Chapter 3

The adaptation return

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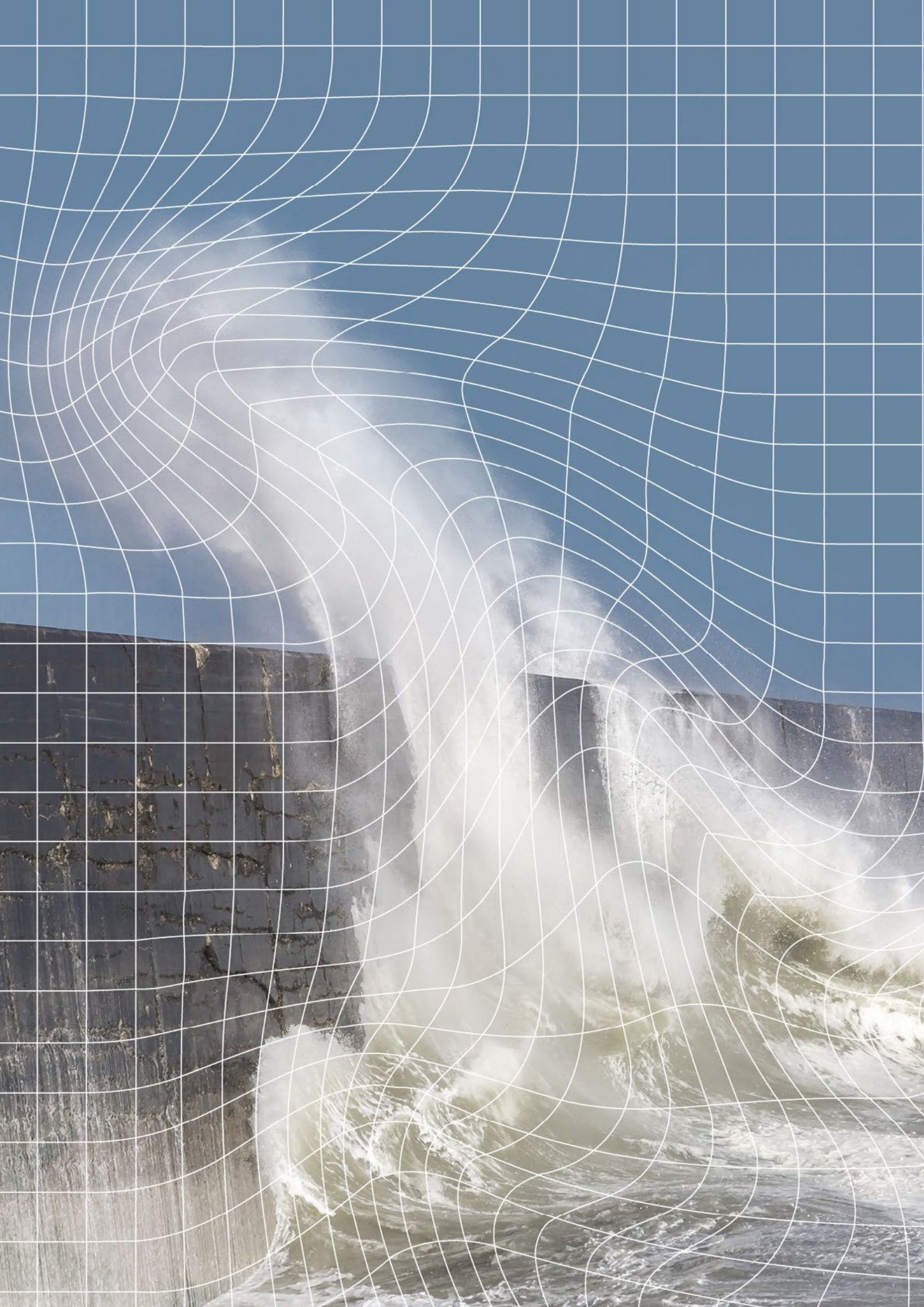


Introduction and key messages

This chapter synthesises the results of the risk assessment on the benefits that further adaptation can bring in addressing the risks and opportunities from climate change and what cross-cutting issues need to be addressed for effective adaptation planning. The analysis in this chapter informs the Committee's ten principles for effective adaptation.

It summarises the evidence from the CCRA3 Technical Report on actions that can be taken in the next five-year period through the UK's national adaptation programmes. We look at several types of benefit from adaptation:

- Avoided impacts from climate change including both financial and non-financial impacts (e.g. property damage, deaths).
- Benefits from climate change opportunities.
- Other direct benefits, e.g. in terms of improved health and biodiversity.
- Indirect benefits through employment and related induced impacts.

Since CCRA2 was published, more information has become available on the economic benefits of adaptation, both from international work and UK analysis.[1,2] Economic benefits include both those that are within the markets, some of which are direct financial returns or financial cost savings, and those that are non-market such as human wellbeing and improvements in natural environment, only some of which have manifestations in markets.

Our conclusions are:

- **'Good' adaptation should minimise the risks and maximise the opportunities from climate change. It should be conducted in a way that maximises social net benefits, including through maximising positive distributional effects and minimising negative trade-offs.** In addition, the Committee's criteria for good adaptation plan scores from its previous progress reports includes setting clear priorities, with specific, outcome focussed objectives; focussing on the policies and actions that will achieve the highest benefit; reflecting regional differences in climate change impacts; and ensuring effective monitoring and evaluation is in place and allocate sufficient resources to deliver the plan.
- **The case for urgent short-term Government action now (as opposed to waiting to act for another year, or five years) has been made clearer in this assessment.** Urgent action now will reduce irreversible impacts and lower the future costs from climate change that would likely ultimately fall back to the Government. This assessment has demonstrated that the gap between the level of adaptation and the level of risk is increasing. There is also better information available about the probability of previously unprecedented events occurring, that the country needs to prepare for now.
- **Two major cross-cutting issues that should be integrated into all sectoral policies to ensure good adaptation planning are assessed for each risk and opportunity in the CCRA3 Technical Report:**
  - **Avoid lock-in.** Early adaptation action – before impacts actually occur - should reduce vulnerability to current climatic variability and

build in resilience for decisions that have long lifetimes, a long planning process like infrastructure investment or a long lag time such as for restoring damaged habitats. Early action is also needed to prevent as far as possible irreversible changes, such as loss of species or ecosystems. Failing to do this can lead to 'lock-in', where delayed decisions, or decisions that don't consider the long-term risks can lead to irreversible changes, incur high damage costs and higher costs of having to then adapt abruptly and quickly. This assessment has given greater weight than previous CCRAs in assessing the potential for lock-in for different risks and opportunities.

  - **Minimise inequalities.** Climate change itself is likely to widen existing inequalities because socially and economically disadvantaged people are disproportionally affected. Actions to address climate change could also exacerbate existing inequalities if not carefully planned. Inequalities have been identified in the risk assessment in relation to where people live, their income level and assets, and characteristics such as age and ethnic background. These characteristics determine current vulnerabilities and capacity to adapt to climate change. The next set of National Adaptation Plans should map these effects and include actions to deliver positive distributional effects, in line with guidance in the Treasury Green Book.

- **Only a combined approach to tackling climate change through reducing emissions (mitigation) and building resilience (adaptation) will be successful in protecting the UK from the worst effects of climate change.** This combined approach is still largely missing in Government policy and business practice, which increases the potential for unintended consequences, including to the UK's own ability to meet its Net Zero emissions target. It also reduces the likelihood of both sets of policies succeeding in their primary purpose and maximising co-benefits.

- **Taking further adaptation action will generate benefits from avoided damages for almost every risk assessed in the Technical Report.** There is a particularly strong case for early adaptation in the three priority categories of action outlined in the Technical Report*:

  - 'No-regret' or 'low-regret' actions that reduce risks associated with current climate variability, as well as building future climate resilience. Examples include reducing water use, peatland restoration and improving passive cooling in homes, all of which are needed to address risks in the current climate.

  - Early action to ensure that adaptation is considered in near-term decisions that have long lifetimes and therefore reduce the risk of 'lock-in', such as for major infrastructure projects.

  - Fast-tracking flexible adaptive management activities, especially for decisions that have long lead times or involve major future change, e.g. land use change.

