The Costs of Adaptation, and the Economic Costs and Benefits of Adaptation in the UK

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Summary

There are no aggregate estimates of the costs of adaptation for England or the UK, and thus no reliable estimates of adaptation finance needs. This paper synthesises the available information in this area and makes a number of recommendations to develop such estimates going forward.

Introduction and challenges

The costs of adaptation can be defined as the costs of planning, preparing for, facilitating, and implementing adaptation measures to moderate harm or exploit beneficial opportunities. The analysis of these costs, especially when combined with analysis of the benefits of adaptation, can help in the allocation and prioritisation of resources, and in identifying potential adaptation finance needs.

Estimating the costs of adaptation at national and local level is extremely challenging. This is because it requires analysis of the site and context specific nature of risks (hazard, vulnerability, and exposure), noting that these change over time, and the corresponding site and context specific analysis of an adaptation response. Delivering adaptation is also widely seen as a socio-institutional process, that needs to go beyond the identification and costing of sequential technical options.

Estimates of adaptation costs also vary with objectives, with future warming levels and scenarios, with definitions and boundaries, and with the sectors and risks included. There is also high uncertainty around the size of future climate risks, and thus the level of adaptation needed, as well as the effectiveness of adaptation. This means there is no definitive cost of adaptation, i.e., it depends, and estimates vary according on the method used, the objective set, and the assumptions made.

It is also highlighted that there is a relationship between the level of adaptation and the level of residual damage after adaptation. Higher adaptation investment will tend to mean lower residual damage. Strictly speaking, it should be the combined analysis of the costs of adaptation and residual impact that should be considered, with a consideration of the trade-off between the two.

There are alternative methods that can be used for estimating the costs of adaptation, all of which have strengths and weaknesses in relation to the challenges above. The choice of method used influences the nature of adaptation considered as well as the magnitude of adaptation costs estimated. There are two broad methods that are considered in this paper. The first is based on an economic analysis, which assesses the future economic costs of climate change, then seeks to identify adaptation based on the benefits (in reducing these impacts) versus the costs. These tend to be the results of modelling exercises focusing on future climate projections (e.g., in the 2050s). The second is more widely used in the international context, and identifies adaptation priority areas, then uses sector, programme, project, or activity-based costing to estimate costs (needs assessment). These tend to be more applied and focus on the period from now to 2030. Both approaches have strengths and weaknesses.

Economic costs of climate change in the UK

The CCRA3 assessed the potential economic costs of all 61 risks and opportunities considered in the CCRA3. While it did not aim to provide an aggregate estimate of total economic costs, it did report that for a selection of nine important risks alone, annual damages could be £5 billion to £10 billion /year by mid-century, rising to £tens of billions/yr late century.

It identified that in the present day (current), 12 risks were rated as high or very high (costs of >£hundreds or £billions/year) - of these, 9 are public and 3 are private in nature. By the 2050s, 21 risks were rated as high or very high – of these, 9 are public and 12 are private in nature. There were also 12 risks for which even indicative valuation was not possible, which were all public in nature, and some of these are likely to be very large. This indicates that while the current climate risk landscape is likely to be dominated by the need for public finance, private finance will become increasingly important.

A subsequent analysis by the COACCH project, reported in the Government CCRA3 report, did include an aggregate analysis, reporting estimate of potentially 1% to 2% of GDP/year by mid-century (though there are both lower and higher estimates in the literature).

Review and analysis of the costs of adaptation

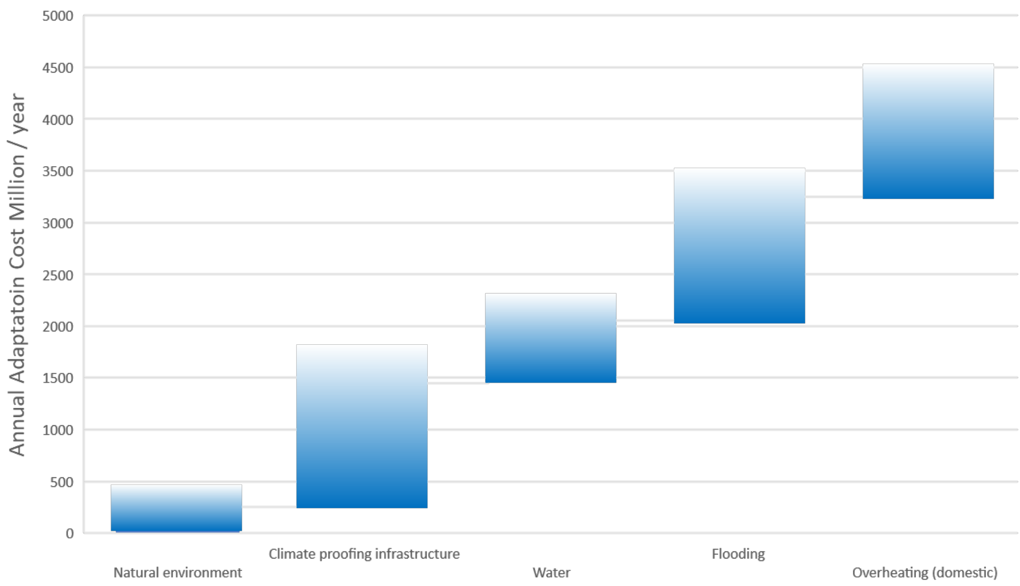
Recent analysis for the UNFCCC and UNEP Adaptation Gap report has compiled the estimated costs of adaptation reported by over 70 countries for the period up to 2030. While these are focused on developing countries, they do provide a benchmark. Based on an analysis of this data and transferring average values from upper middle countries as the nearest proxy, this would imply adaptation costs for the UK of £4 billion/year on a per capita basis but £25 billion/year on a GDP equivalent basis.

