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Adapting to climate change in the UK Measuring progress

Adaptation Sub-Committee Progress Report 2011

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Foreword

Climate change remains the world's greatest environmental challenge. For the past 100 years or so, greenhouse gases have been accumulating in the atmosphere, primarily as a result of burning fossil fuels and changes in land use. Over the same period, global average temperatures have increased by around 0.8°C. The first decade of the twenty-first century was the warmest since instrumental records began. The world is committed to further climate change. Emissions of carbon dioxide from energy use have increased by 30% in the past ten years. Even if emissions peak within the next decade and then reduce year-on-year at 3-4% for the rest of the century, global temperatures still have around a 50:50 chance of rising above 2°C by 2100.

Adaptation is an important part of the UK's response to climate change, alongside reducing greenhouse gas emissions. The UK will not be immune from the consequences of climate change – both from the direct impacts in the UK and from the indirect impacts in other parts of the world. By preparing for these impacts, the UK can reduce the adverse effects of climate change and take advantage of any benefits that a warmer climate might bring.

The Adaptation Sub-Committee was established under the Climate Change Act to help the UK prepare for climate change – both by advising on the risks and opportunities that climate change will bring and by monitoring progress in preparing for these impacts. Progress is harder to monitor in adaptation than in mitigation, because there is no clear metric like carbon emissions and no clear target. In our first report, we established a framework to help assess progress on adaptation – the "adaptation ladder". Here, we develop the framework further to identify indicators of progress and apply these in three of our priority areas – land use planning, managing water resources, and designing and renovating buildings. We have focussed on indicators that measure progress towards adaptation outcomes, rather than relying on traditional approaches that measure the number of adaptation activities.

The results demonstrate how a sharper focus on the UK's current vulnerability to climate can inform national adaptation priorities. In some sectors, such as water, where planning for adaptation is reasonably well advanced, we are not always seeing this planning translate into an equivalent level of action. By taking steps to manage the UK's vulnerability to the climate, local communities, businesses and households can save money today and reduce the costs of climate change in the future. The Government can help by ensuring that its policies enable the uptake of simple cost-effective adaptation measures and incorporation of climate risks into long-term strategic decisions, such as investment in infrastructure and the location of new development.

Lord John Krebs Kt FRS

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Executive Summary

The Climate Change Act put in place a process for assessing and managing the risks and opportunities to the UK from climate change. The Act established the Adaptation Sub-Committee (ASC) of the Committee on Climate Change to provide independent and expert advice on how to assess climate risks and to report regularly on the UK's progress in preparing for the future climate.

This report provides our second assessment of the UK's preparedness, following our first review in September 2010. We start to develop a set of indicators against which to assess and track the UK's preparedness. We focus on three of the priority areas identified in our first report – land use planning, managing water resources, and designing and renovating buildings.

The headline messages are:

- The UK is coping with the current climate, but some sectors such as water supply are near their limits. Vulnerability to climate change is potentially increasing as a result of patterns of development in some areas and demographic trends such as the ageing population.
- There are low-regret actions that could be taken now to reduce vulnerability – for example measures to improve water efficiency, reduce damages to buildings from flooding, and protect buildings from overheating in summer. These measures would save householders money today. However, we found limited evidence of uptake of such measures, particularly in existing homes, reflecting barriers to action. This indicates the need for new policy approaches.
- Climate risks appear not to be fully incorporated into some major strategic decisions, such as land use planning and investment in water infrastructure. Embedding climate change more fully into decision-making could reduce future adaptation costs, such as building new flood defences and maintaining existing defences, and also ensure that climate risks are appropriately balanced against other risks and benefits.

Key messages by chapter are:

Current and future vulnerability to climate change [Chapters 2, 3 and 4]

- The UK is near the limits of coping with the current climate in some sectors and could be pushed over the edge by climate change. For example:
  - While only 8% of water resource zones in England are currently at risk of falling short of demand during a severe drought, this could increase to around 45% by 2035 without remedial action.
  - Security of water supply for consumers is good and improving, but there remains an environmental cost. Environment Agency statistics indicate that 11% of rivers and 35% of groundwater aquifers in England are "probably at risk" of environmental damage due to water abstraction.
- Patterns of development are potentially increasing the UK's vulnerability in some areas. We found that since 2001:
  - In almost all of the nine English local authorities studied, development in areas of flood risk had increased, and in four of them the rate of development was higher than across the locality as a whole.
  - Three of the four coastal authorities saw an increase in development in areas of eroding coastline, and in two of them the rate of development on unprotected coastline was higher than across the authority as a whole.
  - The area of hard surfacing increased in five of the six urban authorities studied, primarily at the expense of urban greenspace, which declined in all six. This is likely to exacerbate surface water flooding risk and the urban heat island effect.
  - These increases in vulnerability may have been offset at least to some degree by increased investment in flood defences and the greater use of adaptation measures in new homes built.
- Some factors increasing vulnerability of the UK are not controllable, such as changing demographics, most notably the ageing population. Old people are most at risk of heat stress and respiratory illness caused by photochemical smog.
- The impacts of climate change are borne disproportionately by some groups such as the elderly and in some locations such as low-lying coastal areas.

Low-regret opportunities for adaptation [Chapter 5]

- We identified a number of low-regret actions for buildings that could save individual householders money, as well as reducing the UK's vulnerability to climate change. These include measures to improve water efficiency (such as low-flow taps and showers), reduce the damages from flooding (such as airbrick covers and door-guards), and protect buildings from overheating in summer (such as increasing window shading).
- We found some uptake of measures in new housing, for example nearly all development in floodplains included at least one measure to manage flood risk, but much more limited evidence of uptake in the existing building stock. This is important given that the existing buildings will still dominate the total stock in future.
- In order to address barriers to uptake, new policy approaches may be needed. In some cases, incentives and improved information may be effective, for example water efficiency improvement requires the wider use of water meters together with consumer behaviour change. In other cases, for example for adapting new housing, tighter regulations may be required to bring all suppliers up to the best industry standards.

Long-term decision-making in land use planning and water resources [Chapters 3 and 4]

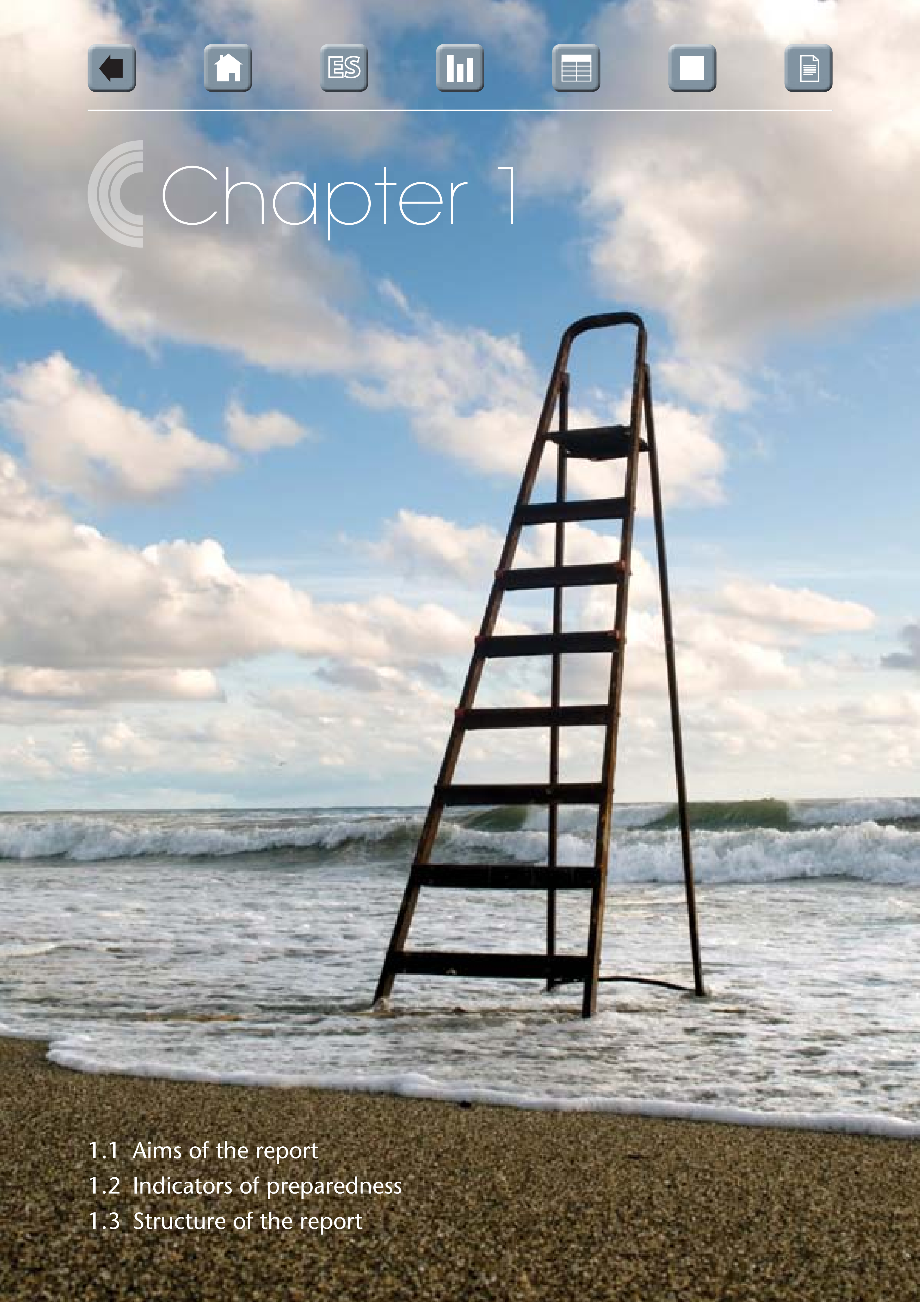
- In land use planning, we found limited evidence of strategic approaches to address climate risks in local authority development plans.
  - Local authorities appear to rely on property-level measures to offset the increased risk from locating new development in areas at risk from climate change, such as floodplains.
  - While we have demonstrated that property-level measures are beneficial, they will not deal with all risks by themselves and may lock in patterns of development that require an ongoing commitment to flood defence.
  - In order to manage vulnerability more effectively, local authorities should explicitly weigh up the potential long-term costs of climate impacts against social and economic benefits from development that are more immediately realised.
- Water companies have not yet made any specific investment in climate adaptation to tackle potential shortfalls in water supply. Delay of investment could lead to higher costs in the future or increased risks of water shortages. We identify scope to better manage the gap between supply and demand caused by climate change through: a greater level of ambition on water efficiency programmes; reforms to the abstraction regime to reflect water scarcity; and more robust approaches to factoring climate change uncertainty into long-term investment planning.

Climate Change Risk Assessment [Chapter 6]

- This report also includes our high-level advice on the principles for the Government's forthcoming Climate Change Risk Assessment (CCRA). We recommend that the CCRA should:
  - **Characterise uncertainties** – transparently report the assumptions made and openly explore the implications of uncertainty in both climate and socio-economic scenarios.
  - **Provide transparent comparison of risks** – ensure that the full range of economic, social and environmental risks and opportunities are assessed and compared, including those that are less easily quantified (particularly environmental risks).
  - **Cross-check results with current vulnerability** – an assessment of current vulnerability is a good starting point for assessing future climate impacts, because it draws on what is already known, establishes a baseline against which changes in risk and vulnerability can be tracked over time, and helps to make the case for prompt action to reduce current risks.

Future work of the ASC [Chapter 6]

- **We will continue to develop and implement our indicator framework for measuring progress on preparing for climate change in the UK:**
  - **Measure progress** – building on the work in this report, we will develop a more comprehensive set of indicators across the priority areas for adaptation, including those not covered so far (emergency planning, managing natural resources, and other infrastructure sectors).
  - **Input into development of the Government's economic analysis of adaptation and National Adaptation Programme** – we will work closely with Defra over the next year to advise on the identification of adaptation measures across key sectors to inform the National Adaptation Programme.
  - **Review lessons for the next Climate Change Risk Assessment (CCRA)** – to help in scoping the second CCRA, we will undertake an assessment of the first CCRA in 2012-13.



Chapter 1

Chapter 1
Introduction: developing indicators of preparedness

Chapter summary

In this report, we start to develop a set of indicators against which progress on adaptation can be assessed based on three questions:

1. Is the UK becoming more or less vulnerable to risks from current and future climate?
2. Are we seeing sufficient uptake of low-regret adaptation actions?
3. Are long-term decisions systematically accounting for climate risks?

We apply the indicator framework to three of our priority areas: land use planning, managing water resources, and designing and renovating residential buildings.

1.1 Aims of the report

This is the Adaptation Sub-Committee's second report, following from our first assessment of the UK's preparedness for climate change in September 2010.[1] It has three key objectives:

1. To develop the framework for assessing preparedness introduced in our first report.
2. To use the framework to take a more quantitative approach to assessing progress in the UK's preparedness for climate change.
3. To deliver our statutory advice to Government on the development of the UK's first Climate Change Risk Assessment.

Our first report introduced the preparedness ladder. This characterised adaptation in terms of outcomes, driven by actions and decisions.

Using the ladder, we identified five adaptation priorities where there is scope for low-regret actions or where decisions today have significant long-term, systemic consequences for future vulnerability:

- land use planning;
- designing and renovating buildings;
- providing national infrastructure;
- managing natural resources; and
- emergency planning.

1 In this report "the UK" covers UK-wide issues for reserved matters and England only issues for those matters that are devolved. The ASC is currently preparing reports for both the Scottish Government and Welsh Assembly Government, which will be published later in the year.

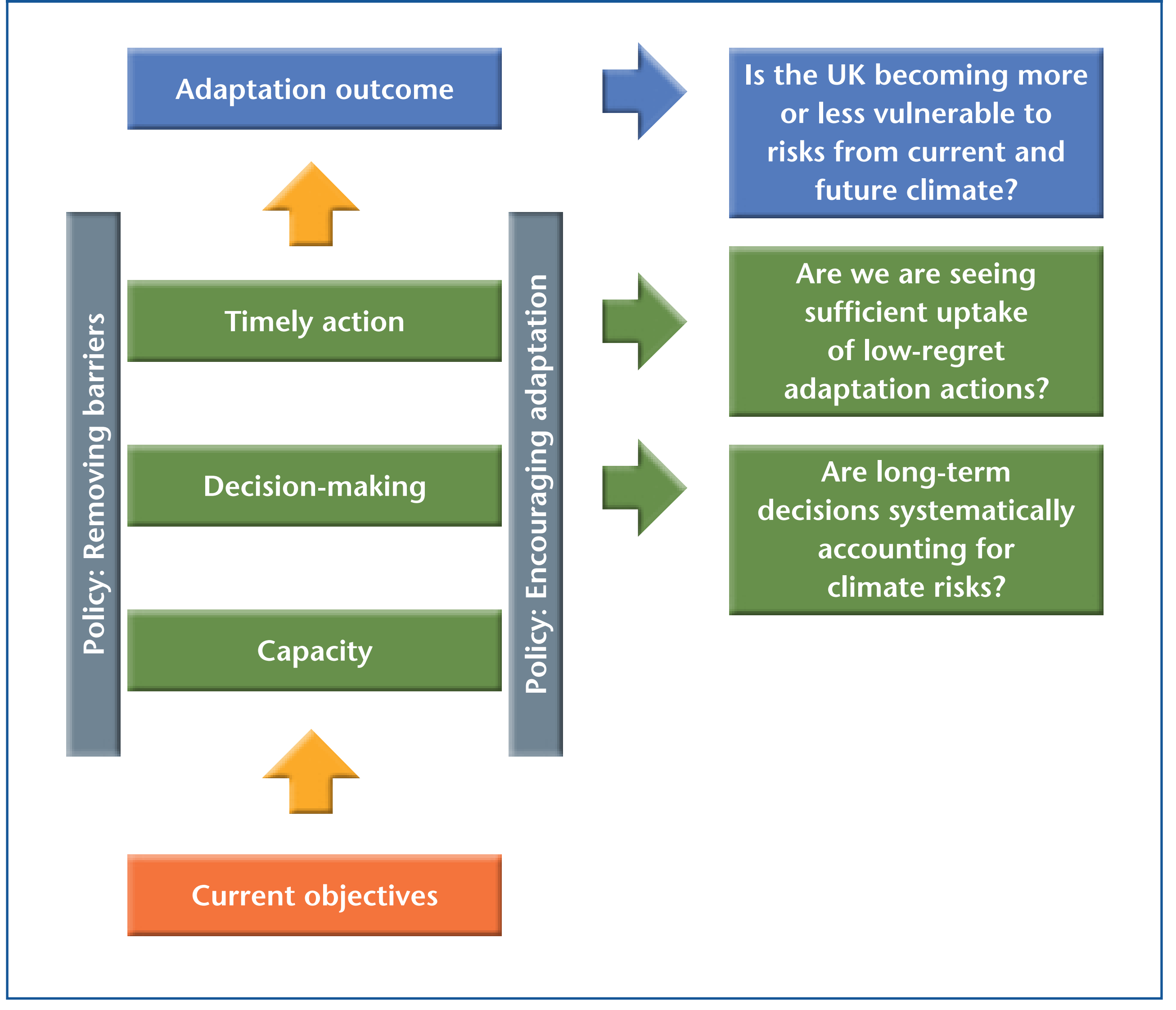


Figure 1.1: Using the ASC's adaptation ladder to assess preparedness

Our first report also highlighted that given the inherent uncertainty associated with predicting the future climate, particularly at a local scale, a sensible starting point for assessing preparedness is understanding vulnerability to the present-day climate.

1.2 Indicators of preparedness

In this report, we develop the ladder into a set of indicators against which progress on adaptation can be assessed, focussing on the priority areas of land use planning (Chapter 3), managing water resources (Chapter 4) and the design and renovation of residential buildings (Chapter 5).

In doing this, we address three questions based on the components of the ladder (Figure 1.1). Box 1.1 describes the approach we have taken in more detail.

Outcomes – is the UK becoming more or less vulnerable to risks from current and future climate?

We have identified two types of outcome-based indicators:

- **Impacts** – the actual (realised) damages from the major effects of climate on the UK economy, society and environment. We can measure the realised impacts of extreme weather, for example deaths brought forward by heatwaves. The problem with this type of indicator is that without a long series of observations, it may be difficult to distinguish year to year variability from long-term trends.
- **Components of vulnerability** – to address these difficulties, a sensible proxy for assessing adaptation outcomes is to understand if the UK's underlying vulnerability to climate risks is increasing or decreasing. Vulnerability is determined by a range of social and economic factors (for example age, health, deprivation, building location and form) which affect exposure to a climate hazard, sensitivity and capacity to respond.[2] Some of this vulnerability may not be readily adapted to, such as the number of elderly people (we term this 'contextual'). But some vulnerability can be addressed, such as the rate of development in areas prone to flooding (we term this 'controllable'). Indicators to track trends in vulnerability provide a baseline against which adaptation outcomes can be measured.

Actions – are we seeing sufficient uptake of low-regret adaptation actions?

We have started to identify indicators of adaptation action. There are two broad categories of action that need to be considered:

- low-regret actions that deliver benefits whatever future climate unfolds; and
- actions that require a more sophisticated decision-making process to determine their suitability and cost-effectiveness.

The minimum we would expect from a society that is adapting well is that low-regret adaptation options are being implemented now. We therefore monitor the uptake of low-regret actions across sectors using economic analysis to identify indicators.

Decision-making – are long-term decisions systematically accounting for climate risks?

Low-regret options are not always available for more complex and long-term decisions that involve trade-offs, either in time or against other objectives. Therefore, in order to assess preparedness, we need to complement our monitoring of outcomes (changes in impacts and components of vulnerability) and low-regret actions with an audit of decision-making.

2 The components of vulnerability we aim to measure are based on the framework developed by the Intergovernmental Panel on Climate Change (2007). More details are in the Glossary.

We have looked at how climate risks are being embedded into decision-making processes that have long-term consequences, locking the UK into particular development pathways. Our focus in this report is on land use planning (Chapter 3) and investment in water infrastructure (Chapter 4).

1.3 Structure of the report

Chapter 2 sets out our assessment of how well the UK copes with today's climate and how the UK's underlying vulnerability to climate is changing. This is an important starting point for assessing preparedness. We find that although the UK generally copes well with the existing climate there are a number of trends that could make the UK more vulnerable in the future.

Chapter 3 looks at the priority area of land use planning, where development decisions made by local authorities today can have a significant effect on climate vulnerability over the long run. It shows how some recent development patterns have potentially increased vulnerability to climate risks, although this is being offset at least to a degree by some adaptation action, for example investment in flood defences and property-level measures to reduce damages in new development. We find limited evidence that strategic planning decisions take account of long-term climate risks.

Chapter 4 assesses the preparedness of the water resource sector for current and future climate, focussing on the provision of public water supply. We show that although water supply is resilient to current climate, many aspects are only just coping and the resilience comes at a continued environmental cost. We find that water companies have made no specific allowance for climate change in their investment plans to secure future supplies.

Chapter 5 sets out our analysis of the preparedness of residential buildings. It identifies low-regret adaptation measures that can have immediate benefits by improving water efficiency, reducing discomfort from over heating, and reducing damages from flooding. We find limited evidence of the uptake of these measures, particularly in the existing housing stock, suggesting that there are barriers to uptake.

Chapter 6 summarises key conclusions, and sets out our high-level recommendations on the Government's Climate Change Risk Assessment. It looks ahead to the development of the National Adaptation Programme. It also sets out the next steps for the Adaptation Sub-Committee in developing an indicator framework against which preparedness can be assessed.

Box 1.1: ASC's approach to the development of outcome-based indicators for assessing progress in adaptation

Assessing preparedness is challenging, because it is difficult to determine in advance what good adaptation looks like:

- **adaptation is context-specific** – effective adaptation depends on who is adapting, where they are, their attitude to risk, and how they weigh up other factors in their decisions. The costs and benefits of options vary by location and decision-maker, unlike carbon emissions that have the same cost regardless of where they are emitted (reflected in the carbon price);
- **adaptation has no prescribed target** – there is no single metric, like tonnes of carbon emitted, against which to assess decisions; and
- **uncertainty** – about the scale, timing and spatial nature of how the climate might change puts greater weight on flexibility and keeping options open. The benefits of flexibility are harder to evaluate against other, less flexible options that might provide more certain, short-term benefits.

Due to these challenges, the approach taken in the UK and internationally to assessing progress in adaptation has up to now largely focussed on process-based assessments of capacity and awareness-raising.[3] These efforts are important and need to continue. However, a more comprehensive assessment should also evaluate adaptation based on empirical outcomes, namely understanding how adaptation efforts are materially reducing the costs and damages from climate change, where it is cost-effective to do so, and harnessing any benefits.

We have used our preparedness framework (Figure 1.1) to develop an initial set of indicators that we can use to track trends in realised impacts, components of vulnerability and the uptake of adaptation actions.[4] To do this, we broadly assessed the most significant consequences of current climate variability across our priority areas. We assessed the key drivers of vulnerability to these consequences and any relevant adaptation actions. We also identified available indicators and datasets we can use to track trends.

This is one of the first times that an evaluation framework for adaptation has put the empirical assessment of vulnerability at its heart.[5] In doing so, we build on existing indicator frameworks used previously in the field of environmental sustainability.[6]

Establishing a coherent and credible indicator set is an iterative process. A number of important limitations remain that need to be overcome. For example, we have found that the evidence to prioritise the most significant climate consequences is limited. The Climate Change Risk Assessment (CCRA) should help here. We will review our indicator set once the CCRA has been published.

Tracking trends in vulnerability alone will not provide a full picture of the UK's preparedness. We have therefore supplemented our assessment framework with: (i) economic analysis of the uptake of low-regret adaptation actions and (ii) an in-depth look at whether climate risks are being embedded into long-term decisions taken today.

3 As highlighted by Tompkins (2009) who attempted to develop a systematic categorisation of observed adaptation in the UK and found that most examples were related to capacity-building. A previous study by West and Gawith (2005) found similar results. A number of studies that have reviewed and compared efforts on adaptation in developed countries have generally been process-based. For example, Preston (2009) reviewed adaptation plans in the UK, Australia and USA against a suite of planning processes. Massey (2008) assessed adaptation in 29 European countries based on comparing and contrasting adaptation policy activities.

4 AEA Technology (2011) commissioned by Adaptation Sub-Committee.

5 Vulnerability assessments are more established in development literature. For example, the Climate Vulnerability Monitor assesses the impacts of climate change on 184 countries by combining factors on health, weather disasters, habitat loss and economic stress to produce climate vulnerability profiles (DARA 2010). In New York City, the Climate Change Adaptation Task Force is developing a set of climate change indicators that are a combination of outcome and process measures (Jacob 2010).

6 Our approach is a modified version of the Pressure-State-Response (PSR) framework. In the context of climate change, pressure can be interpreted as physical climate hazards (such as heat-waves, extreme weather events, sea level rise), state can refer to the impacts and drivers of vulnerability to those hazards, and response to adaptation actions.

Chapter 2

Chapter 2
How vulnerable is the UK to the climate?

Chapter summary

The starting point for assessing preparedness is to understand how well the UK copes with today's climate and how the UK's underlying vulnerability to climate is changing.

Our assessment is that the UK generally copes well with the current climate, although extreme weather events have measurable impacts.

However, this hides some important characteristics that will exacerbate the UK's vulnerability to climate change:

- There is evidence that some sectors, such as public water supply, are near their limits of coping with current conditions and in some cases at an environmental cost.
- Vulnerability to climate change is potentially increasing in some areas due to patterns of built development.
- Vulnerability is distributed unequally across the UK, being higher among certain groups such as the elderly and in certain areas such as low-lying coastal communities.
- The impacts of climate change may rise suddenly in some cases, as extreme events increase and certain thresholds are passed.

2.1 Introduction

In this chapter, we assess the UK's vulnerability to current climate, and the way this is likely to change in future. An assessment of the current position is a good starting point for assessing future impacts, because it draws on what is already known, and establishes a baseline against which changes in risk and vulnerability can be tracked over time.

As part of our assessment, we summarise new research on the relationship between climate and economic output. We also consider the extent to which current systems are resilient to climate risks, and trends in key variables that will drive future vulnerability.