* See Watkiss, P and Betts, R (2021) CCRA3 Technical Report Chapter 2 – Method

- **Benefit-cost ratios for adaptation actions are largely positive, and in some cases very large even with partial quantification of benefits.** The net benefits of adaptation action are typically context- and site-specific and are therefore challenging to estimate at a national level. The evidence available, however, shows that many of the adaptation actions highlighted in the Technical Report have net positive benefits, i.e. their benefits outweigh their costs, and some have very high net benefits (benefit-cost ratios of 10:1 or higher). These include for example, early warning systems for extreme heat and flooding events, surveillance for pests and diseases, and water efficiency labelling.

- **There is a lack of available evidence about the size and value of climate change opportunities and the adaptation actions that will deliver them.** It is likely that some of these benefits will not be fully realised without further action. An example is supporting the construction industry to develop the skills base in building climate-resilient homes.

- **Adaptation measures can have important wider benefits, such as improving human health and the natural environment.** Taking these benefits into account increases the net benefits of adaptation and encourages integrated win-win solutions, such as increasing urban greenspace or improving water efficiency. Such solutions can only become apparent if climate change risks are integrated into sectoral plans and investments from the start.

We set out our analysis in the following sections:

1. What is good adaptation?
2. Avoiding lock-in
3. Addressing distributional effects and inequalities of climate change
4. Tackling climate change through mitigation and adaptation
5. Direct economic benefits from adaptation action
6. Other benefits of adaptation action
7. Funding of adaptation

What is good adaptation?

Adaptation is acting to reduce the damages and maximise any positive benefits from climate change impacts.

Adaptation is needed to build resilience to climate change that has already happened or is projected to occur.
Adaptation represents actions to reduce the negative impacts and maximise any positive benefits from climate change that is occurring now or will occur in the future. It is distinct from climate change mitigation which seeks to stop further climate change from occurring. Both approaches are needed to address climate change:

- Mitigation alone cannot prevent all climate change impacts because climate change is already happening due to past emissions of greenhouse gases, and even very ambitious global action to reduce emissions will take time to implement.

- Adaptation alone cannot prevent all climate change impacts because some impacts cannot be adapted to, and adaptation may become ineffective or prohibitively expensive especially at higher levels of warming.

The level of climate change that the UK will have to adapt to is determined by:

- The impacts of past emissions that have already changed the climate

- Global action on mitigation now and into the future and

- Exactly how strongly greenhouse gases (and other atmospheric components like aerosols) affect global and regional temperature and other climate variables, such as rainfall and sea level rise.

The success or otherwise of global efforts to reduce emissions will have a profound impact on the UK's climate in the second half of this century, whereas the level of climate change projected up to 2050 is now largely fixed. Chapter 1 goes into more detail on how we define the boundaries of likely future climate change and the basis of using warming levels of 2°C to 4°C for adaptation planning.

Good adaptation seeks to prepare for the changing climate while maximising social benefits.
'Good' adaptation should act to minimise the risks and maximise the opportunities from climate change, while also adhering to the principles for policy appraisal set out in the UK Government's Green Book. These are:

- Maximise net economic benefits (from a societal perspective)

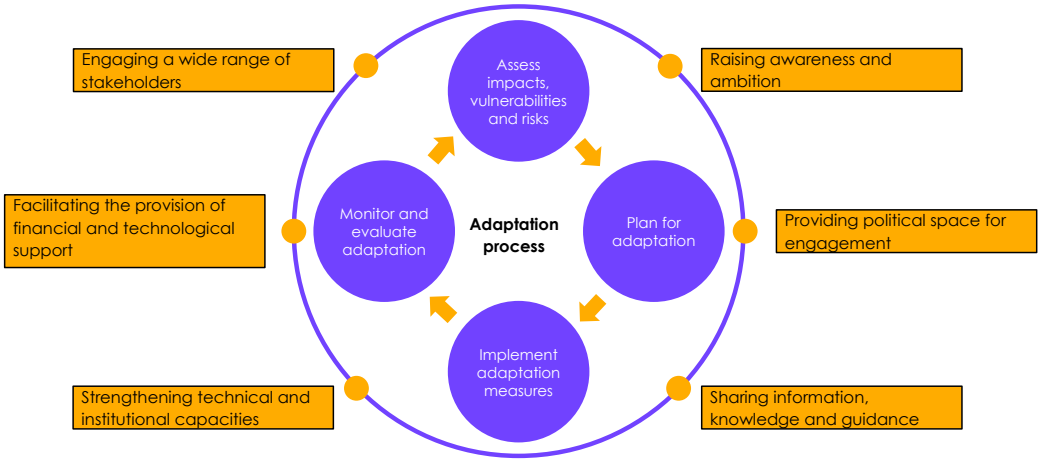
- Have neutral or positive distributional effects (social equity)

- Minimise negative consequences that result from the action (e.g. increases in greenhouse gas emissions, or negative impacts on biodiversity)

The Government has a role to provide the enabling framework and address market failures to support good adaptation planning in the UK. It can do this through providing information, supporting the coordination of local action, devising a framework of targets, incentives and reporting, and directly funding adaptation action.[3]

The UN sets out how this cycle of understanding and undertaking adaptation should operate at the country level; all of the components shown need to happen to support good adaptation (Figure 3.1).

Figure 3.1 The Adaptation cycle under the UN climate change regime



Source: UNFCCC: What do adaptation to climate change and climate resilience mean? | UNFCCC.

Building on this framework, the Adaptation Committee sets the following criteria for good adaptation to underpin any future national policy, in order to create meaningful interventions and governance processes:[4]

- Clear priorities that ensure the most important issues are addressed.
- Specific, outcome-focused, and measurable objectives that describe outcomes rather than processes and activities.
- A focus on a core set of policies and actions that will achieve the biggest benefit compared to cost.
- Reflection of regional differences in climate change impacts, allowing local organisations to play a role in adaptation action.
- Underpinned by effective evaluation and monitoring of progress.

There is a well-established evidence base on the economic benefits of early Government intervention in adaptation.

The UK Government's first National Adaptation Programme in 2013 set out a detailed economic case for adaptation in the UK.

The economic rationale for government intervention in adaptation in the UK is well-established and was set out in detail in the first UK National Adaptation Programme (Table 3.1)[5], as well as the more recent reports from the Global Commission on Adaptation.[6] There has also been extensive research looking at the long-term costs of inaction for various climate-related risks, including in the CCC's own analysis of adaptation for housing and land use, which shows that the costs of waiting until an impact occurs before acting far outweigh taking adaptive action early.[7,8]

Table 3.1
Economic rationale for Government intervention in adaptation

Barriers to market-led action	Description
Uncertainty	Where action is deferred or avoided due to a lack of certainty about future conditions, leading to confusion about the best course of action.
Information failure	Where organisations and individuals do not have perfect information about their vulnerability or exposure to risks (now or in the future) which can make it hard for them to plan efficiently. An example is a lack of awareness of individual flood risk.
Policy failure	Where the framework of regulation and policy incentives creates barriers to effective adaptation. For example, competing policy objectives can mean that adaptation is 'crowded out' in favour of other policy requirements that have stronger legal or reputational penalties for inaction. Another example is where actions to meet another policy objective are taken that exacerbate climate change risks; for example, making homes more airtight to improve energy efficiency, which can increase overheating risk.
Governance failure	Where institutional decision-making processes lead to barriers to effective adaptation. An example is a lack of coordination in multi-sector responses such as adapting to coastal change.
Behavioural barriers	Where economically rational decisions are not made. For example, there may be low public willingness to accept the degree of risk being faced.

Source: HM Government (2012) National Adaptation Programme - Annex

The case for urgent short-term Government action (as opposed to waiting to act for another year, or five years) is also clear in principle, though efforts to improve quantification of the short-term and long-term impact of delaying action are ongoing.

Urgent adaptation cannot wait for another year, or five years. It is needed now.

There are four reasons why taking action to adapt now (rather than delaying for another year or five years) will reduce irreversible impacts and costs from climate change that will ultimately likely fall back to the Government. These can be illustrated by looking back at the impacts of inaction since our independent report for the second UK Climate Change Risk Assessment was published in 2016:

- **Lock-in has increased.** Since CCRA2 was published, over 570,000 new homes have been built in England alone that are not resilient to future high temperatures, which will mean that costly retrofit will be needed to make those homes safe and habitable. CCC analysis shows that it is around four times more expensive to retrofit shading than including it at new build stage. In the next five years, over 1.5 million homes are due to be built; these will also lock-in increased climate vulnerability unless planning and building policy requires adaptation measures now.

