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An Independent National Adaptation Programme for England

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Policy brief
March 2013



Grantham Research Institute on
Climate Change and
the Environment



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Acknowledgements

We are grateful to Matthew Bell, Darius Campbell, Sebastian Catovsky, Kat Deyes, Dagmar Droogsma, Rebecca Evernden, Jo Lovell, Kathryn Humphrey, Virginia Murray, Jouni Paavola, Clare Pinder, Kiran Sura, Lola Vallejo, Daniele Viappiani, Olly Watts and Ken Wright for their comments and feedback. All conclusions and remaining errors are our own. Financial support by the Grantham Foundation for the Protection of the Environment and the UK Economic and Social Research Council is gratefully acknowledged. This policy brief 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.

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Summary

There is a case for early Government action to promote and enable better adaptation to climate change. Although the UK's climate is relatively benign, it is already vulnerable to extremes of weather. Climate change will exacerbate these risks. Adaptation is about risk management – to reduce harm and exploit the potential benefits of climate change both today and in the long term. Adaptation has socio-economic benefits today and tomorrow through increasing the resilience of the UK's economy, its natural environment and society.

The purpose of this policy brief is to contribute to the National Adaptation Programme that is currently under preparation by the Department for Environment, Food and Rural Affairs. The Climate Change Act (Her Majesty's Government, 2008) requires the Government to put in place, and update every five years, a National Adaptation Programme (NAP), which addresses climate change risks. This policy brief aims to contribute to this process by offering an analytical framework and formulating a rational basis for thinking about adaptation. It aims to inform the first NAP report, due in mid-2013. While the NAP is formally just for England, the analysis and lessons here are applicable to the UK as a whole.

The NAP is important because climate change poses new challenges that are best addressed through a coordinated and strategic approach. Dealing with climate risks is not new. However, adaptation to climate change poses several new challenges:

- The first new challenge is that *climate risk can no longer be assumed to be constant*. Policy must shift toward a forward-looking risk management paradigm, based upon future trends, risks and adaptation needs.
- The second new challenge is that *in some cases action is needed now* to cope with the scale, speed and potential irreversibility of climate change impacts. Action will need to be more anticipatory and less reactive than it has been in the past.
- The third new challenge is that *it is impossible to know what future climate we need to adapt to*. Dealing with this depth of uncertainty will require a flexible and iterative approach to making long-term decisions, which reduces vulnerability and risk today and in the future, whilst avoiding foreclosing options. The process must proactively learn from, and respond to, new information, rather than being a one-off 'optimised' decision.

The first NAP report is an opportunity to establish a strategic approach to climate change adaptation in the UK. The first NAP is an initial milestone in an ongoing, iterative process, rather than a self-contained strategy. Its main purpose is to:

- *highlight areas of likely risk*, and resolve analytical difficulties in assessing risks so that they do not prevent action;
- *establish the principles for good adaptation over the long term*, including a sensible approach to uncertainty; and
- *define an initial set of specific, time-sensitive priorities for Government action* – it should also identify potential gaps in those priorities and lay out an agenda to fill these gaps through further research and consultation.

A coordinated, strategic approach does not imply Government-led adaptation. Most adaptation is undertaken by private actors – households, firms and civil society – and their actions cannot be planned centrally. However, private adaptation is likely to come up against barriers, including

financial, behavioural and informational barriers, as well as a lack of capacity and skills. These barriers justify a role for Government action to help ensure prosperity in the face of climate change.

The role of the state is to provide an enabling framework that encourages and supports decentralised adaptation. The role of the public sector – Government departments, local authorities and public agencies – can be categorised into four types, which represent different state functions and grades of public intervention:

- *providing* adaptation services directly, if the public sector commissions or delivers adaptation as a public good;
- *enabling* adaptation in areas where policy needs to overcome private barriers to adaptation, or provide stronger incentives through price and regulation;
- *assisting* with adaptation, for example with help to vulnerable people and other support to ensure a fair and equitable adaptation outcome; and
- *informing* about climate risks to overcome knowledge barriers, and providing public information (climate and other) as a way to support private adaptation.

There are many adaptation actions that it would be sensible to initiate now. There are three key areas on which early adaptation efforts should focus:

- *Adaptations with early, robust benefits*. Fast-tracking adaptation makes sense if the proposed measures have immediate, robust and cost-efficient benefits, such as water efficiency and better environmental management.
- *Areas where decisions today could 'lock-in' vulnerability profiles for a long time*. Fast-tracking adaptation is desirable if a wrong decision today makes us more vulnerable in the future and if those effects are costly to reverse. Several strategic decisions potentially fall into this category, including those on long-term infrastructure (e.g. the location of new airports, rail links and wind farms), land-use planning and the management of development trends, such as regional water demand.
- *'Low-regrets' adaptation measures with long lead times*. It makes sense to fast-track adaptations that have long lead times, such as research and development.

To illustrate the need for timely action, 12 priorities for Government action are identified (Table S.1). The list includes many measures that aim to prevent vulnerability from becoming greater. For example, ensuring that new long-lived infrastructure and buildings are suitable for the climate over their lifetime (priorities VIII, X, XI) and do not negatively affect the resilience of the surrounding area (priority XII). Similarly, land management decisions should aim to enhance natural capital, to protect ecosystem services and also to retain flexibility for adaptation in the long-term (priority XII and V). Another priority is to ensure there is adequate capacity within Government, at appropriate levels, to deliver effective adaptation (priority III).

These actions have strong benefit-cost ratios. This analysis suggests that in many cases the priorities for adaptation involve refining existing regulation and policies, rather than implementing major new investment programmes. For example, the Government could reassess whether current water regulation (priority VIII) and the Common Agricultural Policy (priority V) promote long-term resilience to climate. Acting early to implement programmes for existing public infrastructure (priority X) can minimise costs by enabling retrofits to be part of routine maintenance.

Table S.1. A preliminary set of priorities for Government action

Cross-cutting priorities	I	Establish better monitoring systems: a system of new and linked existing indicators, including lead-indicators of vulnerability, is an important tool to inform both public and private sector decision-making.
	II	Provide user-relevant information, guidance, incentives and tools for private adaptation: the development and dissemination of material to inform adaptation throughout the economy can remove barriers to private adaptation and innovation in information services for adaptation.
	III	Build capacity to deliver effective and efficient adaptation across the Government: this includes developing appropriate, integrated decision-making frameworks (see Section 5), local implementation capacity, and coordination.
	IV	Ensure critical services and systems are ready to cope with current climate variability and extremes of weather: being able to respond to extreme events, such as floods and droughts, and taking a more long-term view than in the past will focus preparation for the additional challenges from climate change.
Agriculture, biodiversity and ecosystems	V	Refine current agricultural and related policy frameworks: ensure they enable (and do not hinder) near-term and long-term climate resilience and food security, and preserve or enhance the long-term resilience of land to climate change.
	VI	Encourage research and development into new ‘adaptive’ technologies, markets and measures: this can be done through research and pilot-funding (or seed-funding), innovative partnerships and/or the removal of barriers to private innovation.
Water	VII	Encourage the uptake of water-saving measures with clear benefits today: this may include end-user water efficiency and reduced leakage.
	VIII	Enable water companies to make appropriate investments in supply-side measures: subject to careful economic analysis, investments in reservoirs, bulk water transfer, and waste-water reuse will make it easier to cope with long-term changes in climate.
	IX	Refine current water abstraction licensing: this will ensure the long-term sustainability of public water supplies and avoid negative impacts on the resilience of ecosystems.
Infrastructure, buildings and land management	X	Ensure new and existing public infrastructure and buildings are resilient to extreme weather and climate change: this may include, for example, schools, hospitals and flood defences.
	XI	Use policy tools to encourage the resilience and robustness of private infrastructure, buildings and land management: the priority focus may be on areas of national importance and areas with critical implications for the public (e.g. property developers, insurance, health care providers, water companies, energy operators, transport operators and telecommunications).
	XII	Ensure that major new developments, such as infrastructure, buildings and land management, support (and do not hinder) long-term resilience: this includes the resilience of natural ecosystems and can be achieved through both regulation and private markets.

Source: Analysis by the authors (see Appendix C and Table 3).

1. Introduction

There is a case for early Government action to promote and enable better adaptation to climate change. The UK is reasonably well-equipped (though not perfectly) to deal with current climate risks. But less frequent events, like the 2007 floods and 2003 heat wave, can have a significant impact on society, economic output and essential services. Climate change will exacerbate these risks. Adaptation is about risk management – to reduce harm and exploit the potential benefits of climate change both today and in the long term. Dealing with climate risks is not new. Throughout history it has been a defining trial for people. However, adaptation to climate change is more challenging and may come up against additional barriers that necessitate an important role for Government action.

The Climate Change Act (Her Majesty’s Government, 2008) requires the UK Government to put in place, and update every five years, a National Adaptation Programme (NAP), which addresses climate change risks. The NAP is to be based on a comprehensive Climate Change Risk Assessment (CCRA), “containing an assessment of the risks for the United Kingdom of the current and predicted impact of climate change”¹, which is also mandated every five years. The first CCRA was published in January 2012 (DEFRA, 2012a).

The Government is currently working on its first NAP, which will be published in 2013. Specifically, Section 58 of the Climate Change Act (Her Majesty’s Government, 2008) requires the NAP to set out:

- a. the objectives of Her Majesty’s Government in the United Kingdom in relation to adaptation to climate change,
- b. the Government’s proposals and policies for meeting those objectives, and
- c. the time-scales for introducing those proposals and policies, addressing the risks identified in the most recent report under [the CCRA].

The purpose of this policy brief is to contribute to this process by offering an analytical framework and formulating a rational basis for thinking about climate change adaptation.

The first NAP, due in 2013, is an opportunity to establish a coordinated, strategic approach to adaptation in the UK. The first NAP should be an initial milestone in an on-going, iterative process, rather than a self-contained strategy. It should be a strategic document, which catalyses action, both within Government and beyond. It should:

- *highlight areas of likely risk*, and overcome the analytical difficulties in assessing risks to make sure that they do not prevent action;
- *establish the principles for good adaptation*, including a sensible approach to dealing with uncertainty (Ranger *et al.*, 2010; Fankhauser & Soare 2012); and
- *define an initial set of specific, time-sensitive priorities for Government action*, identify potential gaps in those priorities, and lay out a path to filling them through further research and consultation.

¹ Extract from Section 56.1 of the Climate Change Act of 2008 (August 2012).

A strategic approach to adaptation is important because climate change presents important new challenges for decision-makers. These new challenges require a departure from the status quo in climate risk management. An understanding of these challenges and the methods to overcome them is an essential foundation for a NAP.

The first challenge is that climate risk can no longer be assumed to be constant. Policy must shift toward a forward-looking risk management paradigm based upon the best understanding of future risk. In the UK, average temperatures have already risen by about 1°C since the 1970s and sea levels have risen at a rate of around 1mm per year (and more in recent years). The UK will continue to warm. For example, projections for parts of southern England have suggested a ‘very likely’ range of warming of 2.2-6.8°C by 2080; the range of uncertainty is large but so is the confidence in significant warming. Projections of future rainfall are less certain, but parts of the UK are expected to become wetter in winter and some projections suggest parts will be drier in the summer. As well as changes in the mean climate, the frequency and intensity of extreme weather events will also change. For example, conditions similar to the extreme heat experienced in 2003 could become the norm by the middle of the century, with extremes reflecting the new baseline.