2.2 Vulnerability to the current climate

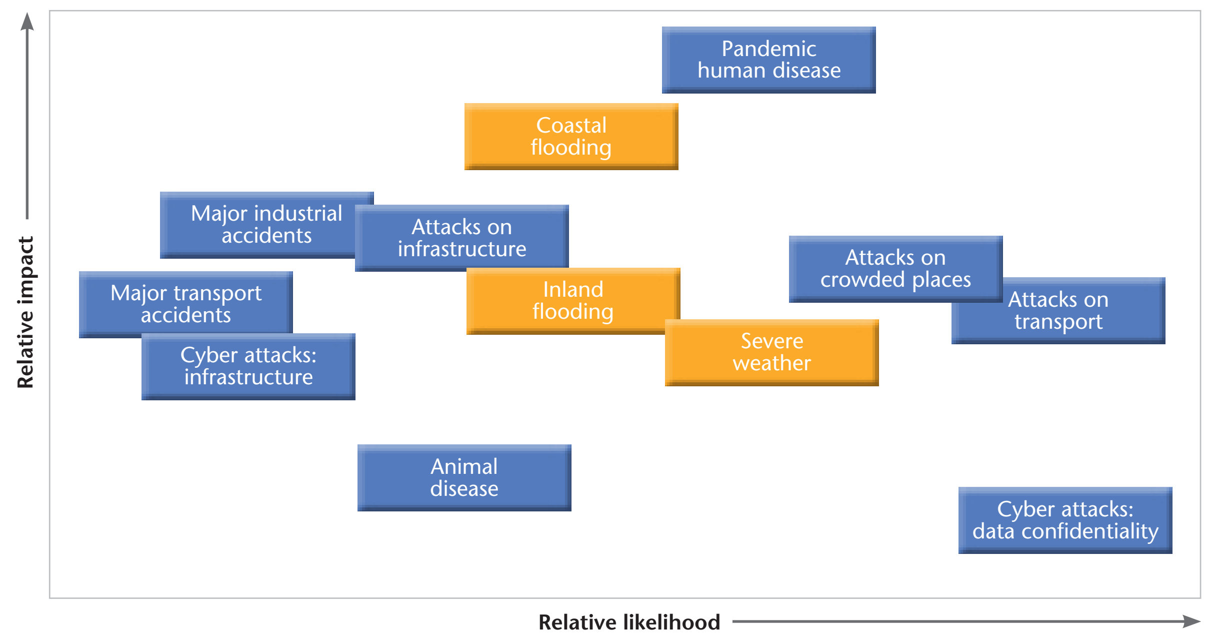
While the UK is generally well adapted to the current climate, extreme weather events can have a measurable effect. Three of the largest risks to the UK identified by the Government's National Risk Register are weather-related, namely coastal flooding, inland flooding and severe weather (Box 2.1).

Box 2.1: UK National Risk Register

The Government monitors the most significant emergencies that the UK and its citizens could face over the next five years through the National Risk Register (NRR).[1] The register assesses impacts against numbers of fatalities, illness or injury, the disruption to people's daily lives, and the effect on the overall economy.

The weather features strongly in the latest NRR assessment. Coastal flooding is identified as the second highest risk in terms of impact. Inland flooding and severe weather including heat waves, drought, cold weather, heavy snow and storms and gales are also considered significant (Figure 2.1). The climate and weather could also be a contributing factor in some of the other risks such as human and animal diseases.

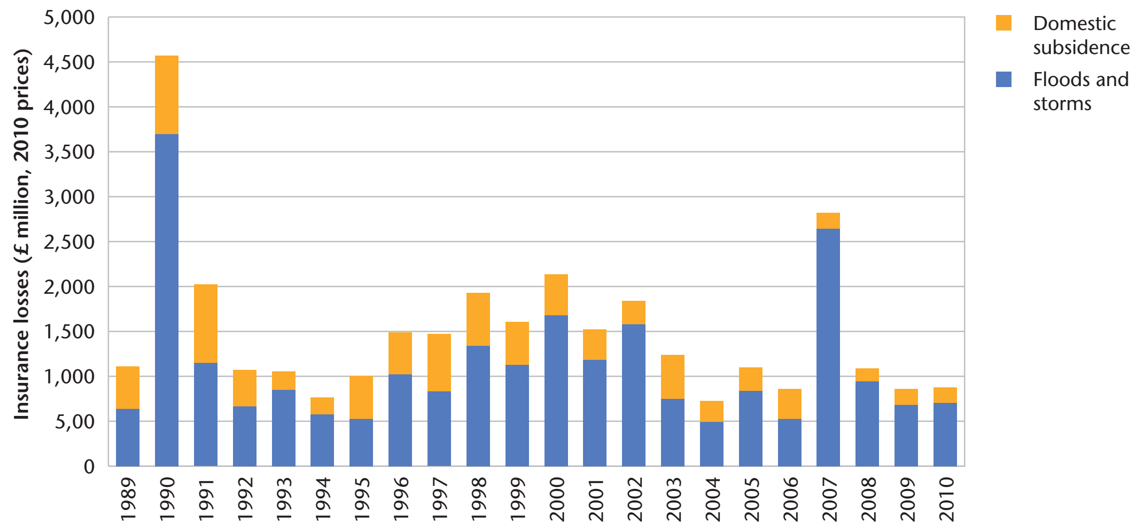
Figure 2.1: National risk register matrix showing major emergency risks to the UK



Source: Cabinet Office (2010).
Note: Boxes in orange show the risks that are weather-related.

1 Cabinet Office (2010).

Figure 2.2: UK insurance losses due to floods, storms and subsidence



Source: Association of British Insurers.

Annual insured losses from damage to property and business disruption from flooding, storms and subsidence have been around £1.5 billion on average over the past twenty years or 0.1% of GDP (Figure 2.2).[2] On top of this, extreme weather events can also disrupt business activities, essential services (energy, water and information and communication systems) and provision of supplies (transport), and increase the costs of emergency services.

One-off events can have a significant impact on economic output. Effects can be positive or negative depending on the type of climate event and the sector, for example:

- GDP fell by 0.5% in the last quarter of 2010 primarily as a result of weather-related disruption of transport and retail services from the heavy snow and ice.[3] Without this disruption, the Office for National Statistics estimate that output would have been broadly flat.
- The hot summer in 1995 resulted in gains for the tourism industry of around £240 million, but losses of £385 million for the clothing and footwear industry.[4]

2 Data from Association of British Insurers http://www.abi.org.uk [accessed June 2011]. Insurance penetration for UK household insurance is high: 90% of owner-occupied houses have buildings insurance but we do not have data for rented properties. 92% of owner-occupied houses have contents insurance, but for rented properties the figure is much lower, bringing the average down to 78%.
3 Office for National Statistics (2011b).
4 Subak et al. (2000).

In order to build on this evidence, we undertook a study to examine the historical impact of a range of extreme weather events on the performance of individual UK manufacturing businesses. We found a negative relationship between summer heatwaves and labour productivity in the sector.[5] The chemicals industry was the most strongly affected.

- Higher average temperatures over a sustained period of time can affect manufacturing output by increasing costs (such as operating and supply chain costs), decreasing worker productivity (either from discomfort and/or increased leisure time) and reducing demand for some manufacturing goods.[6]
- Initial calculations suggest that a heatwave of the order experienced in 2003, for example, would translate into a loss of manufacturing output of around £400 – £500 million.

2.3 Factors driving the UK's vulnerability to climate

In part because of its temperate climate and developed economy, the UK is generally well adapted to variability in average climate, with only extreme weather events having measurable impacts. This broad assessment, however, hides some important characteristics that are likely to increase the UK's vulnerability to the impacts of climate change:

1. Some systems are near their coping limits. Some sectors, such as public water supply, are only just coping with current conditions and in some cases at an environmental cost (more details in Chapter 4). As the climate changes, they are unlikely to remain resilient without further action.

- There have been few instances of significant water supply disruptions to consumers in recent decades, except in the most severe droughts and disruptive floods. 8% of water resource zones in England are currently at risk of falling short of demand in a severe drought. Without any additional investment this could increase to around 45% of zones in 2035, with climate change contributing to the deficit in at least 80% of these cases.
- Environment Agency statistics indicate that 11% of rivers and 35% of groundwater aquifers are "probably at risk" of environmental damage. In other words, reliable water supply is achieved at an environmental cost.

5 Martin et al. (2011) commissioned by the Adaptation Sub-Committee.
6 Subak et al. (2000).

2. Vulnerability is increasing through a combination of demographic trends and patterns of economic development in some areas.

- The population of the UK is ageing. Over the last 25 years the percentage of the population aged 65 and over increased from 15% in 1984 to 17% in 2010, an increase of 1.7 million people.[7] Vulnerability to heat increases with age, which means more people will be at risk of suffering from heat-stress and respiratory illness caused by photo-chemical smog.[8]
- There is evidence that the pattern of development in some areas is potentially increasing vulnerability to current and future climate, particularly in relation to flood risk and heat stress. Chapter 3 reviews in more detail how land use planning decisions over the past ten years have affected vulnerability. Development in floodplains increased over the past ten years in almost all local authorities surveyed, and at a greater rate than in the locality as a whole in almost half of them. This increase in vulnerability has been offset at least to some degree by increased investment in flood defences as well as through the uptake of measures to reduce damages from flooding in individual properties.

3. Vulnerability varies across the UK. The impacts of extreme weather events and the climate are concentrated among certain groups and in certain areas, as they are in other countries.[9]

- Vulnerability varies from place to place due to geography and the physical characteristics of locations. Currently, the combination of its southerly location and the urban heat island effect means that temperatures in buildings in London are above the comfort threshold of 26°C for around 18 days each year (5% of the year), compared with only two days per year in the North East. In the 2003 heatwave, 47% of all deaths in central London were attributable to heat during the period of peak temperatures.[10]
- Vulnerability is also determined by the characteristics of local populations, including age structure, income levels, education, health and mobility. A recent study by the Joseph Rowntree Foundation has found that these socio-economic characteristics can have a significant effect on the inherent vulnerability of a local community to climate risks. For example, the study found that the North West and Yorkshire had a higher proportion of communities vulnerable to flood risk than the South East.[11]
- Sometimes the physical and socio-economic characteristics of communities can combine to exacerbate the vulnerability of certain groups. For example, coastal communities have higher proportions of older residents, lower employment levels and poorer transport links.[12]

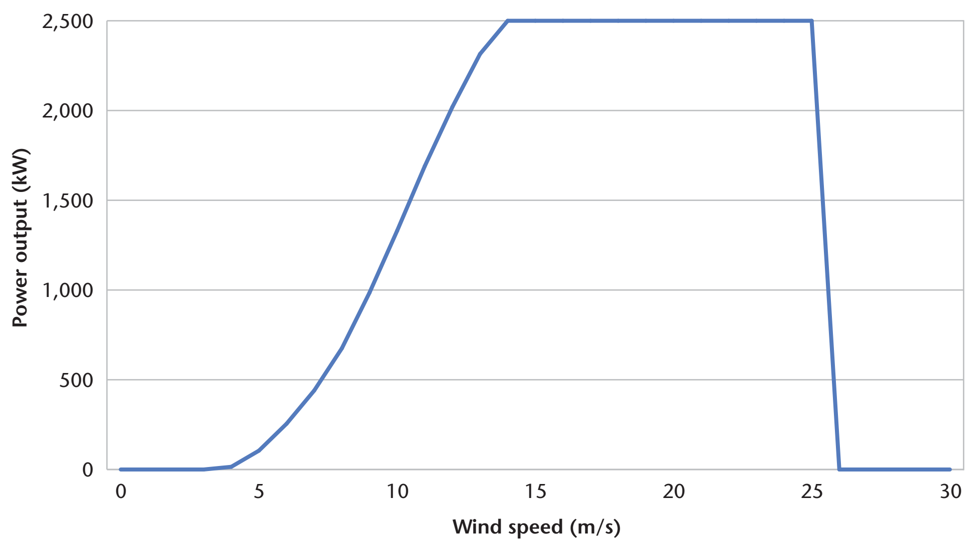
7 Office for National Statistics (2011a).
8 Vassallo et al. (1995).
9 Intergovernmental Panel on Climate Change (2007) concluded, with evidence form countries other than the UK, that the poor and the elderly are most at risk from climate change.
10 Government Today http://www.govtoday.co.uk/index.php/Low-Carbon/action-is-required-to-ensure-our-national-infrastructure-stands-the-test-of-time.html [accessed July 2011].
11 Lindley et al. (2011).
12 Zsamboky et al. (2011).

4. Impacts may increase suddenly. However, as the world warms, the UK is expected to experience more frequent and more intense extreme weather events, including heatwaves, droughts, and floods.[13] In some cases, the effect of these future changes in climate may be non-linear and sudden, as certain thresholds are passed, exacerbating the UK's existing climate vulnerabilities. For example:

- Water use by households increases sharply when the temperature rises above 15°C according to observations from one water company. Increasing from an average of around 160 litres of water per day to almost 200 litres per day at 20°C.[14]
- The effects of climate change on future wind speeds could have implications for wind power generation, an important element of the UK's decarbonisation strategy (Figure 2.3).[15] It is unclear how wind speeds will change in the future as a result of climate change. This needs to be kept under review.

Climate change will also bring some business opportunities to the UK, including for some types of agriculture, tourism, and through reduced winter heating demand.[16]

Figure 2.3: Wind turbine power output (kW) in relation to wind speed



Source: Environmental Change Institute (2005).
Note: All wind turbines have a specific wind speed range under which they operate. Wind turbines shut down during periods of high wind for safety reasons.

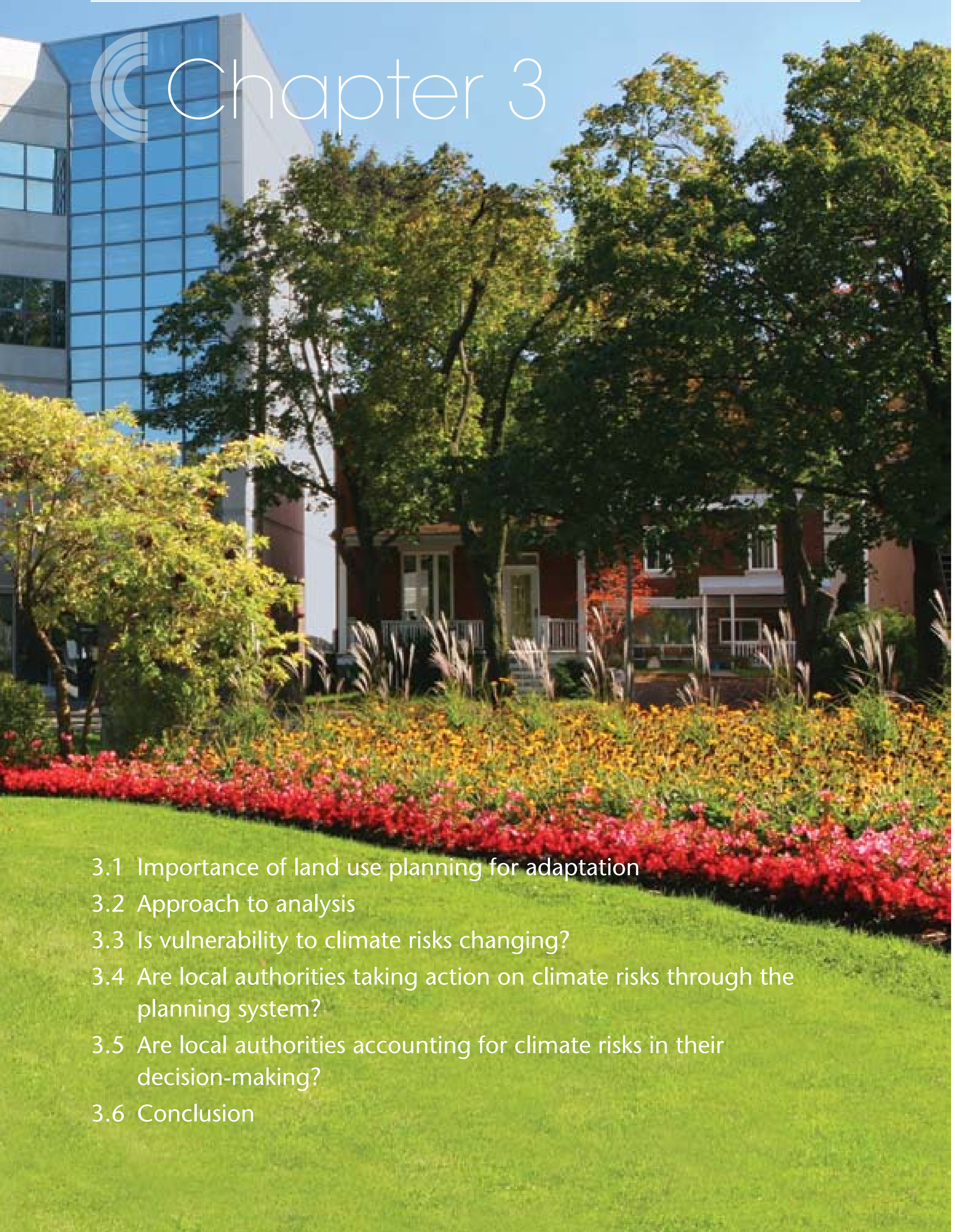
13 UK Climate Impacts Programme (2009).
14 UK Climate Change Risk Assessment, to be published in January 2012.
15 Environmental Change Institute (2005).
16 Ciscar et al. (2011).

The UK will not just be affected by the impacts of climate change and extreme weather events within its borders, but also by impacts in other parts of the world.[17] The world is becoming increasingly globalised, characterised by a complex web of trade, migration and political networks, through which the consequences of climate change are and will continue to be transmitted. Over time it may well be that international impacts have more significant consequences for the UK, providing both risks for UK society and the economy and opportunities for UK businesses.[18]

2.4 Conclusion

While the UK is generally well adapted to the current climate, it has some important characteristics that increase its vulnerability to the impacts of climate change in the future. By planning ahead and taking timely adaptation action, the UK can reduce the costs and damages from climate change and take advantage of some opportunities. This is the starting point for a more detailed sectoral analysis, where we look at the UK's preparedness in three key priority areas (land use planning, designing and renovating buildings, and water resources). We look at the underlying vulnerability of each priority area to present-day climate risks, and the actions and longer-term planning that institutions are taking to reduce this vulnerability.

17 Government Office for Science (2011).
18 Putt del Pino et al. (2011).



Chapter 3

Chapter 3
Land use planning

Chapter summary

Land use planning is a key determinant of vulnerability to climate change as decisions on the location and design of new development have implications for many years in the future and may be practically irreversible. Land use planning was identified as a priority in the ASC's first report. In our study of land use change over the last ten years in eleven local authorities, we found that:

- Development in areas of flood risk increased in eight of the nine local authorities at risk from river and coastal flooding and in four of them the rate of development was higher than across the locality as a whole.
- Three of the four coastal authorities saw an increase in development in areas of eroding coastline, and in two of them, the rate of development on unprotected coastline was higher than across the authority as a whole.
- The area of hard surfacing increased in five of the six urban authorities studied, primarily at the expense of urban greenspace, which declined in all six authorities. This is likely to exacerbate surface water flooding and the urban heat island effect.
- Development applications sampled included variable levels of adaptation at the property level, from nearly all applications (96%) in areas of river and coastal flood risk, to 55% of applications in areas of surface water flooding risk. In one London borough 70% of applications included measures to reduce water stress and 28% of applications had measures to deal with heat stress.

This indicates that land use planning decisions are potentially to increasing the vulnerability of some areas to climate impacts. Equally, adaptation measures such as investment in flood defences and use of property-level measures can at least in part offset this vulnerability. However, development decisions may be locking in a legacy of future costs from the maintenance of infrastructure (such as flood defences) and impacts from residual climate damages. Questions remain as to how these costs will be met in the future.

Local authorities face difficult trade-offs when planning the future of their localities, as the costs to the local economy of constraining development in areas at risk from climate impacts can be significant. In a small minority of authorities there are few, if any, alternative sites available for development.

- Although we found some evidence of long-term, strategic planning for adaptation, such as Shoreline Management Plans, it was unclear how influential these initiatives were on local development plan policies and actual development decisions.
- We found limited evidence that local authorities were factoring in long-term costs when making decisions on the strategic location of new development in their Local Plan.

Local authorities should take a strategic approach to managing vulnerability at the scale of communities as well as at the property level. This will require explicitly weighing up the long-term costs of climate impacts against social and economic benefits from development that are more immediately released.

3.1 Importance of land use planning for adaptation

The land use planning system is a priority area for early adaptation action because it is a primary mechanism for determining how vulnerability to climate change can be managed, particularly in towns and cities. Land use planning decisions can directly help to increase resilience to climate risks, but can also lock future generations into a development pathway that increases vulnerability or one that will be very costly to maintain or reverse.

From an adaptation perspective, the land use planning system is one of the most important functions delivered by local government. Local authorities are responsible for preparing strategic policies in the 'development plan',[1] on which decisions about individual planning applications are based. Policies set out what is expected of development in order for planning permission to be obtained. They identify specific locations or set criteria for types of locations that are suitable for particular land uses and also stipulate standards for the design of new development. Local authorities also make decisions on individual planning applications (called 'development management'), considering national and local planning policies to determine if a development proposal is acceptable.[2]

Guidance for local authorities, both on preparing local plan policies and on development management, is provided by central Government and includes reference to various climate risks. Planning Policy Statement 25 (revised 2010) seeks to *"ensure that flood risk is taken into account at all stages of the planning process to avoid inappropriate development in areas at risk of flooding, and to direct development away from areas at greatest risk".*[3] The supplement to Planning Policy Statement 1: Planning and Climate Change (2007) contains policy guidance in relation to climate change adaptation, seeking to *"shape sustainable communities that are resilient to and appropriate for the climate change now accepted as inevitable".* As well as policy guidance, the Planning Act 2008 introduced a statutory obligation for local development plans to incorporate climate change policies.

3.2 Approach to analysis

We have analysed actual development decisions and planning policies across a sample of local authorities.[4] Our main analysis has been based on eleven local authorities within five broad localities (north London, Tees Valley, Humberside, South Hampshire coast and the Severn Valley) representative of a range of climate risks facing communities.

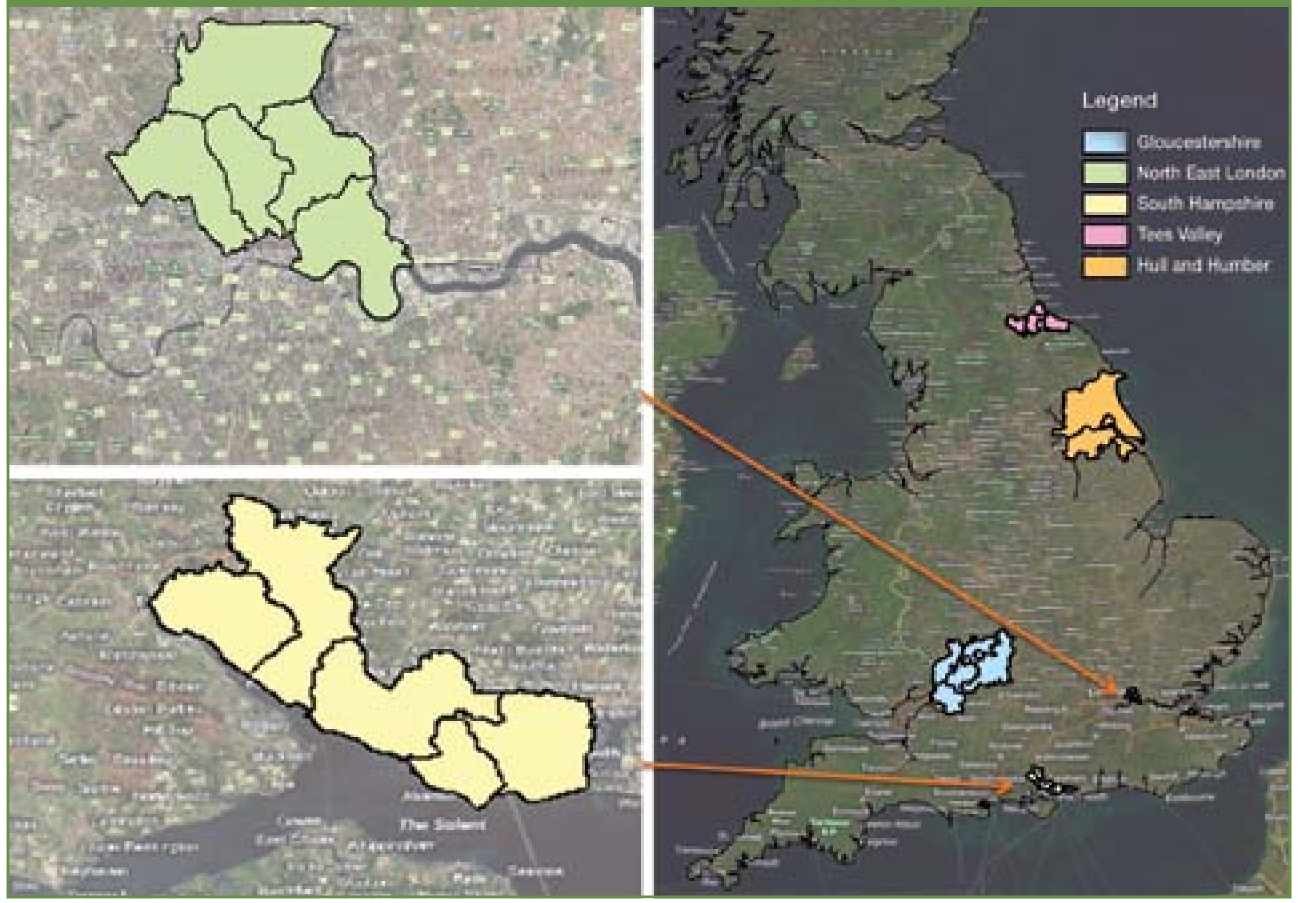
- Hull and East Riding have the highest number of properties at risk from flooding of all local authorities in England[5] and one of the most rapidly eroding coastlines.
- Hull, Tewskesbury, Gloucester and South Gloucestershire were all significantly affected by the 2007 flooding and the centre of Stockton-on-Tees faces significant flood risk.

1 Currently called the Local Development Framework (LDF).
2 Arup (2011) commissioned by the Adaptation Sub-Committee, gives an overview of the land use planning system in relation to adaptation to climate change.
3 PPS 25 places great emphasis on applying a sequential approach to development in order to minimise risk. This sequential approach directs the most vulnerable development to areas of lowest flood risk, gives priority to the use of sustainable drainage systems and ensures that all new development in flood risk areas are appropriately flood resilient and resistant.
4 Arup (2011).
5 Environment Agency (2009a).

- Densely urban London boroughs like Islington and, to a lesser degree, Haringey were disproportionately affected by the 2003 heatwave (see Chapter 2) and are likely to be at a high risk of surface water flooding.
- South Hampshire's coast faces a combination of river, coastal and surface water flood risk, high rates of coastal erosion and in some areas risk from heat stress.

Trends in development within these localities will be broadly representative of the types of decisions being made in areas facing similar risks. Figure 3.1 depicts the localities studied and Box 3.1 summarises the approach we have taken to the analysis.

Figure 3.1: Broad localities studied by ASC analysis



Box 3.1: Approach taken to analysis of land use planning and adaptation

1. Spatial analysis

The project quantitatively analysed development trends in eleven local authorities within the five localities by comparing Ordnance Survey Mastermap data for 2001 and 2011. Mastermap has four broad categories of land use:

- **Man-made:** Features that have been constructed, for example, areas of tarmac or concrete. The area of land covered by buildings is a subset of this category.
- **Multiple:** Features that are a mixture of land uses but are not depicted separately within the data, for example, the area around a dwelling may be a mixture of man-made and un-made surfaces.
- **Natural:** Features that are not man-made but possibly man-altered, for example, cliffs, areas of water and uncultivated/cultivated vegetation.
- **Unknown or Unclassified**: Features that could not be identified, including areas of land undergoing change at the time of mapping (for example incomplete development sites).

We mapped the change in area covered by buildings within areas at risk from climate-related impacts, such as flood risk zones and coastal erosion.[6] This analysis provides a quantitative baseline and a retrospective view of land use change over the past ten years (2001 and 2011).

Mastermap is used to inform the Department for Communities and Local Government's annual Land Use Change Statistics and is generally recognised as the leading Geographical Information System (GIS) dataset by professionals. There are, however, some shortcomings with using the Mastermap dataset to assess land use change between two time periods. For example, there can be errors with the re-categorisation of land use between 2001 and 2011 and in some localities we found anomalies in the change in total land area of an authority between the time periods which we had to correct for. We were able to identify change in land covered by buildings within the nine authorities who have areas at risk from flooding, changes in buildings in four coastal authorities and changes in man-made and natural areas within six urban authorities.