There are some European estimates of adaptation costs emerging. A recent analysis of the costs of adaptation in France estimate short-term annual costs of Euro 2.3 billion/year. Importantly, this includes the costs of the processes and plans needed, as well as early technical options. This highlights the need to move away from a narrow cost-curve perspective for adaptation, and the importance (and costs) of broader enabling activities.

Moving to the UK there are some estimates at the sector level and for individual CCRA3 risks. While it is stressed that it is not appropriate to consider adaptation as a set of technical solutions (i.e., as with a mitigation cost curve), there will be some large investment needs (costs) for a number of the important risks (e.g., flooding, over-heating, water, infrastructure). These provide another source of potential adaptation costs. However, these are indicative only. Further, it is critical that these are not considered as a cumulative set of adaptation costs, because they are not based on the same frameworks or assumptions, i.e., they are based on different objectives and thus trade-offs between costs and residual damage (and further, only costs and not residual damage are reported).

The review has identified some adaptation costs, notably associated with flooding (from LTIS), overheating, natural environment, over-heating and for infrastructure. However, there are many gaps on the potential adaptation costs for many CCRA3 risks.

The costs of adaptation depend on the level of adaptation (versus level of residual risks) and whether current as well as additional costs are included. Taken together, this initial review indicates adaptation costs / investment needs for a small selection of (albeit important) risks could be around £5 billion /year (very approximately) this decade. However, costs are likely to increase very significantly after 2030.



Indicative costs of adaptation for a selection of major CCRA3 risks.

Expanding to all 61 risks in the CCRA3, it would seem plausible that the costs of adaptation this decade could be £10 billion/year or even more, if this includes proactive adaptation. This would require significant public sources of adaptation finance (floods, health, natural environment) but also significant private/household sources of finance (overheating in properties, water). It is also worth highlighting that while the investment in mitigation is quite capex intensive, adaptation is likely to include higher opex costs (recurring, associated with ongoing operations, maintenance, etc.).

Review and analysis of the costs and benefits of adaptation

The monetary valuation study in CCRA3 also undertook an evidence review of the costs and benefits of further adaptation action for all 61 individual risks and opportunities. This review was based on the available evidence, thus the findings are partial, and can only be considered indicative. Furthermore, it is stressed that there are a very large number of caveats in transferring the results of existing cost-benefit studies of adaptation. This is due to the high site- and context-specificity, but also because the long time periods and high levels of uncertainty make quantification of benefits and thus economic analysis challenging. Nonetheless, the review found an increased body of evidence, particularly since previous CCRAs, and identified potentially high economic benefits from further adaptation for many of the CCRA3 risks and opportunities. The findings for a selection of individual risks are summarised in the figure below. This identifies that many early adaptation investments deliver high value for money. The benefit-cost ratios typically range from 2:1 to 10:1. The analysis also found that adaptation also often leads to important co-benefits, so as well as reducing potential losses from climate change, it often generates direct economic gains, or leads to social or environmental benefits.

Recommendations

It would be useful for the CCC/CCRA4 to develop estimates of current adaptation spend in government and more widely (climate budget tagging) and undertake a more detailed estimate of the costs of adaptation for England/UK, combining modelling and programme/project costing method. This would provide information on likely adaptation financing needs, including for the public finances and the private sectors, as well as the split between risks/sectors.

Introduction

There are no aggregate estimates of the costs of adaptation for England or the UK, and thus no reliable estimates of adaptation finance needs.

This policy paper synthesises the available information in this area and makes a number of recommendations to develop such estimates going forward. The paper has been produced separately by Paul Watkiss (Paul Watkiss Associates) to provides inputs to the Climate Change Committee and to Defra on the costs of adaptation, to help inform the CCC's adaptation finance initiative and Defra's early planning for UK Climate Change Risk Assessment 4.

Methodological issues with the costs of adaptation

The costs of adaptation can be defined as the costs of planning, preparing for, facilitating, and implementing adaptation measures to moderate harm or exploit beneficial opportunities.

In theory, it is relatively simple to estimate the costs of adaptation, as the sum of actions to address climate impacts or exploit opportunities. However, in practice, estimating these costs is extremely challenging (and much more so than estimating the costs of mitigation). This section outlines the issues with estimating the costs of adaptation. It draws heavily on the forthcoming UNFCCC review of the costs of adaptation, also by this author.

It requires analysis of the site and context specific nature of risks, noting that these change over time, and the corresponding site and context specific analysis of an adaptation response. There is also high uncertainty around the size of future climate risks, and thus the level of adaptation needed. Delivering adaptation is also widely seen as a socio-institutional process, that needs to go beyond the identification and costing of technical options.

The challenges to estimating the costs of adaptation are set out below. It is highlighted that estimates of adaptation costs also vary with objective, assumptions, future warming levels, levels of residual impacts, and other factors, which include political as well as scientific perspectives. These issues influence what is counted as adaptation, as well as the size and nature of the costs assessed.

