Centre for Climate Change Economics and Policy

Grantham Research Institute on Climate Change and the Environment

An Independent National Adaptation Programme For England

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Appendices

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This policy paper is intended to inform decision-makers in the public, private and third sectors. It has been reviewed by at least two internal referees before publication. The views expressed in this paper represent those of the author(s) and do not necessarily represent those of the host institutions or funders.

Appendix A: Vulnerability hotspots

Table A.1 Near-term risks and opportunities identified by the Climate Change Risk Assessment (CCRA)

Timescale of impact	'Hot spot' policy area/sector	Examples of specific 'medium' or 'high' risks and opportunities from the CCRA (Bold=high risk in at least one climate/emissions scenario, *italic = medium or high risk for only the 'upper' scenario)*
Near-term risks and opportunities (2020s)	Flood management	- **Expected annual economic damages to residential and non-residential properties** - **Flood risks to public infrastructure and services (schools, hospitals, energy infrastructure,** power stations, transport) and historical sites - **Non-residential properties,** residential properties and people exposed to significant risk of flooding - Risks to vulnerable groups.
	Water supply	- **Agricultural demand: increasing water demand for irrigation** *and rising number of unsustainable water abstractions* - **Reduced water available for public supply** and rising number of people affected by water supply-demand deficits *(possible deficits)* - *Potential restrictions to abstraction for industry and energy generation.*
	Health	- **Mental health** and mortality of those effected by extremes (floods) - **Rising summer mortality and morbidity due to high temperatures** - **Declining cold-related winter mortality and morbidity.**
	Energy supply	- Increasing energy demand for cooling (summer) - **Declining energy demand for heating (winter).**
	Food production	- **Increasing water demand for irrigation** *(potential restrictions)* - **Increasing wheat production** *(sugar beet and potato yields)* - Threats related to drier soils, increased erosion (due to heavy rainfall) *and increasing flood risk* - *Risks to livestock (deaths due to heat stress, fertility).*
	Wider business	- **Insurance industry exposure to UK flood risks** - **Accessibility and affordability of residential flood insurance** - Availability of mortgages in flood prone areas - Loss of staff hours related to temperature *and potential rising risk of business interruption due to flooding* - **Opening of Arctic shipping routes** - **Expansion of tourist destination in the UK** *(but potential flood risk).*
	Natural environment	- **Threats related to pests and diseases (e.g. forestry**, biodiversity) - **Threats related to northward spread of non-native species** - **Impacts related to species migration and changing habitats (particular risks to specialist species)** - **Rivers and lakes: biodiversity risks due to warmer conditions, reduced summer water quality and insufficient summer river flows to meet environmental standards** (consequent risks to ecosystems) - Coastal: risks to species and habitats (coastal flooding, erosion).

		- Marine species: declining water quality from sewer overflow - *Rising risks from wildfires and droughts to forestry and ecosystems.*
	Emergency management	- **Rising flood risk** - **High summer temperatures (inc. summer mortality).**
	Buildings and infrastructure	- **Flood risks to major private and public infrastructure, and services (schools, hospitals, energy infrastructure,** power stations, roads and railways) - Overheating in buildings.