2. Sample of applications

GIS is very effective at tracking physical changes that are in some way visible (such as development in flood risk areas) but not at picking up detailed design interventions where many adaptation measures occur (such as underground flood storage tanks). The project has therefore assessed a representative sample of application documents, committee reports, decision reports and relevant assessments to find out if adaptation measures are being incorporated into major planning applications within the climate risk areas over the time period 2001 to 2011. A proportionate sample was taken for analysis, based on number of applications determined across development categories.

3. Case studies

We have identified case studies of good practice, where a development application has proactively considered climate risks and incorporated measures to mitigate them, or where approval was given with adaptation conditions and/or obligations added.

4. Local Development Framework preparation

We have qualitatively assessed how climate risks and adaptation measures were accounted for in the preparation of Local Development Framework (LDF) policies in three local authorities within the localities (Hackney, Stockton-on-Tees and North East Lincolnshire) who have all adopted (or are close to adopting) their LDFs. Our approach has been to assess if the local planning authorities have:

- systematically identified the priority climate risks and opportunities affecting their localities and the implications for development;
- appraised and included adaptation measures in relevant policies and considered whether they have actively engaged with neighbouring local authorities on strategic approaches to adaptation, for example at the catchment scale or along a stretch of coastline; and
- put in place processes to monitor and evaluate the effectiveness of planning policies and development management decisions in reducing vulnerability to climate risks.

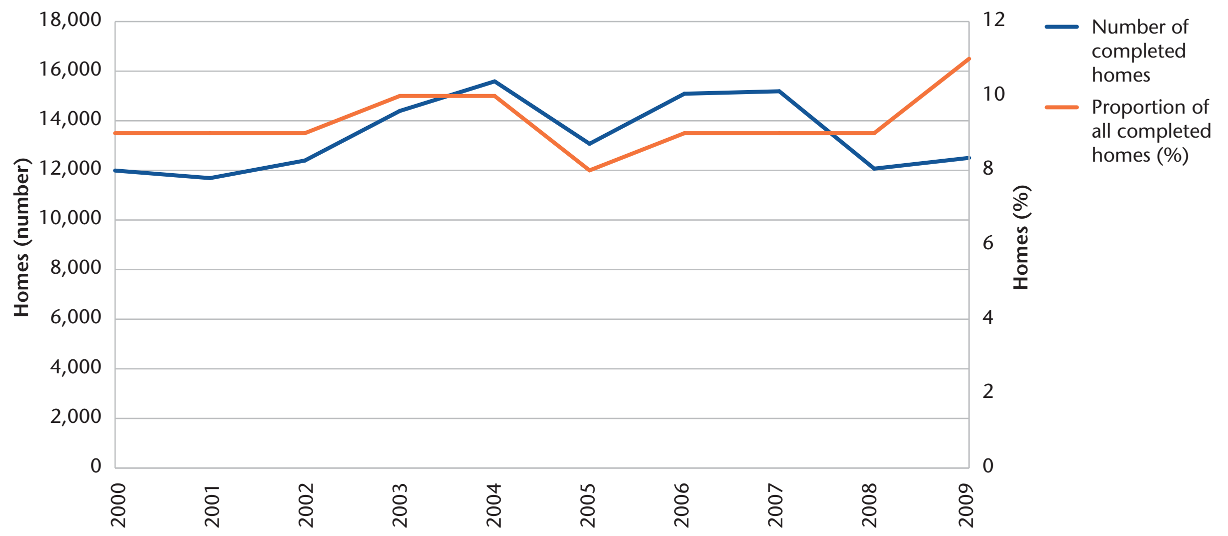
6 For coastal erosion, we assessed land use change within buffer zones identified from the relevant Shoreline Management Plans (Flamborough Head to Gibraltar Point and North Solent). Actual rates of erosion will vary significantly within the buffer zones, reflecting local geology and coastal processes.

3.3 Is vulnerability to climate risks changing?

Development in flood risk areas

The rate of new development in areas of high flood risk has remained fairly constant over the last 10 years. The cumulative impact of these new developments has potentially increased vulnerability to flood risk. In the last decade, between 12,000 – 16,000 new homes have been built every year in areas of high flood risk.[7] This has remained a fairly constant proportion (around 10%) of all new residential development (Figure 3.2). This compares with a stock of approximately 1.3 million homes currently located in areas of high flood risk (equivalent to 4.5% of the total housing stock). Much of the new development will have been on previously developed ('brownfield') land[8] already located in the flood risk areas.

Figure 3.2: Number of new homes and % of all new homes built within areas of high flood risk in England (2000-2009)

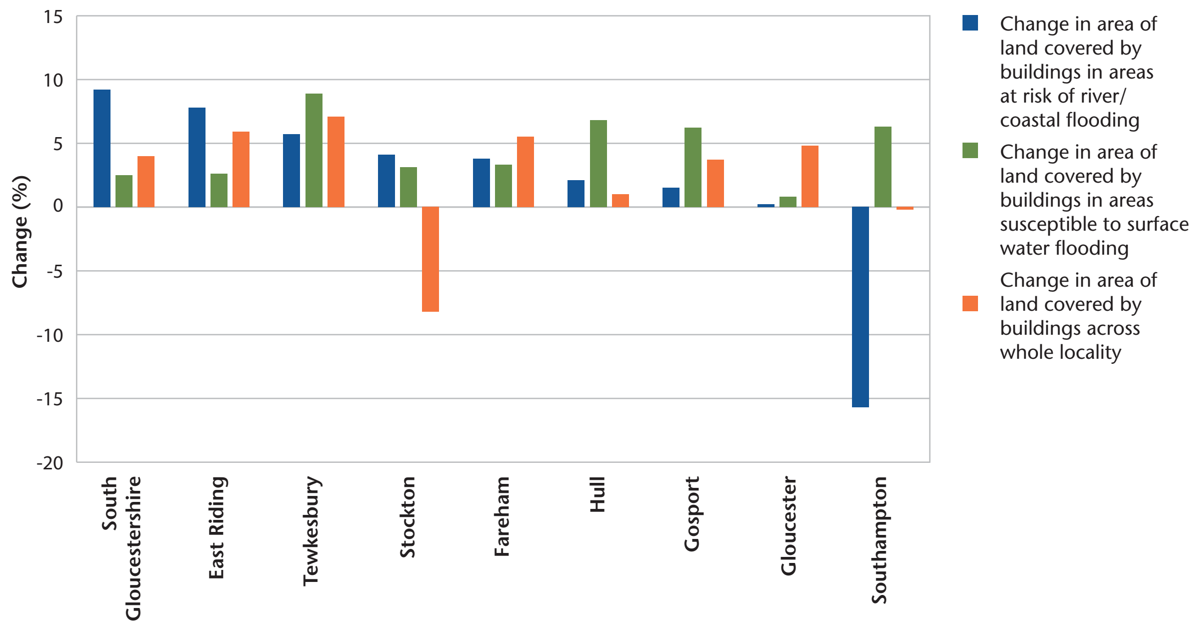


Source: Department for Communities and Local Government Land Use Change Statistics (2010b).
Note: High flood risk areas defined as Flood Risk Zone 3, which does not account for flood defences. Figures on percentage of new dwellings located in flood risk zone 3 from DCLG Land Use Change Statisitics. Figures on number of dwellings calculated by applying the annual proportion of new dwellings in high flood risk areas to the total number of completed dwellings obtained from DCLG Housing & Planning Statistics (2010a).

Eight of the nine local authorities studied have seen an increase in the amount of buildings within areas of river/coastal flood risk in the last ten years. In four authorities the rate of development has been higher in river/coastal flood risk areas than across the locality as a whole. Development in areas at risk from surface water flooding has also been higher in five of the authorities (Figure 3.3).

7 Flood risk zone 3. Defined as areas where flood risk is high, although does not account for the presence of existing flood defences.
8 Department for Communities and Local Government (2010b). 80% of all residential development in England was on previously developed land in 2009.

Figure 3.3: Change in area covered by buildings within river/coastal flood risk categories and in areas susceptible to surface water flooding, compared with change in area of buildings across the locality as a whole (2001-2011)

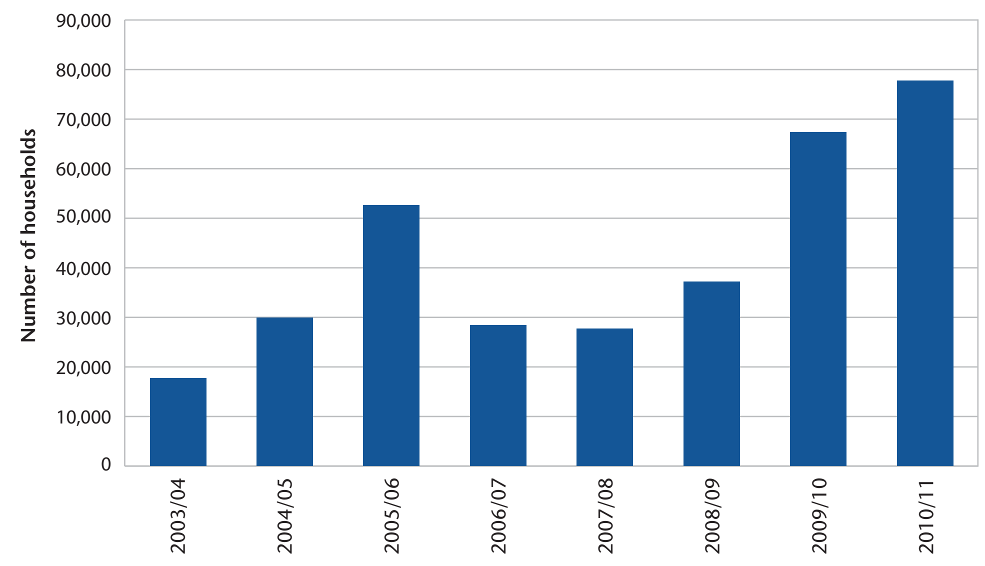


Source: Arup (2011) for Adaptation Sub-Committee.
Note: River/coastal flood risk categories are a combination of the three categories used by the Environment Agency's National Flood Risk Assessment (NaFRA): low, moderate and significant. Southampton experienced a slight decrease (0.2%) in buildings across the locality as a whole and a significant decrease (15.7%) within river/coastal flood risk areas. Further investigation of the Mastermap data identified three large development sites within the flood risk areas which were classified as 'Buildings' in 2001, but in 2011 are now classified as 'Unknown'. These are likely to be vacant or half constructed development sites. These three sites alone account for approximately 75% of the total decrease in built-up area. However, as they are likely to still be built-up, in reality there probably has not been any reduction in the amount of developed land within the area of flood risk. The decrease in built-up area across the whole of Stockton (8.2%) is due to a number of derelict industrial sites being reclassified as 'unknown' on Mastermap, probably reflecting de-industrialisation over the last decade. Note we did not assess change within Islington as it has no area of river/ coastal flood risk, or Haringey which has less than 5% of its area at river/coastal flood risk.

Increases in vulnerability from development in areas of flood risk can be offset to some degree through the provision of flood defences as well as by measures to make individual properties more resilient. The number of households benefiting from new or improved flood defences has increased from just under 18,000 in 2003 to nearly 340,000 in 2011 (Figure 3.4). The costs of the infrastructure required to deliver this protection is significant. Maintenance and building costs were in the region of £570 million in 2009/10[9] with replacement costs estimated to be £20 billion. As well as the financial costs of building and maintaining defences, there can also be an environmental cost through the disruption of natural processes, both in the floodplain and along the coastline, and damage to sensitive habitats.[10]

9 Environment Agency (2009b). Consists of Environment Agency construction programme (£270m) and maintenance programme (£161m) plus local authority revenue support grant (£87m) and local authority and internal drainage board construction programme (£52m).
10 Natural England (2008). Coastal squeeze (where intertidal habitats are trapped between fixed sea defences and rising sea levels) is the primary cause of unfavourable condition in coastal Sites of Special Scientific Interest (SSSI), contributing to the adverse reasons in 74% of the total area in unfavourable condition in 2008.

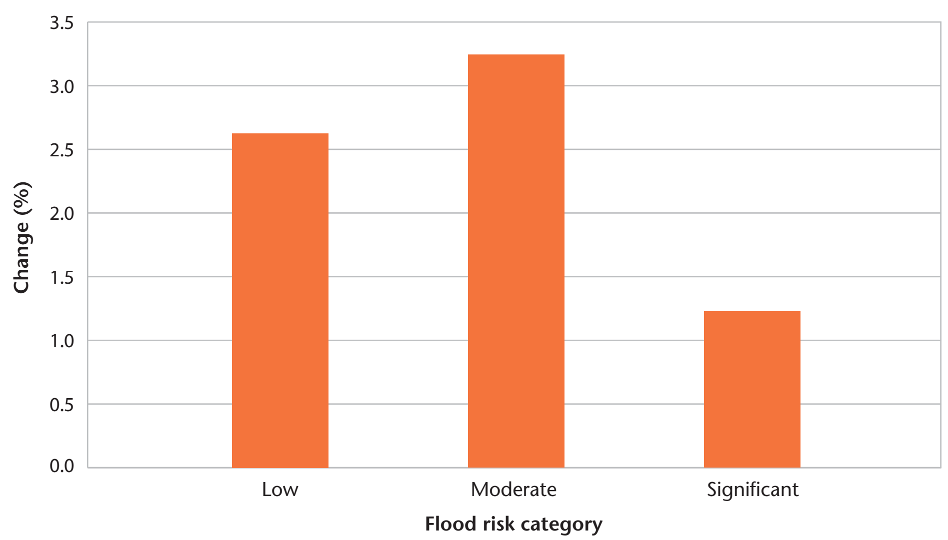
Figure 3.4: Number of households benefitting from flood defences since 2003/04 (England)



Source: Environment Agency (2011).

Even when accounting for flood defences, residual flood risk has increased across the nine authorities studied over the last ten years. The rate has been higher in areas of moderate risk, where there is between a 1 in 200 and 1 in 75 chance of flooding in any given year (Figure 3.5). This does not account for the effect that property-level resilience measures may have in reducing vulnerability (discussed in Section 3.4).

Figure 3.5: Change in area covered by buildings within low, moderate and significant flood risk categories across nine local authorities sampled (2001-2011)

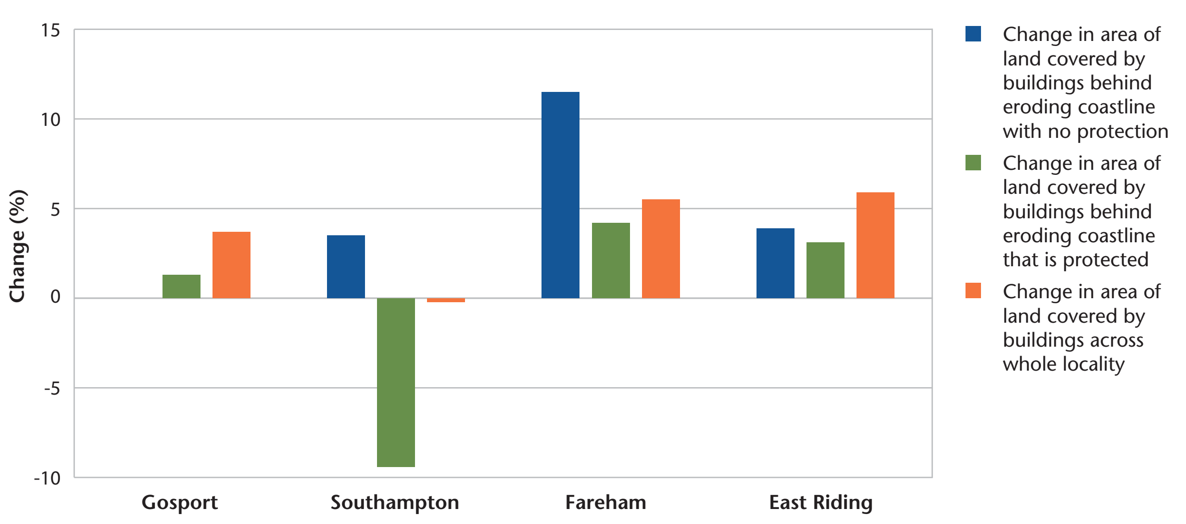


Source: Arup (2011) for Adaptation Sub-Committee.
Note: The flood risk categories are from the Environment Agency's National Flood Risk Assessment. These consider the chances of weather severe enough to cause a flood, and the likelihood this will overwhelm defence structures or lead to their failure. The three flood risk categories are defined as: low (less than 1 in 200 chance of flooding in any given year); moderate (1 in 200 to 1 in 75 chance) and significant (greater than 1 in 75 chance). This figure represents the aggregate percentage change in developed area across the nine authorities surveyed in each of the three flood risk categories. There were some significant variations between authorities. For example, Southampton saw a 21% decrease in land at significant flood risk (reflecting the changes noted in Figure 3.3), whereas East Riding saw a 12% increase.

Development in areas at risk from coastal erosion

In our analysis, three of the four coastal authorities saw an increase in development in areas of eroding coastline, and in two of them, the rate of development on unprotected coastline was higher than across the authority as a whole (Figure 3.6). Development in areas at risk of coastal erosion will potentially increase vulnerability, although the number of properties currently at risk from coastal erosion is relatively small.[11] Even where development is behind protected coastlines, the shore in front of a seawall will continue to erode with sea level rise, increasing the probability of sea-wall failure. When failure does occur, rapid erosion can take place. Development in these areas is therefore still likely to be locking in vulnerability.

Figure 3.6: Change in area covered by buildings behind eroding coastline (protected and non-protected) compared with change across the locality as a whole (2001-2011)



Source: Arup (2011) for Adaptation Sub-Committee.
Note: The decrease in built-up areas behind the protected coast in Southampton is likely to be for the same reason as noted in Figure 3.3, as the flood risk zones and coastal buffer zone are very similar in area. As such, there almost certainly has not been an actual reduction in built-up area at risk from coastal erosion.

A proportion of this development is likely to have been temporary[12] or at least not allowed within the immediate vicinity (30 m) of the coastline. We found evidence of local plan policies specifically limiting development proposals that would require additional coastal protection, for example Holderness District Local Plan (East Riding). Further research is needed to assess the type of development being approved on eroding coastlines.

11 Department of Environment, Food and Rural Affairs and Environment Agency (2011). It is estimated that approximately 200 properties are currently vulnerable but by 2030 this will be nearer to 2,000.
12 Temporary planning permission may be permitted, with a condition of consent being removal before the development is affected by erosion.

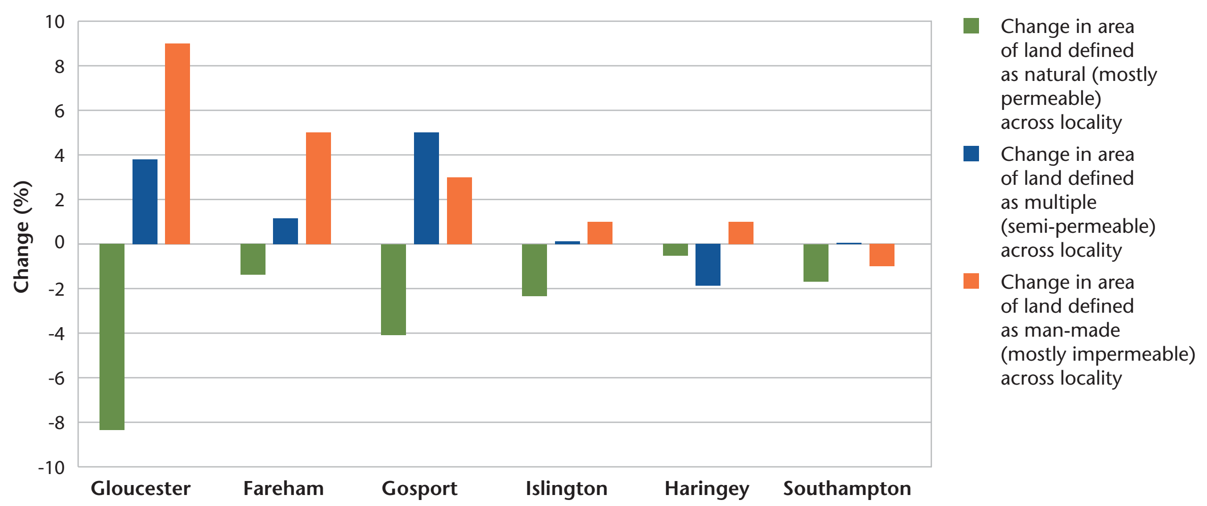
Change in hard surfacing in urban areas

A change in the area of hard surfacing in urban areas, such as tarmac and concrete paving, can exacerbate the risk of surface water flooding and increase the intensity of the urban heat island effect. Over recent decades, there has been a strong drive to concentrate development within existing built-up areas, in part to regenerate previously run-down urban areas as well as to reduce pressure on undeveloped ('greenfield') land. Development trends show that the planning system has been effective in delivering this policy.[13]

In our analysis, the area of hard surfacing increased in five of the six urban authorities studied. (Figure 3.7). This increase has primarily been at the expense of urban greenspace which has declined in area in all six authorities.

In one London authority the area of hard surfacing increased by 6% in the part of the borough at highest risk from heat stress. Recent research into land use change in London[14] shows similar trends, with an estimated 12% loss (equivalent to around 3,000 ha) in vegetated garden land due to an increase in the area of hard surfacing since 1999. Nationally, 20% of all greenfield development since 2001 has been within urban areas, primarily on recreation grounds and school playing fields.[15]

Figure 3.7: Change in area of natural, multiple and man-made surfaces in six urban local authorities (2001-2011)



Source: Arup (2011) for Adaptation Sub-Committee.
Note: The change in area to 'unknown' or 'unclassified' was not accounted for. Changes to these categories over time reflect a mix of actual changes to land cover and an improvement over time of the accuracy of OS data, which prevents meaningful conclusions to be drawn from these categories.

13 Government Office for Science (2010). The proportion of new dwellings on brownfield sites rose from 50% in 1991 to 80% by 2008 and the density of new dwellings has increased by 72% between 2001 and 2009. There has been relatively little development of greenfield land outside urban areas, particularly in recent years where the conversion of previously undeveloped land is now around one-third of the average rate during the period 1945-75. Development in the designated green belt has remained consistently at around 2% of all new dwellings per year over the last decade.
14 London Wildlife Trust (2011).
15 Government Office for Science (2010).

With good design, increasing the density of urban development can be delivered in ways that help address the risk of surface water flooding and urban heat island effects. Measures include the incorporation of greenspace, permeable paving and sustainable drainage systems. As the importance of some of these measures has only been widely recognised recently, the majority of the man-made surfaces seen in Figure 3.7 will have been impermeable.

3.4 Are local authorities taking action on climate risks through the planning system?

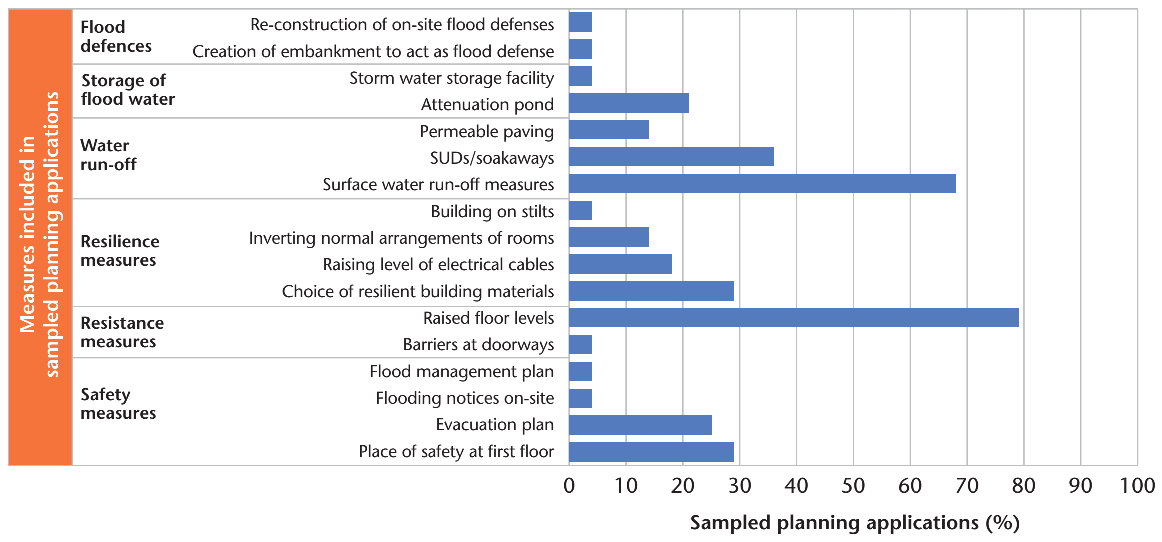
Awareness of climate risks in recent years has increased among local authority planners.

- We found that awareness was low when local authorities began preparing their Local Development Frameworks around 2005/2006. None of the authorities we analysed undertook strategic assessments of the vulnerability of their locality to the full range of current and future climate risks. River and coastal flooding were the most consistently identified climate risks, primarily through the strategic flood risk assessment process introduced through Planning Policy Statement 25. We found that while the strategic flood risk assessments included future climate scenarios, the evidence documents supporting the Core Strategy generally only used the current risk scenarios.
- Later drafts of all three Core Strategies contained stronger adaptation policies. These were generally introduced following consultation, where we saw evidence of proactive engagement on adaptation by statutory consultees (typically the Environment Agency, internal drainage boards and Natural England) and some non-governmental groups (such as the Royal Society for the Protection of Birds).

The recent emergence of adaptation in local planning policies is starting to result in development applications containing design features to reduce climate risk. Practically all (96%) of the applications we analysed included at least one measure to manage river and coastal flood risk (Figure 3.8)[16] either through developers putting forward measures in their planning application or through conditions attached to planning consents by local authorities.

We also found evidence of the Environment Agency directly advising both applicants and planning authorities on how development can affect flood risk and identifying design measures that can reduce the risk.

Figure 3.8: Proportion of sampled planning applications and consents in areas of river and coastal flood risk incorporating flood risk management measures

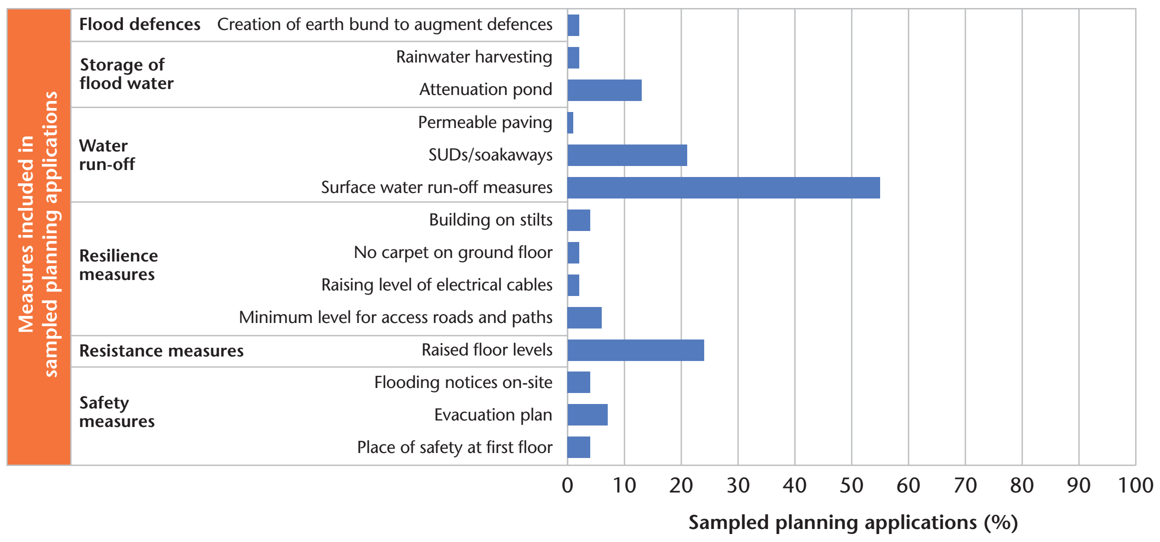


Source: Arup (2011) for Adaptation Sub-Committee.
Note: Sample of applications and consents for major development in areas at risk of river and coastal flooding in two local authorities (East Riding and Stockton). Note that the category 'surface water run-off measures' refers to conditions requiring applicants to provide details in their application of measures to limit surface water run-off to a specified level.