The second challenge is that, in some cases, action is needed now to cope with the scale, speed and potential irreversibility of climate change impacts. Reactive measures could become increasingly ineffective. The economic case for anticipatory action, that is ‘acting ahead of time’, will increase, particularly where there are ‘tipping points’ in vulnerability or where impacts are irreversible, such as the loss of a particular species. In addition, transformative adaptations, such as relocating coastal populations, have long lead times and so require early action. There is also a need to identify decisions today that could ‘lock-in’ future risk, for example, long-term investment and planning decisions, that could commit the UK to a more vulnerable future. If we fail to account for climate change in long-term investments and policies today then the impacts of climate on the UK will rise progressively and sometimes irreversibly.

The third challenge is that it is impossible to know what future climate we need to adapt to. Dealing with this depth of uncertainty will require a new approach to making long-term decisions. Climate change adaptation strategies need to be robust enough to cope with the fact that our understanding of the UK’s climate in the future is still evolving. We know that as climate models are refined their predictions change. In the past, the majority of these changes have been small. But there are examples where projections have changed significantly and decision-makers need to be aware of the risk of surprises. For example, between 1998 and 2002, some projections of the UK Climate Impacts Programme (UKCIP) changed dramatically. Central rainfall projections for south-east England changed from a 5 per cent reduction to a 20 per cent reduction in 2050 (Dessai & Hulme, 2007). Why is this important? A water planner who in 1998 designed a reservoir to cope with a 5 per cent decline in rainfall would now be scrapping those plans. If the reservoir had been built, it could soon require costly retrofits. In summary, an over-reliance on model projections can lead to maladaptation (Hall, 2007). In the long run this could expose the UK to greater risks, wasted investments or unnecessary costs.

These challenges have direct implications for the NAP. They suggest that a good climate change adaptation strategy should:

- Adopt a forward-looking, long-term approach to risk management.
- Aim to reduce vulnerability and risk today and in the future, whilst avoiding foreclosing options.
- Promote flexible and iterative risk management. Risk management should be a continuous process of change management that proactively learns and responds to new information, rather than being a one-off ‘optimised’ decision.

The remainder of this brief is structured into five sections that cover the main issues that we believe the NAP needs to address:

- Section 2 identifies the main climate vulnerabilities in the UK.
- Section 3 discusses initial adaptation priorities for the coming decade.
- Section 4 reviews the role of Government in adaptation.
- Section 5 discusses ways to embed good adaptation practice in policy-making.
- Section 6 concludes with an illustrative set of priority actions for Government.

2. The main climate vulnerabilities in the UK

Adaptation, and therefore the National Adaptation Programme (NAP), needs to be informed by a broad sense of the likely vulnerabilities to climate change. This involves extensive risk screening but, compared with the Climate Change Risk Assessment (CCRA), there may be less focus on detailed quantification and more focus on the strategic exploration of regional or sector differences in vulnerability and exposure, the drivers of vulnerability, and the range of possible climate outcomes.

An assessment of climate vulnerabilities is broader than an impact assessment in that it takes into account adaptive capacity. The vocabulary of adaptation is often confusing and different parts of the literature use terms such as vulnerability, impact and risk in different ways. Following a common definition (Füssel, 2007; Füssel & Klein, 2006), vulnerability is interpreted as the combined effect of:

- the potential impacts of climate change (which are in turn determined by the system’s exposure and its sensitivity); and
- the capacity of a society or system to adapt.

Understanding vulnerability is not the same as setting adaptation priorities. In setting priorities, factors other than vulnerability also matter, including the urgency of action (e.g. because of imminent decisions with long-term consequences) and the ease with which a risk may be reduced (reflected perhaps in a benefit-cost ratio). But the identification of vulnerability hotspots is nevertheless important.

2.1 Our understanding of climate change impacts

The CCRA offers an initial assessment of climate change risks for the UK. The CCRA suggests that:

- Today, the UK as a whole has a relatively low vulnerability to its climate, but it does have a number of key vulnerabilities, particularly to extremes of weather, which may be aggravated by future climate change.
- In terms of sector hotspots, the CCRA’s list of risks is dominated by flood-related impacts and risks to biodiversity and natural habitats. Water resources will also come under increased pressure.
- Risks from climate change vary significantly between regions and individuals (see also Lindley *et al.*, 2011). In addition to the CCRA, the NAP can be informed by a growing body of regional risk assessments that have been developed by local authorities and regional partnerships.²

² For example, the Department of Environment, Food and Rural Affairs commissioned assessments by nine Climate Change Partnerships to coincide with the publication of the CCRA. These are available from: <http://www.defra.gov.uk/environment/climate/government/risk-assessment/>

The consequences for the UK of climate change occurring elsewhere in the world could be as important as the direct domestic impacts (Foresight, 2011a, b, c). Areas of concern include: issues of security and global influence; the exposure of businesses in the UK, particularly in the financial sector, to global assets and supply chains; the effect on global resources and commodities on which the UK depends (e.g. raw materials); and the trans-boundary effects of health risks and migration.

Wider socio-economic trends could change the UK’s exposure and sensitivity to climate change. Broader trends and stresses, such as population growth, changes in land-use, urban development and growing water demand, could exacerbate vulnerability to climate change and need to be understood better (Table 1).

There may also be opportunities. Impact studies, including the CCRA, often highlight the potential benefits (in the short term) for agriculture in the UK. New business opportunities could also arise in many areas where the UK has a strong commercial track record, such as science and engineering, climate information and financial services.

Table 1. Socio-economic trends and other stresses that affect vulnerability

Category	Trend
Demographics	The UK’s aging population implies a growing national vulnerability to heat.
Development	Development is changing the profile of vulnerability across the UK. For example, the Adaptation Sub-Committee of the Committee on Climate Change (ASC, 2011) reports that around 13 per cent of new homes built since 2000 are located on flood plains. While many are protected, it is impossible to eliminate all risks. For example, the Association of British Insurers estimates that the costs of an extreme flood event (0.1 per cent annual probability) across the Thames Gateway could increase by £4–5 billion, triple current likely damages, as a result of new developments.
Consumption	Water demand is expected to rise steadily. By 2020, water demand is expected to be 5 per cent higher than it is today, even taking into account planned improvements in water efficiency and leakage reduction (Ranger <i>et al.</i> , 2010). The main drivers of rising demand are expected to be population growth and growing demands from industry.
Environmental degradation	Biodiversity in the UK has already declined significantly as a result of long-term stresses, such as pollution and land conversion (UKNEA, 2011). While conservation efforts and regulation since 2000 have slowed these declines, the degradation of many key ecosystems and habitats continues and this increases vulnerability to climate change. Natural ecosystems are already extremely vulnerable to shocks, such as pests and diseases, which also reduce resilience to the changing climate.
Source: Analysis by the authors.	

2.2 Our understanding of adaptive capacity

Adaptive capacity is much less well-understood than climate impacts. In reviewing the vulnerability literature, we find that:

- The evidence base about the adaptive capacity of the UK is scant and the concept is often ill-defined. For human systems, adaptive capacity can be thought of as the ability of institutions, communities, governments or individuals to design and implement effective strategies to manage climatic changes and to cope with the consequences of climate change. This has many driving factors, including the strength of institutions, income, education, access to climate information, flexibility in planning processes, and sufficient financial and human resources (Adger *et al.*, 2007; Brooks *et al.*, 2005; Tol & Yohe, 2007). Ecological systems have a natural adaptive capacity, which is defined by the characteristics of a particular species and the diversity of an ecosystem, but also by man-made constraints, such as the fragmentation of habitats.
- Information about weaknesses in adaptive capacity for different sectors, regions or population groups is still patchy. Some findings about the adaptive capacity of sectors are available from the CCRA,³ but it is not possible to make an assessment across all NAP sectors. Differences in adaptive capacity between regions or population groups are even less well-understood (although see ESPON, 2011, on regional adaptive capacity). The adaptive capacity of ecosystems is largely unknown, given the complex influences of other stressors (e.g. land-use change) and shocks (e.g. pests and diseases).

Given the limited evidence about adaptive capacity, the NAP will need to take a strategic perspective. It should consider where adaptive capacity will most be needed and where the capacities required will be different from today due to future climate change. It should prioritise those areas where there are considerable structural barriers to realising adaptive capacity.

2.3 Addressing evidence gaps

There are still important knowledge gaps about UK vulnerability to climate change. The CCRA was an important first step in understanding vulnerability, but its findings must be interpreted with care (see Box 1). A summary of the evidence gaps identified by the CCRA is given in Appendix B [available online at: <http://www.lse.ac.uk/grantham>].

The NAP needs to start a process of understanding, prioritising and closing identified evidence gaps. These gaps can result from a wide range of barriers and restrictions. Priorities for further research will be determined by the potential importance of the risks (the value of more information) and the ease with which they may be closed (the cost of more information).

Evidence gaps need not prevent action on adaptation. It is most important to understand where the evidence gaps and deficiencies in assessment methods lie. Coupled with this knowledge, the NAP should aim to identify appropriate robust strategies that take full account of the uncertainties in risk (Sections 3 and 5).

Box 1. Evidence gaps and the interpretation of the 2012 UK Climate Change Risk Assessment (CCRA)

Evidence gaps

The Climate Change Risk Assessment (CCRA) highlights the large uncertainties attached to its risk assessments, including, in some cases, uncertainty about the direction of change. Confidence in a large number of its findings are classified as ‘low’ to ‘medium’ confidence, with only risks that are already being experienced and those relating to increased temperatures being classified as ‘high’ confidence. For some future climate aspects, the uncertainties extend even deeper, with models offering conflicting projections. An important example is the propensity for, and impacts of, droughts. The Met Office Hadley Centre has concluded that while there may be a tendency for increased drought, it is not yet possible to robustly project changes in UK meteorological droughts arising from increased greenhouse gas concentrations (Murphy *et al.*, 2009).