- **Irreversible impacts are occurring that might have been avoided or reduced if greater adaptation measures had been taken.** Since 2018, over 4,000 heat-related deaths have been recorded in England. There is growing evidence that these deaths are associated with high indoor temperatures in homes, care homes and hospitals. While the current Heatwave Plan for England is central to the acute public health response to heatwaves, these findings indicate more strategic prevention action is required from a range of actors.

The number of heat-related deaths in the UK is projected to increase by around 250% by the 2050s in the absence of further adaptation[9], due to climate change and an ageing and growing population. Further adaptation to buildings is required to provide better passive cooling. Looking at damage to the natural environment, the UK has had several major wildfires (Saddleworth Moor, the Flow County, Mourne Mountains) since 2016. These were reported to together severely damage between 70-140km^2 of peatlands, heathland and forest (the area of a medium to large city) and led to increased greenhouse gas emissions, though these estimates vary by source.[10] Damage costs from single events like these will grow in the future and without adaptation in place, the Government is likely to increasingly bear these costs as the insurer of last resort.

- **The future costs from climate change are growing.** This CCRA has highlighted that the risks from climate change have worsened due to increasing magnitude (informed by new evidence) but also a lack of adaptation in the past five years. Fifty-six per cent of the risks studied now have an urgency score of 'more action needed' compared to 35% five years ago. Similarly, the magnitude of future impacts for 14 risks has increased since CCRA2 was published. This means that the resulting costs of climate change over the century are estimated to be higher now than they would have been five years ago, and higher than would be the case had more action been taken following CCRA2.

The UK already faces unprecedented extreme weather events that it may not be prepared for.

There is also a growing probability of unprecedented extreme events occurring. Examples from the Technical Report where quantification has been possible include extreme heat and rainfall:

- **Extreme heat.** The chance of experiencing a prolonged spell of extremely high summer temperatures, like that observed in 2018, is now around 10 - 25% each year compared to less than 10% a few decades ago. There is also a growing chance of experiencing daily maximum temperatures of over 40˚C.

- **Extreme rainfall.** There is currently a 1% chance every year that monthly winter UK rainfall could be 20-30% higher than the maximum observed to date.

Protecting homes from increasing flood risk through investment in flood defences is one of the few examples of where the avoided damages from taking action have been calculated for the present day. The Environment Agency releases statistics of homes protected during major flood events, and since 2015, more than 300,000 homes have been better protected from flooding through the EA's investment programme. Similar analysis needs to take place for other hazards and adaptation actions.

A new Defra-funded study on the economics of adaptation will be completed in 2022, following on from the publication of CCRA3.

Defra is funding a new project on the economics of adaptation, linked to this CCRA assessment, which will be completed in 2022. It will consider the case for further action for a set of priority CCRA3 risks, including the costs of inaction, and then assess the economic benefits and costs of further adaptation.

The CCRA3 approach builds on a well-established literature on identifying short-term beneficial types of adaptation action.
The CCRA focusses on those actions that are needed in the next five years, i.e. short-term responses, even though the benefits of these actions accrue over the long-term. The assessment considers three types of early adaptation priorities for more urgent risks and opportunities within the next five-year cycle.

These include:

- Addressing any current adaptation gap by implementing 'no-regret' or 'low-regret' actions that reduce risks associated with current climate variability, as well as building future climate resilience. Examples include reducing water use, peatland restoration and improving passive cooling in homes, all of which are needed to address risks in the current climate.
- Intervening early to ensure that adaptation is considered in near-term decisions that have long lifetimes and therefore reduce the risk of 'lock-in', such as for major infrastructure projects.
- Fast-tracking early adaptive management activities, especially for decisions that have long lead times or involve major future change, e.g. land use change. These approaches build in flexibility and allow the use of new evidence in forthcoming future decisions.

Avoiding lock-in is a major reason for taking early adaptation action, well in advance of impacts occurring

Decisions need to incorporate climate change risks and opportunities so that they do not lock-in policies and technology that are not resilient.

Lock-in is defined as 'where actions or decisions are taken that have long-term effects, but where these effects are not included in the decision itself which potentially increases future risk or causes irreversible change'. Some of the actions that can be taken to avoid lock-in include: acting early to avoid irreversible change; building flexibility into policies and systems; planning with long-term climate change in mind; and applying decision making under uncertainty (DMUU) approaches.

An example is integrating climate resilience into the designs for new homes, which is vastly cheaper than forcing retrofit later. The costs of installing a package of passive cooling measures at the new build stage was estimated by CCC analysis to be around £2,300 for a small semi-detached house, compared to £9,200 to retrofit the same measures.[11]

Lock-in will also arise if development in flood risk areas is not resilient to current and future flood risk and where flood risk management measures are currently, or will become, insufficient to manage the risk. Planning policies permit development in areas at risk of flooding, providing mitigations are incorporated, however, evidence suggests this does not occur for all developments. Planning applications for development in areas at risk of flooding need to be supported by independent evidence that flood risk from all sources, including surface water, has been assessed and mitigated and takes account of the implications of climate change.

Understanding the potential for lock-in is an important part of any climate change risk assessment, and the CCRA3 Technical Report method has given greater weight compared to CCRA2 in assessing the potential for lock-in as part of the assessment of future magnitude scores. This is because risks that involve the potential for lock-in are likely to require earlier and more direct intervention.

The CCRA Technical Report's qualitative assessment of potential for lock-in for each of the 61 risks and opportunities identifies three types of lock-in (Table 3.1):

- 'Business as usual' planning. Decisions are taken that plan for the future, but don't adequately take account of changing climate risks. For example, the building of new infrastructure, with a long life-time, which does not consider future climate risks that may be expensive or difficult to retrofit against later.
- Adaptation action is not taken. For example, the degradation of peatlands without restoration, which can lead to irreversible loss.
- Maladaptive decisions. Decisions are taken to address climate risks, but end up exacerbating vulnerability or exposure, or having negative knock-on consequences. For example, the application of neonicotinoids to control rising levels of viruses in sugar beet that are becoming more common with warmer winters, but with a result of killing bees in contact with the treated crops and hence reducing the natural capacity to deal with future risks.

Table 3.2 sets out examples of lock-in risks from across the Technical Report.

Table 3.2
Coverage of lock-in across the CCRA3 Technical Report

	'Business as Usual' planning	Lack of decisions or actions, or maladaptive decisions
Natural environment	Habitat designations are based on historical standards that aren't flexible enough to account for change Managing invasive species on the basis of today's climate only. Pests and pathogens are very difficult to manage once established Planting unsuitable tree species for the future climate increases risk for the plantation and could negatively impact the ecosystem services provided in the surrounding area	Cultural norms can prevent any transformation needed in order to improve resilience (e.g. changing land use type) Hard engineering such as hard flood defences stop the coast from adjusting naturally to sea level rise
Infrastructure	Increased reliance of electrification without boosting resilience and redundancy in the energy system and ICT means that other infrastructure systems like transport will become highly vulnerable to impacts on those sectors, and any impacts that occur will have more knock-on impacts New development in coastal areas that does not take into account long-term sea level rise or coastal erosion risk New Carbon Capture & Storage infrastructure being planned without consideration of future water deficits	Continuing to build new homes and related infrastructure in flood plains – and especially flood plains which are predicted to experience higher risks in the future
Health, Communities and Built Environment	Building new homes and hospitals, care homes etc. without passive cooling for current/future high temperatures, or protection against increasing extreme weather Continued development on the floodplain Late action in planning for increasing numbers of elderly people that will be at risk from extreme heat in future care settings Choice of future production methods that are highly water intensive	Hard engineering such as hard flood defences stop the coast from adjusting naturally to sea level rise
Business	Investing in technologies and selecting sites that could become stranded assets due to climate change Risk insensitive site locations for new assets - not taking into account long-term conditions	Lacking information on the risks down the supply chains or supply chains that are locked to certain suppliers or countries Hard engineering approaches to flood protection and lack of understanding of natural solutions

	Planning on the basis of current flood protection levels for specific sites - these will change	
International Dimensions	Fixed trade agreements could lead to low responsiveness of supply chains to long-term climate change Global finance system is locked to a certain set of pocesses	'Just in time' food supply chains that have little flexibility to change in response to shocks

Source: The Third UK Climate Change Risk Assessment Technical Report [Betts, R.A., Haward, A.B. and Pearson, K.V. (eds.)]. Prepared for the Climate Change Committee, London.