The uptake of measures to manage surface water flood risk was lower than for river and coastal flooding. We found that 55% of applications in areas at risk from surface water flooding included at least one adaptation measure (Figure 3.9). Only 21% of applications included sustainable drainage systems and 11% permeable paving.

16 Chapter 5 presents the cost-effectiveness of several of these individual measures.

Figure 3.9: Proportion of sampled planning applications and consents in areas of surface water flood risk referring to flood risk management measures

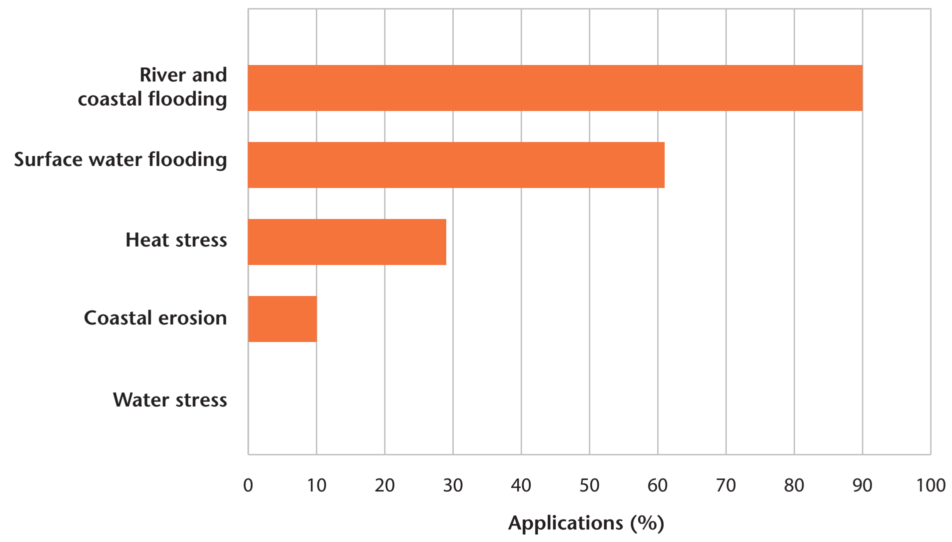


Source: Arup (2011) for Adaptation Sub-Committee.
Note: Sample of applications and consents for major development in areas at risk of surface water flooding in three local authorities (East Riding, Islington and Stockton). Note that the definition of 'surface water run-off measures' is the same as for Figure 3.8.

Based on our analysis of one London borough, we found relatively widespread take-up (70%) of some water-saving measures and lower uptake (28%) of measures to manage heat stress. The water-saving measures included low flow taps/showerheads and toilets as well as rainwater harvesting, often justified on energy efficiency grounds. The measures to manage heat stress predominantly included passive design to reduce internal heat gain, for example enhanced natural ventilation and awnings/ screens to protect rooms from the sun. A small number had selected specific building materials to reduce heat stress or included reflective surface measures (painting external walls in light colours).

We found variable awareness of how current risks may be exacerbated by climate change. The majority of applicants (90%) referred to how river and coastal flood risk is likely to change in the future. A substantial, but smaller, proportion of applications (61%) considered how surface water flood risk may be exacerbated in the future. In the London borough assessed, one third of applications noted how heat stress may increase with climate change. Awareness of how risks from coastal erosion and water stress may change in the future was even lower (Figure 3.10).

Figure 3.10: Proportion of applications sampled in climate risk areas with assessment documents explicitly referring to that risk in relation to climate change



Source: Arup (2011) for Adaptation Sub-Committee.
Note: Sample of applications and consents for major development across the three authorities surveyed (East Riding, Islington and Stockton). Note for heat and water stress only applications in Islington were sampled.

In summary, the results of the analysis from our representative sample of local authorities and using the indicators we have identified for land use planning (Table 3.1) are that:

- development in areas at risk from river and coastal flooding has continued over the last decade, potentially increasing vulnerability. This may be offset to some degree by investment in flood defences and property level adaptation measures. However, even when accounting for the presence of flood defences, residual flood risk across the areas studied has still increased;
- development is continuing to occur in areas at risk from coastal erosion, although some of this is likely to be temporary in nature; and
- the increase in hard surfacing is increasing vulnerability to surface water flood risk and heat stress in urban areas. There has been some uptake of property-level measures to reduce these risks, although at a lower level than for river and coastal flooding.

Table 3.1: Indicators for assessing preparedness in land use planning and broad indication of trend. The direction of the arrow depicts the trend in that indicator (increasing, decreasing or no apparent trend). The colour depicts the implications of that trend for vulnerability: red = increasing vulnerability, green = decreasing vulnerability, yellow = neither increasing nor decreasing.

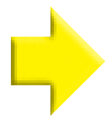
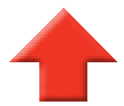
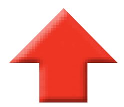
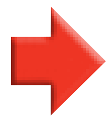
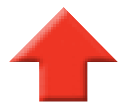
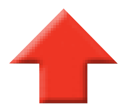
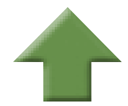
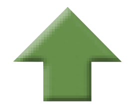
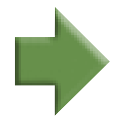
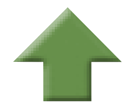
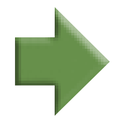
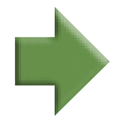
	Indicator	Dataset available	Trend
Damages from climate hazards			
Impact	Insurance claims for weather related causes (flooding, storms, subsidence)	Association of British Insurers	
Impact	Number of properties flooded	None identified	
Components of vulnerability	**Development in flood risk areas**		
	Number of buildings constructed in areas prone to river, coastal and surface water flood risk, not accounting for flood defences (2001 – 2011)	OS Mastermap – ASC sample Environment Agency – Fluvial & Coastal Flood Risk Zones and Areas Susceptible to Surface Water Flood Risk	
	Number of buildings at low, moderate and significant likelihood of river and coastal flooding, accounting for flood defences (2001 – 2011)	OS Mastermap – ASC sample Environment Agency – National Flood Risk Assessment (NaFRA)	
	Proportion of new dwellings built in areas of high flood risk (1989 – 2009)	Department of Communities and Local Government – Land Use Change Statistics	
	Development in areas at risk from coastal erosion		
	Change in land covered by buildings in areas at risk from coastal erosion (protected and non-protected) (2001 – 2011)	OS Mastermap – ASC sample	
	Factors affecting risk of surface water flooding and heat stress		
	Change from 'natural' to 'man-made' surfaces (2001 – 2011)	OS Mastermap – ASC sample	
	Change in area of urban greenspace	We could not identify a national dataset that maps change in the extent of specific areas of urban greenspace (e.g. parks, gardens, green corridors).	
	Waste heat	We could not identify a suitable dataset, but will scope the potential for using heat maps.	

Table 3.1: Indicators for assessing preparedness in land use planning and broad indication of trend. The direction of the arrow depicts the trend in that indicator (increasing, decreasing or no apparent trend). The colour depicts the implications of that trend for vulnerability: red = increasing vulnerability, green = decreasing vulnerability, yellow = neither increasing nor decreasing.

	Indicator	Dataset available	Trend
Actions	**Catchment/neighbourhood-level measures**		
	Resolution of Environment Agency flood risk planning objections	Environment Agency	
	Number of properties with 'increased protection' from flood risk	Environment Agency	
	Uptake of sustainable drainage and permeable paving measures	ASC sample of applications	
	Property-level measures		
	Uptake of measures to increase resilience and resistance to flood risk in new development	ASC sample of applications	
	Uptake of measures to manage surface water run-off rates in new development	ASC sample of applications	
	Uptake of measures to reduce heat gain in new development	ASC sample of applications	

3.5 Are local authorities accounting for climate risks in their decision-making?

Local authorities face difficult trade-offs when considering the implications of development on vulnerability. Restricting development in flood risk areas, particularly in town and city centres, can have significant implications for local economic growth. It can result in constraints on development and may risk blighting communities or businesses already located in flood risk areas. Alternative areas for development may be greenfield sites which planning policy has protected for good reason, or whose development may bring into play wider sustainability issues, for example increasing travel distances. For a minority of authorities there are few, if any, alternative locations available. For example, 96% of Hull's land area is at risk from flooding. However, the average area of land at flood risk across all English local authorities is generally much lower, at around 9% (Environment Agency, 2009).

Notwithstanding these difficulties, it is important that the apparent short-term benefits of development are properly weighed against the longer-term costs resulting from increased vulnerability.

Our analysis found that local authorities were often relying on property-level resilience measures to manage risks, perhaps reflecting these trade-offs. Even these measures involve some upfront expenditure, although less so for new development than for retrofitting existing building stock (as shown in Chapter 5). These costs are evidently seen as preferable to the costs of restricting development.

It is not clear that property-based measures alone will be sufficient to counter the potential increase in vulnerability, resulting in an increased reliance on flood defences. This will lock in a legacy of costs for future generations for expanding and maintaining the necessary flood defence infrastructure to protect existing and future development. The projected change in intensity and frequency of flood events is likely to increase these costs further in the future.[17] Some communities will become increasingly reliant on expensive capital infrastructure to remain viable. Furthermore, there are questions regarding where the future cost burden will fall, with policy increasingly moving towards encouraging local contributions, for example from developers and local authorities.[18]

We found that these long-term costs were generally not being accounted for in strategic development planning. We found little evidence of the social and economic benefits from development in climate risk areas being explicitly and openly weighed up against the long-term costs of climate impacts and the legacy of defences. It is not evident that the planning system is consistently enabling those local communities and business who face climate risks to be aware of the implications of decisions being made on the long-term future of their locality.

There is evidence of long-term climate risks starting to be assessed in some localities. Although these strategic approaches are a step in the right direction, we found limited evidence of them being formally adopted in local plan policies.

- There have been strategic reviews of long-term options for dealing with climate risks across the whole of the South Hampshire coast,[19] coastal cities like Hull and Portsmouth[20] and the Thames estuary.[21]
- The Shoreline Management Plan process, which appraises options for coastal management over long timescales (100 years) through partnerships between local authorities and the Environment Agency, is well established.

17 Environment Agency (2009b). The Environment Agency estimates that investment will need to be in the region of £1040 million a year by 2035 (an 80% increase from current levels) plus inflation. This excludes the costs of managing surface and groundwater flooding.
18 Department of Environment, Food & Rural Affairs and Environment Agency (2011).
19 http://www.push.gov.uk/work/sustainability-and-social-infrastructure/content-strategic-flood-risk-assessment.htm [accessed June 2010].
20 Institute of Civil Engineers (2010).
21 Environment Agency (2009c)

- Strategic approaches are also being taken to some other risks, for example on surface water through the London Drain partnership[22] and on river flooding through the Catchment Flood Risk Management plans.[23]
- The Flood and Water Management Act has also started to put in place a number of mechanisms that will enable strategic approaches, including identifying lead local flood risk authorities who are responsible for developing and maintaining information on flooding.

3.6 Conclusion

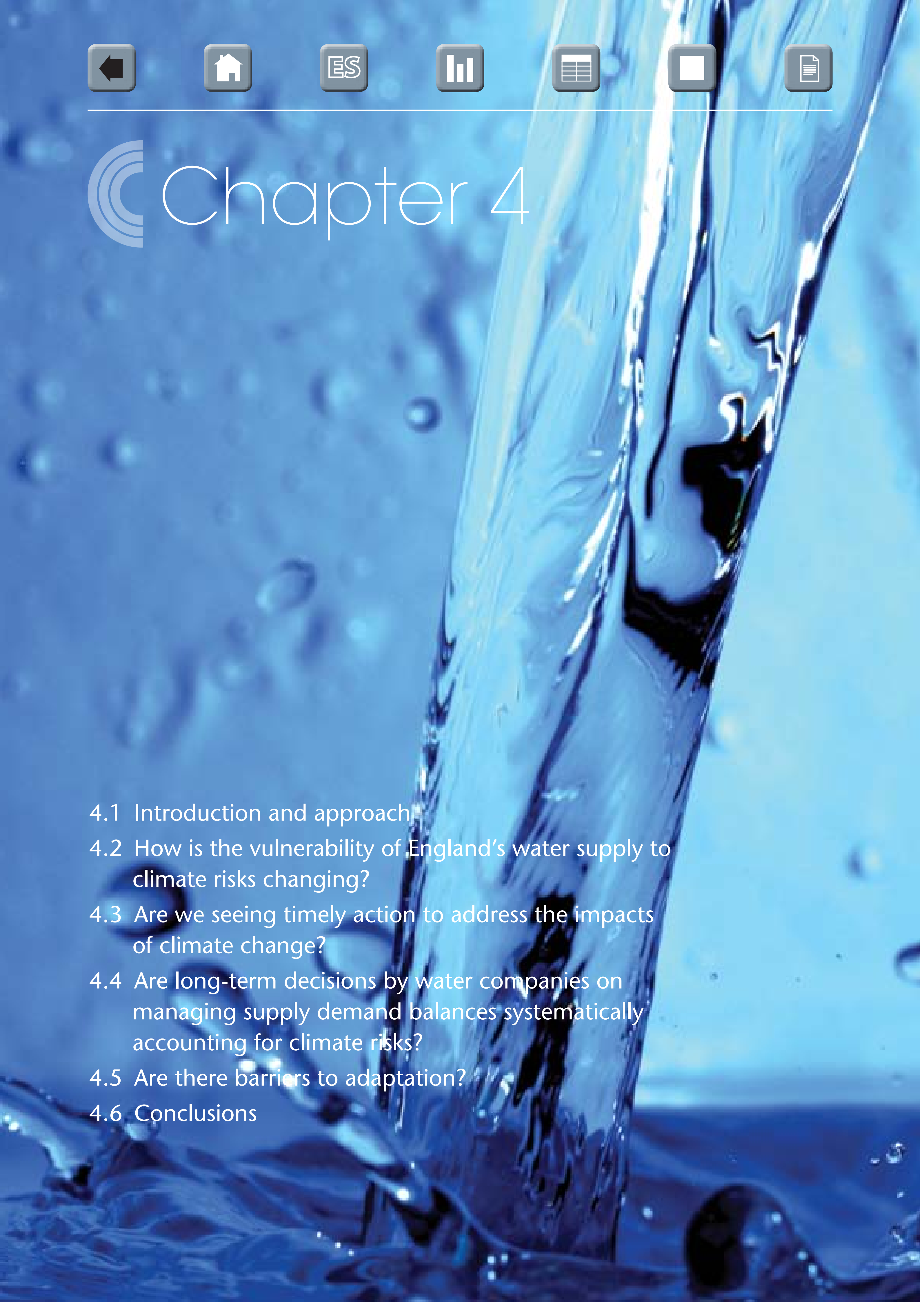
The land use planning system should enable more transparent assessment of climate change considerations against other, shorter-term priorities. Better information and different approaches are needed in order that decision-makers are able to openly weigh up trade-offs between long-term risks such as climate change and shorter-term priorities. This does not appear to be happening widely or consistently at present. There may be a role for developing localised indicators that allow communities to understand how development decisions are affecting their vulnerability to climate risks.

Our analysis has shown that national planning policy guidance on river and coastal flood risk has resulted in the significant uptake of adaptation measures at property level. The effectiveness of this guidance on the design, and to a lesser degree the location of development, has been reinforced by having a dedicated body (in this case the Environment Agency) to assist local authorities with the implementation of the guidance. Other climate risks either do not have specific guidance (for example on heat stress) or existing guidance is not being widely used (for example on surface water flooding and coastal erosion).

There is a risk that the move to more localised planning could make emerging strategic approaches to considering long-term climate risks less effective, although the forthcoming duty to co-operate has the potential to play an important role here. Our analysis suggests that these partnerships need to have more influence on actual local plan policies.

The capacity of local authorities and statutory agencies is a potentially significant barrier. Research[24] identified capacity issues for local planning authorities in relation to awareness of climate risks and adaptation. Budgetary constraints since this research was carried out have increased with potential implications for local planning authority capacity. It will also be very important to ensure that the important role played by statutory agencies is not weakened.

22 http://www.environment-agency.gov.uk/research/planning/33586.aspx [accessed June 2010].
23 http://www.london.gov.uk/priorities/environment/water-management/rainwater-drainage [accessed June 2010].
24 Town & Country Planning Association (2009)



Chapter 4

Chapter 4
Managing water resources

Chapter summary

There have been few instances of significant water supply disruptions to consumers in recent decades, except in the most severe droughts and disruptive floods. Security of supply has improved through continued investment by water companies.

Current levels and patterns of abstraction have come at an environmental cost. Environment Agency statistics indicate that that there is 'probably a risk' that abstraction is environmentally damaging to 11% of rivers and 35% of groundwater.

Climate change is likely to increase stress on the water supply system. Water companies estimate that there could be supply shortfalls in about 45% of England's water resource zones by 2035, with climate change contributing to this impact in at least 80% of cases. Lower river flows, a likely consequence of climate change, will exacerbate the pressure that abstraction places on the environment.

Water companies are investing £1.4 billion of capital between 2010 and 2015 to address potential supply shortfalls. However, as yet there has been no specific investment to address shortfalls driven by climate change. Our analysis suggests that there is greater scope for low-regret demand management measures. Water companies have a key role to play here as do government and householders.

There is a need to better incorporate long-term climate uncertainty into investment planning in a way that allows water companies to plan adaptation that is proportionate to risk and allows regulators and consumers to evaluate this. This should help make the case for low-regret measures and highlight where more difficult trade-offs need to be made in investment decisions.

The current abstraction licensing regime is a significant barrier to progress because current mechanisms do not fully account for environmental impacts of abstraction and there is insufficient flexibility to respond to changing water availability.

4.1 Introduction and approach

The provision of water is a clear priority for adaptation. It sits in two of the ASC's priority areas for adaptation: managing natural resources and providing national infrastructure. Water is a natural resource that needs to be shared across sectors (household consumers, business and industry). The way in which these services are supplied has significant impacts on the viability and condition of many important freshwater habitats and their dependent biodiversity.

Water companies have significant investment planned for maintaining and building new infrastructure to abstract, store, treat and distribute water. The most recent water price review by Ofwat allowed for a capital investment programme of £9.6 billion between 2010 and 2015 for water supply, including £3.2 billion for infrastructure renewals and £1.4 billion for maintaining the supply demand balance.[1] Much of this will still be in place in the second half of the century, when the climate will be different to today. It is therefore

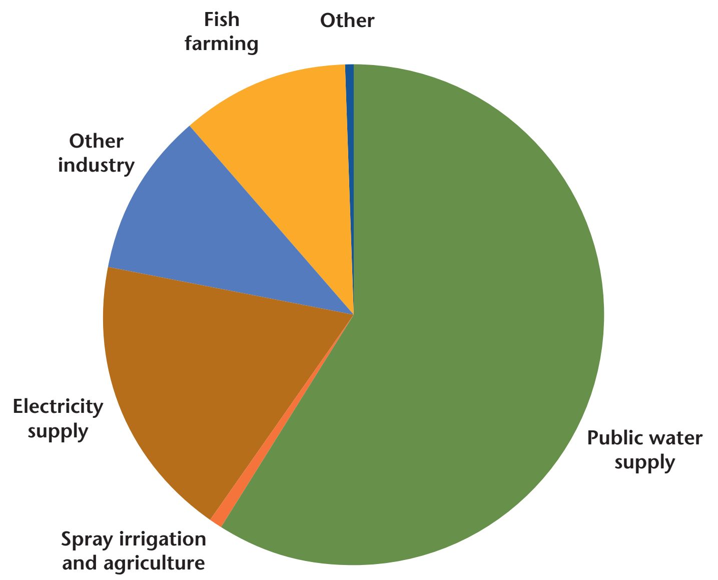
1 Ofwat (2009b) pg 65.

important that climate change is factored into the way this infrastructure is planned, designed and built.

In this chapter we assess the preparedness of England's water sector for current and future climate, focusing on the provision of public water supply and the impact of abstraction on the environment. We focus on water supplied by water companies to households and businesses as it accounted for the majority (59%) of the 25 billion litres of freshwater abstracted in England in 2008 (Figure 4.1). We consider the risks from changing rainfall and temperature (aridity) to water supply but not the impacts of extreme weather on supply infrastructure (such as flooding), or the preparedness of wider parts of the water sector, such as wastewater treatment or the implications of climate change for meeting water quality standards.

In line with the Adaptation Sub-Committee's preparedness ladder (Chapter 1) we assess whether water supply is becoming more or less vulnerable to changing aridity by looking at how the overall supply demand balance has changed and the underlying trends in demand and supply. Indicators that summarise these trends in vulnerability are presented in Table 4.1 at the end of this section. We also examine whether this results in a resilient water supply by looking at the incidence of drought orders, and the impacts of abstraction on the environment. We review how these risks could change in the future and look at whether low-regret measures are being brought forward to address these risks. Finally, we assess whether climate risks are being robustly incorporated into long-term water company decision-making and if there are barriers to action that may require a policy response.

Figure 4.1: Freshwater abstraction (non-tidal) in England (2008)



Source: Contains Environment Agency information © Environment Agency and database right.
Notes: Total volume is in millions of litres.

4.2 How is the vulnerability of England's water supply to climate risks changing?

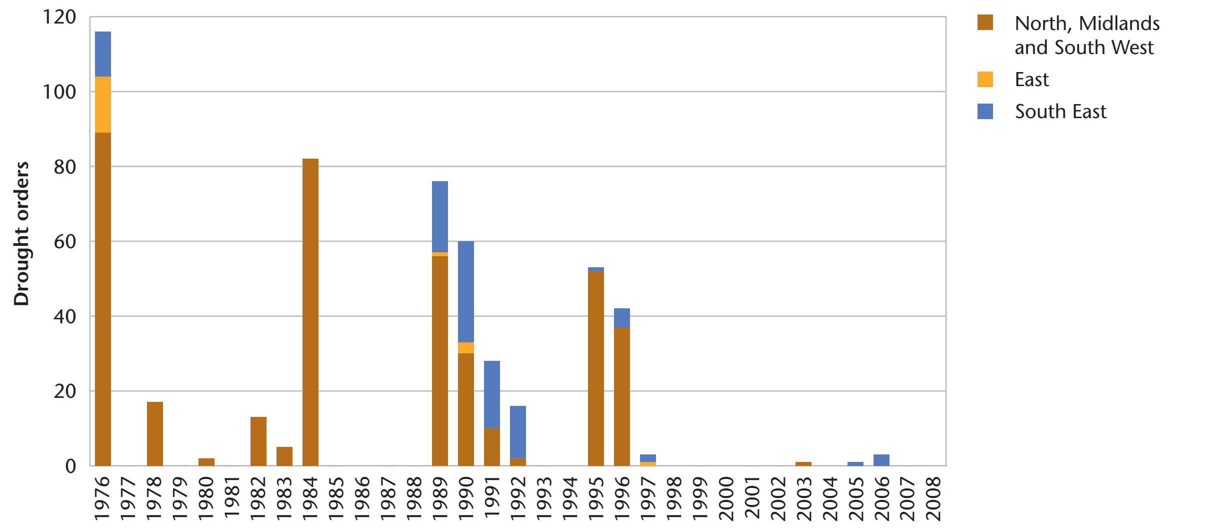
Water supply to consumers is broadly secure against current climate risks as reflected in a low incidence of drought orders. While some customers are still at risk of water shortages, overall vulnerability has decreased since the 1990s. Demand has remained relatively constant and there have been increased investments in supply resources since privatisation of the water industry.

This apparent resilience comes at an environmental cost. Current levels of abstraction place freshwater ecosystems at risk of damage by altering water levels and flow with knock-on impacts on water quality and river morphology.

Impacts of drought

Disruption caused by drought is infrequent, as indicated by the low incidence of drought orders over the last 30 years (Figure 4.2). The number of drought orders provides an indication that there has been sufficient water to meet demand. However, it is not a robust indicator to assess how climate vulnerability of the system is changing.[2] This is because the number of drought orders reflects both the severity of the drought (a function of the prevailing weather) and the appetite of abstractors and the Environment Agency to apply for drought orders.

Figure 4.2: Drought orders in England (1976-2008)



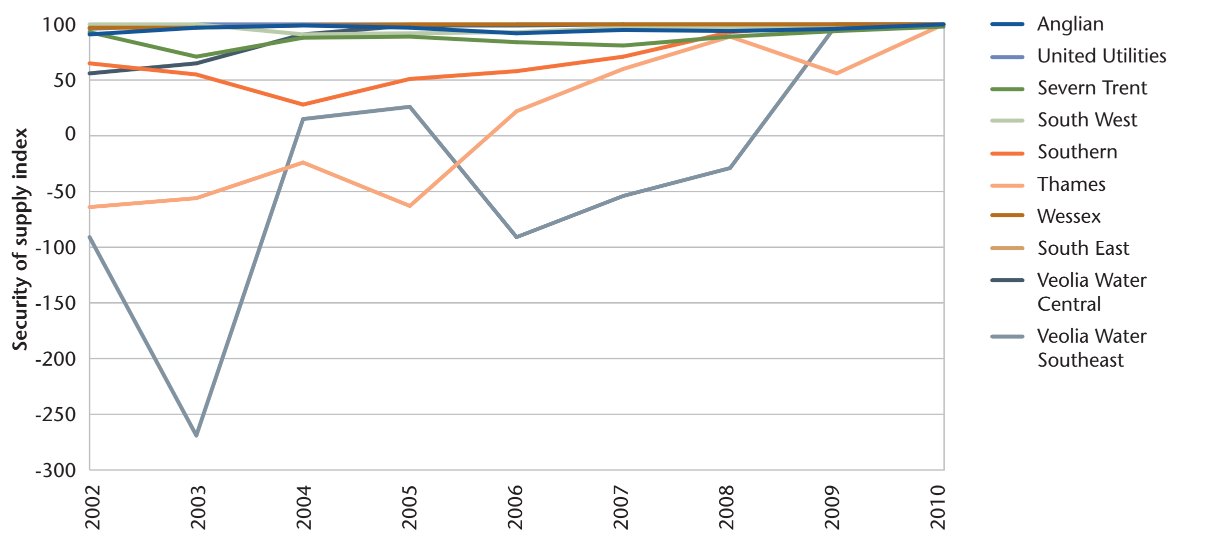
Source: Water Supply and Regulation Division, Defra.