The CCRA itself, and recent reviews, highlight several methodological issues and evidence gaps:

- i The quantification and portrayal of uncertainty is based on a single modelling approach, the United Kingdom Climate Projections 2009 (UKCP09), which some researchers have questioned. This could lead to an underestimation of the range of uncertainties about risk that are identified by the CCRA (Frigg *et al.*, 2013; Oreskes *et al.*, 2010).
- ii The risk assessment focuses only on impacts for which evidence is available; for example, it does not include an assessment of how the UK may be affected by impacts in other countries, cross-sectoral impacts (indirect effects), interdependencies between impacts (e.g. the societal impacts of declining ecosystems) and major catastrophic events (Watkiss & Hunt, 2012).
- iii The selective assessment of 100 key risks that were identified through a bottom-up process was both too wide and too detailed (e.g. assessing the risk from particular pathogens), thus lacking a sense of priority.
- iv To achieve coverage of all sectors, the risk assessment employs an overly simplified modelling method, for example, using damage functions that are driven by only a single climate variable. This ignores many natural processes that are known to be important. For example, experts have identified a potentially major issue with the CCRA’s crop yield projections, which omit the effects of a changing frequency of extreme heat and rainfall (Semenov *et al.*, 2012). The assessment also omits many of the (often uncertain) inter-linkages between impacts, for example, the effects of pests and diseases on crop yields (this is shown as a separate metric and not linked to crop yield metrics). The absence of these inter-linkages could be a significant gap in the CCRA. Indeed, for the crop yield risk metrics, the CCRA itself states that “the [wheat yield] metric developed is thus considered too crude for any objective assessment of the future impact of climate change on yield” (Knox & Wade, 2012).
- v There is a limited inclusion of societal change projections, such as economic growth scenarios and developments in new technologies, for example, by including only baseline forecasts of population growth.

3 Measurements of adaptive capacity in the CCRA have focused on the structural and organisational capacities of institutions. Structural adaptive capacity refers to the freedom of the system to respond within structural limits and includes decision timescales, activity levels, maladaptation and sector complexity. Organisational adaptive capacity describes the capacity of specific organisations, for example businesses, farms or local governments, to respond to the challenges of climate change. Within the CCRA, this has been assessed using the PACT framework, where response levels are ranked within a hierarchy of increasing capacity from core-business-focused (R1) to stakeholder responsive (R2), efficient management (R3), breakthrough projects (R4), and strategic resilience (R5).

Box 1. Evidence gaps and the interpretation of the 2012 UK Climate Change Risk Assessment (CCRA) (continued)

Implications for the National Adaptation Programme

The issues identified in the previous section have implications for the way in which the CCRA informs the National Adaptation Programme (NAP):

- The identification of adaptation priorities must go beyond the first CCRA. Firstly, the CCRA provides only a partial coverage of impacts and so by focusing only on its risks, the NAP could delay action in areas that require an immediate response (Section 3). Secondly, issues relating to the method (i, iv and v in the previous section) mean that the specific quantification of risks cannot be relied upon directly for designing adaptation plans. For example, over-reliance on the wheat yield projections (which alone suggest an opportunity), could lead farmers to incorrectly assume that there are no risks to future wheat yields, potentially leading to maladaptation.
- The CCRA does not take account of current policies (such as planned improvements in infrastructure) and so cannot be used to assess where the NAP should propose additional action is required to tackle the impacts of climate change.
- Estimates of the total economic impacts of climate change on the UK in the CCRA are likely to be an underestimate (Watkiss & Hunt, 2012) and therefore could underplay the economic benefits of adaptation relative to other investments.

Implications for the second CCRA

The second CCRA should first and foremost be informed by an assessment of the objectives of the CCRA. For example, should the objective be to raise general public awareness of climate change, to justify mitigation of greenhouse gas emissions, or to inform adaptation? Different objectives will require a very different design for the CCRA. We suggest that the CCRA should be primarily designed to inform societal adaptation, and in particular, the NAP. With this in mind, the following recommendations are made:

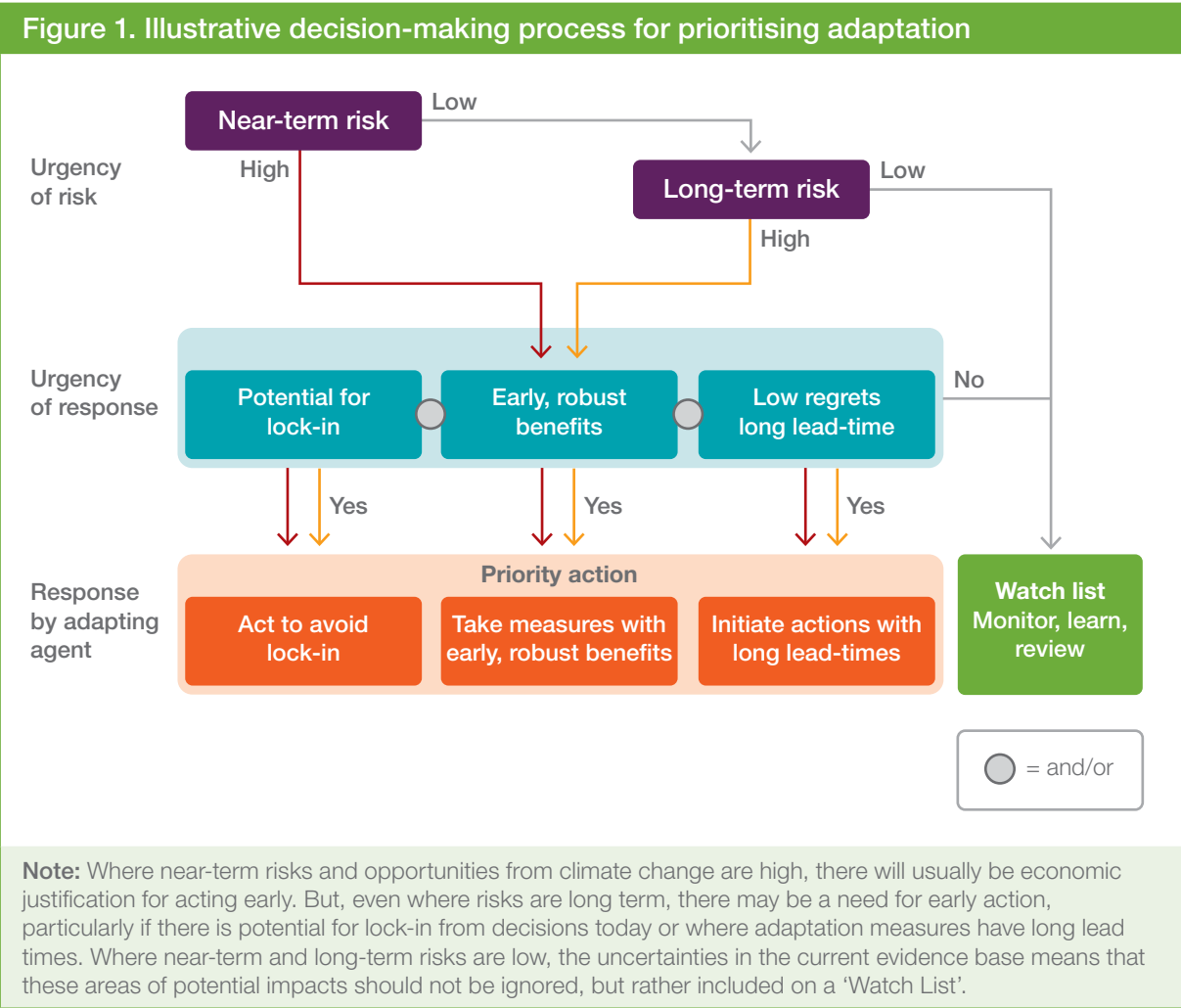
- The second CCRA should be much more strongly founded on an understanding of the current vulnerability of the UK to weather and climate. This includes, for example, a detailed knowledge of relevant operational limits and tipping points in critical systems, sectoral vulnerabilities and social coping capacities. This assessment should also capture indirect impacts and cross-sectoral linkages.
- The second CCRA should maintain its broad overview of risks to the UK, but this must be made truly comprehensive – rather than being defined by current modelling capacity.
- The characterisation of specific risks to the UK must take account of all the known important influences. Rather than attempting to provide detailed quantitative risk estimates, based on a partial and unreliable method, the primary goal of the CCRA should be to assess the rough range of possible risk, taking account of all known factors, where evidence is limited. This might be achieved, for example, through more thorough sensitivity testing of findings and a shift away from partial probabilistic modelling to scenario-based approaches.
- The ‘broad and shallow’ risk assessment should be complemented by ‘narrow and deep’ analyses specifically designed to inform adaptation. For example, they should focus on areas of high priority adaptation and should be designed to answer specific questions from decision-making. The CCRA should involve stakeholders to identify these needs.
- Risk assessments should provide a more comprehensive evaluation of social and economic impacts, for example, taking account of the economic importance of a sector in terms of employment, outputs and social vulnerabilities.
- The CCRA should assess the level of risk given current policy.
- The CCRA must present scenarios of expected socio-economic changes and other trends that are of relevance to risk and to the design of adaptation strategies.
- The CCRA and the Economics of Climate Resilience study should be more closely linked, and if possible, designed and conducted in parallel. This will help to ensure that the CCRA is properly designed to inform an economic assessment of the UK’s adaptation priorities.
- The CCRA should adopt methods which enable it to capture the regional diversity of risk.

3. The focus for initial adaptation

Adaptation is a long-term process; the first NAP will have to indicate which measures need to be fast-tracked over the coming decade and which can wait until later. In other words, the NAP will have to set priorities for adaptation. Even in areas of high vulnerability, not all adaptation has to start at once. Some measures can be implemented at short notice, such as a farmer’s decision about the right crops to plant, which is made one season ahead. Others require long-term planning and preparation.

As a rule of thumb, there are three main situations where it is advisable to bring adaptation forward. Priority actions will usually be justified where there is a high level of near-term risk or if there are long-term risks which require adaptations with long lifetimes or lead times (Fankhauser *et al.*, 1999; ASC, 2010; Ranger *et al.*, 2010). This suggests the following key areas for early UK adaptation efforts (see Figure 1 and examples in Appendix C [available online at: <http://www.lse.ac.uk/grantham>]):

- *Adaptations with early, robust benefits.* Fast-tracking adaptation makes sense if the proposed measures have immediate, robust⁴ benefits that would otherwise be forgone; for example, where there is an existing vulnerability or there are expected near-term impacts from climate change.



4 Robust means that a measure has benefits over the plausible range of future climate changes for a region; that is, the benefits are robust to uncertainty about future climate.

- *'Low-regrets' adaptation measures with long lead times.* It makes sense to fast-track 'low-regrets' adaptations that have long lead times, such as research and development, even if the benefits will not accrue until later.
- *Areas where decisions today could 'lock-in' vulnerability profiles for a long time.* Fast-tracking adaptation is desirable if a wrong decision today makes us more vulnerable in the future and if those effects are costly to reverse. Several strategic decisions potentially fall into this category, including those on long-term infrastructure (e.g. the location of new airports, rail links and wind farms), land-use planning and the management of development trends, such as regional water demand.

Measures within each of these categories should be subject to careful appraisal to ensure they are rational and cost-effective.⁵ The first two categories of measures are less sensitive to future climate outcomes and can generally be assessed using standard Green Book techniques (e.g. cost-benefit analysis). Analysing lock-in is more complicated and requires techniques that deal adequately with climate uncertainty; locking in a response to the wrong climate scenario can also be expensive. Section 5 elaborates more on the appraisal techniques the NAP should promote.