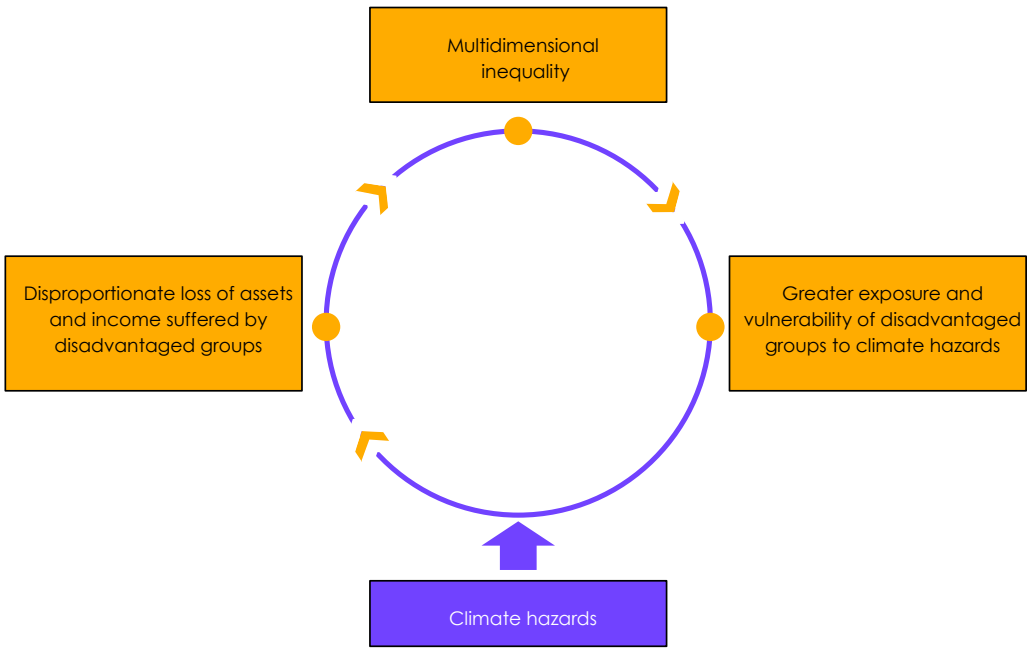
Distributional effects and inequalities of climate change

Adaptation should be an important component of the Government's levelling up agenda.

There is increasing public demand to ensure a just transition as the climate changes, and growing activism and awareness for climate justice.
This demand is highlighted by the adoption of the principle of 'fairness, including for the most vulnerable' by the UK Climate Assembly in their final report*. Strong adaptation planning should go beyond merely avoiding worsening inequality and endeavour to reduce inequality. This requires a particular focus on reducing risk for disadvantaged or exposed communities, and in keeping with the Government's commitment to levelling up across the whole of the UK to ensure that no community is left behind. This links closely to mitigation efforts, which also acknowledge the need for a just transition, as the UK society and economy changes to meet Net Zero targets. Similarly, as the UK transforms to become increasingly adapted to climate change, existing inequalities must be reduced, which will require targeted support to the households and communities most at risk.

While CCRA2 identified distributional effects as a cross-cutting issue, this assessment has gone further to consider inequalities for each risk and opportunity, where possible.
Existing inequalities mean that certain groups are more exposed to climate hazards (for example, coastal communities exposed to sea level rise) and/or more vulnerable to climate hazards (for example, low income households with limited financial savings). Climate change can exacerbate these existing inequalities, leading to a disproportionate impact on some populations over others and resulting in greater subsequent inequality in a negative cycle (Figure 3.2).

Figure 3.2 Cyclical relationship between climate hazards and inequality



Source: Islam, N. and J. Winkel, 2017.
Notes: Illustration of the negative cycle of climate hazards leading to greater inequality.

* https://www.climateassembly.uk/recommendations/index.html

Three main related factors have emerged from the CCRA3 Technical Report of different distributional effects of climate change: location; income and assets; and demographics.
Different risks will have different patterns of spatial inequalities. Specific areas highlighted as having high exposure across a range of risks in the Technical Report include coastal areas, rural, or remote areas. Income and assets are key determinants of adaptive capacity and low income and assets result in households and businesses with insufficient insurance and limited resources for recovery. Finally, demographic factors such as age, gender, and people with underlying poor health could increase vulnerability to individual risks. While not discussed in the CCRA3 Technical Report, there may also be an inter-generational effect, with future generations experiencing greater impacts and suffering compounded inequalities compared to current generations.

"Socially and economically disadvantaged and marginalized people are disproportionally affected by climate change" (IPCC, 2014)

While some risks are skewed towards one factor, in practice these distributional effects can overlap and reinforce each other, with location related to income inequality, in turn related to social and demographic inequalities. Examples of how distributional effects interact with and compound climate risks along lines of inequality are illustrated in Figure 3.3.

Continuing the example for coastal communities, socially vulnerable communities (a demographic effect) on the coast (a location effect) are disproportionally exposed to coastal flooding and erosion. When further considering income levels and insurance penetration (an income and assets effect), the Relative Economic Pain (ratio between uninsured loss and income) becomes significantly higher in vulnerable communities than elsewhere, increasing their overall vulnerability to the climate risk. This is borne out by past events; after the 2007 floods, those on the lowest incomes were eight times more likely to report severe mental health deterioration than those on the highest incomes, thus leading to poor health and compounding their existing inequalities.

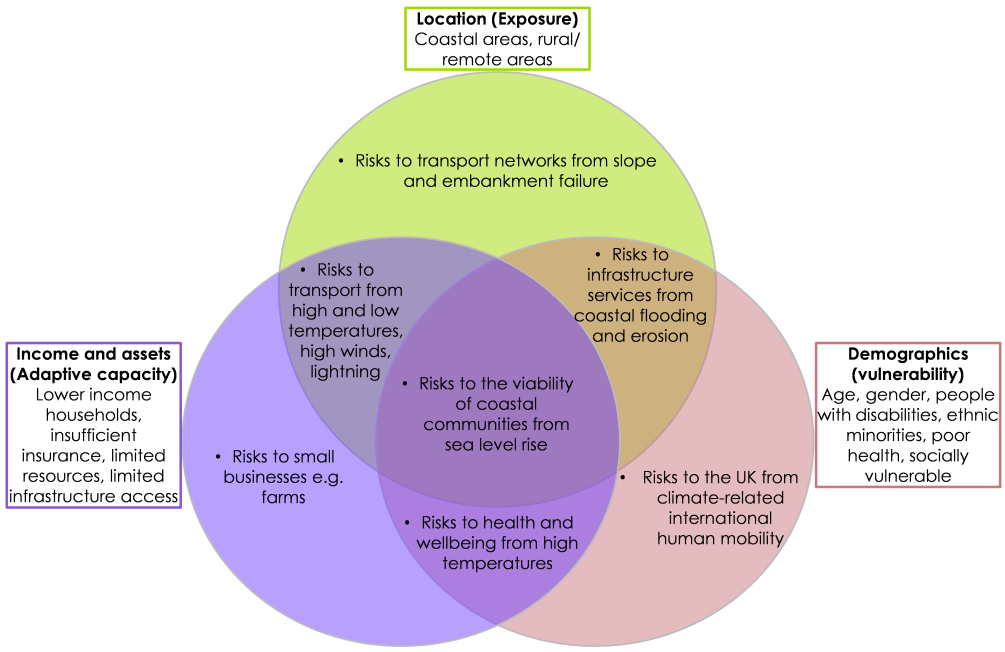
Climate change opportunities are also subject to distributional effects with benefits likely to be captured by some groups more than others.

Access to outdoor green spaces is unequally distributed across UK communities.

The CCRA3 Technical Report identifies an opportunity for health and wellbeing from warmer summers and winters, with potential for increased use of outdoor space for physical, leisure and cultural activities. However, access to outdoor space has been shown to be concentrated among wealthier groups and be diminished for lower income and ethnic minority groups, presenting unequal opportunities from a changing climate. The decline of green spaces in urban settings is also a limiting factor on enjoying this benefit. Similarly, other opportunities from climate change may not be realised equitably.

"Several years after the 2007 floods, those on the lowest incomes were eight times more likely to report severe mental health deterioration than those on the highest incomes" (CCRA3 Technical Report Chapter 5 – Health, Communities and Built Environment).

Figure 3.3 Examples of climate risks with distributional effects



Source: CCC analysis.
Notes: Venn diagram with examples of risks which are increased by one or more distributional effects. Risks within the green circle are higher in specific locations due to higher exposure; risks within the pink circle are higher for certain demographic groups due to higher vulnerability; risks within the purple circle are higher for people or households with lower incomes and/or assets due to reduced adaptive capacity. This diagram is not a comprehensive mapping of risks against distributional effects but illustrates how these three main factors can overlap to compound some risks in particular situations.