2 An increase in drought orders could be considered a sensible adaptation, as this provides added control of water during dry periods. So we would not necessarily expect to see the incidence of drought orders to decrease with time.

Overall vulnerability to water shortages

The overall security of water supply has either remained high or improved to a high level over the last ten years. Customers are now less likely to be affected by water shortages (Figure 4.3). However, in 2010, four water companies reported that they could have struggled to supply some of their customers, to their target level of service, during a severe drought, potentially affecting around 650,000 people.[3]

Figure 4.3: Trends in security of supply for water companies with a security of supply index less than 100 (2002-2010)



Source: From data reported to Ofwat ('June returns').
Notes: The security of supply index represents how likely consumers are to receive a target level of service. The target level of service relates to the frequency with which water companies are likely to impose water restrictions on users and varies between company. A score of 100 indicates that all customers should receive the target level of service, with increasing risk that this will not be met below 100. (Security of supply = (1 – (percentage deficit[2] x percentage population affected x 100)) x 100 rounded down to the nearest whole number. The data is presented is reported for year end (June)).

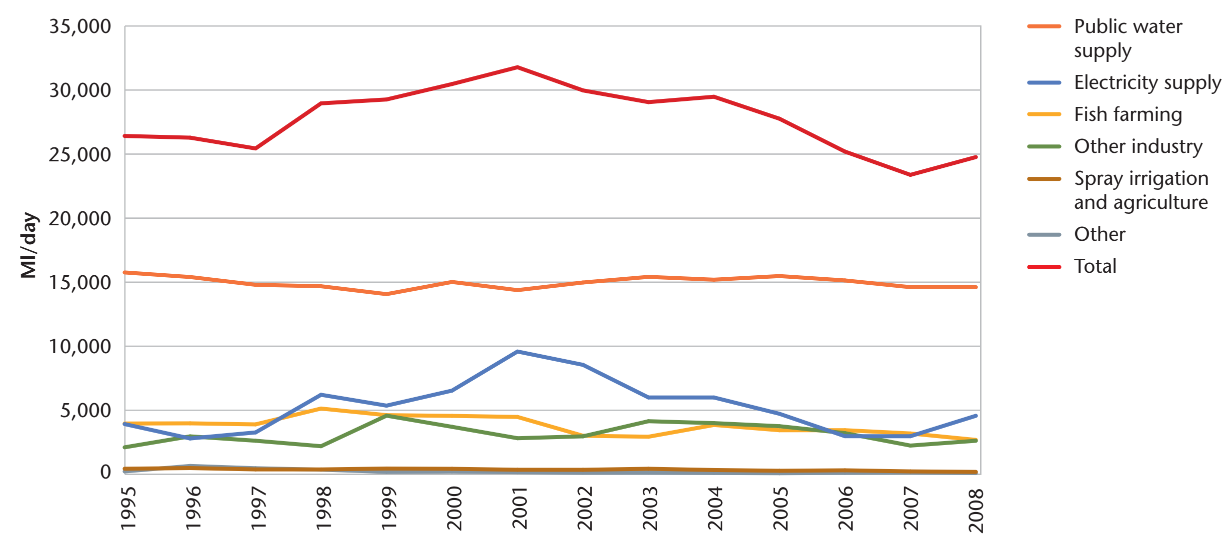
3 This figure was calculated from data submitted to Ofwat in the 2010 'June returns spreadsheet 10ai and 10aiii' using supply demand deficits reported for a dry year or for a critical period in a dry year along with the number of people affected in those areas.

Trends in demand

Total demand for water in England has fluctuated since the mid-1990s, with a decline in use since 2001 (Figure 4.4). The recent decline is less noticeable in the East and South East.

- Much of the variability arises from changes in water used for electricity supply.[4]
- Public water supplied for businesses and households has changed little overall since the mid-1990s (Figure 4.5a).
  - There has been a slight decline in consumption by commercial users.
  - Household water consumption has remained relatively constant between 2000 and 2009 despite factors that could have increased demand, such as increases in population (4.8% between 1995 and 2009)[5] and a move to single occupancy homes. Consumption per person has changed little overall since 2000, but there have been reductions in use since 2003. These recent efficiency savings have been most consistently delivered by metered households where consumption fell by about 1.3% per year between 2003 and 2009 (Figure 4.5b). During this time there has been an increase in the number of metered households. There was no clear downward trend in usage by unmetered households.
  - There has been little change in the water lost during supply since 2000 (Figure 4.5a). However, leakage, which is the main component of these losses, has decreased significantly since 1995 (35%).[6]

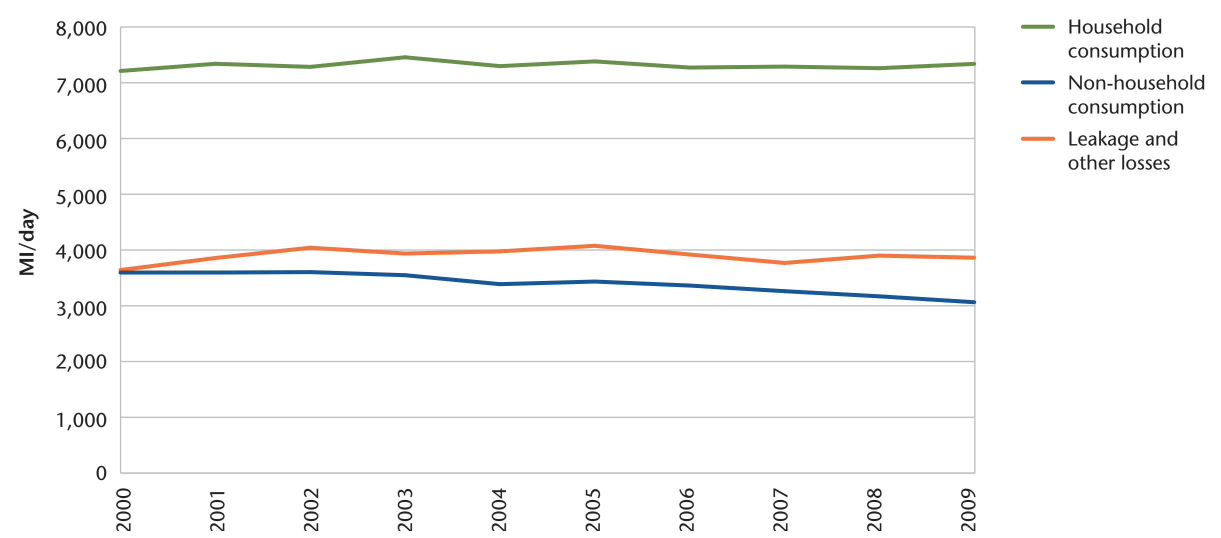
Figure 4.4: Freshwater abstractions (non-tidal) in England by sector (1995-2008)



Source: Contains Environment Agency information © Environment Agency and database right.

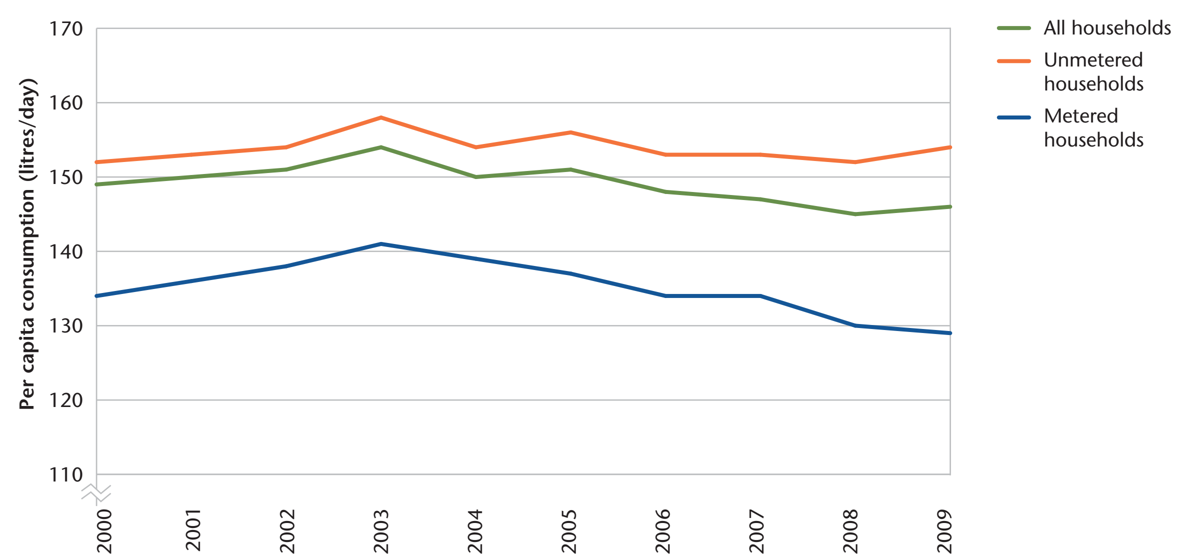
4 Historically this was thought to alter the pressures on supply less than public water abstraction because most of the water used by the energy sector is rapidly returned to the point of abstraction. But, current investigations suggest that a high proportion of water may be lost during evaporative cooling, commonly used in gas and coal powered energy generation (Defra personal communication). Whatever the outcome, reductions in water abstraction by electricity suppliers will reduce pressure on the natural environment during periods of low river flow.
5 Office of National Statistics (2006, 2010).
6 Ofwat (2010).

Figure 4.5a: Public Water Supply in England– household, non-household and leakage and other losses (2000-2009)



Source: Contains Environment Agency information © Environment Agency and database right.

Figure 4.5b: Public Water Supply in England – per capita consumption (2000-2009)



Source: Adaptation Sub-Committee calculations using Environment Agency information © Environment Agency and database right.

Trends in supply

There has been increasing investment in water supply infrastructure, particularly since privatisation. Case studies show how the investments have improved the security of the public water supply sector to drought and increases in demand (Box 4.1).

Box 4.1: Examples of measures taken to improve the security of supply

Water storage

Essex and Suffolk Water is currently enlarging their Abberton reservoir. The enlarged reservoir will be filled by transferring water from outside the region. This improves resilience to variability in rainfall patterns by allowing greater storage of water during times of surplus (generally winter) and usage during drier periods.

Water transfer schemes

United Utilities is constructing a pipeline for transferring water around its region. Merseyside traditionally receives its water supplies from sources in North Wales while Greater Manchester receives the majority of its water from the Lake District. The West East Link pipeline will allow water to be moved across the region to where it is needed most, and improves security of supply during periods of scarcity.

Desalination

Thames Water opened a desalination plant in Beckton in 2010, which has the capacity to supply around 1 million people with water during drought; peaks in demand or when river flows are low. While this secures water supply, desalination is an energy intensive process.[7]

Groundwater recharge

Thames Water also operates an artificial recharge scheme in north London. Water is pumped into a natural reservoir below ground during times of surplus for storage, allowing use during drier periods. The scheme could potentially supply about 1 million people.

7 Thames Water currently uses biodiesel to power the process, which can reduce carbon emissions, although there are potentially additional environmental impacts associated with the use of biofuels.

Impacts of abstraction on freshwater habitats

Current levels and patterns of abstraction come at an environmental cost. Environment Agency statistics indicate that:

- for 11% of surface water bodies current levels of abstraction mean that there is a 'risk' or 'probably a risk' that water flows fail to support 'good ecological status'[8,9], which could result in environmental damage; and
- for 35% of groundwater bodies, current levels of abstraction mean that there is a 'a risk' or 'probably a risk' that groundwater levels do not achieve 'good quantitative status'[10] and so fail to adequately recharge rivers and wetlands, which could result in environmental damage.[11,12]

The impact could be more significant if all issued abstraction licenses were used to their full allocation or new licenses were issued.[13]

- A separate study conducted in 2008 showed that if all abstraction licenses were used to their full allocation there would be a risk that abstraction could cause 'unacceptable damage to the environment' in 33% of water bodies.
- The same study suggested that, for a further 35% of catchments, issuing new licenses could lead to 'unacceptable damage to the environment' if all current licenses were used to their full allocation.

8 Environment Agency (2010d).
9 As defined under the Water Framework Directive there is a risk that 'these bodies do not support good ecological status – the objective for a water body to have biological, structural and chemical characteristics similar to those expected under nearly undisturbed conditions'. If a water body fails to meet these characteristics it may not be able to support dependent habitats. See European Union (2000) for further details. Note that this statistic excludes heavily modified water bodies such as reservoirs or canals.
10 An expression of the degree to which a body of groundwater is affected by direct and indirect abstractions.
11 Environment Agency (2010c).
12 Note that due to changes in methodology the statistics on the number of water bodies currently at risk of failing to meet good good ecological status (above) are not directly comparable to the statistics presented here.
13 Environment Agency (2008).

Table 4.1: Trends in indicators for assessing the preparedness of water supply to changing aridity
The colour of the arrow represents what effect the stated trend has on vulnerability (red – increasing vulnerability; green – decreasing vulnerability, yellow – neither increasing nor decreasing vulnerability), The arrow indicates the direction of trend as described by the indicator (up – the indicator trend has increased; down – the indicator trend has decreased; right – the indicator trend has neither increased or decreased). Question marks highlight where data was not available, or too limited to determine a trend. These indicators are currently shown at the national level.

	Indicator	Data available	Trend 2000 – 2010
Impact	Supply demand balance – Drought orders	Water Supply Division, Defra	?
Components of vulnerability	Supply demand balance – Security of supply by water company[14]	Ofwat (June return data)	green up arrow
	Total demand – Freshwater abstraction ('non-tidal') by sector	Environment Agency	green down arrow
	Public water demand – Total water put into public water supply	Environment Agency	yellow right arrow
	Drivers of household demand – Population[15]	Office of National Statistics	red up arrow
	Drivers of household demand – Average per capita consumption	Environment Agency	yellow right arrow
	Water supply – Catchments where additional water is available for licensing	Environment Agency limited time series	?
	Waterbodies at risk of environmental damage from abstraction	Environment Agency limited time series	?
Actions	Proportion of properties metered	Ofwat	green up arrow
	Uptake of water efficiency measures (measured through water saved through demand management)	Ofwat limited time series	?
	Total industry leakage	Ofwat	green down arrow
	Winter storage reservoirs for irrigation	No data available	?

14 In future we will look at the number of people affected by potential water shortages.
15 It is also relevant to consider single occupancy homes.

Future pressures on water supply

Both climate change and other drivers will affect supply and demand. The likely direction of both will be towards increased resource scarcity and system stress. If not addressed this could lead to water shortages, higher costs to society and/or damage to the environment. Water companies project that during severe droughts there could be a gap between supply and demand in about 45% of resource zones by 2035 without remedial action.[16,17] Water companies have set out preferred strategies to close these gaps through increasing supply and reducing demand. These strategies are used as the basis for investment planning.

Climate drivers

Climate change is likely to exacerbate pressures on supply for consumers and on the environment, although the magnitude of future change is highly uncertain.

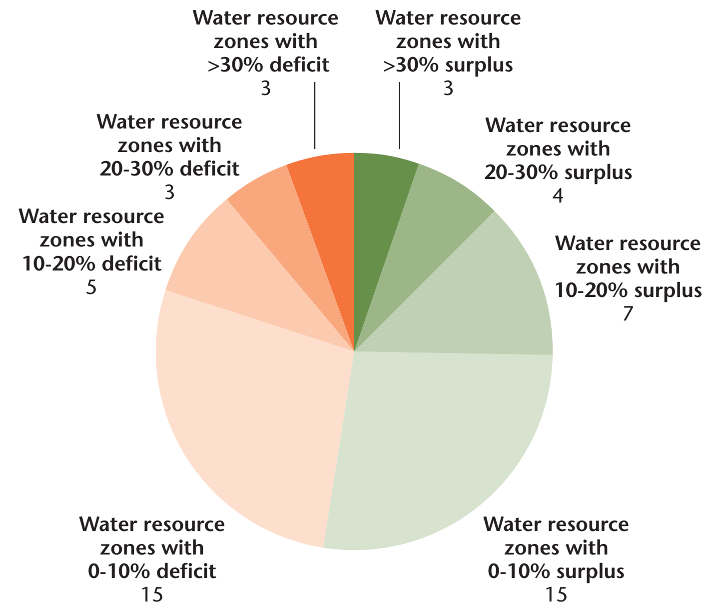
Climate change is expected to alter the distribution of rainfall and temperature. Climate models indicate a general trend towards wetter winters and drier summers, but there are differences between model projections. For instance, the Environment Agency estimates that by 2050 average river flows might increase by 10 – 15% in winter and fall by over 50% in summer and early autumn.[18] A combination of changing temperature and rainfall could increase the possibility of drought, although overall it is not clear how the frequency or severity of droughts is likely to change.[19] Reductions are also expected in groundwater levels and recharge to aquifers. More extreme, drier winters and prolonged periods of aridity could also reduce recharge of reservoirs.[20]

Water company plans identify that climate change is a factor in at least 80% of areas projected to have a potential shortfall between supply and demand by 2035.[21] At a national level an average 3% reduction in supplies is expected, much of which is projected to occur in the South East. Uncertainty over these projections is high, for instance altering water available for use by +/- 400 million litres in one resource zone alone, equivalent to the water used by about 2.7 million people.[22]

Climate change may also increase demand with projections around: 2 – 4% for household users, and 4 – 6% for industrial and commercial users. The scale of these changes is small, relative to the other drivers, such as demography and industrial patterns. However, climate change could increase demand for irrigation significantly, during times when water is scarce.[23]

16 Adaptation Sub-Committee calculation based on supply demand deficits reported by water companies in their revised draft / final Water Resource Management Plans submitted by water companies to the Environment Agency in 2009. The gap between supply and demand is taken to be the difference between water available for use and demand with head room in a dry year.
17 Note that this figure does not illustrate the range of uncertainty associated with climate change. We come back to the issue of how climate change uncertainty is considered in investment planning in Section 4.4.
18 Environment Agency (2008). Note that these figures are based on river flows projected using data from UKCIP02 climate projections. New projections using UKCP09 are due for release by the Environment Agency.
19 Burke et al. (2010a,b).
20 Environment Agency (2009d).
21 Data on the climate change impact were supplied by Matthew Charlton from Charlton and Arnell (2011). Data were only available for 60 out of 78 resource zones in 2008.
22 Charlton and Arnell (2011).
23 Downing et al (2003) and Environment Agency (2008).

Figure 4.6: Water company projections of water resource zones with a potential gap between supply and demand in 2035



Source: Adaptation Sub-Committee calculations based on revised Water Resource Management Plans 2009.
Notes: Surplus/deficit taken to be the difference between water available for use and baseline demand with headroom in a dry year or a critical period in a dry year. Includes water companies with available data (55 out of 78).

The potentially large reduction in summer flows is likely to significantly increase pressure on freshwater habitats and the percentage of habitats where abstraction contributes to environmental damage. We expect the UK's Climate Change Risk Assessment to provide further information on the likely scale of change.

Non-climate drivers

There are likely to be ongoing reductions in the volume of water that can be abstracted from sensitive water bodies, to safeguard freshwater habitats through the Water Framework Directive. The magnitude of the reductions is still to be agreed, but could be significant. For example, in the London region these reductions could be equivalent to 25% of current supplies according to some estimates.

Non-climate drivers are likely to increase water demand. Water demand across the UK could rise steadily by 5% over the next 10 years. Factors behind this underlying trend include changes in demography, consumer preferences and use of water in business and industry. New uses for water such as carbon capture and storage could also increase demand. Uncertainty over the magnitude of future change is high with the Environment Agency projecting that demand could be between 15% less and 35% more than today by the 2050s.[24] Government regulation and policy can have a major effect on demand and thus affect the future vulnerability of the water sector.

24 Environment Agency (2009d).

4.3 Are we seeing timely action to address the impacts of climate change?

This section looks at the actions water companies are taking in their investment plans to secure water supplies in the face of the pressures set out above. We assess whether the overall level of action is sufficient and the extent to which low-regret measures are being brought forward.

Is the overall level of action sufficient?

As yet there has been no specific investment to address the impacts of climate change on water supply or demand, even though water company plans suggest that some additional investment is necessary. Sustained absence of additional action to address the impacts of climate change could lead to higher costs in the future or increased risks of water shortages.

- Water companies are spending £1.4 billion over the next five years to address potential supply shortfalls arising from non-climate change drivers, such as projected increases in population. This £1.4 billion does not include specific investment to address the additional impacts of climate change on the supply demand balance.[25]
- Water companies proposed additional investments totalling around £1.5 billion to address the impacts of climate change on supply and demand between 2010 and 2015, primarily based on evidence from the UKCIP02 climate change scenarios. This was not included within price limits due to Ofwat's requirement that the companies' proposals should be based on evidence from the revised UKCP09 scenarios. The release of the projections was not compatible with the price review timetable. Ofwat put in place a "notified item" allowing companies to propose investment using UKCP09 to address climate change impacts before the next price review in 2014. Companies have not yet taken the necessary steps to revise their proposals and agree any additional investment with Ofwat through this process.

Are low-regret measures brought forward first?

It makes sense to implement low-regret measures first where possible. Demand management options are generally considered to be low-regret compared to supply-side measures from an adaptation perspective because they:

- are robust to climate change uncertainty; and
- provide co-benefits by reducing abstraction (and therefore pressure on freshwater habitats), energy use and costs to metered householders.

Supply-side measures are also needed given that:

- consumer behaviour may be a barrier to realising these savings and sustaining them over the long term; and
- there are limits to the level to which it is desirable or possible to reduce water use by households – as some level of water use is essential.

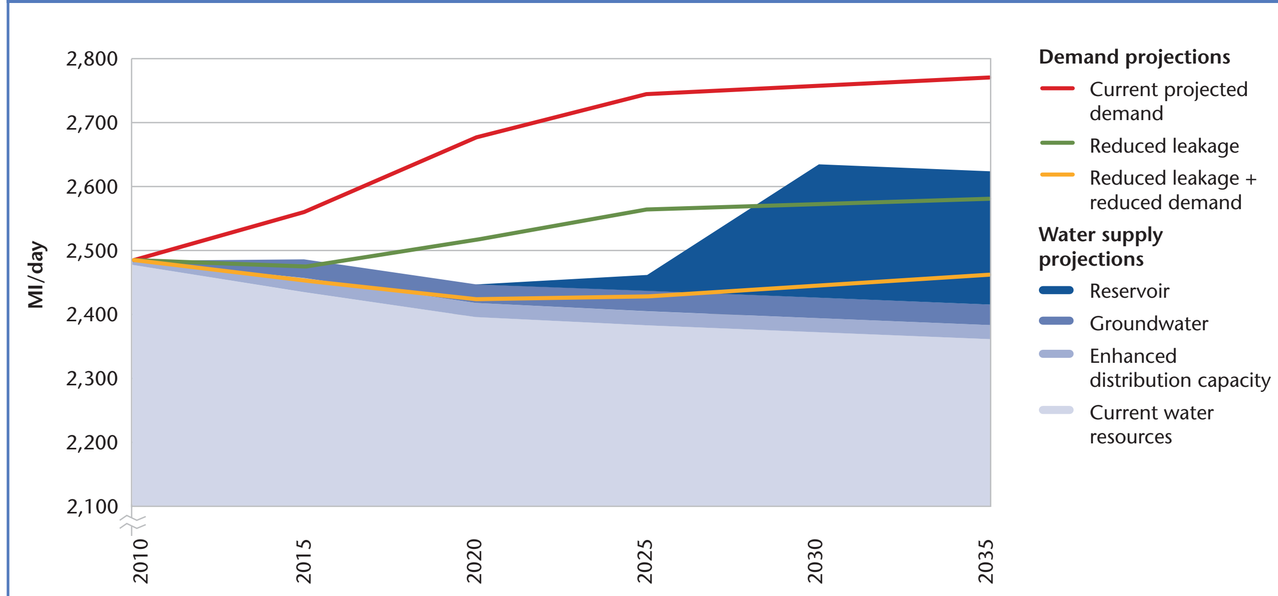
25 Oftwat (2009b).

In the South East our economic analysis suggests that reducing consumption from today's average of 160 litres per person per day to around 115 litres could be cost-effective[26] compared to the long run-marginal cost of increasing supply through other means (Chapter 5).[27]

Current projections of demand by water companies range from 135 to 165 litres per person per day in 2035 in the plans that we looked at (Table 4.2).[28] The demand management programme proposed by water companies is unlikely to approach the level of 115 litres per person, although there is some additional activity on demand.

- **At a national level, around half of the deficit in the period between 2010 and 2015** (323 million litres water per day – equivalent to the water used by about 2.3 million customers) is addressed with demand measures; the other half with supply.[29]

Figure 4.7: Thames Water preferred strategy to address a potential gap in supply and demand (2010-2035)



Source: Revised Draft Water Resource Management Plan 2009 and Final Business Plan Annex B5 2009.
Notes: Thames Water preferred investment programme for water resource zones currently in deficit (London and Swindon and Oxfordshire). 'Current projected demand' represents projected baseline demand plus target headroom and includes regulatory requirements on water efficiency. 'Reduced leakage' shows how demand would be reduced by TW's preferred investment in leakage and 'Reduced leakage plus reduced demand' shows how demand would be reduced by leakage and enhanced activity on demand management.

- **Water companies tend to bring forward demand management measures first (for an example see Figure 4.7). But the overall balance of supply and demand side measures proposed to 2035 was variable in the plans that we examined (Table 4.2).** Four companies put forward equal activity on supply and demand. The remaining four set out mainly supply-side measures. It is unlikely that these measures would reduce demand significantly towards 115 litres per person per day.

26 This is compared to the current national average use of 148 litres of water per person per day. The savings from this analysis are scalable i.e. it is likely that the possible savings at a national level could take demand below 115 litres per person per day. This is based on the full uptake of cost-effective measures looked at in the analysis.
27 It should be noted that there are local variations in demand. This analysis looked at average savings in demand. In future it will also be important to consider the scope to reduce demand during droughts, when usage can typically increase (Chapter 2).
28 This takes into account regulatory efficiency savings from leakage, metering and some additional efficiency programmes. It also reflects likely trends in use across society.
29 Ofwat (2009b).

There is greater scope to reduce consumer demand for water. Water companies have a key role in realising these savings, alongside action by consumers. Actions by both will be strongly influenced by the regulatory regime set by the Government and delivered by its agencies.

Table 4.2: Water companies' preferred strategies to address a potential gaps between supply and demand (2035)

	Current projected demand (litres per person per day)		Current projected deficit in 2035 (Ml)	Preferred measures to close deficit (%)	
Water Company	2007/2008	2034/2035		Demand (of which leakage)	Supply
Anglian and Hartlepool	?	?	-190	**30** (14)	**70**
Bristol	149	140 *	-50 *	**52** * (6)	**48** *
Essex and Suffolk	156	134	-68	**18** (6)	**82**
Severn Trent	127 /148	135 / 144	-234	**46** (19.5)	**54**
South East Water	167.5 **	166.4 * **	-104	**25** (3.1)	**75**
Sutton and East Surrey	175	165	-12	**40** (0)	**60**
Thames	157	147	-362	**51** (32)	**49**
Veolia South East	150	128	-2	**42** (9)	**58** ***

Source: Adaptation Sub-Committee calculations based on data extracted from Annex B5 of Final Water Company Plans (2009) and revised Draft Water Resource Management Plans (2009)
Notes: Data on average demand per person is for normal year unless otherwise stated. Data for 2035 deficits is for dry year. Demand represents current projected demand and includes regulatory requirements on water efficiency. Deficit represents a summation of deficits in individual water resource zones for each water company. Deficit calculated as water available for use minus demand with headroom.
*Data shown for 2030
**Data shown for Dry Year
***Veolia South East's supply-side measures are only planned if the demand measures fail to give the expected savings.
In some cases the preferred investments provide more water through demand management and supply measures than required to close the projected gaps between supply and demand. Therefore the percentages shown cannot be directly related to the deficit.