UNFCCC (2022) lists the key challenges with estimating the costs of adaptation.

- In simple terms (UNEP, 2015), the costs of adaptation can be assessed by estimating the current and future impacts of climate change, assessing how adaptation can reduce these impacts (benefits) and how much this action might cost. However, there is a further trade-off with the impacts of climate change after adaptation, i.e., residual damage, because it is often costly to reduce impacts to zero. In practice, estimating the costs of adaptation is extremely challenging, because:
- It is also highlighted that there is a relationship between the level of adaptation and the level of residual damage after adaptation. Higher adaptation investment will tend to mean lower residual damage. Strictly speaking, it should be the combined analysis of the costs of adaptation and residual impact that should be considered, with a consideration of the trade-off between the two.
- There is currently no single, agreed quantitative goal or objective for adaptation (the equivalent of the targets to limit future warming or emission reduction targets for mitigation), at either the global or national level. The costs of adaptation vary with the objective adopted, and whether this is defined by economic efficiency, levels of acceptable risks, or to maintain current levels of damages.

- Adaptation is location, time, and context specific, and must be assessed in terms of specific impacts, which vary by risk. This differs to mitigation, which is assessed in terms of common burdens (tCO_2). This also means it takes time and resources to estimate adaptation costs.
- Adaptation costs vary with the sectors and risks considered. The broader the number of sectors and risks, the higher the costs of adaptation will be. Most studies focus on a smaller number of risks and have a partial coverage of adaptation costs. In general, there has been less consideration of household and private adaptation, and these could increase the estimated costs of adaptation, potentially significantly.
- The costs of adaptation will vary with future emissions trajectories (scenarios) and levels of warming, i.e., whether the Paris Agreement goals are met. However, the costs of adaptation also vary for any individual scenario, because of the large uncertainty and wide envelope of projected change from climate and impact models.
- Adaptation levels and costs vary if a static baseline (current society and economy) or a future socio-economic baseline, including development, economic and population growth, are included (non-climate drivers), because the latter affects stock at risk, exposure, and vulnerability.
- Adaptation costs are higher if countries' existing adaptation deficits are included, this deficit being the existing adverse impacts of current climate variability and extremes, i.e., that have always occurred. These deficits exist because many developing countries have underinvested in disaster risk reduction to current risks. While the existing adaptation deficit is not primarily caused by climate change, future adaptation will be less effective if it is not addressed first.
- Similarly, adaptation costs are much higher if options that build general resilience are included. In contrast, if adaptation is only included based on a strong climate rationale, then a smaller set of actions will be costed.
- Adaptation is often described as a process, and involves capacity building and governance change, ideally as part of an iterative risk management framework. It is much less a set of technical options (as is the case for mitigation). It is also non-linear and involves complex temporal aspects, this means the effectiveness of adaptation may change over time. However, most current cost estimates are based on technical (engineering) costs.
- Many adaptation studies omit opportunity, transaction costs and monitoring costs, and exclude design, management, and technical assistance costs, thus real-world adaptation cost out-turns are likely to be higher in practice.
- However, countering this, non-technical options, learning and innovation all have the potential to reduce future adaptation costs (compared to current estimates). Furthermore, soft options, have potentially lower costs or offer wider co-benefits when compared to engineering-based options.
- Assessing costs within an economic framework affects estimates, because taking time preference (discounting) into account affects the attractiveness and choice of options. A further issue relates to the indirect impacts of climate change, including cross-sectoral and economy wide effects. Including these effects can increase or decrease impacts and adaptation costs.

- Adaptation that considers distributional issues and equity, may involve different interventions and different groups, which may alter costs. Similarly, mitigation and adaptation can involve positive synergies, but also potential negative trade-offs. If trade-offs are considered, this may limit least cost adaptation options, and mean different actions with potentially different costs.
- There are barriers and constraints to adaptation (physical and ecological limits, technological limits, information and cognitive barriers, and social and cultural). These have the potential to increase costs, and in some cases, there will be limits to adaptation.

Reflecting this complexity, there are no common methods for assessing the costs of adaptation. A range of methods can be used, see below. These various methods address the challenges on estimating the costs of adaptation differently, as they can adopt alternative perspectives or framing, and different assumptions. It is stressed that there is not the same consensus on methods that exist for mitigation, where a standardized approach has been developed based on scenarios, marginal abatement costs and cost curves.

As a consequence, there is no single, definitive cost of adaptation for a country, i.e., it depends (on the method used, the objectives set and the assumptions made, noting different actors may have different views around key framing perspectives). The framing of adaptation, and the choice of methods and key assumptions, make a large difference to adaptation costs, altering estimates by at least an order of magnitude (UNEP, 2015). This means comparisons between developing country estimates should be treated with caution unless harmonised methods and assumptions are employed.

The UNFCCC (2022) list the methods that can be used to estimate the costs of adaptation include the following.