Table A.2 Additional long-term risks and opportunities identified by the CCRA

Timescale of impact	'Hot spot' policy area/sector	Examples of specific 'medium' or 'high' risks and opportunities from the CCRA (Bold=high risk in at least one climate/emissions scenario, *italic = medium or high risk for only the 'upper' scenario)*
ADDITIONAL long-term risks and opportunities (2050s to 2080s)	Flood management	- Sewer overflow spill frequency.
	Water supply	- **Public water supply demand deficits** *(increasing household demand due to climate conditions)* - Declining water quality - Lower summer river flows - Rising number of unsustainable water abstractions for agriculture and **risk of restrictions.**
	Health	- **Mortality and morbidity due to summer air pollution** - Rising sunlight and UV exposure.
	Food production	- Growing flood and erosion risk to agricultural land - **Opportunities to grow new crops** - **Increasing sugar beet** *(and potato)* **yields and grassland productivity** - Mixed effects on UK fisheries (negative impacts on cod, haddock and other cold water fish and shellfish, but **opportunities related to plaice and sole**) - *Risks to livestock (milk production, fertility).*
	Wider business	- Rising risk of business interruption due to flooding
	Natural environment	- Increased ocean acidification - Disruption to marine ecosystems due to warming, including declining productivity of cold water fish and shellfish, disruption to breeding of sea birds and intertidal invertebrates - Priority habitats lost to coastal erosion - Declining climate conditions and rising risk of pests for some tree species (beech and spruce in England) and **improving climate conditions for others (spruce in Scotland)** - Rising risk of wildfires.
	Emergency management	- Increasing risk of wildfires.
	Major infrastructure	- Damage to road and rail bridges from rivers (scouring) - *Reduced energy transmission efficiency (over ground)* - *Disruption to road network/traffic due to flooding and landslides.*

Notes

Summary of key near-term risks and opportunities taken from CCRA Tables ES1, 4.7, 5.2, 6.1, 7.2). In bold are the high risks in the 2020s (where risk is estimated to be high in at least one scenario).

Summary of key additional long-term risks and opportunities taken from CCRA Tables ES1, 4.7, 5.2, 6.1, 7.2. In bold are the new high risks (where risk is estimated to be high in at least one scenario).

Risks and opportunities are included if they are rated as 'medium' or 'high in at least two CCRA scenarios. In italics are those risks and opportunities that appear only under the 'upper' scenario. As the CCRA is focused on highly specific indicators (e.g. "forest extent affected by red band needle blight"), here we make generalisations to draw out the broad hotspots of risk.

Appendix B: Evidence gaps identified by the Climate Change Risk Assessment (CCRA)

	Research gaps *Caused by a current lack of research to derive confident assessments.*	**Information barriers** *e.g. level of data monitoring and accessibility of data, due to copyright or confidentiality issues.*	**Risk tolerance** *e.g. understanding of what society deems acceptable risk and loss.*	**Influence of behavioural and social factors** *e.g. growing demand.*	**Model dependence and critical gaps** *e.g. for example use of model averages only.*	**Non-domestic** *e.g. interlinkages between UK and global impacts.*
Built environment and infrastructure	Future cycles of the CCRA should aim to exploit more recent research into urban heat island effects which were unavailable when the CCRA analysis was being undertaken.	Current lack of coherent transport data across the UK; detailed inventory of all hard infrastructure and past climate events is needed; gaps remain in data on water and flood risk across UK.	Much more analysis is required on the links between estimates of annual flood damages and insurance premiums, and how this may change in the future.	No current evidence on how households and industry will react to greater water scarcity.	UKCP09 projections provide information on averages but little on weather extremes.	Climate change impacts for other parts of the world relevant to the UK energy sector (e.g. the Middle East).
Agriculture and forestry	Studies have not yet made full use of UKCP09 projections; unknown effects of higher CO_2 concentration on soils.	Need for national datasets; need a national annual monitoring scheme on forestry growth.	Unknown links between bio-diversity and timber production.	Unknown potential changes in tourism numbers from climate change.	CCRA assessed weather impacts on animals' welfare based on averages, not weather extremes.	No assessment made on the broader (global) food and drinks supply chain.
Natural environment	Development of systems-based approaches that can improve understanding of the multitude of interactions within the natural environment.	More detailed bio-geographical information is needed to increase resolution of knowledge, especially in Northern Ireland.	Absence of evidence of what constitutes acceptable losses in eco-systems e.g. loss of habitats to create new flood plains.	Lack of current evidence on how climate change may influence migratory routes.	Need to develop better vulnerability assessments based on potential weather extremes and not averages.	Absence of detailed knowledge of different invasive non-native species, pests and diseases.
Health and wellbeing	Absence of evidence on the long-term anxiety, mortality and mental health effects of flooding and other natural disasters.	New surveillance system required for the rapid monitoring of temperature and mortality.	The cost-effectiveness of different adaptation options for the National Health Service needs to be investigated.	Unknown behavioural effects of warmer temperatures on people and society.	Little research has been done on the joint occurrence of extreme events, such as a heat-wave occurring at the same time as poor air quality.	Unknown impacts that climate change in other countries will have on UK health and well-being.
Business and services	Insufficient research on productivity losses resulting from less water abstraction and over-heating.	Confidential nature of data on certain sectors (financial institutions) limits ability to evaluate risks.	Lack of detailed and business specific case-studies on what would be acceptable losses.	Lack of information on potential societal equity impacts.	Information on disruption to businesses caused by extreme weather events remains limited.	Complexity of business supply chains means that the impact of climate change on them is difficult to analyse.