Adaptation measures could create further unequal impacts without a better understanding of how climate change affects inequalities.
The current understanding of inequalities that are likely to increase with climate change is limited and incomplete across sectors, highlighting an important area for further research. Without a more robust understanding of existing inequalities in each sector, it is highly likely that some adaptation measures may further increase these distributional effects inadvertently, undermining public trust and support for climate action. The next set of National Adaptation Plans should map out distributional effects, considering future societal trends for example, in employment, transition to Net Zero and demographics, which may alter the baseline. Based on this mapping, actions should be proposed to avoid a deepening cycle of inequality and negative climate impacts from adaptation planning across government, using guidance in the Treasury Green Book.

Government has recently taken welcome steps to improve the consideration of climate change in economic appraisal. New supplementary guidance was published for the Green Book on adaptation in 2020 (Guidance on Accounting for the Effects of Climate Change).

Following internal review, the UK Government is considering the case for extending the lower discount rate of 1.5%, applied to health impacts, to environmental impacts. The discount rate used for climate change risks should be lowered, as higher incomes in the future will not compensate for the welfare loss due to climate impacts, including some irreversible changes.

Climate change cannot be addressed from mitigation or adaptation alone. Both are needed, and they need to be integrated to respond to the threats from climate change.

Both adaptation and mitigation are needed together to address climate change. Climate mitigation is needed to reduce levels of greenhouse gas emissions to ultimately limit the scale of changes in hazards that the world will experience. However, even with very high levels of global greenhouse gas emissions reductions, adaptation will still be required to reduce vulnerability and exposure to inevitable changes in climate hazards, and to plan for uncertain but plausible higher levels of warming (Chapter 1 and 2). Importantly, very high levels of mitigation are not by any means guaranteed globally or in the UK at present. If global emissions do not start to decrease dramatically, and/or if climate sensitivity is high, very high impacts in the UK and worldwide are projected. Chapter 1 explains the range of climate scenarios that need to be planned for in more detail.

Out of 15 relevant major UK Government announcements on addressing climate change made over the past three years, only four have included integrated plans and goals on adapting to climate change alongside mitigation.

Adaptation and mitigation have yet to be successfully integrated across government policy. Since CCRA2 was published in 2017, adaptation has not been given the level of attention it needs by the UK Government. It is essential that it is properly integrated into decision making alongside reducing emissions. Out of 15 relevant major UK Government announcements linked to addressing climate change made over the past three years, only four have included integrated plans and goals on adapting to climate change alongside goals and plans for reducing emissions (Figure 3.4). In some others, adaptation is mentioned as an additional requirement rather than being part of core of the policy or programme, but in many it is simply absent despite adaptation considerations being critical to delivering effective policy.

Figure 3.4 Integration of adaptation in major announcements since 2017

Relevant announcements without adaptation	Relevant announcements with adaptation mentioned but not integrated	Relevant announcements with adaptation integrated
1. UK's updated Nationally Determined Contribution (2020)	7. 25-Year Environment Plan for England (2018)	12. Flood and Coastal Erosion Risk Management Strategy for England (2020)
2. UK Treasury cost review of transitioning to a green economy (2020)	8. Ten-point plan for a Green Industrial Revolution (2019-20)	13. Taskforce on Climate-related Financial Disclosure Reporting Requirements (2020)
3. Green Homes Grant (2020)	9. Environmental Land Management Scheme for England (2020)	14. Green Book Supplementary Guidance on Climate Change (2020)
4. Future Homes Standard Consultation (2020)	10. Infrastructure Strategy (2020)	15. UKRI Strategic Priorities Fund (2018)
5. UK Climate Assemblies (2019-20)	11. Planning White Paper (2020)	
6. Industrial Strategy (2017)		

Source: CCC.
Notes: 'Relevant announcements without adaptation' include those where adaptation is missing despite the CCC specifically recommending it be included; or where including adaptation considerations would directly address the risks or opportunities set out in this assessment; or where including adaptation would contribute to a strengthened national or government dialogue. 'Relevant announcements with adaptation mentioned but not integrated' represent policies where the word adaptation is mentioned, or cases where there are a narrow set of actions related to adaptation, but where adapting to climate change is not viewed as a core requirement in order to achieve the wider aims of the strategy and where the actions as set out would not enable this. 'Relevant announcements with adaptation included' are those examples where adaptation is part of the core aims and where there are specific actions in the relevant strategy or announcement.

Climate change poses significant risks to the UK's ability to reach Net Zero greenhouse gas emissions by 2050.

The CCRA3 Technical Report has considered climate change risks to meeting the UK's Net Zero target, as well as potential synergies and trade-offs between mitigation and adaptation actions (Table 3.3). Most of the direct climate risks to achieving Net Zero fall in the natural environment and infrastructure sectors. Potential benefits and trade-offs are highlighted in the areas of people and built environment and natural environment, but also for business and international dimensions.

Table 3.3
Net Zero – climate risks, synergies, and trade-offs with adaptation*

Sector	Direct risks from climate change to Net Zero	Actions with benefits for both adaptation and mitigation	Potential trade-offs between adaptation and mitigation
Natural environment	• Risks to soil quality (including peat) and other land cover that leads to reduction in carbon sequestration capacity or even emitting carbon • Increased emissions from wildfire • Reduced plant productivity (crops and trees) from soil moisture deficits • Reduced woodland, crop or livestock productivity from pests and diseases • Risks for marine biodiversity (and natural carbon storage) from warming and acidification • Changing conditions (heat, water scarcity, flood, fire) do not allow for productivity gains from agriculture to be met, so that land cannot be freed up for increased forestry	• mixed species planting • peatland restoration • soil conservation, precision farming • saltmarsh/ wetland creation and restoration • Improved habitat connectivity and condition will assist in species movement to more climatically suitable areas • New crop varieties with higher yields and improved climate resilience through (e.g. reduced soil erosion from planting triticale) • Tree planting for natural flood management • More nitrogen-efficient farming • Marine and coastal habitat protection	• Planting of trees in climatically unsuitable areas, monoculture planting and where trees compete with other land uses (e.g. peat soils) and could negatively affect ecosystem services (e.g. water availability) • Increased connectivity from forest expansion could promote spread of pests and diseases • Over-emphasis on bioenergy crops without corresponding attention on biodiversity and landscape resilience and food supply (e.g. increased soil erosion, water quality reductions) • Increased irrigation demand for agriculture to support high yield cereals • Offshore wind platforms acting as 'stepping stone' habitats for invasive marine species

* More detailed lists of the links between Net Zero and adaptation are given throughout the CCRA3 Technical Report

Infrastructure	• Storms, high or low winds reducing offshore wind production • Greater reliance on electricity networks and ICT increasing impacts of outages • Flood risk to new infrastructure sites (e.g. EV charging stations, coastal CCS sites) • Reduced water availability impacts on hydropower • Insufficient water availability for CCS and hydrogen production • Subsidence risk to buried infrastructure • Performance thresholds of Net Zero infrastructure (e.g. PV, wind turbines) are exceeded more often due to increased extreme events • Increased exposure to extreme weather of people using active travel (walking/cycling), Increased risks to rail from shrink/swell subsidence, flooding	• Use of natural flood management approaches to reduce flood risk to Net Zero infrastructure, and reduce the carbon intensity of flood management	• Increased water demand from biomass, CCS and hydrogen production, putting added strain on the natural environment at times of low flows • Increased carbon intensity if de-salination plants, increased treatment or pumping are needed to address water scarcity • Increased carbon intensity from larger amounts of mechanical cooling of ICT infrastructure
People, communities, and the built environment	• Challenges in designing and implementing the right mix and types of technologies for low carbon heat and energy efficiency in buildings in a warming climate	• Significant reductions in outdoor air pollutants from shift to Net Zero • Tree planting and increased urban greening benefits for carbon storage, flood and heat mitigation • Low-carbon materials in new flood defences • Reduced winter heating demand lowering emissions • Low-carbon energy generation will reduce the negative trade-offs from increased summer cooling demand • Passive cooling would reduce summer energy demand • Lower discolouration of buildings by reduced NOx and CO2 emissions	• Increased overheating and/or poor indoor air quality (damp, mould) risk from more airtight homes without adequate ventilation/ passive cooling • Increased carbon intensity from air conditioning or other summer cooling demand • Greater UK-based tourism driven by reduced flying could place added pressure on heritage assets or vulnerable locations, such as the coastline

Business	• Changes in peak electricity demand from higher cooling demand could pose challenges to balancing energy supply from low carbon sources • Supply chain disruption to key materials needed to support Net Zero e.g. rare earth metals	• Business opportunities from integrated building retrofit for mitigation and adaptation • Reduced water demand by businesses could also reduce energy use	• Emphasis on transition risk in business reporting may reduce attention paid to physical risk • Increased carbon intensity from higher levels of office air conditioning • Reducing the carbon intensity of supply chains by increasing efficiency and reducing stock holdings would lower supply chain resilience
International dimensions	• Need for increased domestic food supply if global food security falls • Changes to supply chains in response to climate shocks could increase (or decrease) carbon emissions • Changing trade relationships or impacts on global governance exacerbated by climate change could affect Net Zero delivery in the UK		• Reduction in land available for agriculture globally in order to meet Net Zero could increase food security pressure • Increase in wetland habitats could become a breeding ground for insect vectors of disease

Source: The Third UK Climate Change Risk Assessment Technical Report [Betts, R.A., Haward, A.B. and Pearson, K.V. (eds.)]. Prepared for the Climate Change Committee, London.