- Sector, programme, project, and activity-based costing. This approach dominates the international costs of adaptation reported by developing countries as part of their submissions to the UNFCCC and for adaptation finance needs. Nationally Determined Contributions and National Adaptation Plans focus on the costing of identified adaptation actions (be they sectoral, programmatic or project based). These can be high level costing exercises, through to at the most detailed, bottom-up activity budgets for project implementation.
- Sector integrated assessment/damage costs. These are the main source of cost of adaptation estimates in the literature and involve the use of sector models (global, regional, national, local) to assess future climate change impacts, and then technical adaptation responses (and associated costs and benefits). Such approaches have been used commonly for coastal and river protection, as well as agriculture. Examples include coastal adaptation costs estimated by the DIVA model (Brown et al. 2021).
- Integrated assessment models (global). These models combine the scientific and economic aspects of climate change within a single, integrated analytical framework, and can quantify the economic impacts of climate change, and in some cases, the costs and benefits of adaptation, albeit in a stylised form. While primarily applied at the global level, these have also been used to downscale results to regions or countries. Examples include applications for Africa (De Bruin and Ayuba, 2020) and in Asia (ADB 2009, and later studies).
- Computable general equilibrium (CGE) modelling. These are macro-economic models that allow analysis of how impacts cascade across sectors of the economy, as well as

price effects. They often use sector impact and adaptation studies as inputs, Examples include the original 2010 World Bank EACC national studies, as well as more recent studies (Ciscar et al., 2016: 2020).

- Econometric modelling. There have been a number of studies that use econometric (statistical) analysis of current climate and economy linkages and use these relationships to look at future climate impacts, and in some cases adaptation, AfDB (2019).
- Investment and financial flow analysis. These focus on the likely costs of planned adaptation, based on analysis of current financial flows, now and in the future, and apply an adaptation mark-up to these. An example is the UNDP Assessment of Investment and Financial Flows (IFF) to Address Climate Change (UNDP, 2011), which provided national /sector estimates in 15 countries.
- A variation of the IFF is to base the analysis of adaptation costs (and sometimes benefits) on climate budget tagging or CPIER studies, aligning to national development planning.
- Decision support tools. There are also a suite of decision support methods that can be used for adaptation, to identify priorities, and which generate cost estimates. These include a suite of standard decision support tools, with the use of cost-benefit analysis, cost-effectiveness analysis, which are often suitable for no – or low-regret adaptation, but do not account for uncertainty (see next bullet). These are more commonly used for project appraisal, rather than producing national estimates.
- Decision making under uncertainty. Recognising that appraisal for proactive, planned adaptation involves (deep) uncertainty, a suite of alternative decision support tools have emerged, that allow decision making under uncertainty, e.g., by focusing on flexibility, robustness. These are also primarily used in project appraisal, although there are some applications at aggregated levels.
- All of these have strengths and weaknesses. The appropriate method to use will depend on the objectives of the exercise (the reason for estimating costs of adaptation), but also on the time, resources and expertise available.

Economic based methods have a strong theoretical basis and look to make rational choices on adaptation investment. They can also address future climate change scenarios and even uncertainty. They therefore provide information that aligns to UK Government appraisal, and can also be used to assess the costs and benefits of adaptation, and thus the case for action.

However, much of the economic literature in this area uses highly stylised analysis of adaptation, focused on technical options, centred on the 2050s, and so does not provide short-term information on the costs of adaptation (or finance needs) in the immediate future, i.e., the 5 year reporting periods of the CCRA and NAP cycle. They also often apply a static if-then approach to future uncertainty, looking at costs and benefits for one scenario at a time. A more recent literature addresses the latter problem through the use of decision making under uncertainty (DMUU) but these involve more complexity, time and resources and are primarily applied at the project level.

Project-based costing methods have many advantages, especially as they are relatively easy to complete and provide practical information on near-term actions to inform adaptation finance needs and early implementation.

However, these methods also have some disadvantages. They do not fully capture many of the challenges with estimating adaptation costs and these types of studies typically cost long lists of identified activities. They are usually based on an estimate of the costs of activities (e.g., they estimate the cost to deliver a national programme of climate smart agriculture, or a large coastal project), rather than as the result of an analysis or appraisal. There is rarely any consideration of the benefits of adaptation (in reducing climate change impacts), adaptation effectiveness, or an analysis of the costs and benefits of adaptation or the appropriate level or scale of adaptation. They rarely consider uncertainty. This means that the adaptation assessed is unlikely to be the most economically efficient outcome and may not prioritise the greatest risks or deliver the greatest adaptation benefits (for available resource levels).

They also tend to focus on short-term programme or project priorities, largely concentrating on direct government interventions, with less consideration of implementation costs or enabling conditions. Only a few take a more strategic approach or consider longer-term issues (including uncertainty). Furthermore, these costing approaches often tend to include activities associated with the existing adaptation deficit (current climate variability) as well as broader development, i.e., they have a very broad climate rationale.

Definitions and Typology of Adaptation

Related to the challenges above, the costs of adaptation depend on the definition of adaptation. While definitions are relatively harmonised, there are a wide set of adaptation typologies, that influence adaptation costs.

The IPCC AR6 (2022) has updated as follows:

Adaptation. In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects.

Resilience. The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure.

The AR6 also reports that resilience is an entry point commonly used, although under a wide spectrum of meanings.

The AR6 also introduces transformative adaptation, alongside incremental and transformational adaptation.

Incremental adaptation. Adaptation that maintains the essence and integrity of a system or process at a given scale (Park et al.,2012). In some cases, incremental adaptation can accrue to result in transformational adaptation (Tàbara et al., 2018; Termeer et al., 2017). Incremental adaptations to change in climate are understood as extensions of actions and behaviours that already reduce the losses or enhance the benefits of natural variations in extreme weather / climate events.