Appendix C: Indicative list of priority adaptations

Table C.1 Agriculture

Key risks and opportunities	Types of adaptation options	Potential for lock-in	Early benefits	Adapting agent	Role of the public sector	Urgency	Comments and open questions
Near-term potential increasing yields of some crops (particularly wheat), if other factors are not limiting (e.g. extremes); long-term potential for larger changes in yields and new crop types.	Shifting cultivars, planting times etc.	Low	High	Farmers	**INFORMING:** overcoming potential information barriers in responding to long-term changes. Public goods related to research and development.	Watch list	Evidence: requirement to incorporate full range of determinants into crop yield projections (extremes, non-climate threats etc.). Policy: how do current regulatory frameworks (such as the Common Agricultural Policy and Rural Development Programme) enhance or limit adaptive capacity in the sector?
Near-term increasing threats related to extremes, drier soils, increased erosion and flooding. [CCRA: Low-Mid 2020s, Mid 2050s]	Sustainable farming approaches; new crop varieties and farming methods. [research and communication of knowledge and skills.]	Low	High	Farmers	**INFORMING, ENABLING AND PROVIDING:** providing public goods related to research and development. Providing information and appropriate regulation, and incentives, to overcome behavioural and financial barriers. Valuing ecosystem services.	High	Evidence: identification of regions at risk. Evidence: need to better understand co-benefits/trade-offs of adaptation measures for water quality, ecosystems and flood risk management. Policy: how do regulatory frameworks enhance or limit incentives for sustainable farming (agri-environment payouts, land management)?
	Integrated Land						

	management (see Table C.2)						
Near-term risks related to increased demand for irrigation [CCRA: High 2020s] and longer-term restrictions to water abstractions.	Water efficient farming practices, shift to non-water-intensive agriculture, farm-based winter water storage.	Low/Medium – most short-lived investments, some longer-lived farm infrastructure.	Case dependent	Farmers	**INFORMING AND ENABLING**: overcoming information and behavioural barriers, and externalities related to unsustainable water abstractions.	High	Evidence: identification of regions at risk. Evidence: better understanding dependencies on water supplies, licensing and environmental impacts.
Near-term changing domestic consumption patterns and pressures from energy crop production (Defra, 2012b). **Long-term risks and opportunities (such as rising prices) related to changing global food systems and food security** (Foresight 2012).	Unknown. Potential long-term expansion of production.	Medium. Changes in land-use may have a medium lifetime.	Low	Farmers	**INFORMING**: overcoming information and behavioural barriers.	Watch list	Evidence: significant uncertainties in the impact of long-term global climate change on UK agriculture, and costs/benefits of measures to adapt to the potential threats and capture any opportunities.

Sources: HM Government (2012), Foresight (2012), DEFRA (2012b).