Are other measures being brought forward as appropriate?

There are other measures that are important to consider for adaptation. We do not assess these options comprehensively, but have briefly considered leakage and abstraction management.

Reducing Leakage

Reducing leakage alleviates pressures on supply and is favourable from an adaptation perspective because it is relatively insensitive to climate compared to supply-side measures. The savings are also more certain than those from managing consumer demand. There has been significant activity on reducing leakage to date, with levels 35% lower than the mid-1990s at a national level. Water companies are planning additional activity on leakage (Table 4.2).

Further reductions in leakage are possible. But a robust cost-benefit appraisal is needed to determine whether this is cost-effective compared to other options. In the current price review period water companies were asked to set out investment to reduce leakage to 'the economic level' – the point at which it becomes more expensive to continue to reduce leakage in comparison to the development of other demand or supply options. Leakage targets are related to this. In future, water companies will be asked to plan to a 'sustainable level of leakage' which more explicitly factors in the costs that customers are willing to pay to reduce leakage below this level.

Flexibly managing abstraction

Managing abstraction to use water from areas of relative surplus instead of relative scarcity is an important adaptation measure. It allows more efficient allocation of water between users and can reduce the pressure that abstraction places on the natural environment. The relative level of scarcity varies between different sources of water and different habitats. It also changes seasonally and with prevailing weather conditions, and so may be affected by climate change. For instance, rivers are at higher risk during a dry summer than groundwater sources that have the capacity to store winter rainfall. Because of this a flexible approach to management is needed.

The high number of water bodies that are still at risk of damage caused by abstraction highlights that further action is needed. The Government has started a programme to 'Restore Sustainable Abstraction', which aims to reduce areas in water stress. Previous reviews of abstraction licencing have highlighted that the current pace of change is slow and there is high uncertainty over the level and timing of future reductions.[30] If this is not resolved quickly there will either be significant impacts on the natural environment or potentially high costs to consumers if water companies have to implement reactive measures to reduce abstraction rather than take a strategic approach.

There is scope to manage resources better locally both within and between water companies.

- For instance, work by Southern Water and WWF has shown that there is scope to significantly reduce environmental risk associated with abstraction by reprioritising abstraction from the River Itchen to other water resources during periods of low rainfall.
- The Environment Agency calculated that in the 2004 business plans water companies were planning to develop 500 million litres of additional water per day, over and above what would be needed if water was transferred between resource zones. This can contribute to increasing resilience during localised water shortages and reduce the need for investment by £1.4 billion.[31,32]

30 Less (2011).
31 Environment Agency (2009d).
32 Cave (2009).

4.4 Are long-term decisions by water companies on managing supply demand balances systematically accounting for climate risks?

We complemented our analysis on the uptake of actions by considering how water companies are including long-term climate risks in their plans.

All water companies have recently published Adaptation Reports required under the Climate Change Act 2008. In our review of these reports it is clear that water companies are actively considering current and future climate risks across the range of their operations. However, the reports did not provide sufficiently detailed information for us to assess whether water companies are systematically accounting for long-term climate risks in their investment planning in relation to managing the supply demand balance.

To better understand how climate risk is considered in managing the supply demand balance we looked at Water Resource Management Plans. Here, water companies are required to consider the impact of climate change on supply in planning their investment programmes (alongside other factors that could influence the supply demand balance).[33]

In our assessment, the current guidance on investment planning does not fully account for the uncertainty associated with climate change. Neither do water companies present a robust assessment of the implications of climate uncertainty in their plans for future investment that use this guidance. Planning focuses on a medium climate change scenario, along with an additional supply buffer. While companies are asked to sensitivity test their investment plans to different future scenarios, it is not clear that this is comprehensively factored into decision-making. This means it is hard to know how well water supplies would cope if futures outside the medium scenario were to be realised.

Understanding the full range of uncertainty associated with climate builds the case for low-regret measures and can enable robust decision-making on investments in long-lived assets. This was demonstrated in a case study we conducted with Thames Water that explored the implications of assessing a range of climate scenarios when making long-term water resource management decisions (Box 4.2).[34] We found that:

- In the near term (to the early 2020s) there is a case for investment in options such as leakage reduction or metering as these measures are prioritised for implementation regardless of the climate scenario.
- Over the longer term (2050s to 2080s) the climate scenario and time horizon influences the choice of options affecting the robustness of decisions. For example, a reservoir designed to meet 2050s demand may not have the capacity to deliver what could be required under a high climate change scenario in the 2080s. This demonstrates the importance of assessing how robust an investment will be to the range of plausible futures over the payback time of the asset. Assessing the range of climate scenarios also allows for appraisal of incorporating flexible measures when specifying the design of an asset, for instance, including options to increase the capacity of a new reservoir at a later stage.

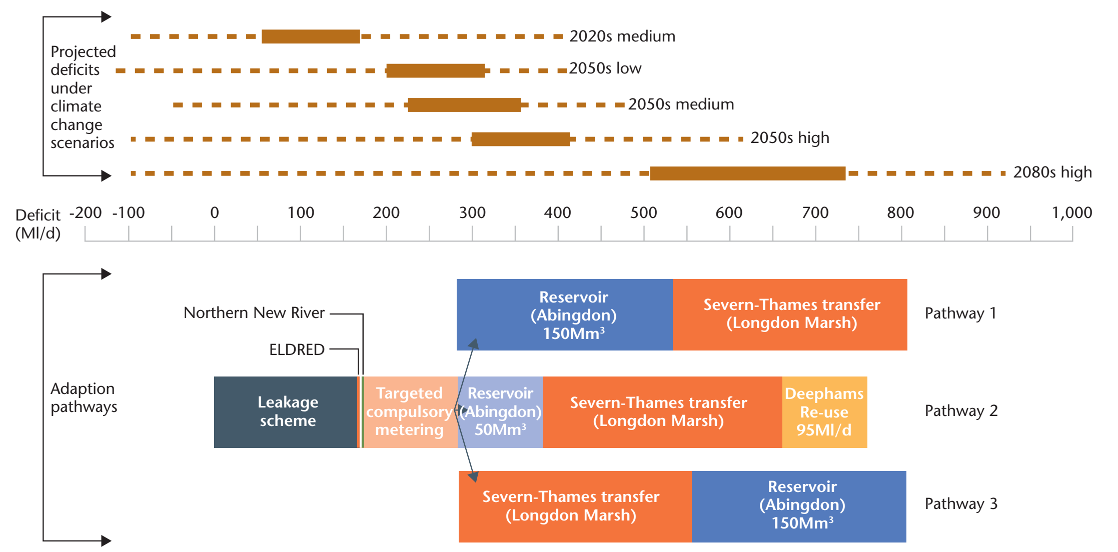
33 Water Resource Management Plans require water companies to consider whether or not additional investment is needed in order to secure supplies that meet projected demand. The Environment Agency provide guidance to water companies, requiring them to first project likely water demand and water availability from supply sources to determine whether there is any deficit over a 25 year period. They then appraise options to close any deficit. The preferred options are included in Business Plans put forward in the 5 yearly price review. Ofwat then make price allowances for investments that they agree are required in the next five years.
34 Atkins (2011) commissioned by the Adaptation Sub-Committee.

Box 4.2: Case study on water resource planning in London[35]

Thames Water serve over 6.5 million customers in London, an area with a growing gap between supply and demand during droughts. The company plans to address this through a combination of moderate groundwater resource schemes, demand management and leakage reduction. They are also considering a new supply reservoir in Abingdon and inter basin water transfers.

This case study considered the implications of assessing the full range of climate uncertainty for the investment programme.[31] From this, we constructed an investment decision tree for London (Figure B4.2) which sets out three different investment pathways under a range of climate scenarios.

Figure B4.2: Water resourcing investment decision tree for London, 2020s to 2080s



Source: Atkins (2011) commissioned by the Adaptation Sub-Committee.
Notes: In 'projected deficits under climate change scenarios' the size of the gap between demand and supply is presented. The brown dotted lines represent the full range of uncertainty in the deficit driven by climate change in each scenario. The brown boxed area delineates the size of the deficit that water companies typically use for investment planning. We used the deficits in these boxed areas to develop a least cost programme for each scenario. Three of these least cost programmes are presented in 'Adaptation pathways'. Options are sequenced in order of priority for implementation. The length of the bar in each pathway shows the cumulative amount of water provided by the options and illustrates how much of the deficit they close. Leakage, ELRED and Northern River New are selected under all scenarios. After this, the mix of options to close larger deficits varies with the climate scenario and time period used in planning, illustrating that this is a key decision point.

The modelling showed that considering a range of climate uncertainty affects the:

- size of the potential gap between supply and demand. For instance the size of the deficit driven by climate change alone varies by about 25% in the 2050s depending on the emissions scenario used; and
- cost-effectiveness of the reservoir as the differences between water available in dry years compared to wet years varies by up to 30%.[37]

These variations influence the investment plans developed for each scenario:[38]

- Some options were robust to climate uncertainty and selected in each scenario modelled in the project. These included small resource schemes, leakage reduction and targeted metering.
- Long-term asset options were sensitive to different climate scenarios – for instance, the reservoir option would require larger capacity in the high scenarios for both the 2050s and 2080s. It should be noted that the outputs are theoretical and based on limited data analysis.

35 Atkins (2011) commissioned by the Adaptation Sub-Committee.
36 This study was only able to quantitatively assess the reservoir option against the climate scenarios. We were unable to assess the inter-basin transfer option (Severn-Thames Transfer). Other supply options, such as desalination, because they were shown to be relatively insensitive to climate.
37 The variation is driven by uncertainty over the level of future rainfall within a given emissions scenario rather than differences between emissions scenarios.
The climate sensitivity of other options was not quantitatively assessed. The water transfer is likely to be sensitive to climate change, but it was not possible to assess this within the constraints of the study. The effect of climate change on the other options was not considered to significantly affect the overall investment programme.
38 Options were selected using a precautionary approach that focuses planning on the dry end of scenarios, which is consistent with current industry guidance.

4.5 Are there barriers to adaptation?

A barrier that we identified is the relatively narrow consideration of climate uncertainty in water resources investment planning. Future price reviews will need to deal with uncertainty over climate change when deciding whether or not to fund investment. Making fuller use of the climate projections using risk-based approaches to decision-making will allow decision-makers to ensure their long-term planning is resilient to future climate change. This approach will improve transparency for regulators and consumers.

There are additional barriers to adaptation in the current abstraction regime. It does not adequately reflect the environmental costs of abstraction and there is insufficient flexibility for abstractors to respond to changes in water availability.

- **The signals to encourage abstractors to use water from areas of relative surplus compared to relative scarcity are weak**. Abstraction licence charges are mainly limited to recovery of the administrative costs of the scheme. There are mechanisms to limit the environmental risks of abstraction. For instance, 'hands-off flows'[39] can be used to constrain water use during vulnerable periods in some instances. But these safe-guards are not always in place. This lack of incentive also results in demand management measures having a lower priority in water resource planning decisions.
- **Under current mechanisms it is difficult to modify licences to be more responsive to environmental pressures and risk**. Around 80% of current abstraction licences are not time-limited. While licences are being modified through the Restoring Sustainable Abstraction programme, this is a costly and time consuming process.

4.6 Conclusions

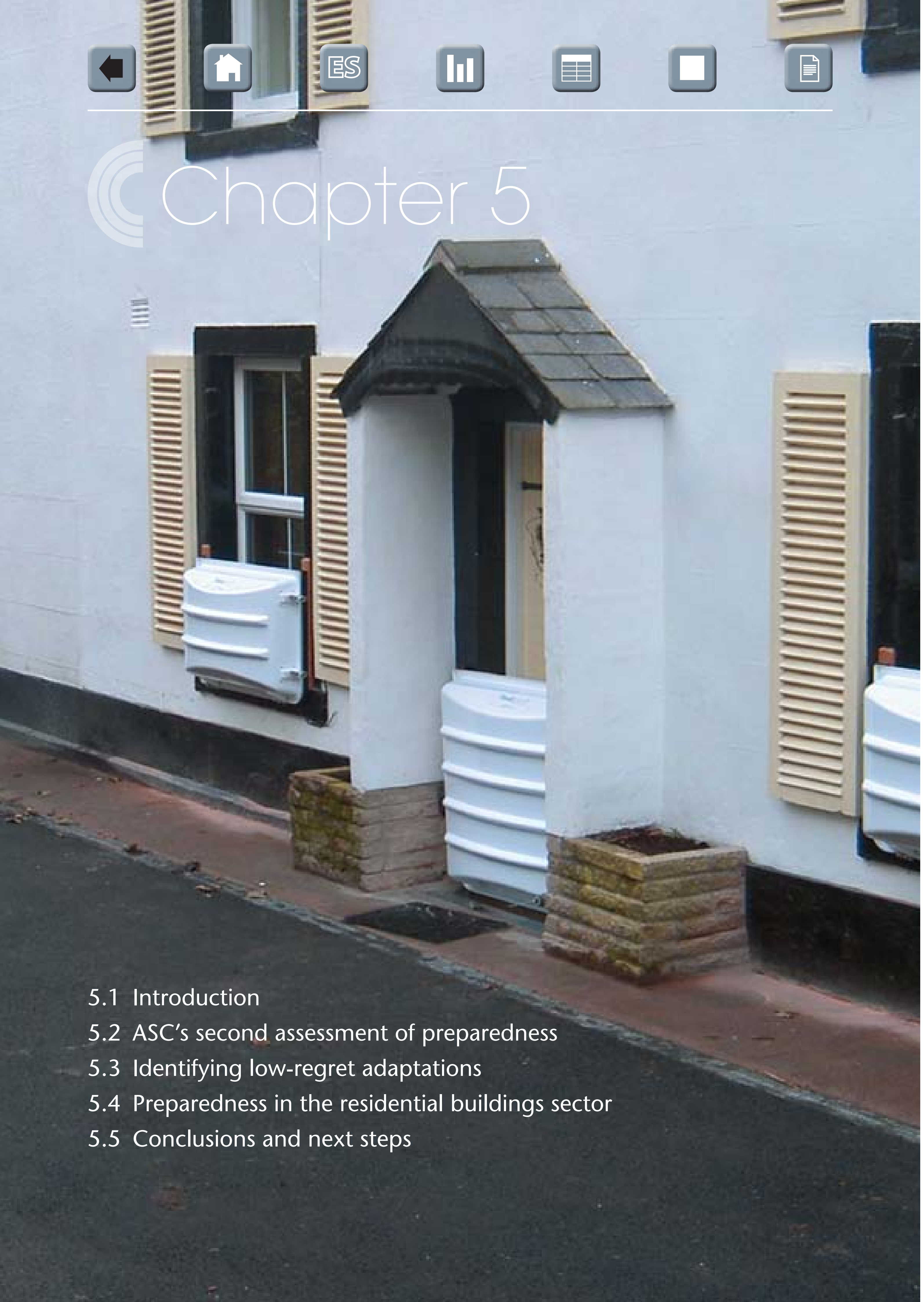
This chapter has demonstrated that the water sector has been successful in providing a reliable supply of water to consumers to date, although at an environmental cost. In future, pressures on water supply and freshwater ecosystems are likely to increase due to climate and non-climate drivers. To secure supplies and improve environmental performance key priorities include:

- low-regret demand management measures implemented to reduce pressures on supply where this is cost effective;
- a full range of long-term climate uncertainty considered in water resource planning in order to build the business case for low-regret measures and assist robust decision-making on investments in long-lived assets; and

39 Conditions on licences that require abstraction to stop or be reduced when a river flow or level falls below a specified point.

- greater flexibility introduced to the abstraction regime so that it reflects the environmental costs of abstraction and is responsive to changes in water availability (through space and time).

The Water White Paper and revisions to the guidance governing water company investment planning provide opportunities to set out steps to reform the abstraction regime; and the economic regulation of water companies, to enable more proportionate adaptation in the sector.



Chapter 5

Chapter 5
Designing and renovating buildings

Chapter summary

Buildings are a priority area for adaptation, because decisions concerning the design, construction and renovation of buildings are long lasting and may be costly to reverse. Buildings are already vulnerable to current climate risks such as flooding, storms, overheating and subsidence. Plumbing, domestic appliances and the behaviour of occupants influence water demand – a priority target for adaptation (Chapter 4). In the future, rising temperatures may make buildings more uncomfortable, and more extreme weather events such as flooding may expose occupants to greater risk unless action is taken.

The risk and severity of climate impacts are context specific. The risks of flooding and coastal erosion depend on the location of properties, while risks of extreme temperatures are worse in city centres than in rural areas because of the urban heat island effect. Adaptation measures for managing these risks can be implemented at various spatial scales, from individual buildings, to wider neighbourhoods or the catchment scale.

Our analysis has identified a range of cost-effective, low-regret investments that can be implemented to manage overheating and flooding and help conserve water in new and existing homes in appropriate locations:

- A number of end-of-life upgrade measures to promote water efficiency, including low-flow and click-lock taps, low-flow toilets and low-flow showers, could be installed in existing homes at zero additional cost over the lifetime of the equipment. If implemented in full, these could reduce water use by around one-third.
- A package of measures to reduce the damages from flooding would require investment of between £500 – £2,500 per home. The package includes airbrick covers, door-guards, repointing of walls, drainage bungs or non-return valves.
- A number of low-cost measures to reduce overheating in existing homes, improve comfort levels for occupants and avoid the need to invest in alternative cooling measures, such as air-conditioning. These include energy-efficient appliances to reduce waste heat and increased window shading.
- A similar range of cost-effective measures for new homes can be implemented at the design and construction stage. However because the proportion of new homes in overall housing stock is relatively low, the total benefits to society are modest.

From our sampling of local authority development applications, we found some evidence of the uptake of these low-regret adaptation actions in new homes (see Chapter 3). However, we found less evidence on the uptake of low-regret measures in existing homes.

New policy approaches are required to promote the wider uptake of low-regret measures across the housing stock. These should address existing barriers to action including weak incentives, lack of information, lack of access to finance and hidden costs. Existing building-related initiatives such as the Green Deal and the Code for Sustainable Homes may provide opportunities to promote adaptation across the buildings sector.

5.1 Introduction

In our first report we identified buildings as a priority area for adaptation where there is both a need and an opportunity for early action. This chapter offers insights into the sector's preparedness, in terms of the uptake of low-regret adaptation measures. It also introduces a way of identifying and presenting cost-effective adaptation measures.

Climate risks and buildings

Buildings are already susceptible to climate risks today. As set out in Chapter 2, buildings are one of the main pathways through which the costs of today's weather are felt. Average insured losses from damage to property and business disruption from flooding, storms and subsidence are around £1.5 billion each year.[1] The Environment Agency estimate that 1 in 6 properties across the UK are at risk from flooding.

Buildings and urban form also influence how people experience climate variability. For example, during the 2003 and 2006 heatwaves night-time temperatures in London were 6-9°C higher than those recorded for surrounding rural locations, because of the urban heat island effect.[2] Currently, temperatures in London buildings are above the comfort threshold (26°C) for around 5% of the year (18 days).

Similarly, building occupants consume the majority of water and energy supplied by utility companies. Households and business premises use 60% of all water abstracted. Usage varies with prevailing weather conditions. For example, according to estimates from one water company, water use can increase from an average of around 160 litres of water per day to almost 200 litres per day when temperatures reach 20°C.[3]

The location, design and fabric of new buildings will influence their vulnerability to future climate change (see Chapter 2). In the future climate change is projected to make water more scarce in many populated catchments (see Chapter 4). Rising temperatures may make buildings uncomfortable for occupants and more frequent and severe weather events such as flooding may expose occupants to greater risk unless action is taken. These risks are a concern both for new buildings and the existing housing stock. Around 70% of homes that will exist in 2050 have already been built.[4] Both current and future climate conditions should therefore be considered in the design and renovation of buildings.

ASC's first assessment of preparedness

Our first report provided a qualitative assessment of the state of preparedness of the buildings sector in the UK, and identified the design and renovation of buildings as a priority area for adaptation. This is because building decisions can affect climate vulnerability over the long term, given their long lifetimes, and because there is scope to reduce that vulnerability through low-regret measures that would yield benefits today.

1 Association of British Insurers data more details in Chapter 3.
2 London Climate Change Partnership (2011).
3 UK Climate Change Risk Assessment, to be published in January 2012.
4 Three Regions Climate Change Group (2008), based on a replacement rate of around 1% per year.

We found evidence that the building sector in the UK has started to build adaptive capacity and taken some action:

- The Department for Communities and Local Government (CLG) reported a relatively high level of capacity to assess and manage the risks from climate change.[5] In May 2010, CLG initiated a new project under the cross-Government Adapting to Climate Change programme, to raise awareness of the implications of the changing climate for the built environment and to promote action.
- The Code for Sustainable Homes guides the industry in the design and construction of sustainable homes for the future. Aspects relevant to climate change adaptation include minimum standards for energy and water use, and a requirement for sustainable urban drainage in larger social housing developments.
- Defra has provided £5.6 million to fund the installation of flood resistance measures in high risk homes – focussed on keeping water out of properties.[6]

Generally action in this sector has tended to focus on new homes. There may be unexploited potential to improve the resilience of the existing housing stock.

5.2 ASC's second assessment of preparedness

For our second report we have undertaken an in-depth and quantitative assessment of preparedness in the residential buildings sector. We have evaluated a range of measures (see Box 5.1 for our approach and Appendix 5.1 for a full list of measures) to identify the low-regret options available in this sector. These include the way in which new buildings are planned (discussed in Chapter 3) and constructed, but also the methods, materials and equipment used to renovate existing buildings. Low-regret measures are cost-effective to implement today, provide benefits that are less sensitive to precise projections about the future climate, and potentially offer co-benefits or no hard trade-offs with other policy objectives.

We have only considered property-level measures that would be implemented by householders and developers. We did not consider measures beyond the individual house scale, including where local authorities and national agencies have responsibility, such as community-scale sustainable drainage systems and flood defence infrastructure.

Our analysis is based on two regions, selected to represent the major climate risks facing the residential buildings sector: the South East for water stress and heat stress, and the Aire catchment in Yorkshire and Humber for flooding.

5 National Audit Office (2009).
6 Department for Environment, Food and Rural Affairs (2010).

Box 5.1 Identifying low-regret adaptation measures using adaptation cost curves

Low-regret options can be identified through standard appraisal techniques such as cost-benefit, cost-effectiveness and multi-criteria analysis. However, doing so involves considering and comparing a large number of potential options. We chose adaptation costs curves as a way of handling this complexity, and synthesising and presenting the available information.

Given its context-specific nature, adaptation is less amenable to a cost curve approach than mitigation, where it is a standard technique. There are challenges associated with developing adaptation cost curves, notably:

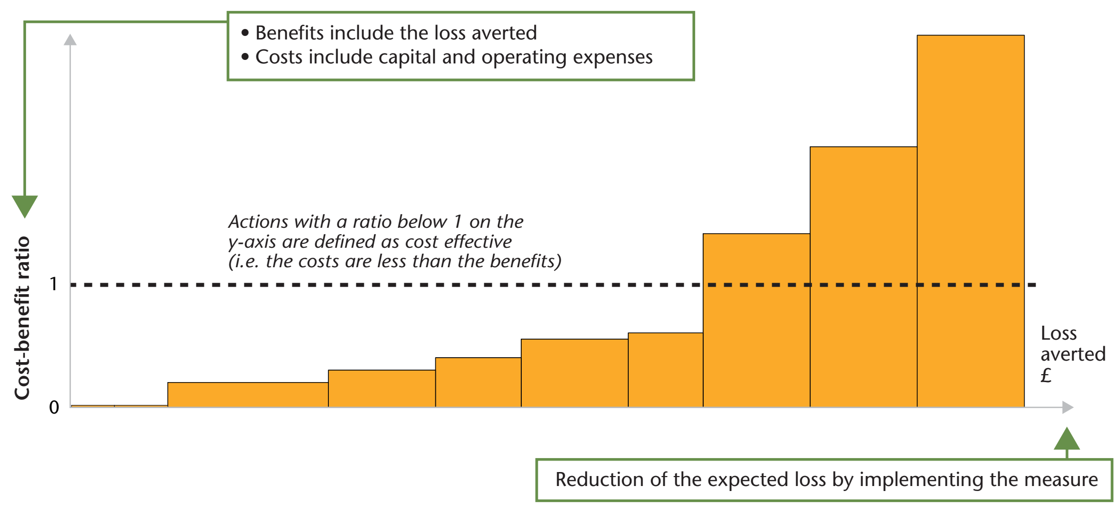
- dealing with the uncertainty surrounding the future impacts of climate change;
- calculating a monetary value for the loss averted, that is the benefit from adaptation; and
- scaling up local cost curves to the national level, given that adaptation is a local response to a local impact.

However, by making some amendments to the methodology, it is possible to use cost curves to compare a range of adaptation measures available to the residential buildings sector (Figure 5.1). Specifically, we commissioned work to identify:[7]

- low-regret measures: namely, the options that perform well against a range of climate scenarios and have a cost-benefit ratio of less than one today; and
- the benefit of individual measures: the width of individual bars on the curve relates to the amount of damages avoided. Options that are complementary and apply to different parts of the house or housing stock can be combined together to calculate total damage avoided (for example measures that apply to new build and those that apply to the existing stock). For options that are substitutes (such as different types of shower fittings), the width of the bars should be used to compare their relative benefits. However they should not be added together.

To identify the low-regret measures that we would expect to see being implemented across the UK we have developed a societal cost curve, which presents the costs and benefits of each option from a UK (rather than a household) perspective. The resulting curves set out the technical potential of action, which is the total damage that could be averted at the sites we have studied, if all measures were implemented in full to the existing housing stock and to new buildings. Household cost curves were calculated to compare socially desirable measures with the individually beneficial measures. Table 5.1 sets out the main technical challenges and the key assumptions underpinning our method.

Figure 5.1: Conceptual adaptation cost curve framework[8]



Source: Economics of Climate Adaptation Working Group (2009)

7 Davis Langdon (AECOM) (2011) commissioned by the Adaptation Sub-Committee.
8 Economics of Climate Adaptation Working Group (2009).