Transformational adaptation. Adaptation that changes the fundamental attributes of a social-ecological system in anticipation of climate change and its impacts.

Transformative change. A system-wide change that requires more than technological change through consideration of social and economic factors that, with technology, can bring about rapid change at scale.

There is also an issue of the limits of adaptation.

Limits to adaptation. These are the point at which an actor's objectives or system's needs cannot be secured from intolerable risks through adaptive actions. These include hard limits, where no adaptive actions are possible to avoid intolerable risks, and soft limits, where options are currently not available to avoid intolerable risks through adaptive action, but which might be available in the future. (AR5)

The Climate Change Risk Assessment 3 Method (CCRA3) (Watkiss and Betts, 2021) also included additional definitions for adaptation, as follows:

Reactive adaptation - Adaptation in response to experienced climate and its effects.

Pro-active planned (anticipatory) adaptation - Planned adaptation to expected climate effects. Note this can be taken by both public and private actors.

There is also the term **autonomous adaptation**, which is adaptation that happens without explicitly or consciously focusing on addressing climate change. This term is often incorrectly used to include private sector adaptation (when in reality, private action can be planned). The term autonomous adaptation should really be limited to action that happens automatically (i.e. reductions in thermostat controlled household winter heating demand). Autonomous adaptation is much less relevant for finance, because this action happens unconsciously and does not involve finance (although it does involve a cost or benefit).

The MDBs have developed finance typologies for looking at adaptation investment projects. These are important because these recognise that adaptation can be differentiated in different ways to the classic definitions in the literature (as above). The type of adaptation investment for which finance is needed are split between (ADB, 2020):

Climate resilience (climate-proofing) of projects. This involves the integration of adaptation in investments. In this case, adaptation is a secondary objective. An example is the integration of adaptation measures in a planned road project.

Adaptation projects. The targeted investment in projects to address climate risks and deliver adaptation. An example is a new coastal protection scheme to manage rising sea levels, although it could also be a large capacity building project for adaptation. In this case adaptation is the primary or principal objective of the project.

- A variation of this is where a project has strong adaptation co-benefits, i.e. where there are multiple objectives, one of which is adaptation.

The **adaptation finance gap** (UNEP, 2014) has been defined as the difference between the estimated costs of meeting a given adaptation target and the amount of finance available to do so.

Estimates of the Economic Costs of Climate Change in the UK

The level of adaptation should, in theory, be dictated by the level of climate change impacts, especially when adopting a strong economic perspective. The UK CCRA3 valuation report (Watkiss et al., 2021) estimated the potential economic (societal) costs of climate change for all 61 risks. These are presented for present day and 2050s only – not the 2080s – to allow greater focus on adaptation costs.

Economic valuation of CCRA3 Risks, Current and 2050s, by theme.

Risk / Opportunity	Present Day	2050s
NE1. Risks to terrestrial species and habitats f	Unknown	Unknown
NE2. Risks to terrestrial species/habitats from pests, pathogens, invasives	Unknown	Unknown
NE3. Opportunities from new species colonisations in terrestrial habitats	Unknown	Unknown
NE4. Risk to soils from changing climatic conditions	H	H
NE5. Risks to natural carbon stores and sequestration	VH	VH
NE6. Risks to and opportunities for:		
Agriculture	L - H	H +H
Forestry	(variability)	L - H
NE7. Risks to agriculture from pests, pathogens and invasive species	M	M
NE8. Risks to forestry from pests, pathogens and invasive species	M	M
NE9. Opportunities for agricultural and forestry productivity	+M	+H
N10. Risks to aquifers and agricultural land from sea level rise	L	Unknown
N11.Risks to freshwater species and habitats	H	H
N12. Risks to freshwater species/habitats from pests, pathogens, invasives	L	L
N13. Opportunities to freshwater species and habitats from new species	+L	+L
NE14. Risks to marine species, habitats and fisheries	L - M	M
NE15. Opportunities to marine species, habitats and fisheries	+L	+M
NE16. Risks to marine from pests, pathogens and invasive species	L	M
NE17. Risks and opportunities to coastal species and habitats	L	M
NE18. Risks and opportunities from climate change to landscape character	Unknown	Unknown

Risk / Opportunity	Present Day	2050s
I1. Risks to infrastructure networks from cascading failures	H	VH
I2. Risks to infrastructure services from river, surface, groundwater flooding	H	H – VH
I3. Risks to infrastructure services from coastal flooding and erosion	M	M
I4. Risks to bridges and pipelines from flooding and erosion	M	M
I5. Risks to transport networks from slope and embankment failure	M	M – H
I6. Risks to hydroelectric generation from low or high river flows	L	M +M
I7. Risks to subterranean and surface infrastructure from subsidence	M	M
I8. Risks to public water supplies from reduced water availability	M	H
I9. Risks to energy generation from reduced water availability	L	Unknown
I10. Risks to energy from high and low temperatures, high winds, lightning	M	H-VH +H-VH
I11. Risks to offshore infrastructure from storms and high waves	L	H-VH +H-VH
I12. Risks to transport from high and low temperatures, high winds, lightning	M - H	M – H
I13. Risks to digital from high and low temperatures, high winds, lightning	Unknown	M