C.2. Biodiversity and ecosystem services

Key risks and opportunities	**Types of adaptation options** *n.b. adaptation options here are not connected to specific risks as they have benefits in mitigating all (many) risks.*	**Potential for lock-in/ irreversibility**	**Early benefits**	**Adapting agent**	**Role of the public sector**	**Urgency**	**Comments and open questions**
Threats relating to terrestrial, marine and freshwater species: Threats related to new and existing pests and diseases [CCRA: mid 2020s, High 2080s]. Threats related to northward spread of non-native species [CCRA: mid 2020s, High 2080s]. Species migration and changing habitats – inability to track climate space (higher risks to specialist species) [CCRA: mid 2020s, High 2080s]. **Rivers and lakes: biodiversity and ecosystem risks due to warmer conditions, reduced water quality and**	Enhanced preparedness and mitigation to reduce the impact and increase resilience to shocks, such as floods, wildfire, pests and diseases, including: - Monitoring systems/early warnings - Preparedness planning - Enhancing biosecurity.	Low	High	Public, private and NGOs		High	
	Conservation: - Conserve protected areas and other high quality habitats - Conserve range and ecological diversity of habitats and species - Maintain existing ecological networks.	High	High	Public, private and NGOs	**ENABLING AND INFORMING:** providing an enabling framework with appropriate incentives.	High	Evidence: analysis required on the effectiveness of existing actions and policy, and future needs. Evidence: requirement to identify particular areas and habitats at risk to climate and non-climate factors and high value habitats.

insufficient summer river flows to meet environmental standards [CCRA: mid 2020s, High 2080s]. **Coastal: risks to species and habitats (coastal flooding, erosion**) [CCRA: mid 2020s, High 2080s]. **Marine species: declining water quality from sewer overflow, risks related to ocean acidification and warming, including declining productivity of cold water fish and shellfish, disruption to breeding of sea birds and intertidal invertebrates.** **Rising risks from wildfires and droughts to forestry and ecosystems** [CCRA: mid 2020s].	Integrated land management; 'joined-up' policies and activities aimed at capturing multiple benefits in land-management; including biodiversity, ecosystem-services (e.g. water quality, water conservation, flood control, soil quality management), leisure etc.	Low-High	High	Public, private and NGOs	**ENABLING AND INFORMING**: enabling start-up finance for projects. Providing guidance, information and tools. Coordinating action.	High	Evidence: understanding the effectiveness and scalability of existing initiatives is desirable (e.g. RSPB Futurescapes) and policies (e.g. CAP agri-environment schemes).
	Accommodation. Development, restoration and extension, including: - Restoring high value habitats - Building buffer zones around high quality habitats - Developing ecologically resilient and varied landscapes - Establishing new ecological networks - Making space for natural development of rivers and coasts - Adapting ecosystems to new climate conditions where necessary (e.g. gradually adapting wetlands to drier conditions).	Low-High	Case dependent	Public, private and NGOs	**ENABLING AND INFORMING**: providing an enabling framework with appropriate incentives. Coordination and capacity building.	High	Evidence: planning specific measures and understanding their costs and benefits.
	Reduce sources of harm not linked to	High	High	Public	**ENABLING AND**	High	Policy:

climate (such as pollution controls, land use planning).				**INFORMING**: regulating to overcome externalities.		understanding the effectiveness of existing actions and policy, and consequent future needs, is required.
Raising awareness of the value of biodiversity and ecosystem services (including education).	Low	High	Public, private and NGOs	**INFORMING**	High	
Species translocation and ex-situ conservation.	Low	Low	?	**ENABLING:** ensuring no adverse environmental impact.	Watch list	Evidence: analysis required to identify potential species under threat, and risks and benefits of action.
Monitoring frameworks	Low	High	**?**	**?**	High	Policy: are current monitoring frameworks (including national ecosystem assessment) adequate?
Developing innovative initiatives, markets and schemes, e.g. payments for ecosystem services.	Low	?	Private	**ENABLING:** providing appropriate regulatory frameworks for price-based mechanisms (e.g. CAP Pillar 2).		

Sources: DEFRA (2012), Hopkins *et al*. (2007), Smithers *et al*. (2008), MacGregor & Webb (2010), Natural England, DEFRA (2011).