An example of where the importance of integrating adaptation with mitigation has been monetised is the case of natural carbon stores and sequestration.
The Government's Natural Capital Accounts report that gross CO_2e sequestration (i.e. the total stock, not the annual flow) within UK natural habitats was estimated at 28 billion tonnes in 2017 (Figure 3.5), with an associated asset valuation of £106 billion.[12] In 2017, forest land removed 18 million tonnes of CO_2e. In contrast, cropland emitted 11 million tonnes in 2017 as a result of the loss of carbon stock when converting grassland to cropland. This means UK croplands provide negative net carbon sequestration.

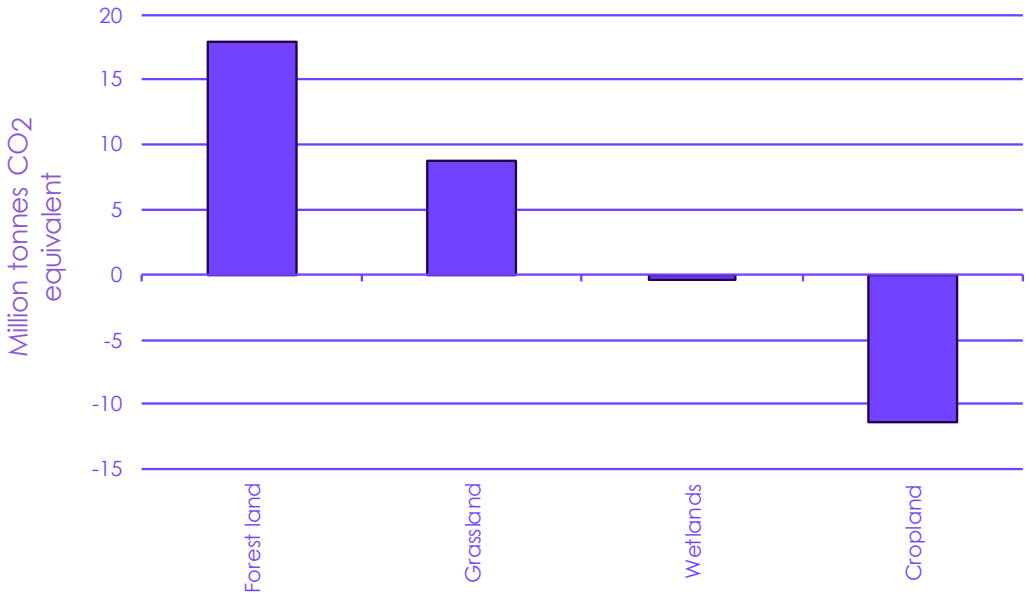
Marine carbon sequestration is significant and requires more research to understand it more fully, but the latest Natural Capital Accounts estimate it at between one-third and more than double the carbon removed by terrestrial habitats.[13]

Climate change will have both positive and negative effects on natural carbon stocks.* Present annual values of the change in soil carbon stocks up to 2060 could range from -£1 billion (losses) to +£2 billion (gains), depending on climate scenario (low or high emissions) and land use decisions.[14]

* See Berry, P. and Brown, I. (2021) CCRA3 Technical Report Chapter 3 – Natural environment and assets

Other estimates focussing on peatlands suggest that increased carbon emissions from peatlands due to hotter, drier conditions could lead to annual average damage costs of £1.1billion (2050s), and up to £1.5 – £2.2 billion (2080s).[15]

Figure 3.5 Net annual natural carbon sequestration by land type, UK, 2017



Source: Natural Capital Accounts, 2019.

The CCRA3 Technical Report considers how the transition to Net Zero will affect climate risk, as well as the risks to meeting Net Zero from climate change.

Understanding the challenges of achieving Net Zero in the context of a changing climate should be a priority for further analysis.

There have been several UK-based studies of the direct costs of achieving the Net Zero target by 2050, both from the CCC's own analysis[16] and an exercise conducted by HM Treasury.[17] The CCC's latest estimates put the net cost of achieving Net Zero at less than 1% of GDP through to 2050 when taking into account the benefits from the falling prices of low-carbon technologies, with scope for the economic effect to be net positive as resources shift from imported fossil fuels to UK investment. The CCC's latest estimates (i.e. the 2020 work on the Sixth Carbon Budget) also began to capture how a changing climate itself would affect the ease and the cost of reaching Net Zero.

The CCRA3 Technical Report considers how the transition to Net Zero will alter the risks from climate change. The transition to Net Zero will change the characteristics of things that are affected by climate change (such as the energy system), altering risks positively and negatively. At the same time, climate change could make the Net Zero target harder in some cases and easier in others (e.g. negatively, by reducing forest productivity from soil moisture deficits, pests or diseases; and positively, by reducing energy demand in winter).

Further work is needed to assess how the Net Zero transition will interact with the effects of increasing climate risk. This is particularly important to encourage synergistic mitigation-adaptation policies.

Direct economic benefits from adaptation action

There are benefits from further adaptation for nearly every risk and opportunity assessed in the CCRA3 Technical Report, either from reducing impacts from climate change (for risks) or enhancing benefits (for opportunities).
The CCRA3 assessment considers the benefits of further adaptation action in the next five years over and above what is already planned, for each risk and opportunity where an adaptation gap was identified and where actions are assessed as being more urgent. The assessment includes the available evidence of these further benefits, including information on co-benefits and trade-offs, and a review of the potential costs and benefits of further actions.*

For nearly every risk and opportunity considered, there are benefits to further action in the next five years. While the Technical Report has not assessed the costs and benefits of specific actions, it identifies a large range of beneficial adaptation actions, shown in Table 3.4. These are not the only adaptation actions that should be considered in policy, but are examples from the literature that occur throughout the Technical Report.

Table 3.4
Beneficial adaptation action in the next five years for the UK

Category	Examples
Engineered solutions	• Building design and retrofit – architecture, shading, ventilation, water efficiency, property-level flood resilience • Road and rail – re-surfacing, change in materials used, earthworks, vegetation management • Drainage • Water supply infrastructure • On-farm water storage • Flood defence investment
Nature-based solutions	• Increasing plant diversity in forestry, hedgerows, arable and horticultural farming • Habitat creation • Peatland restoration • Soil conservation - Buffer strips, mulching, contour ploughing, sediment traps, low-till farming • Water – reducing demand, improving supply • Blue-carbon initiatives e.g. coastal saltmarsh and wetland creation • Managed realignment of coastal areas • Urban greening • Green sustainable drainage systems
New/emerging technologies	• Climate-smart agriculture – precision farming, new crop and livestock varieties, • New modelling and data systems for hazard prediction • Rainwater harvesting systems

* Watkiss, P and Betts, R (2021) CCRA3 Technical Report Chapter 2 – Method, provides a detailed description of the method for assessing the benefits of further action.