3.1 Measures with robust and early benefits

Only a few studies evaluate systematically a wider set of options for climate change adaptation with early benefits. From theory, we know there are five broad forms of measures that are likely to yield benefits that are relatively insensitive to uncertainties in future climate (Ranger *et al.*, 2010):

- measures that are reactive and short-lived (so can be adjusted over time), such as emergency responses and disease management;
- measures that reduce vulnerability to current weather, such as risk information and insurance;
- measures that reduce other stresses that will increase vulnerability to climate, such as natural drainage systems and water efficiency;
- measures that have strong co-benefits, such as green urban spaces; and
- measures that reduce general vulnerability and build adaptive capacity, such as risk education and better healthcare.

This, and the information available from case studies, suggests that high-priority, cost-effective and 'low-regrets' adaptations may, for example, include (Economics of Climate Adaptation Working Group, 2009; ASC, 2011, 2012; Ranger *et al.*, 2010):

- *Water efficiency* measures to ease both current and future pressure on water resources, such as low-flow taps, showers and toilets that are cost-effective when installed as part of an end-of-life replacement.
- *Flood protection* at either the community or building level. For the latter, options like airbrick covers, door-guards, repointing of walls, drainage bungs and non-return valves are often attractive, although flood protection at the community level is generally more cost-effective.
- *Measures to better deal with heat stress.* The 2003 heat wave in Europe revealed shortcomings in heat management plans. France, which suffered the highest casualty rates, has since upgraded its response capacity with a new Heat Health Watch Warning System (Pascal *et al.*, 2006). England now has a regularly-reviewed Heat Wave Plan. In buildings, additional 'no-regrets' measures to deal with heat stress include window shading and investment in energy-efficient appliances that produce less waste heat.

⁵ Such a framework must include an appropriate valuation of non-monetary benefits.

- *Measures to enhance societal resilience* to deal with the direct and indirect impacts of climate 'shocks', such as flooding, heat waves and droughts. For example, the Health Protection Agency (Vardoulakis & Heaviside, 2012) highlights the need to strengthen early warning systems and regularly review the preparedness of public health systems to cope with higher summer mortality due to heat stress.
- *Better environmental management*, as a healthier natural environment provides superior ecosystems services (UKNEA, 2011) and is more resilient to future climate stress.
- *Employing 'soft' engineering solutions* (that is, ecosystem-based approaches to adaptation), such as urban greening to reduce heat stress and increase natural drainage, where effective (Naumann *et al.*, 2011). Such measures tend to be more flexible in managing risk under uncertain, long-term future climate conditions and have immediate co-benefits for the natural environment and well-being.

3.2 Long-term decisions that risk vulnerability lock-in

The NAP needs to identify the potential policies, investments and trends today that could lock-in future vulnerability. Decisions are made every day that affect the exposure of societies to climate hazards and their ability to cope with events when they occur. Examples include (Hallegatte, 2009; Ranger & Garbett-Shiels, 2012):

- Land management and long-lived investment and location decisions concerning buildings and infrastructure will have long-lasting effects on societal vulnerability to climate. The UK's annual investment in infrastructure (energy, water, communications and transport) stands at around 3 per cent of GDP (Her Majesty's Treasury, 2011). These decisions can be difficult and costly to reverse or retrofit later.
- A failure to manage other drivers of stresses, such as growing demand for water, rising and unstable food prices, environmental degradation and increasing prevalence of disease, could also lock-in future vulnerability to climate change. Tackling these issues now can strengthen long-term resilience and adaptive capacity.

Given the on-going pace of socio-economic change, infrastructure investment and development in the UK, avoiding lock-in is an important priority for the NAP. Land management and land-use change are particularly critical areas. For example, since 2000, each year between 10,000 and 16,000 new homes have been built on high risk flood plains (ASC, 2011). Indeed, in some regions, the rate of development on flood plains is higher than across the locality as a whole. The area of hard surfacing in towns and cities is also rising, with negative and difficult-to-reverse consequences for urban flood and overheating risk.

There is a need to incorporate climate change into long-term investment decisions. Key upcoming Government projects and private investment programmes provide an important opportunity to secure a more climate-resilient future for the UK, as well as to show leadership. These include, (Her Majesty's Treasury, 2011):

- major road and rail improvements, such as the new High-Speed Two (HS2) rail network and major road improvements on the M1, M6 and M25 motorways;
- expansion of airports, including major capital investment programmes at Heathrow and Gatwick and proposals for a new Thames Estuary airport;
- investments in new energy infrastructure, including wind, nuclear and gas;
- several major investments in water supply and waste systems, such as the Thames Water investment in the Thames Tideway Tunnel, a major new sewer for London, and the Essex and Suffolk Water enhancement of the Abberton Reservoir;

- the Government's flood and coastal erosion risk management programme. Over the Spending Review period (2011-12 to 2014-15), the Government will spend more than £2 billion in England on the management of flood and coastal risks (DEFRA 2011); and
- in 2011 and 2012, the Government announced the launch of several initiatives aimed at increasing the UK's residential housing supply, including a package to deliver 70,000 new homes, relaxation of some planning constraints on developers and investments of about £750 million in infrastructure investments to support new developments.⁶

The NAP should promote approaches and instruments to help ensure that such decisions are robust and resilient to future climate. This could include, for example, providing appropriate tools and guidance (for example, the 'Climate Ready' programme and guidance such as *Climate Resilient Infrastructure: Preparing for a Changing Climate*, published by Her Majesty's Government, 2011), and creating incentives and appropriate regulatory structures where appropriate (e.g. water regulation and land-planning policy). Many such decisions are taken by private actors, both businesses and individuals, but the Government should also act to ensure its 'own house is in order'.

To ensure decisions are robust against uncertainty, processes need to be flexible, progressive and forward-looking. Flexible approaches aim to implement change iteratively, such that risk is cost-efficiently maintained below tolerable levels, while keeping open options to adjust plans as more is learnt about the future climate. There are several approaches to increasing the flexibility of decisions today (Fankhauser *et al.*, 1999; Hallegatte, 2009), such as:

- Including safety margins for measures and policies today to cope with a wider range of possible climate conditions. For example, a water resource manager might opt to build a safety margin into the design of a reservoir so that it can maintain adequate water supplies under a wide range of future rainfall conditions. This means potentially 'over-adapting' to climate change, but it can be desirable where the extra expenses are low. It is not likely to be desirable where the costs are high, for example building sea walls today that would only be needed if sea levels rise by several metres.
- Designing measures and policies today that can be easily and inexpensively adjusted later to cope with future climate conditions. For example, building a sea wall or reservoir today with larger foundations so that it can be adjusted later if necessary, rather than replaced. Again, this is a good approach where the extra expense is low (i.e. it is 'low-regrets') or the chance of needing to make the adjustment is high. For example, the Thames Barrier that protects London from flooding was designed so that it could be over-rotated (i.e. heightened) to cope with greater than anticipated sea level rise.
- Designing strategies that use a package of adaptation measures that are sequenced over time to reduce current climate risk, while maintaining flexibility to cope with future risks. For example, a decision-maker could focus on 'no-regrets' options in the near term (such as using drought-resistant crops to better cope with current climate conditions as well as promoting economic diversification, primary education and access to credit and markets) while also putting in place flexible measures to help support long-term adaptation (such as investments in agricultural research and development). More inflexible and expensive investments, such as large-scale sprinkler systems for irrigation, that have a lower benefit-cost ratio today and more uncertain long-term benefits, might be delayed until better information is available (with regular review).
- Reducing the lifetime of decisions. Hallegatte (2009) gives the example of the forestry sector, where decision-makers have chosen species that have a shorter rotation time to allow flexibility to cope with long-term uncertainties.

⁶ Growing Places Fund. <http://www.communities.gov.uk/statements/newsroom/2211838>

4. The role of Government

Most climate change adaptation is undertaken by private actors – households, firms and civil society. Private adaptation is sometimes called 'autonomous' and distinguished from the 'planned' action taken by Government. The term private adaptation is preferred here. Adaptation by private actors is no less planned or deliberate than public sector adaptation. Only the decision-maker is different.

The role of the state is to provide an enabling framework that encourages and supports such decentralised climate change adaptation (e.g. Cimato & Mullan, 2010). The roles of the public sector – Government departments, local authorities and public agencies – can be categorised into four types, which represent different state functions and grades of public intervention:

- *Providing* adaptation services directly, if the public sector commissions or delivers adaptation as a public good. This includes ensuring the resilience of public assets, services and operations.
- *Enabling* adaptation in areas where public policy needs to overcome private barriers to adaptation, including financial, moral hazard, legal, behavioural or coordination barriers, or to provide stronger incentives through price signals and regulation.
- *Assisting* with adaptation, for example with help to vulnerable people and other support to ensure a fair and equitable adaptation outcome.
- *Informing* about climate risks to overcome knowledge barriers, and providing public information (climate and other) as a way of supporting private adaptation.

In addition, the state has a monitoring function. It is in the public interest to assess and monitor adaptation progress, even if there is no rationale for public intervention. We return to this issue in Section 5.

How responsibility for public adaptation is split across Government departments is a matter of political preference and cultural norms in governance (e.g. centralised/decentralised). Decisions may also be influenced by economic factors. For example, under the fiscal constraints currently experienced in the UK, there may be a greater focus on creating an efficient enabling environment for private adaptation, and seeking innovative public-private partnerships to deliver public goods. Regional variations in adaptation needs across the UK may justify a more decentralised approach (e.g. local government and delivery agencies). However, there is also a role for a centralised function to:

- monitor vulnerability and regularly measure progress on adaptation;
- identify and help to resolve gaps in Government action and barriers to effective delivery, for example, by raising awareness and overcoming coordination barriers (when dealing with complex, cross-sectoral and national-scale impacts and trade-offs) or a lack of capacity and skills in delivery teams; and
- develop and disseminate information (climate and otherwise), guidance and training to delivery teams ('Government goods'⁷).

⁷ Analogous to a public good within Government.

4.1 Providing public goods

Many climate change adaptation measures are public goods that would be under-provided by the market. Typical examples include community-level flood protection, storm warning systems and coastal defence structures. The NAP needs to outline how they would be supplied, taking into account fiscal constraints. Historically, public goods related to climate protection have typically been provided directly by the state. Public-private partnerships (PPPs) are difficult to structure (Agrawala & Fankhauser, 2008) and therefore rare. An exception is the Broadland Flood Alleviation Project in East Anglia, where flood risk management in an environmentally sensitive area has been outsourced to a private contractor (Environment Agency, 2009).

The NAP also needs to review the best way to ‘climate-proof’ conventional public goods such as the national infrastructure. In cases where their provision has remained in state hands (e.g. most roads), adaptation will also be a Government responsibility. Many of the responsible agencies have already formulated a response strategy, but the NAP is an opportunity to review and strengthen existing arrangements, including those covered by the Adaptation Reporting Power (ARP). In cases where infrastructure services are provided by the private sector (such as water), the NAP should review the regulatory arrangements for adaptation by private infrastructure providers (e.g. Her Majesty’s Government, 2011).

There are public good elements in climate change adaptation research and development, such as the search for drought-resistant crops. The standard approach to protecting the intellectual property of innovators is through patents, while upstream research is incentivised through research grants and prizes. Supporting pilot projects that trial new adaptation approaches (e.g. ecosystem-based adaptation) can also help to build the knowledge base as a public good. Unlike low-carbon innovation, adaptation research and development has attracted very little policy or analytical attention so far, even though it is a potentially important part of the response. Given the likely scale involved, it also requires a global effort, but the NAP should explore how England can best contribute to it.