Table 5.1: Analytical method and key assumptions underpinning the adaptation cost curves

Key Assumptions	Risks		
	Water stress	**Flooding**	**Overheating**
Implementation of measures	**New build:** measures installed at the point of construction. The cost incurred is the **additional cost** of implementing the adaptation measure. The measures are applied to every new home expected to be built in a particular year. **Repair/end-of-life replacement:** measures introduced at either the point of repair (e.g. after a flood) or as an upgrade when the existing fixtures need replacing (e.g. replacing normal taps with water-efficient taps as part of wider renovation work). These measures are applied to a proportion of the existing housing stock in a particular year based on the expected replacement rate for each fixture. For example, if the expected life is 10 years, it would apply to 10% of the existing housing stock every year. **Retrofit:** measures introduced as either a deliberate replacement for existing fittings (e.g. installing a more water-efficient washing machine) or as additional fixtures (e.g. flood-resilient door-guards). The measures are applied to every relevant house of the existing housing stock.		
Stock of housing	3.2 million existing households in the South East of England (excluding London). 32,700 new houses built every year.	6,500 households at risk in the Aire catchment from a 1-in-100 year fluvial flood. Assumed 200 new builds are added to the 1-in-100 year flood risk zone every year. This is 10% of the total homes built in the Aire Catchment, based on national average (see Chapter 3 for further details).	3.2 million existing households in the South East of England (excluding London). 32,700 new houses built every year.
Context specific nature of adaptation	The opportunity cost of water is represented by the long-run marginal cost of water (LRMC). This is the cost to water companies to supply water. By reducing demand at a household level, the need to increase total supply is reduced. To obtain a value for the whole of the South East we calculated a "weighted average" across the water companies in our study area: £0.56/m³. This sits just above the middle of the national distribution; the median is £0.47/m³.	Examined properties at different levels of flood risk (1-in-20 year, 1-in-75 year, 1-in-100 year, 1-in-200 year and 1-in-1000 year events) and different depths of flooding (shallow: up to 5cm, deep 5cm to 1m). Identified options that were robust across different flood events.	The test location of Reading has been extrapolated to the rest of the South East.

Table 5.1: Analytical method and key assumptions underpinning the adaptation cost curves

Key Assumptions	Risks		
	Water stress	**Flooding**	**Overheating**
Dealing with climate scenarios	Ideally climate change would be reflected in future changes to the LRMC. However it was not possible to find future estimates of the LRMC and therefore this analysis used only one LRMC estimate. It could of course be extended once climate impacts on LRMC are derived.	The Environment Agency has modelled the impact of climate change as an increase in river flows of 20% – this is incorporated into the Aire Catchment Flood Management Plan to provide figures for the increase in homes at risk.	We used different scenarios to model the impact of climate change on internal room temperatures. The University of Exeter Prometheus project models the impact of different climate change scenarios on external temperatures on a reference location in the South East (Reading). These findings were then inputted into the AECOM building model to generate the impact on internal temperatures of buildings.
Monetising loss averted to the household. Wider public costs and benefits not calculated unless stated otherwise. All benefits discounted at the social discount rate.	Calculated by taking the LRMC of water multiplied by the quantity of water saved. This provides an estimate of the opportunity cost of water – the value of the water that does not needed to be abstracted.	Estimated the expected damage minus the expected residual damage (both integrated over a range of return periods). This will typically be damages to the building fabric and household contents.	Calculated as the avoided cost of air-conditioning (a/c). This comprises the capital cost of a/c plus the LRMC of electricity for running a/c for overheating hours (LRMC of electricity valued using the CCC estimates).
y axis – calculating the cost-benefit ratios – figures are discounted to 2011, (net present values). Societal curves use the social discount rate (3.5% for 0-30 years and 3% for 31 years onwards). Household curves use a private discount rate of 8%.	For the **societal** curve – capital cost plus maintenance cost of the measure divided by the value of water saved to society (LRMC multiplied by volume of water saved). For the **household** curve – capital cost plus maintenance cost divided by the value of water saved to the household (the metered price of water multiplied by volume of water saved).	For the **societal** curve – capital cost and maintenance cost of the adaptation measure divided by the loss averted (value of avoided damages minus any residual damages). For the **household** curve – assumed that all the benefits of damages avoided accrue to the householder. This assumption is discussed in greater detail in Section 5.4.	For the **societal** curve – capital cost and maintenance cost of the adaptation measure divided by the avoided cost of a/c equipment (capital cost plus the LRMC of electricity). For the **household** curve – capital and maintenance cost of the adaptation measure divided by the avoided cost of a/c equipment (capital and maintenance costs plus electricity cost to the householder).

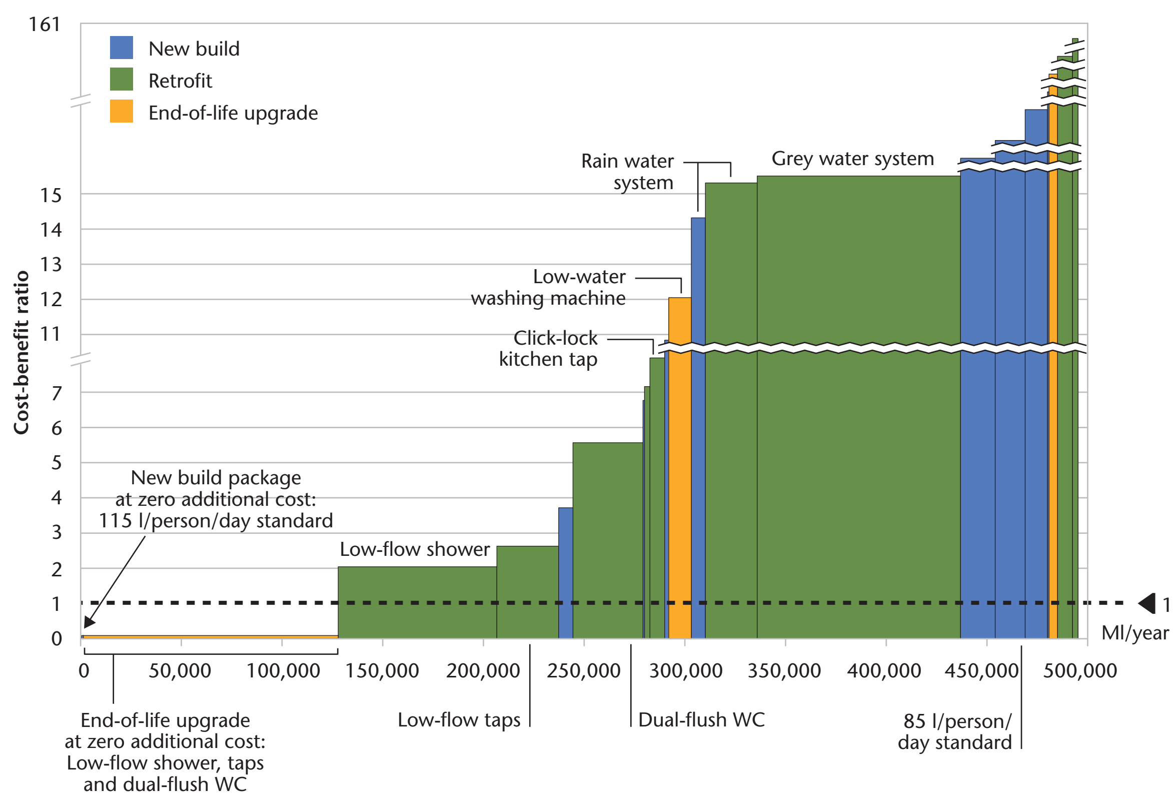
5.3 Identifying low-regret adaptations

Water Stress

We identified a number of low-regret adaptation options to improve water efficiency of both existing and new homes. These improvements can be achieved at a much lower cost as part of an end-of-life upgrade, or at the new-build stage than is incurred when retrofitting to existing buildings. The cost curve (Figure 5.2) for the South East shows that there are a number of end-of-life upgrade measures including low-flow taps, click-lock kitchen taps, dual-flush WCs and low-flow showers that could be installed at zero additional cost to homes over the lifetime of the equipment.

- By 2026, if all existing homes in the South East installed the package of end-of-life measures, average per capita consumption in the South East, could fall from the current level of 160 litres per person per day to around 115 litres per person per day. This could potentially save around 120,000 million litres of water a year. This would have a 15-year accumulated value of around £610 million (net present value discounted to 2011).

Figure 5.2: Water efficiency measures for South East of England – societal cost curve showing technical potential in 2026, millions of litres per year (Ml/year)



Source: Davis Langdon (AECOM) (2011) commissioned by the Adaptation Sub-Committee.

- The water efficiency standard for new builds is currently 125 litres per person per day.[9] Our analysis shows that a lower water efficiency standard of 115 litres per person per day could be achieved at zero additional cost, saving around 4,000 million litres per year by 2026. This would have an accumulated 15-year value of around £20 million (net present value discounted to 2011).

The results are consistent with a recent study[10] which found that similar savings could be achieved (6,000 million litres per year for new buildings and 120,000 million litres per year for retrofitting the existing stock). These estimates are based on a top-down assessment of potential savings whereas our analysis is based on a bottom-up assessment of the savings from individual water-efficient technologies.

Our estimates of the value of potential water savings are conservative, as we have used the current long-run marginal cost (LRMC) of water to estimate the costs and benefits of each adaptation measure. In the future the changing climate and other pressures are likely to place an increasing strain on the system. Water companies may have to invest in infrastructure to meet the future demand for water resulting in a higher LRMC. In turn the higher the LRMC, the greater the benefits of action, as benefits are valued by multiplying the LRMC of water by volume of water saved.

We found that all measures identified as being beneficial for society were also beneficial for householders. We analysed these measures from the perspective of metered households in the region, using a higher discount rate to reflect the time preference of private individuals and the metered price of water to value the savings to the households. The savings to householders, through lower water bills, outweigh any additional costs associated with fitting the water-efficient measures. Presently only 34% of properties in the South East have a water meter.

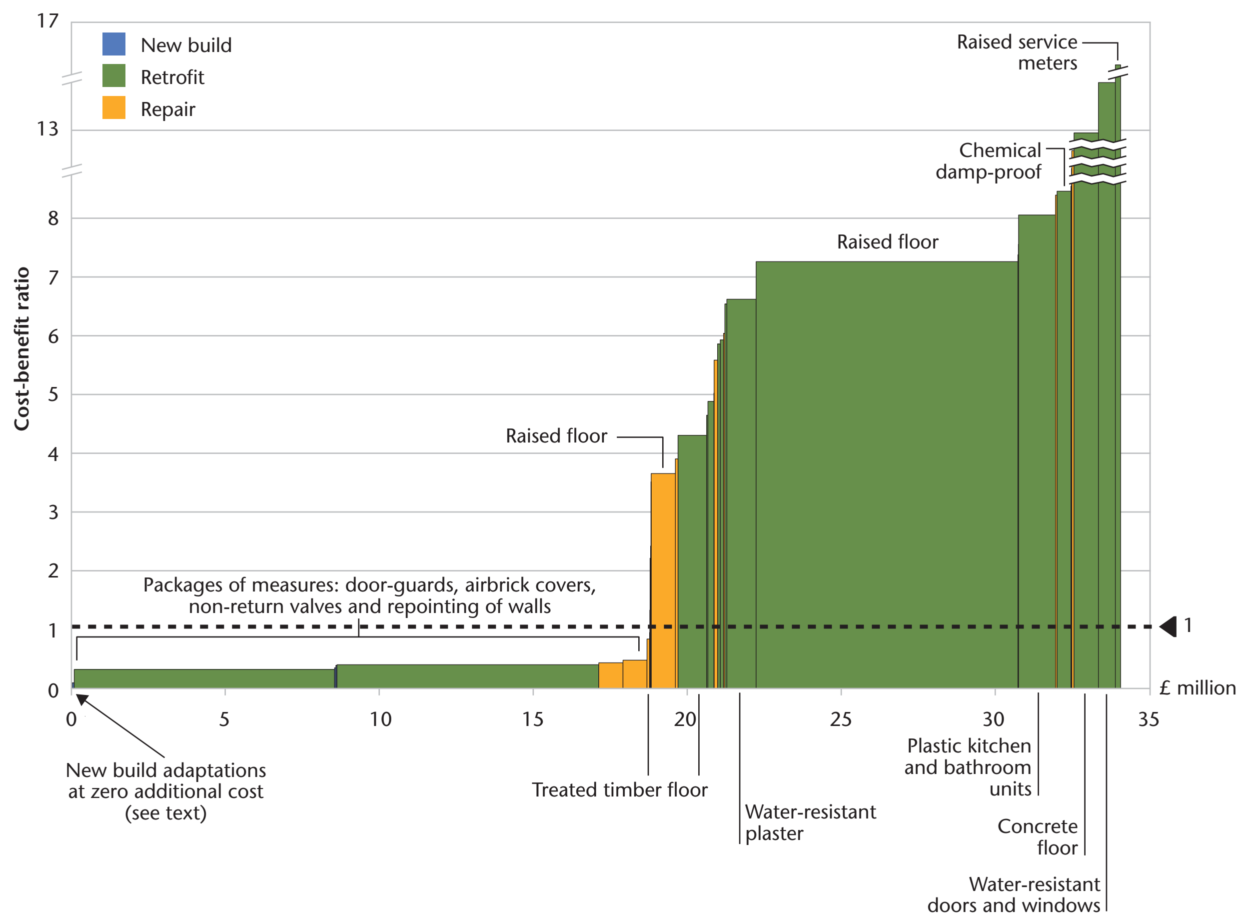
The package of low-regret adaptations that we have identified for delivering water efficiency savings in the South East are also likely to deliver savings in other parts of the country, particularly in areas of severe water stress. However, our cost estimates may ignore the presence of hidden costs associated with fitting water-efficient appliances, such as the inconvenience of searching for water-efficient fittings, as well as potential training costs for plumbers. While these would affect the cost-effectiveness of measures, it has not been possible to value them as part of this initial study.

Flooding

We identified a number of low-regret adaptation options to protect both existing and new homes from flood damage in the Aire catchment in Yorkshire and Humber (Figure 5.3). There are packages of reasonably low-cost measures (£500 to £2,500 per property) that avoid significant damages from up to one metre of flooding. These include airbrick covers, door-guards, repointing external walls up to a height of one metre, main sewer non-return valves, drainage bungs and toilet pan seals.

9 This includes a 5 litres per person per day allowance for external use. This standard does not represent actual water use.
10 Environment Agency (2010b).

Figure 5.3: Flood resilient and resistant measures for Aire Catchment, 1-in-100 year shallow flood – societal cost curve showing technical potential 2011 to 2026, damages avoided (£ million)



Source: Davis Langdon (AECOM) (2011) commissioned by the Adaptation Sub-Committee.

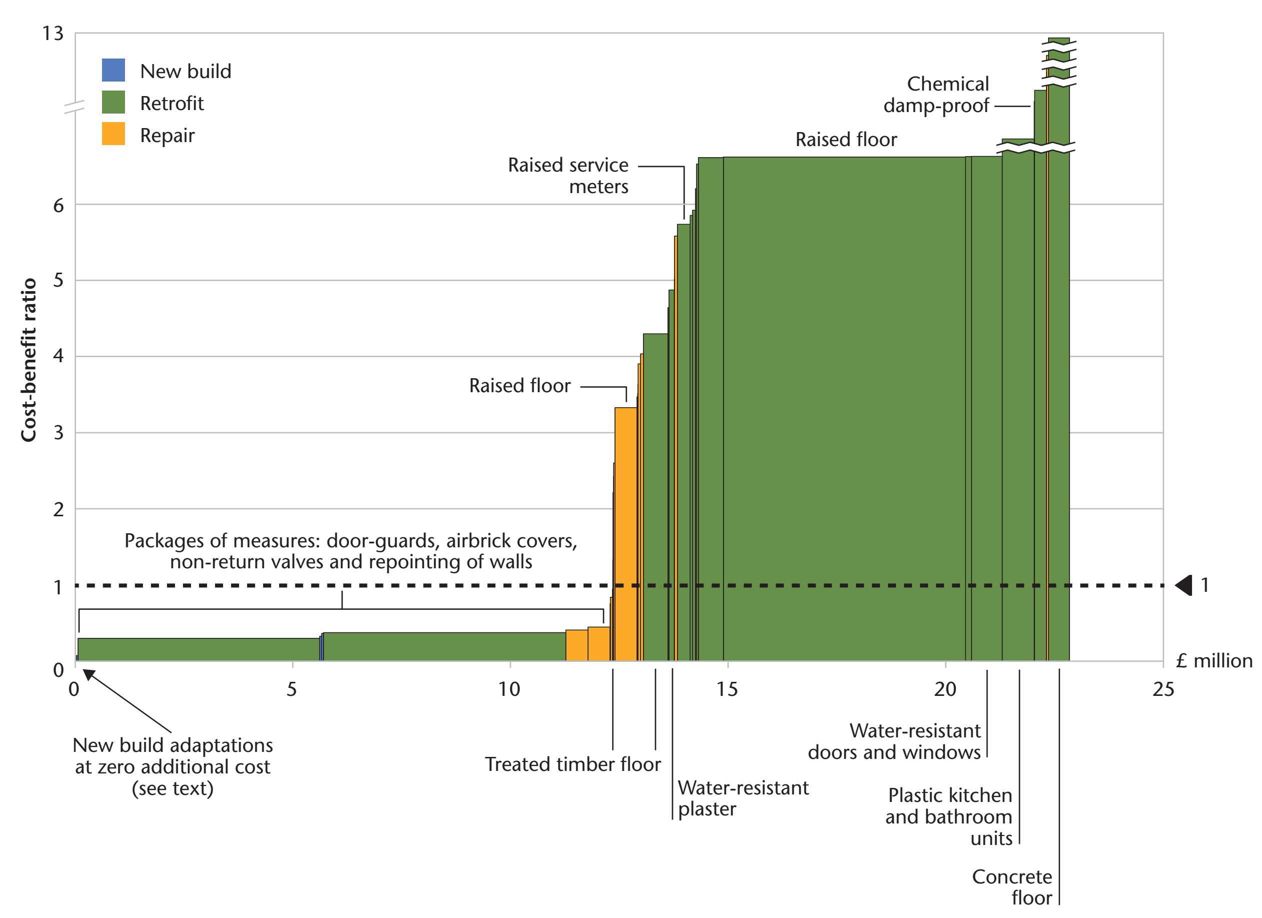
If these options are fitted as a retrofit measure in year one, rather than as part of the repair work (e.g. after a flood), they save more damages from flooding. If all 4,000 existing homes in the Aire catchment at risk from a 1-in-100 year shallow flood installed a low-regret package of measures, they would avoid damages of £9 million over 15 years (discounted to present day). This falls to £1 million if the measures are fitted as part of a repair after a flood. The cost-benefit ratios for retrofit and repair are similar. While it is less costly for households to install measures as part of a repair following a flood, the benefits are less as they would have failed to avoid the damages of the flood. This indicates there is a clear economic case for adapting early in this catchment.

In addition, we found a number of zero additional cost measures that can be incorporated at the new-build stage for properties at a 1-in-100 year flood risk level. These include installing a chemical damp-proof course, moving the washing machine to the first floor, raising the service meters, wall-mounting the boiler and raising the oven.

We analysed these findings from the household perspective using a higher discount rate, as well as at different flood probabilities and for deep and shallow floods (see Figure 5.4 for 1-in-100 year deep flood). The package of measures is robust in all cases, up to and including a flood risk level of 1-in-200 year event and for deep and shallow floods. Figure 5.4 shows the cost curve for the 2,500 homes in Aire currently at risk from a 1-in-100 year deep flood event.

Our findings are broadly in line with a recent study examining the cost-effectiveness of measures to reduce the vulnerability of existing properties to flooding.[11] The study identified a similar range of cost-effective measures, although they were only found to be cost-effective for properties up to a risk level of 1-in-50 year flood event rather than a 1-in-200 year event. It will be important to examine the assumptions to both studies to understand why these differences arise.

Figure 5.4: Flood resilient and resistant measures for Aire Catchment, 1-in-100 year deep flood – societal cost-curve showing technical potential 2011 to 2026, damages avoided (£ million)



Source: Davis Langdon (AECOM) (2011) commissioned by the Adaptation Sub-Committee.

11 Department for Environment, Food and Rural Affairs and Environment Agency (2008).

It is difficult to generalise the results and to say with certainty if these measures are cost-effective beyond the Aire catchment. Climate risks are context-specific, especially flooding where the risk and severity of the impact will be specific to a locality. This is a key constraint that needs to be overcome to scale up the cost curve or apply it to different locations in the UK (see next steps section for further discussion). Furthermore, community-scale flood defences might be more cost-effective than property-level measures.

Heat stress

We have identified a number of low-regret adaptation measures to reduce overheating in buildings, improve comfort levels for occupants and avoid the need to invest in alternative cooling measures, such as air-conditioning in the South East (Figure 5.5). They include energy-efficient appliances to reduce waste heat, and increasing shading through use of curtains and tinted window film. These measures are cost-effective when installed at both the new-build stage and as part of a retrofit. In addition improving roof albedo (white roofs) and installing shutters are also cost-effective for new builds.

Our analysis suggests that if air-conditioning was used instead of these low-regret passive cooling measures in both existing and new homes, it would cost society around £2 billion and £400 million respectively, over 15 years given projected future electricity prices.[12]

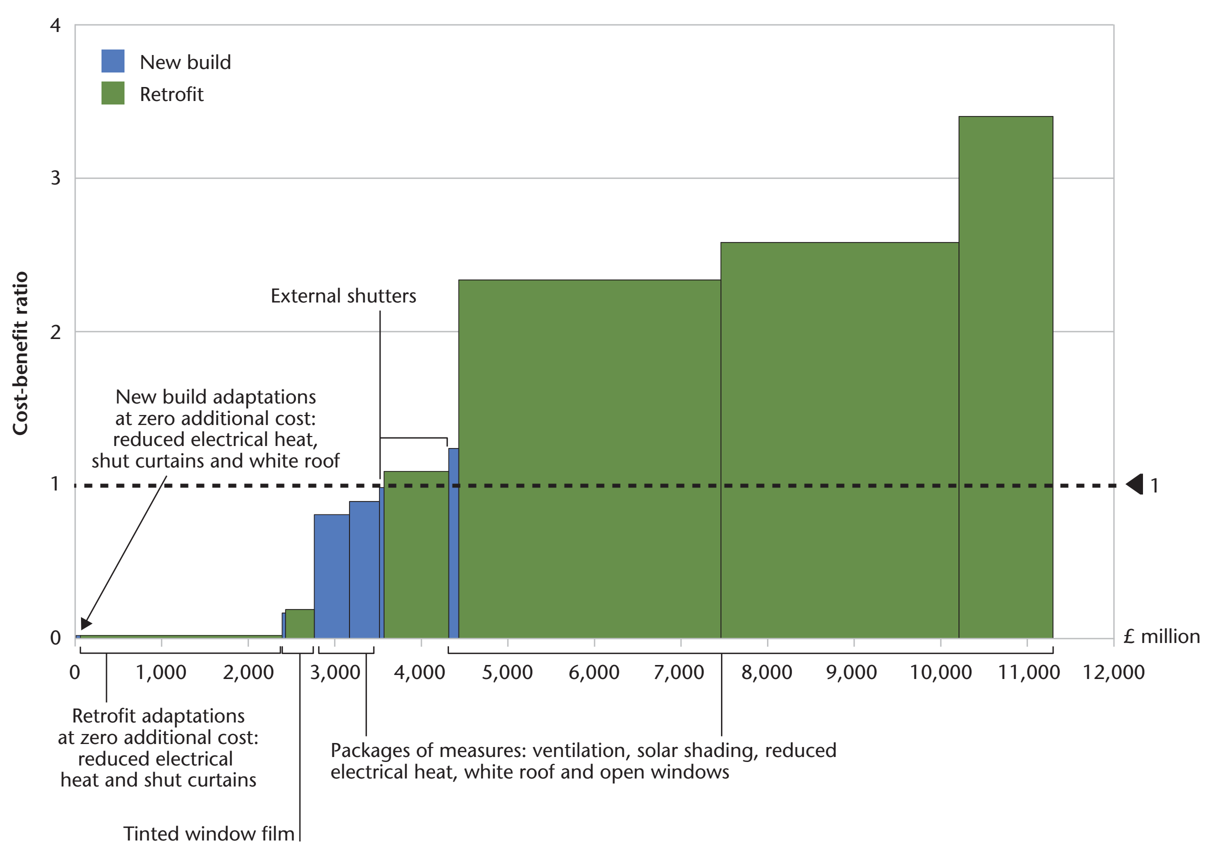
We analysed these findings from the household perspective with a higher discount rate and current and future retail electricity prices. We found that all measures identified as being beneficial for society were also beneficial for householders. This reflects the fact that the LRMC of electricity is less than the retail price of electricity (9.6 pence per kWh versus 14 pence per kWh), which more than compensates for the higher discount rate of private individuals.

The package of low-regret adaptation options we have identified for reducing the impact of overheating in the South East may also deliver savings to other parts of the country, particularly in areas of heat stress. However, our model is built on Reading as a test location and further analysis will have to be undertaken to determine the suitability of these options to other locations.

Other factors will influence the cost-effectiveness of our measures. For instance our cost estimates do not include hidden costs associated with fitting passive cooling appliances, such as the time costs of searching for fittings. On the other hand there are additional benefits to some of these measures that have not been included in our analysis. For example energy efficient appliances will reduce electricity consumption and carbon emissions. Both these factors could be important, but it has not been possible to value these as part of this initial study.

12 This figure includes the full capital costs of air-conditioning equipment, future electricity prices are based on CCC modelling.

Figure 5.5: Passive cooling measures for the South East of England – societal cost curve showing technical potential 2011 to 2026, cost of avoided air-conditioning (£ million)



Source: Davis Langdon (AECOM) (2011) commissioned by the Adaptation Sub-Committee.

5.4 Preparedness in the residential buildings sector

As we observed in our first report, the Government has taken some action to address the climate risks facing the residential buildings sector. Generally action in this sector has tended to focus on new developments, suggesting there may be unexploited potential to improve the resilience of the existing housing stock. For both new and existing homes, we have identified a range of low-regret measures that households could install to reduce their vulnerability to both the current and future climate. Policy, regulation and incentives may help to encourage their full uptake.

Uptake of low-regret measures – new homes

Uptake of low-regret measures in new homes has largely been driven by building regulations and growing awareness among planners of the risks from climate change (more details in Chapter 3).

- Part G of the Building Regulations recently introduced a new 125 litres per person per day minimum water consumption standard in new homes through the installation of more water efficient fixtures and fittings. Part L requires builders to consider heat gain and loss.
- The Government has provided guidance on the types of materials to use on flood prone areas.[13]
- Ofwat has introduced new water efficiency targets for water companies. These targets are met through activities that promote water efficiency for both households and non-households.[14]
- The Code for Sustainable Homes sets voluntary standards, which have been adopted for the development of new social housing. Climate change aspects include minimum standards for energy and water use, and a requirement for sustainable drainage in larger social housing developments.

We have found some evidence of the uptake of low-regret adaptation actions in new builds from our sampling of local authority development applications (more details in Chapter 3).

- Nearly all (96%) of the sampled development applications in areas at risk of flooding and around half (55%) of development applications at risk of surface water flooding included at least one measure to manage flood risk, including raised floor levels, resilient building materials or surface water run-off measures.[15]
- In one London Borough sampled (Islington), we found relatively widespread take-up (70%) of some water saving measures. Just over a quarter (28%) of development sampled in the borough included design measures to reduce internal heat gain, such as enhancing natural ventilation and awnings/screens to protect rooms from the sun.

Uptake of low-regret measures – existing homes

In contrast, we found limited evidence on the uptake of adaptation measures in existing homes, in part because there is less regulation. Retrofit, replacement and repair include both self-installation and professional installation. As such without better information on sales or production data, it is difficult to estimate the take-up of low-regret measures by householders outside of existing Government programmes.

13 Department of Communities and Local Government (2007).
14 Ofwat (2009a).
15 Applies to major development applications received 2001-2011.