C.3. Water (CROSS CUTTING THEME: BUILT ENVIRONMENT AND INFRASTRUCTURE)

Key risks and opportunities	Types of adaptation options	Potential for lock-in	Early benefits	Adapting agent	Role of the public sector	Urgency	Comments and open questions
Risks related to supply shortages: Reduced water for public supply in some areas (mean and extremes). Growing public demand [CCRA: Low]. Population affected by water availability pressures [CCRA: Mid 2020s]. Long-term prospect of public water supply – demand deficits [CCRA: HIGH 2050s].	**Supply-side measures – new and retrofit infrastructure** (e.g. reservoirs, river abstraction, waste water re-use, bulk transfers between regions, winter storage capacity, aquifer storage and recovery, desalination).	High – tend to be long-lived investments, with high sunk-costs	Case dependent	Water Companies	**ENABLING AND INFORMING:** monitoring, informing action, and regulation that overcomes potential barriers that may hold back efficient adaptation.	High	Evidence: better understanding of regional and socioeconomic dependencies required to inform specific infrastructure improvements. Policy: are current and upcoming legislative and regulatory standards and frameworks (e.g. Ofwat, 2010) sufficient to allow efficient and robust adaptation?
	Demand-side (end-user) measures: reduced leakage, metering, water efficient equipment, water re-use, water conservation, regulated water use.	Low–mixture of behavioural measures, and short-lived investments.	High	Consumers	**ENABLING AND INFORMING:** potential role in stimulating behaviour change and providing information.	High	Evidence: requirement to incorporate scenarios of future demand under different policy and socioeconomic assumptions within the evidence base. Policy: are current and upcoming policies (e.g. Ofwat 2010) sufficient to remove disincentives for companies to promote water efficiency by end-users?
	Enhanced monitoring systems, coupled with flexible and responsive decision making and	Low	Medium	Water companies and public sector	**ENABLING**: regulatory frameworks that facilitate flexible decision processes	Watch list	Policy: are current and upcoming legislative and regulatory standards and frameworks (e.g. Ofwat 2010)

	resource planning.			(national monitoring)	**PROVIDING** - where monitoring frameworks are publicly owned		sufficient to allow efficient, flexible, long-term and robust adaptation?
	Water trading between catchments	Low	Medium	Water companies	**ENABLING AND INFORMING**	Watch list	
	Emergency planning (e.g. drought response plans) **and reactive measures.**	Low	High	Water companies and public sector	**ENABLING**: appropriate regulatory structures. **PROVIDING**	Watch list	Response strategies are already in place, but require monitoring to ensure they can cope under future climate change.
Physical impacts on the operation, quantity, quality and structure of existing systems and infrastructure, including accelerated asset deterioration* [CCRA: High – Water UK 2010; Ofwat 2010].	**Building resilience and capacity of existing and new infrastructure** (including reservoirs, pipes, dams etc.). **Response and recovery planning.**	High Low	Low High	Water companies	**ENABLING & INFORMING**: putting in place industry safety standards (e.g. dams) and overcoming potential regulatory barriers that may hold back efficient adaptation	High	Evidence: detailed identification of risks to existing infrastructure, taking account of full range of factors, is required. Policy: are current and upcoming legislative and regulatory standards and frameworks (e.g. Ofwat, 2010) sufficient to ensure efficient and robust adaptation?
Unsustainable water abstractions [CCRA: Mid 2020s, High 2080s]. *Near-term rising demand for agricultural irrigation (High) in some areas.*	Measures to reduce unsustainable abstractions, including licensing, regulation, and water efficiency.	Low/Medium – most are short-lived investments.	High (evidence of negative impacts on ecosystems today)	Consumers (including, industry and farmers)	**ENABLING AND INFORMING**: monitoring, providing information and overcoming behavioural barriers.	High	Policy: how do current regulatory frameworks affect abstractions?
Declining summer water quality [CCRA: High 2050s].	Enhanced water treatment assets (including research into new technologies).	Medium (land acquisition issues for works)	Low	Water companies	**ENABLING AND INFORMING**	Watch list	Evidence: improved understanding of the linkages with climate and non-climate factors is required and better identification of risk hotspots.
	Natural measures –	Low	High	Water	**INFORMING**	High	

	sustainable upstream land-use to increase filtration.			companies / public sector			Policy: are current and upcoming policies sufficient to ensure efficient adaptation? Evidence: better understanding of the effectiveness of natural water quality measures is required.
	Monitoring and restricting pollution at source.	Low	Case dependent	Water companies / public sector	**ENABLING AND INFORMING**	Watch list	

*Includes risks to assets in flood plains, cracking of pipes due to greater soil movements, impacts of reservoir operation, siltation of dams (Water UK, 2010)

Sources: DEFRA (2012), Ofwat (2012), Water UK (2011).