4.2 Enabling private adaptation

The process of climate change adaptation is neither smooth nor automatic. Barriers to adaptation exist throughout the adaptation process, from understanding to planning and managing climate change risks and opportunities (Moser, 2010; Hanemann, 2008; Repetto, 2008). It is the role of Government to address barriers to effective adaptation, and their identification is therefore an important task for the NAP.

There are market failures that may prevent sufficient adaptation. Problems may include both generic market failures and issues specific to adaptation. There may be asymmetric information, for example, between the buyer and seller of a property about its risk profile. There may be issues of moral hazard for people with insurance cover or with at-risk communities holding out for Government assistance. Path dependence may affect the choice between protection and relocation. For example, highly vulnerable coastal towns may be protected because they are historical locations. Another key problem is externalities and more generally a lack of coordination, for example between upriver and downriver communities.

There are behavioural barriers to adaptation. Complex, long-term adaptation decisions are known to be affected by cognitive barriers. The literature identifies inertia, procrastination and implicitly high discount rates as potential behavioural problems (Hanemann, 2008; Cimato & Mullan, 2010). In large organisations, securing buy-in for adaptation measures at board level or among senior management may also be an issue (AEA/ClimateSouthEast, 2010).

There are shortcomings in the institutional and regulatory environment. While Government intervention can be the solution to behavioural barriers and market failure, Government processes and public policy failures can themselves be a barrier to adaptation. For example:

- Flood risk management: the Pitt Review (2008) highlighted important institutional barriers to urban flood risk management following the 2007 floods. The lack of transparency about ownership and responsibility for surface water, and the lack of joined-up strategies for dealing with different types of flooding that occur at the same time were noted as key challenges for improving future flood risk management. The Review’s findings mirror the experience in the United States after Hurricane Katrina (Sobell & Leeson, 2006).
- Water management: the Adaptation Sub-Committee of the Committee on Climate Change (ASC, 2011) has hinted at regulatory barriers that may hold back efficient adaptation in the water sector. They include the design of abstraction licenses – which is already harming the natural environment – and the limited use of water meters, in particular in areas at risk from future (as opposed to current) water shortage. The Government (2011) also hints at the short-term focus of economic regulators, although their mandates explicitly recognise the need to balance short-term and long-term consumer needs.
- Built environment: at the household level, the retrofitting of buildings may be held back by a lack of economic incentives (LCCP, 2009) as well as by barriers that may be partly regulatory (e.g. related to planning) and partly related to hidden costs and lack of information. At the local authority level, planning decisions may be affected by coordination failures, but also by capacity constraints and information barriers. Planning decisions need to be coordinated, for example, among local authorities that share the same water catchment area.
- Adaptation capacity in public agencies: the same gaps in skills and planning that affect private decision-makers also impede adaptation by public agencies. The Adaptation Sub-Committee of the Committee on Climate Change has found shortcomings in (central Government) departmental adaptation plans. The (limited) evidence from the now defunct National Indicator 188 suggests an extremely uneven level of adaptation capacity among local authorities.

A toolbox of policy instruments is available to overcome barriers and enable action. The generic options include regulation, legislation, price signals (markets and taxation) and public investment (in research and development, for example). The choice of the appropriate policy instrument will be context-specific. For example, regulation can be a rapid and effective way of changing behaviour, but imposes higher costs on private actors than price signals. The Government also has more indirect avenues of influence, such as through its own procurement procedures, and by supporting the development of voluntary standards and reporting. The Government can also learn from international experience. For example, in Canada, applicants to the Canadian Strategic Infrastructure Fund are required to demonstrate how their project takes account of climate change (Her Majesty’s Government, 2011).

4.3 Assisting vulnerable groups

Addressing questions of equity and ensuring fairness in adaptation is the purview of public policy, and therefore an important topic for the NAP. Climate change adaptation raises many questions about distribution. Climate change itself is an agent of redistribution as different regions, sectors and population groups will be affected differently (Hanemann, 2008; Lindley *et al.*, 2011). Choices about adaptation can exacerbate (or mitigate) these effects. At a more practical level, people will look to the state for basic protection and assistance in case of emergencies. With climate change, demand for these essential public services will rise.

The extent to which the state should provide an ‘adaptation safety net’ is largely a political choice, influenced by political philosophy, ethics, but also fiscal realities. A related question is how the costs of adaptation should be shared. The basic choice is for adaptation costs to be borne either narrowly by the beneficiaries of a measure, or more widely by a larger population group. The NAP will not be able to answer this highly political question, but it offers an opportunity to initiate a debate. The NAP can also lay out the question and explain the pros

and cons of different options. For example, analysis by the Adaptation Sub-Committee of the Committee on Climate Change shows how, in the area of flood protection, the adaptation burden is gradually transferred to beneficiaries by requiring larger shares of local co-funding, and by moving from community-level protection (paid for by the state) to property-level protection (paid for by homeowners) (ASC, 2012).

There are important knowledge gaps about the societal impacts of climate change in the UK. They include limitations in our understanding of how climate change may exacerbate existing social and economic challenges, for example in urban areas or in exposed rural settings. The difficulty of integrating societal factors into risk assessments has been highlighted by the Climate Change Risk Assessment (CCRA), which showed a lack of accounting for wider societal change, including socio-economic and demographic trends, when assessing risk levels. This is partly down to methodological issues (e.g. how to measure the multiple facets of societal impacts, Lindley *et al.*, 2011; Brisley *et al.*, 2012), and partly down to limited data availability. Zsamboky *et al.* (2011) note a lack of evidence about the number of hospitals, care homes, schools, nurseries and clinics in flood risk areas on the UK coast, which means that there is also little information about the potential impacts climate change could have about access to, and the quality of, social services in coastal areas.

Another critical element is solidarity with vulnerable populations abroad – an issue that goes beyond the scope of the NAP but ought to be acknowledged. Low-income countries will be hit much harder by the impacts of climate change and their capacity to adapt will often be limited (World Bank, 2010). Ensuring climate-resilient development in low-income countries, through both official development assistance and additional climate finance, is an important responsibility. The UK recognises this and the Department for International Development is one of the leading development agencies on adaptation. International adaptation support is first and foremost about fairness and equity, but it is also in the UK's self-interest. The international repercussions of climate change could have economic, social and security implications for the UK (Foresight, 2011a).

4.4 Providing information to inform adaptation

The public sector has a role in delivering information and guidance to support adaptation by other actors, as a public good. Several types of information are necessary for adaptation, such as data about past weather, vulnerability, engineering and climate scenarios. The public sector can also stimulate adaptation by providing guidance and training (e.g. UK Climate Impacts Programme), and particularly by communicating information about success stories, such as the Thames Estuary 2100 Project (Reeder & Ranger, 2011) and the United Utilities West-East Pipeline project (Her Majesty's Government, 2011).

The process of producing information about future climate at local and national scales is a young research discipline. Efforts to date have focused on providing future climate scenarios, which has the benefit of being applicable to a wide range of users. The NAP should continue to encourage this, but must be cautious about how information is communicated and applied, given the remaining uncertainties and potential for misinterpretation and maladaptation. For example:

- Complexity does not necessarily imply reliability or suitability for purpose. Increasing computing power has brought with it the potential to simulate more and more processes at higher and higher resolution. But despite their success in making reliable weather predictions, today's models are far from being able to represent all the processes necessary to provide accurate decadal forecasts.
- A diversity of approaches to providing climate information will reduce the risk of climate change to the country as a whole. There is a possibility that if provision of climate information derives from only one method then the country as a whole is put at risk if the methodology is misleading, inadequate or inappropriate. For example, a reliance on UKCP09 would create such a risk.

- The reliability of information is hard to assess. Robust verification of climate predictions (on decadal timescales and longer) is impossible.
- 'Blues skies' research should be supported. Valuable outcomes are almost certain but their character and sectoral applicability are unknown.
- Expertise in weather forecasting is well-developed and an understanding of how to make and evaluate seasonal forecasts is developing rapidly. A climate-resilient society will make much better, and more widespread, use of this information. The application of such forecasts should be an important element in planning.

However, the barriers to effective adaptation decisions are more than just a lack of access to sound information. Information can only be effective where it is accessible to users and is used properly (Her Majesty's Government, 2011). To encourage the uptake of information for adaptation there is a need to stimulate innovation in its use and generation. Such innovation would benefit from greater supply-side competition. Making national capability information – models, observations, forecasts – open source and freely available could encourage such innovation. The continued funding of national capability as a public good will continue to be crucial, but the benefits of greater competition in forecast generation and interpretation will be significant for climate change adaptation. Table 2 identifies some of the main barriers to the development and use of information for adaptation.

Table 2. Current barriers that prevent improvements to the adaptation evidence base