	• Remote sensing to detect changes in hazards and asset performance • New designs for shipping and offshore infrastructure • Use of big data e.g. monitoring of indoor environmental quality
Behavioural	• Changing sowing dates of crops • Changing management practices for agriculture and forestry • Building operation choices e.g. use of active and passive cooling • Information sharing • Communication • Training and skills development • Public engagement e.g. through citizen science
Institutional	• Adaptation standards • Organisational and site level risk assessments • Changing trade patterns • Supply chain and product diversification • Business continuity planning • Regulation • Emergency management • Advisory services • Humanitarian aid • Transboundary agreements • Diplomacy
Financial	• Insurance • Disclosure of physical climate risk • Targeted adaptation finance • Green finance
Data, R&D	• Monitoring and surveillance • Inspections • Forecasting and early warning systems • Research on climate impacts, adaptation responses, public attitudes and willingness to pay • Provision of decision support tools and information • Traceability standards for supply chains

Source: The Third UK Climate Change Risk Assessment Technical Report [Betts, R.A., Haward, A.B. and Pearson, K.V. (eds.)]. Prepared for the Climate Change Committee, London.

There are strong economic and societal benefits from taking adaptation action.

The CCRA3 Technical Report provides information, where available, on costs and benefits of further action, though it does not provide a full economic assessment of action.

The Technical Report has provided some indicative information on costs and benefits for a number of adaptation measures and highlighted examples of interventions that typically have net benefits. Supporting analysis in the CCRA3 Valuation Report provides an indicative monetary valuation of risks and opportunities in terms of the effects on social value (i.e. aiming to include all costs and benefits that affect welfare and wellbeing, including environmental, cultural,

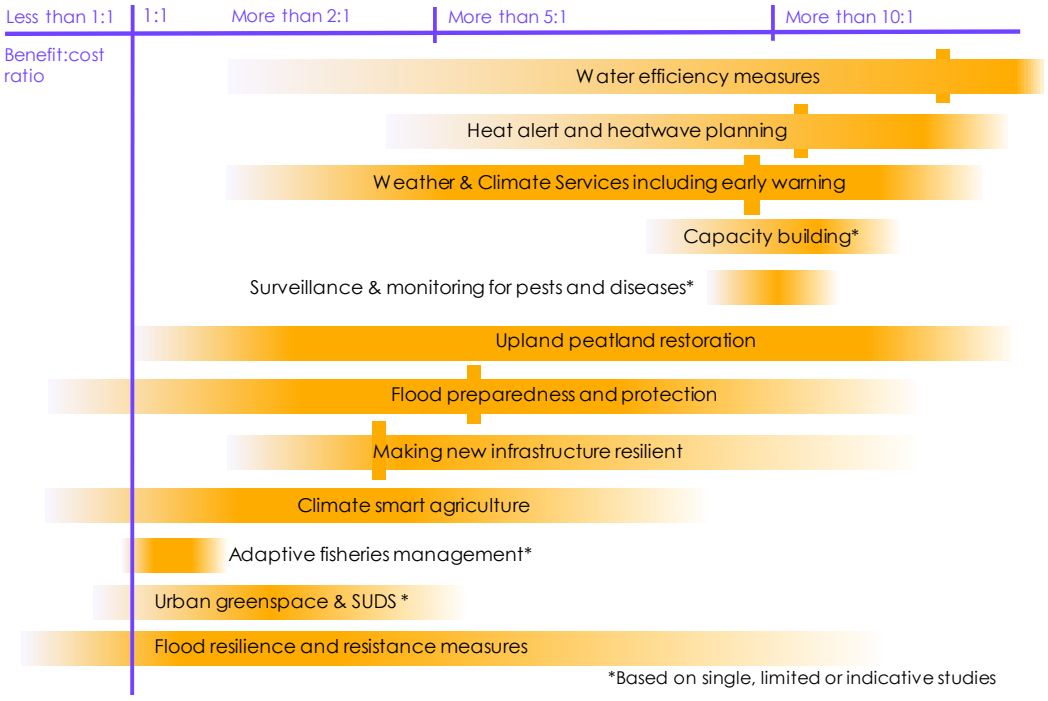
health, social care, etc.) to estimate the costs of climate change before adaptation.

The benefit-to-cost ratios (the ratio of the present value of benefits to the present value of costs) of a selection of measures discussed in the Technical Report are illustrated in Figure 3.6 below.

Some adaptation actions have very high benefit-to-cost ratios in excess of 10:1.

Adaptation actions have high net benefits, and positive benefit to cost ratios, in many cases, even when considering direct benefits alone.
The societal costs and benefits of adaptation measures tend to be very site- and context-specific and can vary significantly depending on the circumstances. An adaptation action that is not cost-beneficial in one context or location can be so in another, and vice versa. The review of adaptation costs and benefits in the Technical Report shows that in many cases, adaptation actions have positive benefit to cost ratios, even when considering the direct reduced impacts from climate change impacts alone (see Figure 3.6). Some adaptation actions such as surveillance and water efficiency labelling have very high benefit-to-cost ratios (10:1 or greater).

Figure 3.6 Benefit-cost ratios of adaptation measures included in CCRA3



Source: Watkiss, P. and Brown, K.A (2021).
Notes: Figure shows the indicative benefit-to-cost ratios and ranges for a number of adaptation measures. It is based on the evidence review undertaken in the CCRA3 Valuation study, which was co-funded by the EU's Horizon 2020 RTD COACCH project (CO-designing the Assessment of Climate CHange costs). Vertical bars show where an average BCR is available, either from multiple studies or reviews. It is stressed that BCRs of adaptation measures are highly site- and context-specific and there is future uncertainty about the scale of climate change: actual BCRs will depend on these factors.

Early action is a key component of effective adaptation. Waiting until a climate impact has occurred before improving resilience often results in higher costs and potentially irreversible losses.

Early action typically has much larger benefits than delaying and taking action after an impact has already occurred.
Delaying action makes it much harder to reduce climate risks and may make large future costs inevitable. There are three types of interventions that are highlighted as priorities for early action.

- **No- and low-regret intervention.** There is a very strong economic case for early action in relation to no- and low-regret interventions, as these have immediate economic benefits from reducing current impacts. Examples include reducing water use or signing up to flood warnings.
- **Climate-resilient design to avoid lock-in.** There is a strong economic justification to intervene early to include adaptation in near-term decisions that have long lifetimes and 'lock-in' risk (see section above on lock-in). In our assessments of adaptation in homes, the economic analysis has found that building homes to be prepared for a future climate with higher temperatures, more flooding and more water stress is far cheaper than retrofitting poorly-adapted homes later. Similarly, previous assessments of adaptation in land use show much larger net benefits when action is anticipatory, i.e. taken in advance of a climate change impact occurring. An example is planting trees that will thrive in the future climate, rather than managing a poorly chosen species mix retrospectively. Analysis of the benefits of these early actions is set out in detail in previous CCC reports on land use[18], and housing,[19] and is also reflected in the Technical Report chapters.
- **Early adaptive management.** For decisions that have long lead times, or where there are large future risks, there is a strong economic case for fast-tracking early adaptive management actions, because of the value of information and opportunity for learning these provide. An example includes flood management planning for London through the Thames Estuary 2100 programme.

At the national level, all three of these types of interventions are likely to be needed.

Relocation or retreat is a fourth type of intervention. However, it may not be a cost-effective option in many cases (unless the impacts are very large).
An example of research into relocation from the Valuation Report relates to protection of electricity substations from flooding. A national-scale analysis looked at direct and indirect economic losses that could occur due to the failure of major electricity assets within England and Wales, as a result of flooding major electricity substations. Of the three potential adaptation options considered: installing flood walls, raising flood walls, and relocation, the installation of a floodwall to protect against failure-related losses results in a positive NPV for all 107 sub-stations; only four substations show a positive NPV for the substation raise option, and no assets showed a positive NPV for the substation relocation option, although investment in the latter options could become more attractive when an asset is approaching the end of its life.

This example also raises the question of what other adaptation measures could be employed in addition to structural flood defences in order to add additional resilience before a relocation option is considered; for example, a wider portfolio of measures shown in Table 3.4. Nature-based solutions such as green sustainable drainage systems could offer an additional benefit for flood protection, particularly against surface water flooding, which is the major cause of current and future flood risk for substations.

There is little available evidence of the benefits of further adaptation to take advantage of the opportunities from climate change.
Chapter 2 sets out the opportunities from climate change that are identified in the Technical Report. Many of these benefits will be realised by non-government action, e.g. by households or the private sector. However, the assessment identifies that in some cases there are likely to be barriers or constraints that prevent or reduce such action, and therefore further government action could help to take advantage of opportunities. This might, for example, create the enabling environment, such as with awareness raising or information provision. An example is government support to improve skills in construction for climate-resilient homes, or providing information about likely future conditions to help farmers to judge when to switch crops to a warmer-climate variety.