C.4.a. Business, industry and services

Key risks and opportunities	Types of adaptation options	Potential for lock-in	Early benefits	Adapting agent	Role of the public sector	Urgency	Comments and open questions
Potential disruption to business inputs and operations, including supply chains, logistics, workforce, utilities, ICT. Loss of staff hours due to temperature [CCRA: Mid 2020s].	Strong risk management culture and appropriate governance structures. Preparedness and response planning. Building resilience, such as ensuring resilient supply networks and selecting resilient suppliers. Insurance, as appropriate.	Low	High	Private	**INFORMING:** voluntary standards required for risk management and business continuity. **ENABLING** (e.g. regulation of working conditions).	Watch list	Policy: do businesses have access to the information they need to adapt?
Climate-sensitive production (e.g. for insurance, agriculture, forestry, water industry etc.), including climate risks to investment funds [CCRA: uncertain]. Rising costs of production due to increase property insurance premiums.	Including climate change in long-term business strategies and risk management planning to capture opportunities and build long-term resilience to climate change. Ensuring appropriate governance and decision making structures. Insurance where appropriate (e.g. agricultural insurance). Innovation to reduce threats and capture opportunities, such as new crop types in agriculture.	Low–High	Case dependent	Private	**INFORMING:** voluntary standards required for risk management.	Watch list	

Risks of physical damages to assets and disruption to production related to extremes of weather (particularly flooding).	Ensure climate change is considered in decisions (e.g. in acquiring, building and retro-fitting assets). Response planning and enhancing resilience of fixed assets. Insurance.	Low-High (new buildings)	Case dependent	Private	**INFORMING:** voluntary standards required for risk management and business continuity.	Watch list	
Risks and opportunities related to changing business environment and markets (e.g. changing profitability and competitiveness of markets and new market opportunities, such as expansion of UK tourism).	Long-term business strategy. Research, new product development and innovation to reduce threats and capture opportunities.	Low	Case dependent	Private	**INFORMING**	Watch list	

Sources: UKCIP (2010), ISO3100, ISO22301.

C.4.b. Insurance industry

Key risks and opportunities	Types of adaptation options	Potential for lock-in	Early benefits	Adapting agent	Role of the public sector	Urgency	Comments and open questions
Rising average levels and volatility of domestic and international losses due to extreme weather [CCRA: high 2020s due to exposure to UK flood risk].	Risk-adequate pricing supported by improved underwriting practices.	Low	Medium	Private	**ENABLING:** implementing an enabling regulatory environment.	Watch list	Policy: what role does the public sector play in providing information to insurers?
	Diversification of risk through reinsurance and innovative financial instruments.	Low	Low	Private	**ENABLING:** implementing an appropriate regulatory environment.	Watch list	Policy: how will Solvency II regulation affect resilience to climate change?
	Selection of lower risk insureds (including withdrawal of insurance).	Low	Low	Private	**ASSISTING:** ensuring accessibility and affordability of insurance for the most vulnerable.	Watch list	Policy: role of the public sector in increasing accessibility of residential weather-related insurance.
	Changes to contractual conditions.	Low	Low	Private	**ENABLING:** ensuring fair insurance to all.	Watch list	
	Supporting risk reduction through innovative product design or other methods.	Low	Medium	Private	**ENABLING:** implementing an enabling regulatory environment.	Watch list	
Risks related to public interventions (public sector insurance, regulation of pricing).	Active engagement with government, regulators to ensure a fair operating environment for insurers.	Medium	High	Private	**ENABLING:** implementing a fair policy, regulatory and legislative environment.	Watch list	
Changes to insurance demand, including opportunities from new lines of business (e.g. renewables) and risks from falling affordability of residential flood insurance.	Responsive, innovative product design and marketing.	Low	High	Private	**ENABLING:** implementing an enabling regulatory and policy environment.	Watch list	

Sources: Herweijer *et al*. (2009), Ranger & Surminski (forthcoming).