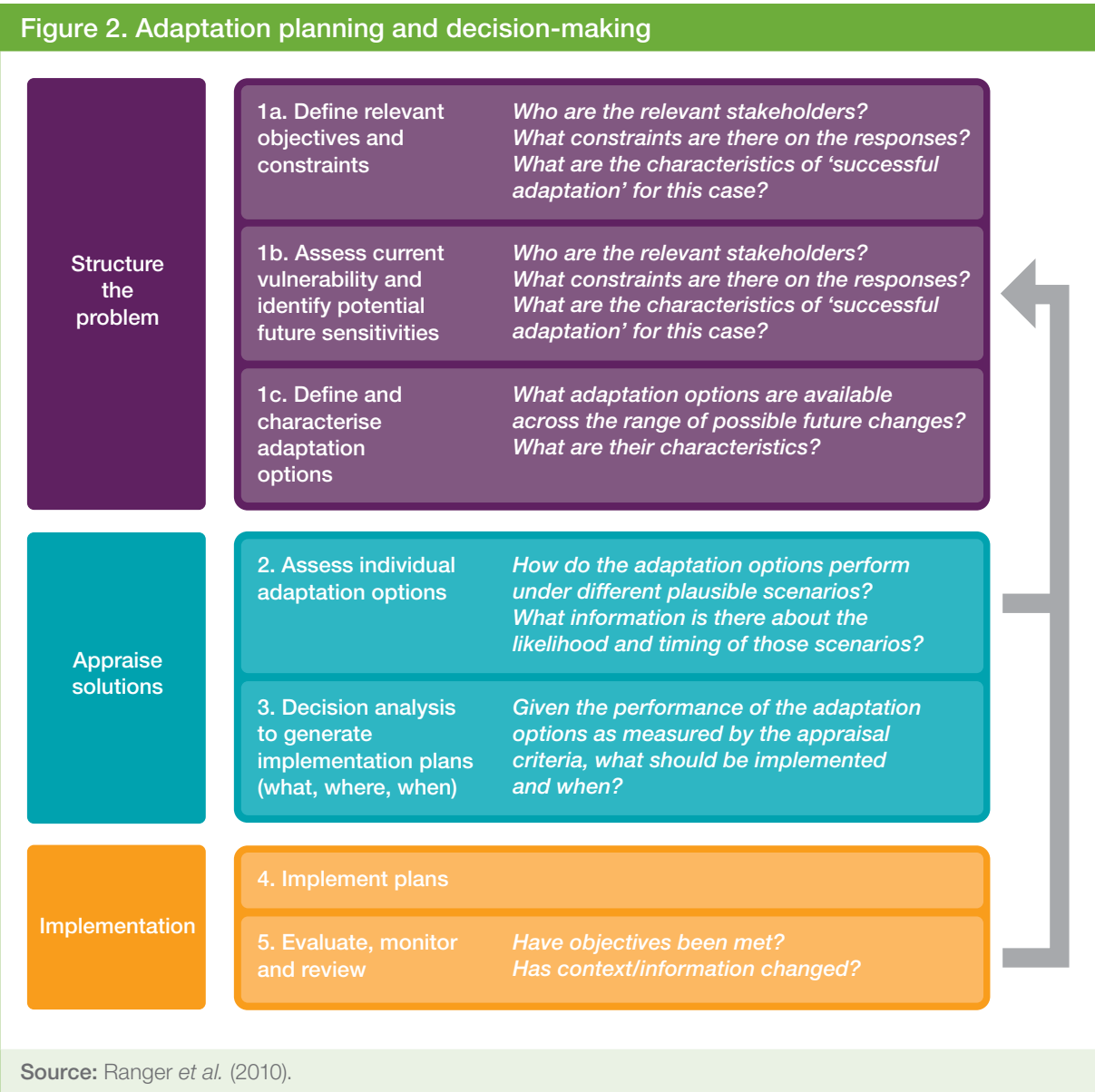
Type of barrier	Example
Legal system – copyright/data protection/no duty to share data	Restricted access datasets about surface water flood risks.
Costs	Prohibitive costs in researching global supply chain risks through disruption caused by climate change.
Commercial confidentiality	Reluctance to provide commercially sensitive data for climate risk assessments.
Data-overload/computational limits	Too much information makes it difficult to prioritise and identify most important risks and vulnerabilities.
Too many divergent results/contradictory findings	Scenarios for Economics of Climate Resilience (ECR) adaptation study.
Use of different risk metrics	Financial versus intangibles such as well-being or trust. The difficulties in measuring non-monetised societal benefits such as ecosystem services.
Challenge of verifying information	Low confidence in reliability of some data.
Short lifetimes of data/need for constant updates	Need for a national monitoring program of forestry growth and climate data.
Terminology (information hidden because it is not identified as relevant to adaptation)	Health and safety considerations, and general risk management can increase climate resilience, but are often not considered when looking for evidence of adaptation action.
Source: Analysis by the authors.	

5. How to ensure good adaptation

To establish a continuous process of adaptation, the UK has to put in place structures that allow the on-going management of climate risks. A first important task in this respect is more systematic adaptation planning. A second challenge is to embed good adaptation practice into the decision-making of relevant organisations on an on-going basis, starting with (adjustments to) the management of current climate risks. A third key task is to establish a framework for the monitoring of adaptation performance.

5.1 Adaptation planning

The National Adaptation Programme (NAP) must implement a flexible and forward-looking risk management process that reduces risk progressively over time while avoiding foreclosing future options. Adaptation is a continuous, iterative process that learns and responds to new information over time (Figure 2). There is a growing literature on how to implement such approaches in practice (Her Majesty's Treasury & DEFRA, 2009; Prutsch *et al.*, 2010; UKCIP, 2010; Ranger *et al.*, 2010; Willows & Connell, 2003; World Bank, 2010). Such approaches are



not revolutionary. Business strategists, military planners and natural resource managers have been using robust approaches in their long-term planning for decades (Lempert *et al.*, 2003). The NAP can learn from such experience.

As a rule of thumb, long-term adaptation measures should be flexible; that is, they should allow for revision at a later date, or be robust to a wide range of climate outcomes. Sophisticated decision tools are complex and time-consuming to apply, but fortunately they provide some fairly robust practical insights, which the NAP should promote (Fankhauser *et al.*, 1999). To the greatest extent possible, long-term adaptations should be flexible and/or robust. Flexibility intuitively means emphasis on behavioural and regulatory, rather than structural, measures. A standard example is the superiority of water efficiency measures over investment in new supply infrastructure. Even for structural measures it is possible to maintain a degree of flexibility, as the well-known example of the Thames Estuary 2100 project shows (Reeder & Ranger, 2010).

There has to be more debate between the Government, the public and stakeholders about adaptation objectives and the acceptability of climate risks. The acceptable level of climate risk in the UK is often set implicitly, as a by-product of other decisions, such as the capital investment programmes of water companies or budget allocation for flood protection from Her Majesty's Treasury. The NAP offers an opportunity for a more explicit analysis and discussion about the right level of climate change protection that should be afforded by policy in areas such as flood management, coastal protection and drought control. Ultimately, these decisions will, out of necessity, be political, but a clearer analysis may help to make them more informed and less opaque.

Engaging stakeholders can increase flexibility by ensuring risk and cost trade-offs are acknowledged and accepted by those that are affected. Stakeholder engagement is an important aspect of good decision-making. This is already well-recognised in UK adaptation practice, including in the inclusive approach taken to the NAP itself (DEFRA, 2012b; McKenzie-Hedger *et al.*, 2006). The UK also has a long track record of engaging with and assisting decision-makers through the UK Climate Impacts Programme. The NAP should highlight the importance of these activities, review their effectiveness to date and make recommendations accordingly.

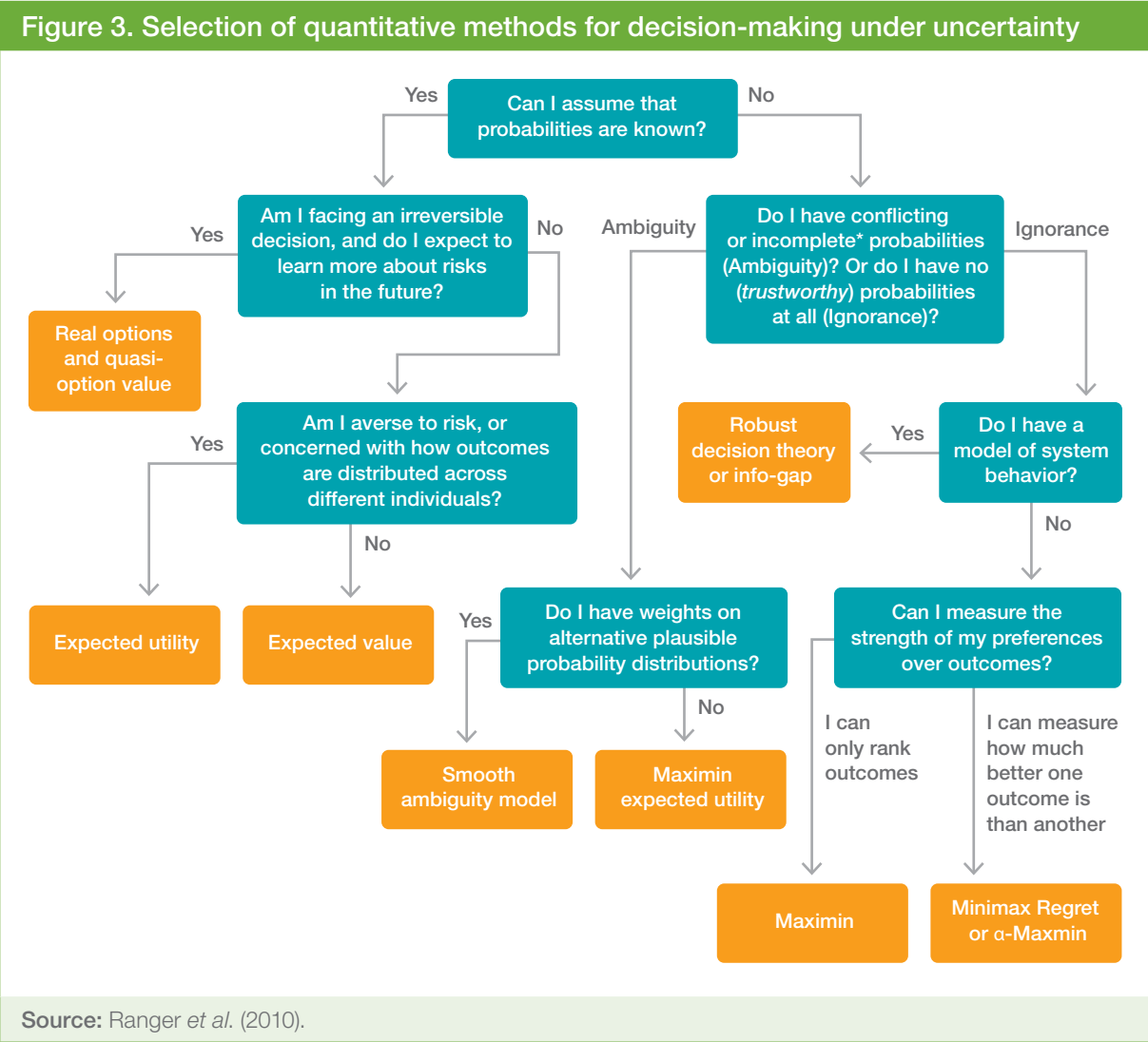
5.2 Good decision-making

There are well-established tools to appraise public adaptation projects when the sensitivity to climate uncertainty is low. The NAP should reiterate their importance, even though it is a well-covered area of public policy. For adaptations with robust benefits, which are insensitive to future climate scenarios, the main tools to ascertain value-for-money are cost-benefit analysis and cost-effectiveness analysis. Analysts who question whether impacts can be monetised may prefer multi-criteria analysis. These methods are well-known to Government agencies, and the Green Book on public project appraisal contains the relevant guidelines.

The NAP needs to recognise and emphasise that long-term adaptation decisions are made under profound uncertainty. The analysis of long-term decisions requires more sophisticated, rarely-used tools that factor in climate uncertainties. Climate models cannot yet, and will not for a long time, produce sufficient information for well-informed long-term decisions – for example, localised, daily or seasonal data, not just on temperature, but also on precipitation, flood probabilities, wind speeds and much else. UKCP09 provides relatively detailed information on many of these factors. However, practitioners have found the tool difficult to apply, and

scientists have questioned the validity of the probabilistic information within the UKCP09 projections for quantitative policy appraisal (Frigg *et al.*, 2013; Stainforth *et al.*, 2007).⁸

The NAP should promote the use of decision-making methods that deal with profound uncertainty. Where a decision is ‘high stakes’, a detailed, quantitative decision-making method may be justified. In such circumstances, maximisation of expected value and expected utility are the preferred tools if the set of possible climate outcomes can be quantified and their probabilities are known (e.g. from UKCP09). Given the reservations of many experts about the UKCP09 probabilistic data and the lack of data for some hazards (e.g. on wind speed), alternative non-probabilistic approaches could be used, including qualitative methods, such as scenario planning; or quantitative methods, such as maximin, which focus on the worst possible outcome. Other alternatives include robust decision-making and info-gap decision theory, which place emphasis on the robustness of a decision across a range of potential scenarios. Option theory also becomes relevant where learning is possible about the true state of the climate. Ranger *et al.* (2010) provide a summary of these different methods and their applicability under different circumstances (see Figure 3).