Risk / Opportunity	Present Day	2050s
H1. Risks to health and wellbeing from high temperatures	VH	VH
H2. Opportunities for health and wellbeing from higher temperatures	+M	+ VH
H3. Risks to people, communities and buildings from flooding		
H3a River and surface flooding	VH	VH
H3b Coastal flooding	H	H
H4: Risks to the viability of coastal communities from sea level rise	L	L
H5: Risks to building fabric	Hi	H
H6 Energy demand		
H6a: Opportunities from reduced winter household energy demand	+H	+ VH
H6b: Risks from increased summer household energy demand	L-M	H
H7: Risks to health and wellbeing from changes in air quality		
H7a: Risks to health and wellbeing from changes in air pollution	L	L
H7b: Risks to health and wellbeing from changes in aeroallergens	Unknown	Unknown
H8: Risks to health from vector-borne disease	L-M	L-M
H9: Risks to food safety and food security	L	L-M
H10: Risks to household water		
H10a: Risks to household water supplies	M	H
H10b: Risks to water quality	Unknown	Unknown
H11: Risks to cultural heritage	Unknown	Unknown
H12: Risks to health and social care delivery	Unknown	Unknown
H13: Risks to education and prison services	Unknown	Unknown

Risk / Opportunity	Present Day	2050s
B1. Risks to business from flooding	VH	VH
B2. Risks to business and infrastructure from coastal change	M	M
B3. Risks to businesses from water scarcity	M	H
B4. Risks to finance, investment and insurance	M	VH
B5. Risks to business from reduced employee productivity	L	M
B6. Risks to business from disruption to supply chains and distribution	M	Unknown
B7. Opportunities for businesses from changes in goods and services	+M	+VH

Risk / Opportunity	Present Day	2050s
ID1: Risks to UK food availability	H	VH | +VH
ID2: Opportunities for UK food availability	L	+H
ID3: Human mobility	L	L
ID4: Violent conflict	L	M
ID5: Law and governance	Unknown	Unknown
ID6: Opportunities international trade routes	+L	+M
ID7: Risks international trade disruption	L	M
ID8: Risk finance sector	H	VH
ID9 Public Health	L	L
ID10 Multiplication	Unknown	Unknown

Key

Risks		Opportunities		
VH		+VH		£billions/year
H		+H		£hundreds of millions/year
M		+M		£tens of millions/year
L		+L		£<10 million/year

In terms of the total risks (not including opportunities):

- For the present day, there are 12 risks rated as high or very high (costs of >£hundreds million/year) (3 natural environment risks, 2 infrastructure risks, 4 health and well-being, 1 business risks, 2 international risks).
- For the 2050s, this increases to 21 risks rated as high or very high (costs of >£hundreds million/year) (5 natural environment risks, 5 infrastructure risks, 6 health and well-being, 3 business risks, 2 international risks).

Note that there were 12 risks were valuation was not possible. All of these were public dominated risks.

It also possible to look at the public vs private split of these risks, in broad terms. Allocating very broadly, taking into account the nature of the sector and whether the risk is related to public goods, it can be seen that there are a larger number of public than private led risks.

Risk / Opportunity	Present Day	2050s
NE1. Risks to terrestrial species and habitats f	Unknown	Unknown
NE2. Risks to terrestrial species/habitats from pests, pathogens, invasives	Unknown	Unknown
NE3. Opportunities from new species colonisations in terrestrial habitats	Unknown	Unknown
NE4. Risk to soils from changing climatic conditions	H	H
NE5. Risks to natural carbon stores and sequestration	VH	VH
NE6. Risks to and opportunities for:		
Agriculture	L - H (variability)	H +H
Forestry		L - H
NE7. Risks to agriculture from pests, pathogens and invasive species	M	M
NE8. Risks to forestry from pests, pathogens and invasive species	M	M
NE9. Opportunities for agricultural and forestry productivity	+M	+H
N10. Risks to aquifers and agricultural land from sea level rise	L	Unknown
N11.Risks to freshwater species and habitats	H	H
N12. Risks to freshwater species/habitats from pests, pathogens, invasives	L	L
N13. Opportunities to freshwater species and habitats from new species	+L	+L
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NE18. Risks and opportunities from climate change to landscape character	Unknown	Unknown

Risk / Opportunity	Present Day	2050s
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I2. Risks to infrastructure services from river, surface, groundwater flooding	H	H – VH
I3. Risks to infrastructure services from coastal flooding and erosion	M	M
I4. Risks to bridges and pipelines from flooding and erosion	M	M
I5. Risks to transport networks from slope and embankment failure	M	M – H
I6. Risks to hydroelectric generation from low or high river flows	L	M +M
I7. Risks to subterranean and surface infrastructure from subsidence	M	M
I8. Risks to public water supplies from reduced water availability	M	H
I9. Risks to energy generation from reduced water availability	L	Unknown
I10. Risks to energy from high and low temperatures, high winds, lightning	M	H-VH +H-VH
I11. Risks to offshore infrastructure from storms and high waves	L	H-VH +H-VH
I12. Risks to transport from high and low temperatures, high winds, lightning	M - H	M – H
I13. Risks to digital from high and low temperatures, high winds, lightning	Unknown	M