The Technical Report found less evidence on opportunities (benefits) in general, e.g. for facilitating new species colonisation, opportunities for wellbeing from warmer temperatures, increased UK food exports and new trade routes, and it found very little information on the potential benefits of further action to support delivery of these direct opportunities. There was also a gap in terms of the costs and benefits of further action. One exception was for the UK wine industry, where some analysis of the economic opportunities, and the possible costs and benefits of further action, was identified.

Adaptation actions can have important wider benefits, such as for health and wellbeing and improved biodiversity. Adaptation can generate wider economic benefits, as well as avoiding climate change damage.
Many adaptation actions generate co-benefits, which are additional to their benefits in reducing the impacts of climate change. Some examples of such actions that are highlighted in the Technical Report include:

- **Peatland restoration.** The benefits of peatland restoration vary by location and the assumptions made about future climate change. According to Watkiss et al. (2019) the range of benefit-to-cost ratios varies from between 1.3:1 to 12:1, depending on how far into the future the analysis goes and which benefits are considered. The net benefits are larger if wider ecosystem services – over and above carbon storage – are included, such as water quality improvements and biodiversity gains from well-functioning upland peat. Climate change also strengthens the case for peatland restoration, as more extreme climate scenarios could lead to irreversible losses for degraded peatland systems, but these potential outcomes can be avoided by early restoration.
- **Improved ventilation in buildings.** As well as aiding the night-time cooling of buildings during hot weather, adequate ventilation is also critical for maintaining good standards of indoor air quality.
- **Green sustainable urban drainage systems.** Blue-green infrastructure in urban areas has a host of known benefits for health and wellbeing, biodiversity, and local environmental quality, as well as for climate change mitigation and adaptation. When considering the benefits from reduced flooding alone, the benefits of green sustainable drainage systems can appear marginal, but when other benefits are included (e.g. amenity value, biodiversity benefits), the benefit-to-cost ratio increases significantly and rise to 2:1 or higher.

Adaptation actions that enhance the resilience of the natural environment have important wider benefits across all of the sectors assessed in the CCRA.
As well as being an important component of interacting risks (see Chapter 2), the natural environment plays an important role across the risks considered in the CCRA of mediating impacts, through its role as an adaptation response. There has been a step change in the understanding of the monetary benefits of biodiversity and the natural environment to people since CCRA2 was published, including through the UK Government's work on natural capital accounting and the publication of the Dasgupta Review of the Economics of Biodiversity.[20] The importance of using a natural capital framework in understanding the benefits of adaptation is summarised in Box 3.1 below. Future iterations of the UK's National Adaptation Plans should consider nature-based solutions in more detail and prioritise those with benefits across protecting biodiversity, reducing emissions and improving climate resilience.

Box 3.1
The role of natural capital in adaptation

The natural environment, in addition to its intrinsic value, provides critical ecosystem services. These include provisioning services (e.g. food and fibre production); regulating services (e.g. water regulation); cultural services (e.g. amenity, recreational and aesthetic benefits) and supporting services (e.g. nutrient recycling). The ecosystems that provide these services (and the flow of benefits provided) can also be thought of as capital assets. The term capital is used to denote a stock that could continue to give, if properly maintained. It also provides a useful analogy to other essential forms of 'capital', although with unique and sometimes less tangible attributes that challenge attempts at generalisation and simplification (see Dasgupta, 2021).

Natural Capital encompasses all components of the natural environment, as well as the processes and functions that link these components and sustain life. Natural capital assets include all biotic (living) and abiotic assets (e.g. species, ecological communities, soils, freshwaters, land, atmosphere, minerals, sub-soil assets and oceans) and include both designated and undesignated habitats and species.

Climate change can have potential impacts on natural capital assets and the benefits they provide. The stability and resilience of ecosystems is maintained by a complex array of natural processes, feedbacks, and functions that are affected in different and profound ways by changes in hazards such as warming temperatures and alterations in seasonal rainfall. While it can be challenging to tease out all of these interacting effects, what becomes clear is that the risks to the natural environment from climate change go way beyond the loss of a single asset or service, and create risks to the stability of biological systems as a whole, including human systems.

However, at the same time, it is possible to use ecosystems to deliver adaptation. Nature-based solutions both aim to recognise and work with (rather than against) the natural resilience and adaptability of the natural environment to preserve natural assets and ecosystem services, and in doing so, maintain the resilience of the core underpinning services they provide.

Source: Adapted from Chapter 3 of the CCRA3 Technical Report (Berry and Brown et al. (2021).

Green finance should help in creating better market conditions for adaptation funding.

An active green finance market is emerging in the UK, which should help to create the right market conditions for adaptation funding if it is integrated as a core aim. Some examples of recent developments in green finance include:

- The use of green 'resilience bonds', for example those now being put in place through water companies. The UK has nearly 80 green bonds already listed on the London Stock Exchange, raising more than US$24bn[55]. Green bonds have focused on mitigation to date and there is no information on the level of resilience bonds. However, the first major resilience bond ($700 million) was recently launched by EBRD.

- The first UK sovereign green bond was announced by the Government in 2020. The stated aims of the Bond were to help finance projects that will tackle climate change, support infrastructure investment and create green jobs across the country. Adaptation should be core to these objectives.

- The Natural Environment Investment Readiness Fund (NEIRF) was launched in 2021 to help make projects more investible in terms of returns and scale and thereby help stimulate private investment.

Funding mechanisms are still not in place for some adaptation measures, and in other cases mechanisms exist but are not incentivising a scale-up in action as adaptation is not considered as a core aim.
A final issue for consideration is the subject of how funds can be made available to support adaptation.

In some cases, funding may be provided privately in response to market signals – for example, households might be expected to pay for property-level flood resilience, if they have good information about their own level of risk and access to finance to make the investment.

However, in many cases missing markets and barriers to action might mean this is unlikely to happen. There may be information failures, the value of the adaptation action may not accrue to where the expense is incurred, there may be a lack of sufficient financial returns, lack of coordinated, large scale, investment opportunities, or a range of other market failures and barriers may prevent effective measures being taken. Examples include flood defences that benefit a wide range of property owners, building-level measures for tenants of private-rented properties, and any measures that protect the natural environment.

Some well-established funding mechanisms for adaptation already exist, such as partnership funding for flood defence schemes, flood insurance and water company financing for water efficiency measures in homes. New environmental land management payments could offer a targeted lever for adaptation in the land use sector, but the details of how these will operate and how far they will achieve this are still not available at the time of writing.

For many of the other beneficial adaptation measures identified above, however, the signals do not exist to encourage effective measures at scale from householders, local authorities or businesses.

This includes building-level measures such as passive cooling, and some nature-based solutions including urban greening and rainwater harvesting.

In other cases there has been an increase in government-funded schemes for the natural environment such as the £640million Nature for Climate Fund, but these lack a specific focus on adaptation and are therefore unlikely to incentivise the best actions in the right places to promote resilience.

The risk assessment has highlighted that resources for local action, such as limited conservation budgets, are also a constraint on implementing adaptation actions which also often have co-benefits for climate change mitigation and biodiversity.

Emerging information from adaptation finance studies in Glasgow[21] highlights that to meet the adaptation finance gap, public funds will need to be scaled up and used in more strategic ways, including to mobilise private investments. Doing this requires the private, public and third sectors to design a process for mobilising public and private resources for innovation, making a broader range of financing instruments and models accessible, as well as developing long-term transformative financing solutions that are aligned to the different interests and requirements of the public and private sectors.

Green finance offers the potential to fund adaptation actions with wide-ranging benefits across climate change mitigation, adaptation and biodiversity protection. The UK Government's Green Finance Strategy identifies climate resilience and an increase in adaptation as strategic objectives to support through green finance. Despite this recognition, the Government does not provide further details on providing funds or financial mechanisms for these goals.

There is an increasing number of options, though not yet at the scale needed to encourage the levels of adaptation required to match the scale of risk.[22] Some suggestions for new financing mechanisms or frameworks mentioned in the CCRA3 Technical Report include:

- Conservation organisations developing finance-ready proposals for investment in biodiversity.
- Lending, advisory services and green 'securitisation', which will help provide finance from institutional investors, and opportunities for banks as underwriters or issuers of green bonds.
- Extending funding mechanisms that currently only focus on low-carbon buildings (e.g. the smart energy programme) to include resilience, which in turn would help to boost profitability and employment in the construction and advisory services.

A key component of the next iteration of national adaptation plans should be a commitment to enable sufficient funding for the necessary scaling up of adaptation action, setting out the mechanisms by which this will be achieved, with a focus on those adaptation actions that have no relevant funding streams at present.

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