainable adaptation is that adaptation in one sector should not unreasonably limit the ability of another sector to adapt. However, there is very little information available on the potential trade-offs that might occur and how they can be optimised for multiple sectors with different needs and responses.															1	1				1	
Evidence Report	Overall	n/a	The CCRA has identified a wide range of evidence and research gaps, both within individual sectors and across sectors, noting that many priority risks arose in cases where flooding, overheating and water scarcity had indirect impacts on other sectors.																1		1			
Evidence Report	Overall	n/a	· In the Agriculture sector there were some detailed models available, for example for specific varieties of potatoes, and excellent field investigations, for example on the yields of grasslands. There was a lack of integrated models that can consider changes in climate at the regional and national scale, which can reconcile the positive influences of temperature, CO2 and potential negative influences of water scarcity and pests and diseases.	1				1	1	1	1				1								1	
Evidence Report	Overall	n/a	· Similarly in the Forestry sector, there has been some good progress made on the development of models but further work is needed to include and integrate factors related to the ecological ranges of species, different geographical characteristics, multiple climate variables, the effects of more extreme weather and potential risks of pests and diseases.	1						1		1									1		1	
Evidence Report	Overall	n/a	· In the Biodiversity and Ecosystem Services research areas the recent National Ecosystem Assessment has made a positive contribution; however there is a lack of standardised and long-term datasets and further work is needed understanding changes and ecosystem dynamics, including the interaction of people within ecosystems.		1		1														1			
Evidence Report	Overall	n/a	· In the Built Environment sector there have excellent studies at the scale of buildings but less is known about how different factors combine to increase the potential risks in urban environments, such as building design, people's behaviour, the role of green (and blue) space and its contribution to cooling. Similar to other sectors some of strong site specific evidence exists but there is a lack of integrated models.		1								1	1							1	1	1	
Evidence Report	Overall	n/a	· In the Health sector, there has been some good work linking climate with winter and summer morbidity and mortalities but further work is needed on the interaction between physical variables (e.g. climate) and social demographics, human behaviour and regional factors to improve projections of future health burdens.		1			1	1	1											1	1		
Evidence Report	Overall	n/a	· In the Transport sector, there has been some good progress on specific risks, like rails buckling in extremely hot temperatures, but more research is needed on how extreme weather events affect transport networks. A detailed inventory of all hard infrastructure, climate trigger mechanisms and thresholds are required to build a better picture of how climate change may cause delays, disruption and potential failure of UK transport networks.				1			1														

Sector	Risk Metric Code	Risk metric	Gaps in information and data (raw info)	Geographical	Socio-economics	Land-use change modelling	Data collection/Public availability	Climate sensitivity	Seasonal sensitivity	Extremes sensitivity	Experimentation/Investigate baseline	Combined climate drivers	Management effects	Ecosystems and Ecosystem Goods and Services	Systems modelling	Flood/erosion modelling	Economics	Natural adaptive capacity	Adaptive responses and feedbacks (natural or non-UKCP09 (extremes))	Combined climate and non-climate drivers	Demographical	Integrated assessments	Adaptive capacity (non-natural)	UKCP09
Evidence Report	Overall	n/a	· The evidence on social vulnerability to climate lacks comprehensive coverage. There are a number of areas, such as flood risk management, where the research is relatively well developed but in other sectors it lags behind the more detailed studies on biophysical impacts of climate change. More research is needed on how social vulnerability affects risk and also how vulnerability may change over time as part of studies on future socio-economic scenarios. The next CCRA would benefit from a set of quantitative socio-economic scenarios to provide a richer picture of how society may change in the medium to longer term.		1																1			
Evidence Report	Overall	n/a	· Providing projections of future changes to extreme events is a developing area of science that is particularly challenging due to limitations in the current generation of climate models. Technical challenges include extreme value estimation in a 'non-stationary' climate and extreme event characteristics such as spatial extents, duration and clustering that are all poorly resolved in climate models. Overall confidence in extreme hot and cold events and coastal flooding is greater than for surface water flooding, storms and gales and drought. As well as continued monitoring, further research on climate change and extreme events is needed to improve future risk assessments.							1										1				
Evidence Report	Overall	n/a	· Robust methods for understanding potential climate risks and the interactions between complex systems, particularly regarding how climate risks may affect financial performance or supply chains of UK businesses. Some recent attempts to model financial systems may provide a way forward (Haldane and May, 2011) but further research is needed to integrate and link potential biophysical impacts to consequences across multiple sectors and ultimately understanding the effects on UK financial institutions, businesses and consumers.												1		1							
Evidence Report	Overall	n/a	Ecosystems typically involve a multitude of complex interactions. Moreover, natural responses to climate change are extremely difficult to predict confidently, as habitats and species can exhibit different responses in different places. In addition the threats posed can be quite different (e.g. between marine and terrestrial habitats). Significant uncertainties therefore exist in the assessment of the climate-related risks facing this sector. The sensitivity of biodiversity to climate change has not yet been estimated with any real degree of confidence. Although understanding is reasonably good in terms of the response of some animal and plant species to climatic changes, knowledge is less well developed in the key areas of species interactions and habitat change.					1			1			1										
Evidence Report	Overall	n/a	Another important consequence is the climate that is likely to prevail in our cities. However, most climate models do not incorporate sufficient resolution to include a representation of urban areas, so projections of Urban Heat Island effects under climate change scenarios are not yet available.	1																	1		1	
Evidence Report	Overall	n/a	A number of impacts identified by stakeholders related to wind and storm damage. Changes in storms and monthly mean wind speeds are projected to be small in the models used within UKCP09, with the sign of the projected wind speed varying from positive to negative. There is, however, some uncertainty inherent in the models used and given its potential significance for many activities in the UK, and past experiences of the damage that storms can cause, some further work to confirm these findings would be worthwhile.							1										1				1
Evidence Report	Overall	n/a	Impacts associated with sunlight/UV exposure are also highly uncertain. The figures are based on limited evidence and do not take behavioural factors into account, although these may affect future exposure levels very significantly. Similarly, predictions of future ground-level ozone concentrations are highly uncertain, as they are based on the modelling of complex emissions scenarios and behavioural processes which are still the subject of debate within the scientific community.					1			1										1			
Evidence Report	Overall	n/a	Finally, the sensitive nature of information and the inherent complexity of many of the networks in the business world make even the identification of risks that can be attributed to climate change a challenge. The complex web of interactions in markets has some parallels with the complexities of ecosystems and these two areas of work certainly require further work for the next CCRA. This assessment and the Foresight examination of the international dimensions of climate change both noted that the numerous dependencies within supply chains make this a particular source of vulnerability but the magnitude of the risk remains highly uncertain.					1			1				1					1				

Annex A: Stakeholder Engagement Evaluation Report

This is provided as a separate document.