Risk / Opportunity	Present Day	2050s
H1. Risks to health and wellbeing from high temperatures	VH	VH
H2. Opportunities for health and wellbeing from higher temperatures	+M	+ VH
H3. Risks to people, communities and buildings from flooding		
H3a River and surface flooding	VH	VH
H3b Coastal flooding	H	H
H4: Risks to the viability of coastal communities from sea level rise	L	L
H5: Risks to building fabric	Hi	H
H6 Energy demand		
H6a: Opportunities from reduced winter household energy demand	+H	+ VH
H6b: Risks from increased summer household energy demand	L-M	H
H7: Risks to health and wellbeing from changes in air quality		
H7a: Risks to health and wellbeing from changes in air pollution	L	L
H7b: Risks to health and wellbeing from changes in aeroallergens	Unknown	Unknown
H8: Risks to health from vector-borne disease	L-M	L-M
H9: Risks to food safety and food security	L	L-M
H10: Risks to household water		
H10a: Risks to household water supplies	M	H
H10b: Risks to water quality	Unknown	Unknown
H11: Risks to cultural heritage	Unknown	Unknown
H12: Risks to health and social care delivery	Unknown	Unknown
H13: Risks to education and prison services	Unknown	Unknown

Risk / Opportunity	Present Day	2050s
B1. Risks to business from flooding	VH	VH
B2. Risks to business and infrastructure from coastal change	M	M
B3. Risks to businesses from water scarcity	M	H
B4. Risks to finance, investment and insurance	M	VH
B5. Risks to business from reduced employee productivity	L	M
B6. Risks to business from disruption to supply chains and distribution	M	Unknown
B7. Opportunities for businesses from changes in goods and services	+M	+VH

Risk / Opportunity	Present Day	2050s
ID1: Risks to UK food availability	H	VH +VH
ID2: Opportunities for UK food availability	L	+H
ID3: Human mobility	L	L
ID4: Violent conflict	L	M
ID5: Law and governance	Unknown	Unknown
ID6: Opportunities international trade routes	+L	+M
ID7: Risks international trade disruption	L	M
ID8: Risk finance sector	H	VH
ID9 Public Health	L	L
ID10 Multiplication	Unknown	Unknown

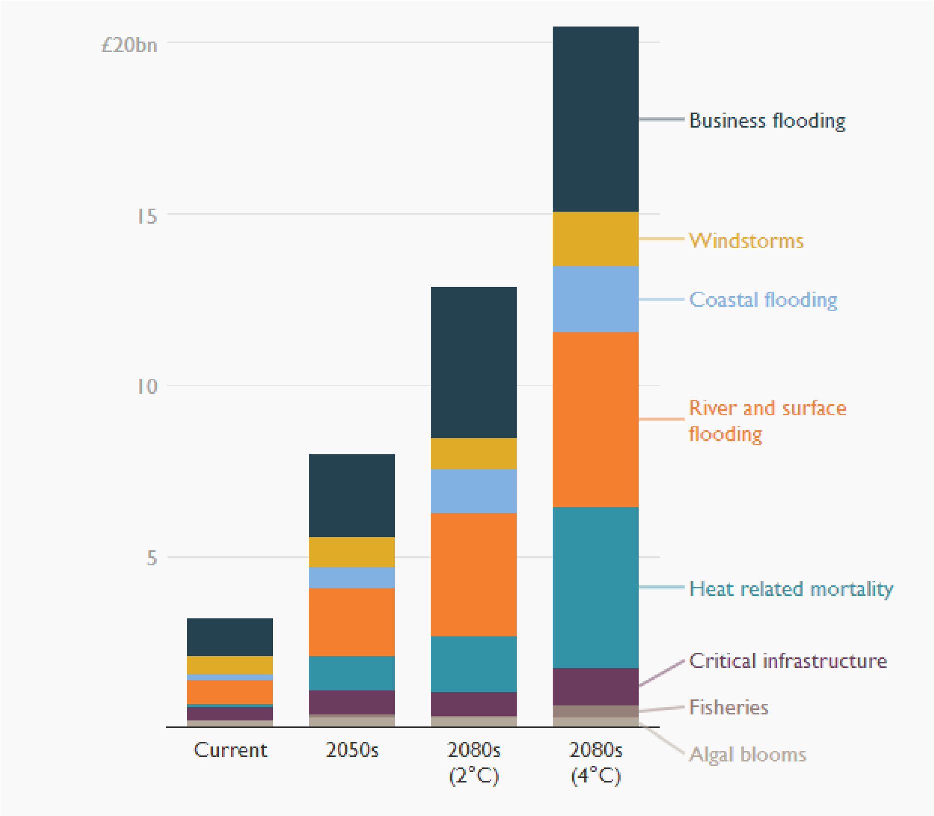
Allocation of CCRA3 risks into broad categories. Green = public; Blue = private.

This reveals (risks only, not opportunities):

- For the present day, of the 12 risks rated as high or very high:
    - 9 are public and 3 are private (public = 3 natural environment risks, 2 infrastructure risks, 3 health and well-being, 1 international risks: private = 1 H&WB, 1 business risk, 1 international).
- For the 2050s, of the 21 risks rated as high or very high
    - 9 are public and 12 are private (public = 3 natural environment risks, 2 infrastructure risks, 3 health and well-being, 1 international risks: private = 2 NE risks, 3 infrastructure 3 H&WB, 3 business risk, 1 international).
    - Note however that there were also a number of unknown risks, which are all public, some of which are very likely to be high or very high.

This is a very interesting finding. It indicates that the current climate risk landscape is dominated by the need for public finance. However, moving to the future, a growing number of areas will emerge where private financing is possible/important. This includes a large number of risks to households (e.g. overheating, water) and to areas with existing markets (e.g. agriculture, energy generation). It is noted that the focus on economic valuation will tend to gravitate towards sectors with market valuation, as this is easier to value, but nonetheless, it does indicate greater finance for adaptation will be needed in the private as well as the public sector.