The Green Book contains guidance about some of these tools, but the NAP should ascertain to what extent they are actually used in decision-making. There may be issues with the guidance itself, people’s familiarity with it, the level of capacity and skills, and the way it is applied in practice. The NAP should recommend changes to current practice where necessary and support good decision-making through, for example, awareness-raising, training, and incentives for uptake.

5.3 Monitoring vulnerability

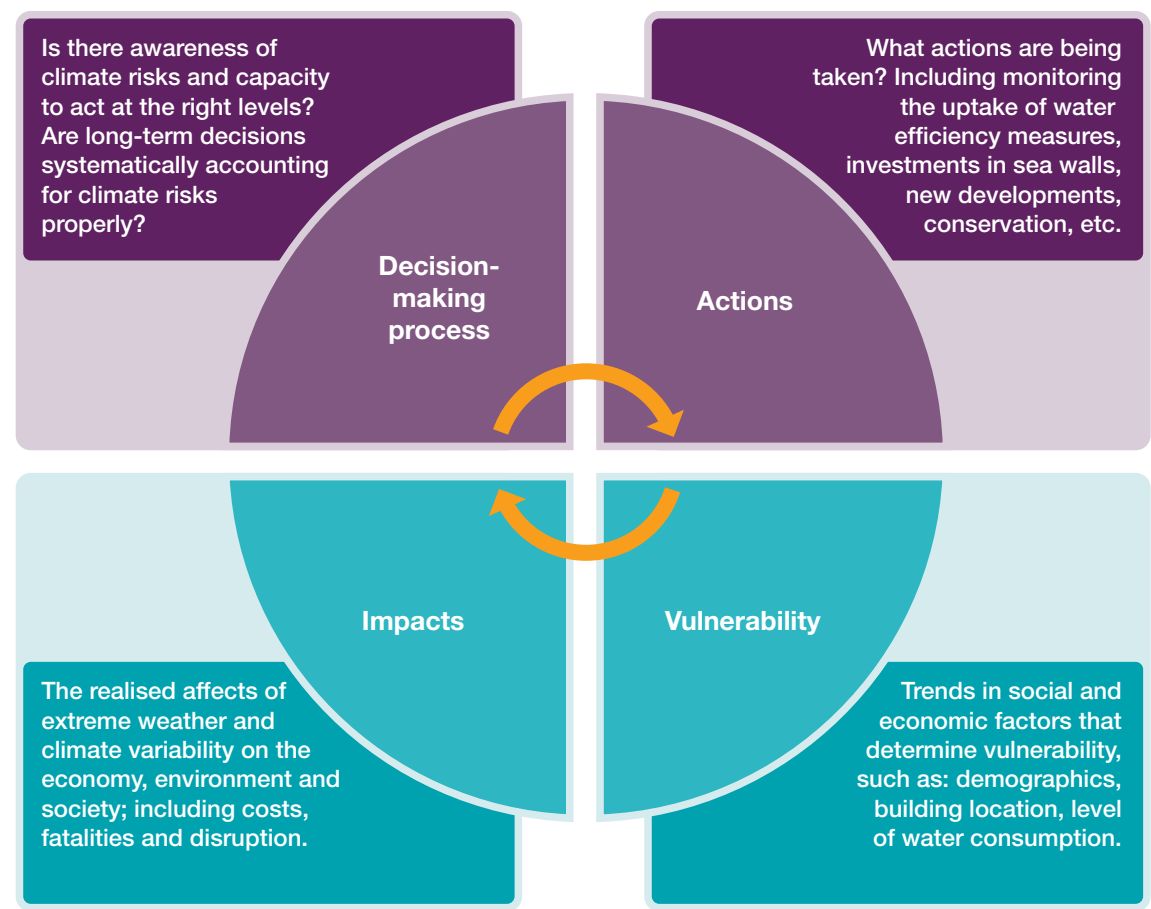
Preparedness for climate change and adaptation are both poorly monitored and poorly understood. Compared to other societal concerns, adaptation performance is monitored relatively lightly. There are many indicators to measure economic performance, including indicators of output, investment, consumer confidence, job creation, price levels and much else. There is detailed information on the health sector, education, the state of the natural environment and other areas of public concern. Adaptation and climate risk has received relatively little attention by comparison, both conceptually (e.g. frameworks to measure progress) and empirically (e.g. collection of data).

The NAP should initiate closer monitoring of adaptation performance (inside and outside of Government), outcomes and risks. There is, as yet, no coherent framework for monitoring preparedness for climate change in the UK. The Climate Change Risk Assessment (CCRA) offers the beginning of such a framework, but it is limited to climate risks and is too focused on the long term. A more comprehensive framework would more broadly track changes in vulnerability as a result of adaptation action, policy changes, socio-economic developments and planning and investment decisions. The Adaptation Sub-Committee of the Committee on Climate Change has proposed a promising framework, which is divided broadly into actions and outcomes (Figure 4). Outcomes include the realised impacts of climate, but also indicators of vulnerability. This includes monitoring the drivers of trends in vulnerability, such as land-use change and development, which allows the Adaptation Sub-Committee to identify potential threats before they become actual risks.

The NAP should initiate more systematic collection of vulnerability and adaptation data, either by the Adaptation Sub-Committee of the Committee on Climate Change or by central Government. Rolling out the monitoring framework devised by the Adaptation Sub-Committee to all aspects of vulnerability will require a substantial scaling up of data collection and analysis. It will necessitate the systematic collection of relevant data on exposure, vulnerability, policies and actions in each of the five NAP areas. This will be the case even if the framework draws on existing monitoring efforts, such as the National Risk Assessment (Cabinet Office, 2012), the National Ecosystem Assessment (UKNEA, 2011) and the Public Health Outcomes Framework for England (Department of Health, 2012). Initially, data may not have to be collected at high frequency, but the establishment of a broad and systematic evidence base is important. This data would facilitate improved risk management today – for example the National Audit Office (2011) found that England’s flood maps do not currently present consistent information – as well as future adaptation policy, and it would feed directly into subsequent CCRA and NAP cycles.

⁸ Climate projections are ‘deeply uncertain’ (Lempert *et al.*, 2003; Oreskes *et al.*, 2010). In technical terms, this means that the uncertainties are such that science is not yet able to provide a complete and unique picture of probabilities of different potential future climates (Stainforth *et al.*, 2007). Any probabilistic projections, like those traditionally used in risk management, would be model-dependent and subject to intrinsic, unquantifiable residual uncertainties.

Figure 4. A framework for monitoring progress on adaptation



Source: Based on ASC (2011).

6. Conclusions

This policy brief outlines the building blocks of a National Adaptation Programme (NAP) that is strategic, forward-looking and iterative. It is not possible to quantify in advance all future climate risks and ‘centrally plan’ an appropriate response. Instead, a good NAP should:

- *highlight areas of likely risk*, and overcome the analytical difficulties in assessing risks to make sure they do not prevent action;
- *establish the principles for good adaptation over the long term*, including a sensible approach to dealing with uncertainty; and
- *define an initial set of specific, time-sensitive priorities for Government action*, identify potential gaps in those priorities, and lay out a path to filling them through further research and consultation.

There are many adaptation actions that would be sensible to initiate now. An initial set of priorities for Government action can be derived from information on climate risks (Section 2), the available ‘low-regrets’ options (Section 3) and a rational approach to characterising the role of Government (Section 4). Based on this, we identify a preliminary set of 12 priorities for Government action. They are summarised in Table 3, with further detail provided in the scoping analysis in Appendix C [available online]. The list does is not intended to be comprehensive, but rather illustrates the case for early adaptation action and outlines a set of important near-term needs.

These actions are adaptation priorities because they are already cost-effective to implement and/or they affect (by avoiding lock-in) England’s vulnerability profile for a long time. The list includes many actions that aim to prevent vulnerability and risk from getting worse due to our decisions today. For example, ensuring that new long-lived infrastructure and buildings are suitable for the climate over their lifetimes (priorities VIII, X, XI) and do not negatively affect the resilience of the surrounding area (priority XII). Similarly, land management decisions should aim to enhance natural capital and protect ecosystem services, but also should retain flexibility for adaptation in the long-term (priority XII). Another priority must be to ensure there is appropriate capacity within Government, at appropriate levels, to deliver effective adaptation policies (priority III).

These actions have strong benefit-cost ratios and the fiscal implications of adaptation need not be substantial. Our analyses suggest that, in many cases, the priorities for adaptation involve the refinement of existing regulations and policies, rather than major new investment programmes. For example, the Government could reassess whether current water regulations (priority VIII) and the Common Agricultural Policy (priority V) promote long-term resilience to the climate. Acting early to implement programmes for existing public infrastructure (priority X) can minimise costs by enabling retrofits to be part of routine maintenance.

An initial set of priorities, as outlined here, should be refined through further work and, most importantly, consultation with stakeholders. The ‘top-down’ analyses presented in this policy brief are just the first step and should be followed by a process of ‘bottom-up’ consultation with stakeholders. The process presented in this brief also identifies many gaps and questions (Appendix C [available online]) that must be addressed as part of the on-going NAP cycle. Adaptation is a long-term process.

Table 3. Preliminary list of priority actions for Government as part of the NAP

	Priority for Government action	Suggested specific examples	Rationale and desired outcome
	Cross-cutting priorities		
I	Establish better monitoring systems: a system of linked, new and existing indicators, including lead indicators of vulnerability, is an important tool for informing both public and private sector decision-making.	<p>More detailed, integrated monitoring of key metrics of current and future vulnerability (ASC, 2011), e.g. water use, water quality, urban development, land use, agriculture and forestry, ecosystems, impact of extreme weather and the impacts of global climate shocks on the UK economy.</p> <p>Strengthening monitoring capacity at local level (e.g. SWIMS⁹), dissemination and data-sharing (e.g. a database accessible to key actors).</p>	<p>Early, robust benefits by:</p> <ul style="list-style-type: none"> reducing the impacts of extreme weather today; improving understanding of vulnerability and capacity in order to design more effective and efficient adaptation; enhancing the capacity to manage growing vulnerabilities before they impact the UK economy and population; monitoring and evaluating progress on adaptation; and raising public awareness of current risk and demonstrating the case for adaptation.
II	Provide user-relevant information, guidance, incentives and tools for private adaptation: the development and dissemination of material to inform adaptation decisions throughout the economy can remove barriers to private adaptation and innovation in information services for adaptation.	<ul style="list-style-type: none"> Developing and disseminating user-relevant climate and impacts data, and scenarios (inc. historical data, socioeconomic scenarios etc.). Providing a range of guidance and tools to inform effective private adaptation, for example, about how to deal with uncertainty in decision-making (e.g. the UK Climate Impacts Programme). Utilising the ‘Adaptation Reporting Power’, narrowly focused, to encourage key organisations to assess their own vulnerability, particularly in terms of critical thresholds, and trends that may increase long-term vulnerability (e.g. water demand, changing land-use). Overcoming private barriers to innovation in information services for adaptation (Table 2). 	<p>Early, robust benefits by:</p> <ul style="list-style-type: none"> raising public awareness of risks and demonstrating the case for adaptation; informing private action to enable more effective adaptation; and enabling private innovation in services, and therefore supporting growth and employment opportunities in adaptation services.