C.5. Health *(theme: health and wellbeing)*

Key risks and opportunities	Types of adaptation options	Potential for lock-in	Early benefits	Adapting agent	Role of the public sector	Urgency	Comments and open questions
Near-term risk of rising summer mortality and morbidity due to heat stress to the public, particularly in major urban centres and southern, central and eastern England (hot spots of vulnerability in elderly population and those with pre-existing illnesses) [CCRA: Mid 2020s, High 2050s].	Preparedness of public health system, including monitoring, strengthening of heat management plans and early warning systems.	Low	High	Public sector	**PROVIDING:** provision of resilient and prepared public health systems.	High	Policy: the Department of Health already has new plans following the 2003 heat wave. Question – to what extent will current plans and processes be able to cope with projected future conditions?
	Ensuring public and private health care facilities maintain comfortable and safe temperature range.	Low-High	High	Public sector or private	**PROVIDING:** (public health care facilities). **INFORMING AND ENABLING:** (private health care).	High	
	Reducing private overheating in buildings through low-regret measures such as window shading.	Low-High	High	Property owners	**INFORMING AND ENABLING:** overcoming information barriers and implementing regulation for new properties and work places. **ASSISTING**: giving assistance to the most vulnerable (including affordable housing). **PROVIDING:** providing public infrastructure.	High	Policy: question – to what extent do current building codes account for future potential overheating?
	Changing behaviour to	Low	Medium	Public	**INFORMING AND**	Watch list	

	avoid heat stress and dehydration.				**ENABLING**		
	Direct assistance to the most vulnerable people during heat waves.	Low	High	Charities, NGOs, local health authorities	**ASSISTING:** supporting the most vulnerable people.	High	
Long-term rising mortality related to summer air pollution (south-east England most affected) [CCRA: uncertain]. **Potential risk of increased natural aeroallergens** [HPA: Uncertain].	Monitoring, early warning systems; strengthening response strategies.	Low	Medium	Public	**PROVIDING:** adequate monitoring, preparedness and response in public health care systems.	Watch list	
	Mitigating measures, such as control of pollution sources (traffic) and controlling pollen sources (e.g. ragweed, certain grasses).	Low	Uncertain	Private polluters	**ENABLING**	Watch list	
	Changing behaviour to reduce impacts.	Low	Medium	Private	**INFORMING:** raising awareness	Watch list	
Physical injury, mortality, morbidity and mental health issues related to extreme weather and secondary affects (such as wildfire) [CCRA: Mid/High 2020s].	Preparedness of public health systems (flood management plans).	Low	High	Public	**PROVIDING**	High	Policy: appropriate adaptation options?
	Support services, adequate social safety nets, early warnings and risk reduction (as above).	Low	High	Public and private	**INFORMING, ENABLING AND ASSISTING**	High	
Long-term rising risk of disease and injury related to global impacts through travelling and living abroad. [HPA: uncertain].	Monitoring and preparedness.	Low	Uncertain	Public	**PROVIDING**	Watch list.	
Potential risk of increased occurrence of skin cancers due to UK exposure [HPA: uncertain].	Changing behaviour.	Low	Uncertain	Private	**INFORMING:** providing information.	Watch list	How effective are current information campaigns?
	Monitoring and public warning systems.	Low	Uncertain	Private	**PROVIDING**	Watch list	How effective are current monitoring and information systems?

Potential increased risk of vector-borne disease related to activity of ticks and mosquitos and introduction of exotic species and pathogens [HPA: uncertain]. **Potential changes in risk from water and food-borne diseases** [HPA: uncertain].	Monitoring and public warning systems.	Low	Uncertain	Public	**PROVIDING**	Watch list
	Preparedness of public health systems.	Low	Uncertain	Public	**PROVIDING**	Watch list
	Mitigating measures, such as changing behaviour and land management to reduce vector breeding sites.	Low	Uncertain	Private	**INFORMING, ENABLING AND PROVIDING:** e.g. related to land management.	Watch list

Sources: DEFRA (2012), HPA (2012), DOH, WHO & WMO (2012).