This is especially the case with measures to reduce the risk of heat stress. We found only anecdotal evidence of action to retrofit existing homes with passive cooling measures, or even air-conditioning. Since 2000 an estimated 360,000 air conditioning units have been sold for domestic purposes across the UK.[16] In London 5% of all domestic conservatories are air-conditioned.[17] Generally, policy responses to heat stress have tended to focus on emergency planning and the response to heatwaves, for example the Government's National Heatwave Plan.

Information on the installation of low-regret water efficiency measures largely comes from the water companies via their water efficiency programmes.

- A recent study estimates that only 1% of existing homes in the South East (35,000 properties) have been retrofitted with water efficient products by water companies.[18]
- Several water companies have run local water efficiency trials offering householders free water efficient fixtures such as low-flow shower heads, shower timers and tap inserts. A recent study found uptake rates ranged from between 6-22% for private housing while in social housing it was between 45-60%.[19]

Following the 2007 flood events and the publication of Sir Michael Pitt's Review there has been a renewed focus on improving the resilience of homes to flooding. The two main drivers behind uptake have been:

- **Government action – funding and regulation**
  - The £5 million Flood Protection Grant Scheme was announced as part of the Government's response to the Pitt Review of the 2007 floods. In the first round of funding, £3 million was made available to 25 local authorities to protect up to 600 properties across England. This offers practical flood protection solutions, including airbrick covers and door-guards. In the second round a further 530 properties were allocated funding.
  - In 2011 the Environment Agency allocated £2.6 million through the Property Level Flood Protection Funding grant scheme, to help around 600 properties in areas with a high risk of flooding that do not benefit from community-level defences. One-third of the money is allocated to households in Yorkshire. The funding will be spent on products for individual properties such as flood barriers for doors or airbrick covers. These help to minimise the damage caused by flood water entering properties and greatly reduce the length of time needed to repair a building and its contents.
  - The Government has developed building standards to improve the flood resilience of buildings through improved design, construction methods and materials.

16 Central Air Conditioning Plant, Government Standards Evidence Base (2009) available at: http://efficient-products.defra.gov.uk/cms/product-strategies/subsector/air-conditioning [accessed June 2011].
17 Pathan et al. (2007).
18 Environment Agency (2010b).
19 Environment Agency (2009a).

- **Experience of a flood event**
  - 27% of households who had experienced a flood said that they had taken some measures to reduce the impact of future flooding, while only 6% of non-flooded households had taken some action.[20]
  - 55% of people living in flood risk areas across England knew they were at risk of flooding and of these three out of five had taken some action to prepare for flooding (approximately 1.7 million properties).[21] But in many cases this involved emergency planning measures, such as checking their insurance, signing-up to Floodline Warnings Direct, or knowing how to turn the electricity supply off, rather than proactive flood protection measures.[22]

Barriers and incentives to uptake

Householders and developers require the right incentives to act. We have found instances where there is either a lack of or misaligned incentives, both of which lead to an inefficient adaptation outcome.

- **Water stress:**
  - The water efficiency measures that we have found beneficial for society were also financially worthwhile for households with a water meter. At present only 34% of households are water metered (2009/10), both in the South East and nationally. Non-metered households do not realise the benefits of water efficiency through savings in their water bills, and therefore have little incentive to take action. In metered households, water use is on average 13% less than in un-metered households.
- **Flooding:**
  - Households will be more likely to take action early if there are clear financial incentives to do so, for example if they face a reduction in the costs of insurance, if they avoid uninsured and non-monetary losses (such as distress), or if their property increases in value as a result. However this is not often the case.[23]
  - For example, insurance companies will not typically pay for betterment to repair flood-damaged properties with resilient materials. They may reduce the excess for properties that install flood-resistant products, but rarely the premium, in part because they do not have good information about the impact of these measures in reducing residual risk.

20 Department for Environment, Food and Rural Affairs and Environment Agency (2008).
21 Figure taken from Environment Agency (2009a). Calculation based on 5.2 million properties at risk of flooding in 2009.
22 Environment Agency (2009a).
23 Department for Environment, Food and Rural Affairs and Environment Agency (2008).

– Investing in flood protection measures may sometimes reduce rather than increase the value of a property, as it singles out the property as being at flood risk and can affect the external appearance of the property.[24]

– Householders may not invest in property-level flood protection measures if there are already protected by neighbourhood or catchment-scale flood defences, or believe the Government will provide such protection in the future. Furthermore, while we have demonstrated that property-level measures are beneficial, by themselves they will not deal with all risks and could produce regrettable patterns of development, that require an ongoing commitment to flood defence.

In the case of new buildings, there is a misalignment of incentives between investors, developers and occupiers.[25] Investors and developers may not provide well-adapted buildings until occupiers demonstrate a demand for them. However, occupiers are unlikely to pay a premium for adaptation that incurs additional upfront costs. Similarly, tenants or owners that intend to sell the property within a relatively short-time frame are unlikely to invest in adaptation if the benefits will accrue to future occupiers, and cannot be recouped through the sale of the property in the case of home owners.

There may be financial barriers if the upfront costs of taking action are too high. Some householders may require grants, loans or other forms of financial support to help cover the upfront costs of adaptation measures. A number of previous research studies have shown that people on low incomes or who are elderly or disabled are particularly vulnerable to the consequences of major floods.[26] These are also the population groups that are less likely to be able to afford the upfront costs of flood protection measures.

In addition there could be hidden costs, which include the costs associated with finding the right product, sourcing reputable providers, time costs of disruption and the costs of differences in quality of the product and service. Many of these costs are related to the cost of acquiring and processing information, or finding a reputable professional who can fit and install them. These are real costs that affect the cost-effectiveness of measures, but they can be reduced, for example through providing appropriate information.

- 70% of people would like retailers to provide more help with choosing the greenest products. 65% expressed interest in water efficient taps and showers, but only 30% knew where to buy them.
- Flood protection measures are not straightforward to choose and install. Typically a householder will need a qualified flood surveyor to advise them on the right package of measures for their property and type of flood risk. Here there is a key role for professional bodies to provide householders with an accessible way to find a reputable professional.[27]

24 Harries (2008).
25 Kashyap et al. (2008).
26 McCarthy et al. (2007).
27 Department for Environment, Food and Rural Affairs and Environment Agency (2008).

While regulation has been effective in driving the take-up of low-regret measures in new homes, it can also be a barrier. Our analysis has shown that white roofs, due to their reflective properties, are a cost-effective measure for reducing overheating. However under the current planning system, householders must apply for permission to paint their roofs white (or a light colour), and authorisation may not be granted for listed properties, properties in conservation areas and where the action is deemed to not be within the character of the area.

5.5 Conclusions and next steps

In our study areas (the South East and the Aire catchment in Yorkshire and Humber), we have demonstrated that there is a range of low-regret measures that can be installed to reduce key climate risks facing the residential buildings sector, namely water stress, heat stress and flooding. More work is needed to test the wider applicability of these measures beyond the study areas, but our initial work suggests a substantial potential for low-cost adaptation across the UK that would yield early benefits.

The available evidence on the uptake of these low-regret measures suggest that some action is taking place in new buildings, but that there is scope for further action, particularly with respect to existing homes, which make up the bulk of the housing stock. There are a number of barriers that prevent the uptake of low-regret measures across the sector.

- Householders need sufficient incentives to take action, for example if they are water metered or if they receive a discount on their insurance premium if they install flood-protection products.
- Information on climate risks, options for managing risks and professional advice on the installation of measures need to be more readily available to reduce any hidden costs that householders and developers may incur.

Existing building-related initiatives such as the Green Deal and the Code for Sustainable Homes may provide opportunities to promote adaptation across the housing sector. For example, the Green Deal could offer an opportunity to improve the water efficiency of existing homes in addition to saving energy.

For new buildings, tighter regulations could provide stronger incentives for the uptake of low-regret measures. We found that a lower per person per day minimum water consumption standard could be achieved at zero additional cost in new buildings.

In the future, we will monitor the uptake of selected low-regret measures to assess how well the buildings sector is preparing for climate change. These indicators on adaptation options can complement the related indicators identified in Chapters 3 and 4 that track trends in impacts and vulnerability in the buildings sector.

The chapter also offers methodological lessons on how to analyse, compare and summarise low-regret adaptation measures. The adaptation cost curves used in this chapter offer an effective way of presenting adaptation information for particular sectors (such as buildings), areas (such as the Aire catchment) and climate risks (such as flooding).

More work is needed to test their suitability for a wider set of issues. There would be merit in exploring the feasibility of developing:

- adaptation cost curves that present what is realistically achievable given the technical potential calculated here;
- scaled-up cost curves that move from regional to national analysis; and
- cost curves for other climate risks.

Cost curves can be useful to study short-term low-regret adaptations. They may not be suitable for long-term adaptation planning, which requires a more complex process of decision-making under uncertainty, involving flexible measures and the risk of lock-in. In these instances other decision methods such as real-options analysis, multi-criteria analysis and expected value or utility analysis maybe more suitable for evaluating and comparing between adaptation measures.

Appendix 5.1 Adaptation measures analysed for reducing the vulnerability of buildings to current and future climate risks.[28]

Water Efficient measures analysed				
Measure	**Water saved per person (m^3/year)**	**Additional cost per household (£) – Retrofit**	**Additional cost per household (£) – End-of-life upgrade**	**Additional cost per household (£) – New build**
Dual-flush WC	4.6	£230 to £540	£0	n/a
Low-flow shower	1.3	£250 to £430	£0	n/a
Low-flow tap (pair)	4.9	£100 to £210	£0	n/a
Click-lock kitchen tap	4.9	£100	£0	n/a
Low-water washing machine	1.0	£490	£110	£100
Low-water dishwasher	0.4	£550	£150	£130
Water butt	0.4	£50	£0	£50
Low-volume, gravity rain water system	n/a	£1,000	£0	£900
Short-retention grey water system	11.4	£1,920 to £2,220	£0	£1,730 to £2,000
115 L/person/day standard*	13.9	n/a	n/a	£0
110 L/person/day standard*	15.7	n/a	n/a	£240 to £290
95 L/person/day standard*	21.2	n/a	n/a	£1,860 to £4,200
85 L/person/day standard*	24.8	n/a	n/a	£2,050 to £5,350
*Denotes a package of measures to achieve a particular water efficiency standard.				

28 Full list of measures are available in: Davis Langdon (AECOM) (2011), commissioned by Adaptation Sub-Committee.

Flood resistant and resilient measures analysed

Resistance measures, such as blocking up airbrick covers keep flood waters out while resilience measures such as fitting plastic kitchen and bathroom units ensure no lasting damage is done once the flood waters recede.

Measure	Additional cost per household (£) – Retrofit	Additional cost per household (£) – Repair	Additional cost per household (£) – New build
Replace sand-cement screeds on solid concrete slabs (with dense screed)	£500 to £1,000	£90 to £170	£80 to £150
Replace chipboard flooring with treated timber floorboards	£750 to £1,400	£390 to £730	£350 to £650
Replace floor including joists with treated timber to make it water	£2,840 to £5,070	£410 to £730	£370 to £660
Replace timber floor with solid concrete	£7,600 to £12,500	£5,170 to £8,160	£4,650 to £7,340
Raise floor above most likely flood level	£28,200 to £44,700	£11,000 to £18,350	£0
Replace mineral insulation within walls with closed cell insulation	£620 to £900	£240 to £390	£210 to £350
Replace gypsum plaster with water resistant material, such as lime	£6,250 to £8,200	£2,725 to £3,600	£2,450 to £3,240
Install chemical damp-proof course below joist level	£5,090 to £9,270	£2,660 to £4,930	£0
Replace doors, windows, frames with water-resistant alternatives	£8,110 to £15,010	£3,710 to £6,640	£3,340 to £5,970
Mount boilers on wall	£1,000	£150	£0
Move washing machine to first floor	£600	£200	£0
Replace ovens with raised, built-under type	£650 to £750	£200	£0
Move electrics well above likely flood level	£700 to £1,100	£250 to £500	£0
Move service meters well above likely flood level	£1,500	£500	£0
Replace chipboard kitchen/bathroom units with plastic units	£3,400 to £9,270	£1,650 to £4,930	£1,490 to £4,440
Flood resistant package, automatic	£900 to £2,660	£680 to £2,400	£670 to £1,860
Flood resistant package, manual	£510 to £2,280	£510 to £2,280	£510 to £1,730

Passive cooling measures analysed

Measure	Additional cost per household (£) – Retrofit	Additional cost per household (£) – New build
High thermal mass + night cooling by natural ventilation	£2,130 to £4,580	£680 to £1,530
External shutters	£1,000 to £1,200	£900 to £1,080
Internal curtains	£0	£0
Window film	£170 to £230	£150 to £210
Reduced internal gains	£0	£0
High thermal mass + night cooling by natural ventilation + solar shading + reduced internal gains + high roof albedo.	£2,130 to £4,580	£680 to £1,530
High roof albedo	n/a	£0
Whole house ventilation + high thermal mass + no window opening	£2,130 to £4,580	£680 to £1,530

Chapter 6

Chapter 6
Conclusions and next steps

Chapter summary

In this report, we have further developed our framework and applied it to selected priority areas in order to assess progress in the UK's preparedness. We conclude that the UK is near the limits of coping with the current climate in some sectors (such as water supply) and that vulnerability to climate change is potentially increasing as a result of patterns of development in some areas and demographic trends (ageing population).

There remains work to do in developing the framework before our first statutory report on progress. We will:

- continue to develop our indicator framework, and in doing so use it to assess preparedness in other priority areas; and
- provide advice on the Government's economic analysis of adaptation to inform the National Adaptation Programme, and review lessons for the next Climate Change Risk Assessment.

We advise the Government should ensure that:

- the Climate Change Risk Assessment fully accounts for uncertainties, provides a transparent comparison of risks, and cross-checks its results with current climate vulnerability; and
- the National Adaptation Programme sets adaptation outcomes and puts in place policies to enable the timely uptake of actions and robust long-term decision-making.

6.1 What we have done

In this report, using our indicator framework we have assessed progress in the priority areas of land use planning, the management of water resources and the design and renovation of buildings.

We found that:

- the UK is coping with the current climate, but some sectors such as water supply are near their limits. Vulnerability to climate change is potentially increasing as a result of patterns of development in some areas and demographic trends, such as the ageing population;
- there are low-regret actions that could be taken now to reduce the vulnerability of buildings. However, we found limited evidence of uptake of such measures, particularly in existing homes, reflecting barriers to action and supporting the need for new policy approaches; and
- climate risks appear not to be fully incorporated into some major strategic decisions, such as land use planning and investment in water infrastructure. Embedding climate change more fully into decision-making could reduce the legacy of future adaptation costs, such as flood defences, and also ensure that climate risks are appropriately balanced against other risks and benefits.

Our analysis has identified a number of barriers to adaptation in the priority areas assessed, but also opportunities for these barriers to be addressed through existing and forthcoming policy mechanisms (summarised in Table 6.1).

Table 6.1: Review of barriers identified in this report

ASC Priority Area	Key Barriers	Relevant Policy Mechanism
Land use planning	• Long-term costs from climate damages and legacy of maintaining and enhancing infrastructure (e.g. flood defences) not being assessed against shorter-term priorities. • Strategic cross-boundary partnerships not influencing local planning policies sufficiently. • Wider uptake of planning policy guidance on surface water flooding, coastal erosion, heat and water stress. • Local authority and statutory agency capacity.	• Reforms to Local Development Frameworks and emerging Neighbourhood Plans • National Planning Policy Framework • Duty to co-operate in Localism Bill • Implementation of the Flood and Water Management Act
Water	• Investment planning does not factor in the full range of climate uncertainties (UKCP09). • Weak signals or incentive to encourage users to take water from areas of relative surplus compared to relative scarcity.	• Water White Paper • Price Review 2014 – covering period 2015-2020
Residential buildings	• Lack of and misaligned incentives, for example households without water meters. • Lack of information on climate risks and the benefits of household action. • Lack of available upfront capital to pay for measures. • Hidden costs including the costs associated with finding the right product, sourcing reputable providers, time costs of disruption and the costs of differences in quality of the product and service.	• Future reviews of the Building Regulations • Local planning policies and development management conditions • Market mechanisms – labelling of efficient products • Green Deal – scope for working with Green Deal providers to help deliver water efficiency measures • Requirements for sustainable drainage in new development under the Flood & Water Management Act

6.2 What we will do next

1. Develop our indicator framework

Working with relevant organisations and partners, we will continue to develop our indicator framework to assess progress across priority areas. This will involve:

- identifying a more complete set of indicators within the priority areas assessed in this report, for example on the extent of urban greenspace, urban waste heat and on the uptake of adaptation measures in buildings;
- identifying indicators in the remaining priority areas, including other infrastructure sectors (transport, energy, information and communications technology), managing natural resources and emergency planning; and
- exploring indicators or other ways to measure progress for the remaining rungs of our preparedness ladder (decision-making, capacity and policy).

We will look to improve our understanding of the interactions between climate impacts, components of vulnerability and the effectiveness of adaptation actions. For some sectors, these interactions are complex and poorly understood, making it challenging to identify the most important components of vulnerability and where to focus adaptation efforts. We will also further review how to develop indicators of social resilience, for example the level of household insurance among lower-income groups.

Our indicator framework may have applicability for others involved in adaptation. For example, localised outcome indicators could be used by communities to assess more transparently how their councils and other local decision-makers (for example, emergency services, statutory agencies and healthcare providers) are accounting for long-term climate risks and taking up adaptation actions. Our next report in 2012 will assess progress in emergency planning, managing natural resources and one other infrastructure sector. In doing this, we will continue to identify and report on barriers to adaptation that are likely to require enabling policy.

2. Input to the Government's economic analysis of adaptation[1] and development of the National Adaptation Programme

The Government's economic assessment will appraise the costs and benefits of a range of policy options to address priority risks identified by the Climate Change Risk Assessment. We will work closely with Defra over the next year to advise and provide new analysis to inform adaptation priorities for the National Adaptation Programme.

1 The Government will be assessing the costs and benefits of various adaptation options through the Economics of Climate Resilience (ECR) study in 2011/12.

3. Review lessons for the next Climate Change Risk Assessment (CCRA)

In scoping the second CCRA, it will be important to learn lessons from the first assessment. We will undertake an initial assessment in 2012-13 in order to inform the scoping of the second CCRA in 2013-14.

As part of this, we will review how the CCRA compares with other recent national assessments, including in the USA and Australia. We will also assess how the latest developments in the science of climate change prediction can feed into the second CCRA.

6.3 Advice to the Government

The statutory framework created by the Climate Change Act provides the opportunity for the Government to articulate, for the first time, agreed adaptation outcomes. The Climate Change Risk Assessment should provide a comprehensive overview of priority risks and opportunities. The economic assessment of climate adaptation should then appraise policy options, based on an understanding of the relationship between the risks, the costs and the benefits from avoided climate impacts. This should inform the setting of adaptation outcomes in the National Adaptation Programme.

It will be important that clear trajectories for meeting the adaptation outcomes are established, so that progress can be assessed. The experience of setting carbon budgets for mitigation policy has demonstrated how setting such trajectories not only gives the market clear signals, but is also essential for obtaining buy-in.

Through our indicator framework, the ASC will track progress in meeting these trajectories as part of our statutory duty to report on progress in the implementation of the National Adaptation Programme.

Climate Change Risk Assessment (CCRA)

The Climate Change Act requires that the first CCRA is laid before Parliament no later than January 2012 and that the ASC advises Government on its preparation. We have not seen the results of the assessment and so cannot provide detailed comments. However, we have engaged closely with Defra and advised them on the development of the method over the last two years.[2] From this, there are three generic principles that the Government should consider when finalising the CCRA this year:

1. **Characterise uncertainties** – the CCRA should report the assumptions made transparently and where appropriate openly explore the implications of uncertainty[3] on the results.

2 The ASC and Defra have engaged in a number of workshops and committee meetings on the development of the CCRA. We have provided detailed technical advice on the method on three occasions, which can be viewed on our website at http://www.theccc.org.uk/adaptation
3 In terms of uncertainty in both future climate projections and in socio-economic scenarios.

2. **Provide transparent comparison of risks** – ensure that the full range of economic, social and environmental risks and opportunities are assessed and compared, including those that are less easily quantified (particularly environmental risks). To do this, it will be important to utilise a range of alternative assessment methods[4] for the weighting and scoring of risks when producing a prioritised list for subsequent policy appraisal.
3. **Cross-check results with assessment of current climate impacts** – as highlighted in Chapter 2, assessment of the current position is a good starting point for assessing future impacts, because it draws on what is already known and establishes a baseline against which changes in risk and vulnerability can be tracked over time.

We will write to the Secretary of State with more detailed comments and advice when we have seen the interim results of the assessment, and continue to provide advice on the CCRA in the lead up to its publication.

National Adaptation Programme (NAP)

The Government is required by the Climate Change Act to lay its adaptation programme before Parliament "as soon as is reasonably practical" following the publication of the CCRA. The ASC is then required to report on progress in the implementation of the NAP two years after this.

In our view, it would be useful for the Government to explore the following elements in preparing the NAP over the next two years:

- **Set the context for adaptation** – the NAP should build on the CCRA by transparently comparing priority climate and non-climate risks. This will be important for making clear the relative significance of climate risks to the UK.
- **Characterise adaptation outcomes** – by assessing the costs and benefits of adaptation for the priority risks identified by the CCRA. In doing this, the NAP should be clear on the level of acceptable risk assumed.
- **Put in place an enabling policy framework to tackle barriers to adaptation** – this will be essential for the sufficient uptake of low-regret action and robust decision-making needed for the achievement of adaptation outcomes. Some examples of the types of barriers to adaptation that we have identified from our analysis are in Table 6.1.
- **Take a partnership approach** – work with local authorities and communities, infrastructure providers, businesses and statutory agencies to reflect their roles and responsibilities within the NAP.

4 For example, multi-criteria analysis.

Glossary

Adaptation
Adjustment of behaviour to limit harm, or exploit beneficial opportunities, arising from climate change.

Adaptive capacity
The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Capital cost
The one-time set-up cost of a project, after which there will only be recurring running costs.

Climate
The climate can be described simply as the 'average weather', typically taken over a period of 30 years. More rigorously, it is the statistical description of variables such as temperature, rainfall, snow cover, or any other property of the climate system.

Climate change
Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere, ocean or in land use.

Climate variability
Climate variability refers to variations in the mean state and other statistics (such as standard deviations or the occurrence of extremes) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

Cost-benefit analysis
Analysis which quantifies in monetary terms as many of the costs and benefits of a proposal as feasible, including items for which the market does not provide a satisfactory measure of economic value.

Cost-benefit ratio
A comparison of the present value of installing an adaptation measure (or package of measures) with the present value of its benefits (or loss averted). A ratio of less than one indicates that the option is a cost-benefical measure.

Cost curve
Graph showing costs and potential benefit (loss averted) from implementing a range of adaptation measures, ranking these from the cheapest to most expensive to represent the costs of achieving incremental levels of benefit.

Discount rate
The rate at which the valuation of future costs and benefits decline. It reflects a number of factors including a person's preference for consumption now over having to wait, the value of an extra £1 at different income levels (given future incomes are likely to be higher) and the risk of catastrophe which means that future benefits are never enjoyed. For example the Social Discount Rate (3.5%) suggests future consumption of £1.035 next year is equivalent in value to £1 today. Discount rates in the private sector generally reflect the real cost of raising capital, or the real interest rate at which consumers can borrow.

Exposure
See definition of vulnerability.

Extreme weather event
An event that is rare at a particular place and time of year. Definitions of 'rare' vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of the observed probability density function. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. Single extreme events cannot be simply and directly attributed to anthropogenic climate change, as there is always a finite chance the event in question might have occurred naturally. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g., drought or heavy rainfall over a season).

Gross Domestic Product (GDP)
A measure of the total economic activity occurring in the UK.

Long-run marginal cost (LRMC) of electricity
The LRMC of electricity supply to end-users is the additional cost of meeting extra demand for electricity. It covers electricity generation, transmission and distribution; comprises fuel, carbon, operation, maintenance and capital costs, as well as energy losses in transmission and distribution. The Committee on Climate Change has estimated figures based on analysis undertaken for the Fourth Carbon Budget recommendations and the Renewable Energy Review.

Long-run marginal cost (LRMC) of water
Similarly for water, the LRMC is the additional cost of meeting extra demand for water. In the long run this will include both operating and capital costs. Water companies have estimated figures for water both on a steady demand basis and a peak demand basis, and these are published by Ofwat in their annual tariffs report.

Low-regret
These are measures that are cost-effective to implement today, where the benefits are less sensitive to precise projections about the future climate, and where there are co-benefits or no hard trade-offs with other policy objectives.

Maladaptation
Any changes in natural or human systems that inadvertently increase vulnerability to climatic hazards; an adaptation that does not succeed in reducing vulnerability but increases it instead. It can also cover spending a disproportionate amount of effort and investment on adaptation beyond what is required.

Mitigation
Action to reduce the sources (or enhance the sinks) of factors causing anthropogenic climate change, such as greenhouse gases.

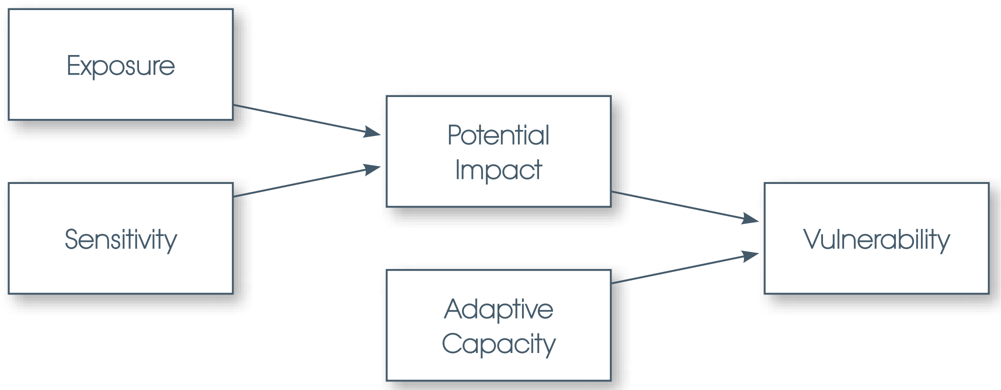
Risk
Combines the likelihood an event will occur with the magnitude of its consequences. Consequences may be defined according to a variety of metrics including economic, social and environmental. Risks can be either adverse costs and damages (true costs including non-monetary costs) or beneficial opportunities.

Sensitivity
See definition of vulnerability.

Technical potential
The theoretical maximum amount of benefit (loss averted) that is possible from implementing a particular set of adaptation measures. This measure ignores constraints on delivery and barriers to firms and consumers that may prevent uptake.

Urban Heat Island (UHI)
The increased temperature of urban air compared to the rural surroundings. The temperature difference is usually larger at night than during the day and is most apparent when winds are weak. Seasonally, UHI is seen during both summer and winter. London's UHI can result in the centre of London being 10°C warmer than the surrounding rural areas.

Vulnerability
Degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of a system's exposure, its sensitivity, and its adaptive capacity.



Exposure – the degree to which an exposure unit (e.g. a person or place) comes into contact with a hazard such as a heatwave event, a flooding event or other significant climatic variations.

Sensitivity – the degree to which an exposure unit has the propensity to be affected (adversely or beficially) by this exposure.

Adaptive capacity – the ability of an exposure unit to adjust and therefore to avoid negative impacts (and conversely to benefit from positive impacts).

Weather
Refers to the state of the atmosphere, across space and time, with regard to temperature, cloudiness, rainfall, wind, and other meteorological conditions.

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