Table 3. Preliminary list of priority actions for Government as part of the NAP (continued)

	Priority for Government action	Suggested specific examples	Rationale and desired outcome
III	Build capacity to deliver effective and efficient adaptation across Government: this includes developing appropriate integrated decision-making frameworks (Section 5), local implementation capacity, and coordination.	<ul style="list-style-type: none"> Delivering appropriate institutional structures, training, guidance and targets that build capacity within central and local Government to take account of climate risks in decisions and deliver adaptation policy effectively (e.g. in land-use planning) at the local level. Ensuring regular review of strategies and integration of risk information within public sector decision-making frameworks. Drawing together cross-cutting networks to deliver adaptation and facilitating collaboration and knowledge-sharing. 	<p>Early, robust benefits by:</p> <ul style="list-style-type: none"> making adaptation more effective and cost-efficient.
IV	Ensure critical services and systems are able to cope with current climate variability and extremes of weather: being able to respond to extreme events, such as floods and droughts, and taking a more long-term view assists preparation for the additional challenges posed by climate change.	<ul style="list-style-type: none"> Implement and regularly review preparedness plans for critical services, such as health care (e.g. the NHS Heatwave Plan), flood management and emergency response. Support the inclusion of climate change related risks into voluntary standards for business continuity and risk management. Incorporate climate change into financial service regulation (e.g. insurance) as appropriate. Establishing (or adjusting) programmes and partnerships to respond to threats from climate to keystone natural systems. For example, building the resilience of the key ecosystems. 	<p>Early, robust benefits by:</p> <ul style="list-style-type: none"> reducing damage and disruption to the UK population, economy, and natural and man-made systems from extremes of weather.

⁹ http://www.kent.gov.uk/environment_and_planning/environment_and_climate_change/climate_change/what_were_doing/swims.aspx

Table 3. Preliminary list of priority actions for Government as part of the NAP (continued)

	Priority for Government action	Suggested specific examples	Rationale and desired outcome
	Agriculture, ecosystem services and biodiversity		
V	Refine current agricultural and related policy frameworks: ensure they enable (and do not hinder) near-term and long-term climate resilience and food security, and preserve or enhance the long-term resilience of land to climate.	<ul style="list-style-type: none">Ensuring that the Common Agricultural Policy (CAP) and Rural Development Programmes facilitate, and do not constrain, autonomous adaptation in the agricultural sector.Ensuring that the Common Agricultural Policy (CAP) and Rural Development Programmes (and other relevant existing policy) promote sustainable land management and the appropriate valuation of ecosystems and biodiversity.	<p>Early, robust benefits by:</p> <ul style="list-style-type: none">promoting near-term resilience of the agricultural sector and ecosystem services against climate shocks. <p>Avoiding lock-in of long-term vulnerability by:</p> <ul style="list-style-type: none">supporting the long-term food security of the UK;enhancing positive use and long-term resilience of ecosystem services for the benefit of the UK.
VI	Encourage research and development into new ‘adaptive’ technologies, markets and measures: this can be done through research and pilot (or seed) funding, innovative partnerships and/or the removal of barriers to private innovation.	<ul style="list-style-type: none">Partnerships and/or seed funding to support the development of more resistant crops.Support for pilots of innovative market instruments (e.g. payments for ecosystem services).Research and pilots related to the development and deployment of adaptation-related technologies, such as ecosystem-based (soft) adaptation measures and sustainable farming techniques.	<p>‘Low-regrets’ measures, with long lead times, that:</p> <ul style="list-style-type: none">promote long-term food security through technological innovation;enable the appropriate valuation of biodiversity and ecosystems services in private decision-making; andbuild UK leadership in technology for adaptation.

Table 3. Preliminary list of priority actions for Government as part of the NAP (continued)

	Priority for Government action	Suggested specific examples	Rationale and desired outcome
	Water supply		
VII	Encourage the uptake of water savings measures with clear benefits today: this may include increased end-user water efficiency and reduced leakage.	<ul style="list-style-type: none">Supporting the widespread roll-out of end-user water pricing based on use (i.e. water metering), with appropriate support to lower income groups (e.g. subsidies or tariffs) (ASC, 2012).Refining regulatory frameworks to ensure they provide appropriate incentives for water companies to reduce water consumption.Ensuring other existing policies with a water element, such as the Green Deal, encourage water efficiency (e.g. Waterwise and EST, 2012).Ensuring that the water requirements of new developments are considered during the planning policy process and appropriate interventions are made (e.g. installing water efficiency measures).Ensuring that the Sustainable Economic Level of Leakage (SELL), considered in the regulation of water company investments, takes into account the long-term sustainability of the water supply system, as well as current costs and benefits of action (ASC, 2012).	<p>Early, robust benefits by:</p> <ul style="list-style-type: none">reducing water consumption (with associated benefits for the environment and emissions abatement policy). <p>Avoiding the lock-in of long-term vulnerability by:</p> <ul style="list-style-type: none">curtailing upward trends in water demand and, hence, reducing the vulnerability of UK water systems to long-term climate change.
VIII	Enable water companies to make appropriate investments in supply-side measures: when subjected to careful economic analysis, investments in reservoirs, bulk water transfer, and waste-water reuse will make it easier to cope with long-term changes in climate.	<ul style="list-style-type: none">Encouraging water companies to consider their Water Resources Management Plans (WRMPs) over a longer duration (beyond the current 25 years), using a standardised decision-making framework, which, for example, considers high-impact, low-probability scenarios to test the robustness of plans to long-term uncertainty (e.g. as part of the Adaptation Reporting Power).Based on the WRMPs, identify urgent (i.e. within the next 5-year price review period) and longer-term supply-side needs.	<p>Avoiding the lock-in of long-term vulnerability by:</p> <ul style="list-style-type: none">ensuring the risks of disruption to supplies are maintained at acceptable levels both in the near term and long term; andensuring a water system that is flexible and robust enough to cope with long-term uncertainty.

Table 3. Preliminary list of priority actions for Government as part of the NAP (continued)

	Priority for Government action	Suggested specific examples	Rationale and desired outcome
IX	Refine current water abstraction licensing: this will ensure the long-term sustainability of public water supplies and avoid negative impacts on ecosystem resilience against climate change.	<ul style="list-style-type: none">Review and reform the current abstraction policy regime to ensure that it reflects risks to future water supplies, reduces consumption where necessary and protects the long-term resilience of the natural environment against climate change.	Early, robust benefits by: <ul style="list-style-type: none">reducing the risk of unsustainable abstractions and associated risks to public water supplies and the natural environment.
Built environment and infrastructure			
X	Ensure new and existing public infrastructure and buildings are resilient against extreme weather and climate change: this may include, for example, schools, hospitals and flood defences.	<ul style="list-style-type: none">Developing prioritised, time-bounded retrofitting programmes for existing infrastructure and buildings to maintain risks below acceptable thresholds (including hospitals, schools, flood defences, roads, etc.).Operationalise guidance about making new public infrastructure and buildings robust against climate change (with regular monitoring and reviews).	Early, robust benefits by: <ul style="list-style-type: none">ensuring existing critical infrastructure is resilient against current weather extremes. Avoiding the lock-in of long-term vulnerability by: <ul style="list-style-type: none">ensuring all new investments are robust against long-term climate change (and therefore avoid unnecessary costs and risks later).
XI	Use policy tools to encourage the resilience and robustness of private infrastructure, buildings and land management: the priority focus may be on areas of national importance and with critical implications for the public (e.g. property developers, insurance, health care providers, water companies, energy operators, transport operators and telecommunications).	<ul style="list-style-type: none">Identify existing critical private infrastructure and buildings (and related services) that are vulnerable to long-term climate change and investigate policies/measures that can encourage appropriate mitigating measures, such as the 'Adaptation Reporting Power' or existing licensing and regulation regimes (e.g. utilities, insurance, care homes etc.).Promote greater robustness of new private infrastructure and buildings, through the planning policy system and public financing schemes (e.g. examples given in Her Majesty's Government, 2011).Exploring tools to encourage uptake of household resilience against flooding and overheating. For example, working with insurers to implement risk-based pricing to encourage adaptation.Implementing mechanisms that encourage investments in adaptation to be reflected in property prices (e.g. voluntary standards).	Early, robust benefits by: <ul style="list-style-type: none">ensuring existing critical private infrastructure and services are resilient against current weather extremes. Avoiding the lock-in of long-term vulnerability by: <ul style="list-style-type: none">ensuring all new investments in critical private infrastructure are robust against long-term climate change (and therefore avoid unnecessary costs and risks later).

Table 3. Preliminary list of priority actions for Government as part of the NAP (continued)

	Priority for Government action	Suggested specific examples	Rationale and desired outcome
XII	Ensure that major new developments, such as infrastructure, buildings and land management support (and do not hinder) long-term resilience: this includes the resilience of natural ecosystems, and can be achieved through both regulation and private markets.	<ul style="list-style-type: none">The planning system (and any public financing schemes) should identify where developments would impact wider resilience and how they could be better designed to enhance resilience (e.g. local water supplies, local flood risk, health and wellbeing, biodiversity and ecosystem services) and enforce appropriate mitigating measures.Creating the right incentives. For example, working with insurers to remove perverse incentives for hard surfacing in urban centres, which reduces urban drainage and increases urban heat island effects.¹⁰Enabling incentives aimed at building wider resilience and enhancing the natural capital of land to allow future flexibility, such as markets for payments for ecosystem services (including, for example, incorporating water services into water pricing).Promoting the uptake of soft (ecosystem-based) adaptation where effective, by providing guidance and supporting pilots.	Avoiding the lock-in of long-term vulnerability beyond the infrastructure itself.

10 For example, currently, some homeowners in urban areas are encouraged pave over their gardens in order to park their vehicles off-road and so reduce their motor insurance premiums.

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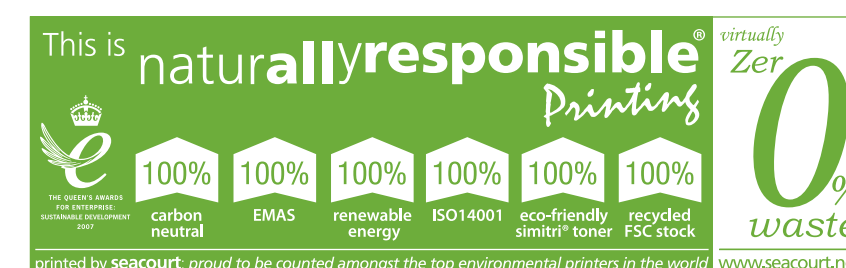
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