C.6. FLOODING *(CROSS CUTTING THEME / BUILT ENVIRONMENT AND INFRASTRUCTURE)*

Key risks and opportunities	Types of adaptation options	Potential for lock-in	Early benefits	Adapting agent	Role of the public sector	Urgency	Comments and open questions
Near-term rising flood risks to residential and non-residential buildings [CCRA: High 2020s].	Community flood protection, including hard infrastructure, managed realignment/retreat.	High – tend to be long-lived measures with high sunk-costs	Case dependent (positive evidence for EU)	Public (few private schemes)	**PROVIDING (INFORMING)**	High (urgent need to incorporate climate change into planned public investments).	Policy: open questions on the allocation of responsibility and the adequacy of planned investments to cope with expected increases in risk?
	Soft infrastructure protection (natural flood storage, urban greening).	Low – tend to be lower cost, reversible	Positive evidence in some areas	Public/ developers	**PROVIDING (public good) / INFORMING AND ENABLING:** overcoming information barriers, incentives for developers.	Medium	Evidence: there is currently a lack of information on effectiveness.
	Building-level flood resistance and resilience, or relocation.	Low-Medium - some measures have long lifetime	Positive evidence in some areas	Property owner/ developers	**ENABLING AND INFORMING:** overcoming information barriers, incentives for homeowners and developers.	Medium (urgency where involves new properties with potential for lock-in).	Policy: open questions on appropriate policy tools?
	Flood response: early warnings, preparation, emergency services.	Low	High	Public (some private)	**PROVIDING**	Watch List	Evidence: there is already action to improve distribution of flood warnings – where are further improvements possible?
Near-term decline in accessibility and affordability of residential flood insurance [CCRA: High 2020s].	Several options: reduce risk (as above), regulate, subsidise, price differentiation, public insurance or public-private	Low	High	Mixed	**ENABLING OR PROVIDING:** providing enabling regulatory frameworks – there is potential for a greater public role.	High	Policy: open questions on the role of the public sector in addressing the affordability and availability of flood insurance and the appropriate policy design?

	partnerships.						
Near-term rising flood risks to critical & public infrastructure and services [CCRA: High 2020s].	Physical measures to reduce risk and build resilience (as above).	High	High	Public & private	**PROVIDING**	High	Evidence: efforts are already underway – open questions on remaining gaps and needs?
	Response and recovery planning.	Low	High	Public & private	**PROVIDING**	High	
Near-term rising risks to vulnerable groups [CCRA: Mid 2020s, High 2080s].	Reduce risk (as above), response planning, enhance social safety nets.	Low-High	Medium	Individual	**ASSISTING:** overcoming information, behavioural and financial barriers.	High (lock-in issues for new housing)	Evidence: open question on the role of the public sector and appropriate policy tools?
Impacts of development on flood hazard and exposure, including development on flood plains and reduced urban drainage [ASC].	Risk-averse land planning and regulation.	High	Unknown	Property developers	**ENABLING:** regulation (land planning and building regulations).	High.	Policy: open questions on the implications of the new National Planning Policy Framework for development in flood-prone areas?
	Enhancing urban drainage (e.g. green spaces and infrastructure).	High	Case dependent	Property developers/ public	**ENABLING:** providing appropriate stimulus for developers. **PROVIDING:** (public good).	High	Evidence: questions on the effectiveness and design of green infrastructure? Policy: what are the appropriate policy tools?
Increases in risk of sewer overflow and spill frequency [CCRA: Mid 2050s, High 2080s].	Higher capacity and design standards for new and retrofit sewers.	High	Case dependent	Water companies	**PROVIDING AND ENABLING**	High	

Sources: DEFRA (2012), Ranger *et al*. (2010), Water UK (2011), Cimato & Mullen (2010).