In terms of economic costs of climate change, a number of known climate threats have very high (aggregate) economic costs (£billions/year) in the UK, even by the mid-century. These include river and surface water flooding to residential properties, business and infrastructure, and the impacts of sea-level rise, coastal flooding and storm-surge to the same receptors. They also include the impact of extreme heat, notably in terms of health and well-being (including fatalities) and overheating in the built environment (residential and business), impacting either in terms of discomfort / reduced productivity, or increasing cooling demand for households and business. The other main hazard, that of water (and the water supply-demand balance) is potentially high in monetary terms in mid- and late-century, although it varies between regions (with England projected to be the most affected). This is projected to occur even though water management plans are already integrating climate change. There are also large potential costs to business and industry. The largest risks are still associated with floods, as well as to financial services, but there is a much wider set of linkages that mean a broader set of risks could be important. Indirect risks (from extremes), cascading risks (to infrastructure) and supply chain risks (business) all potentially involve very high economic costs, though valuation studies are at an early stage. There are almost certainly very large risks to the natural environment, again of the order of £billions/year. These arise from a wide range of risks (including both slow-onset and extreme events), though the evidence base for valuation remains low, both in quantitative and economic terms.



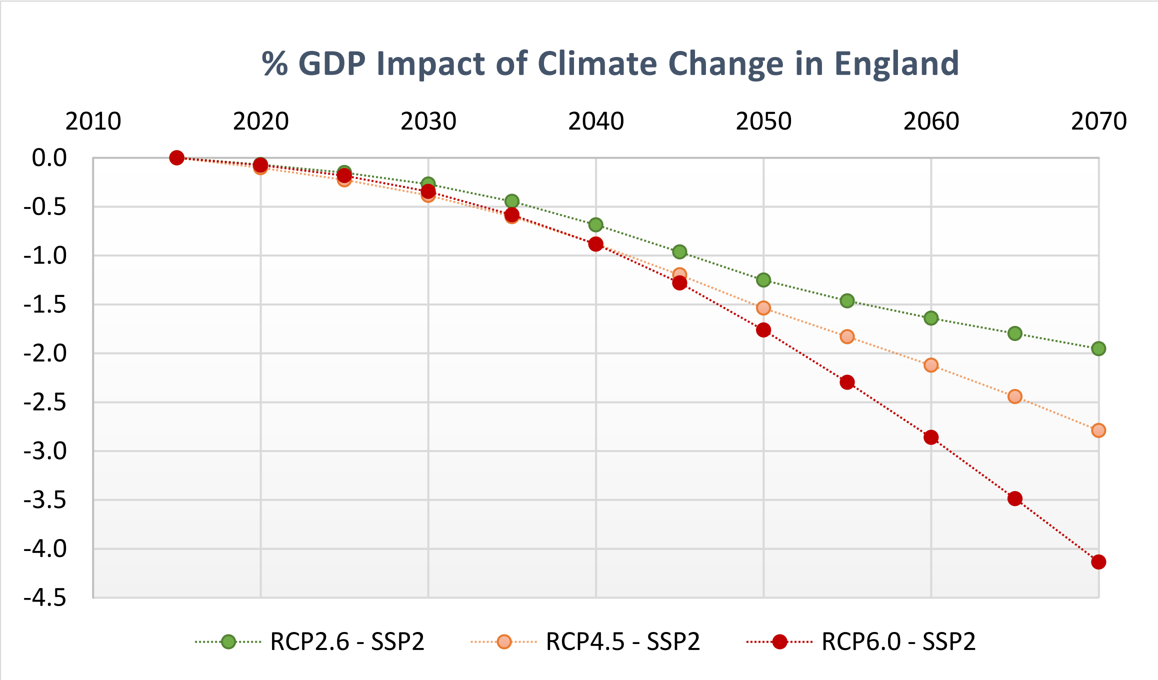
Annual economic costs of climate change in the UK (£Billion) for selection of risks. Source Watkiss et al, 2021.

Values include climate and socio-economic change, presented in current prices with no discounting, central values. Note these values are taken from different sources, and thus some care must be taken in the direct comparison, because they use different climate model outputs, scenarios and assumptions.

Other recent modelling work[i], based on a CGE analysis, shown in the figure and reported in the Government CCRA3 report, estimated the economic costs to England could be 1% to 1.5% of GDP/year by 2045 (central estimate), rising to 2% to 4% by late century. These imply much higher economic costs than above, even based on current UK GDP, of tens of billions/year by mid-century. It is also noted that as a CGE analysis, this excludes non market impacts.

As further examples of UK damages, the IMF (Kahn et al., 2019[ii]), using an econometric analysis, projected a 1% loss in GDP per capita in the UK by 2050, increasing to 4% by 2100 under a high warming scenario. Swiss Re (2021)[iii] estimated the economic costs in the UK at 0.5% to 3.2% of GDP for a 2°C pathway by mid-century. Rising et al. (2022[iv]) estimated climate change damages to the UK are projected to increase from 1.1% of GDP at present to 3.3% by 2050.

Importantly, while global mitigation has high benefits, it only reduces UK climate impacts after 2040. Under current scenarios (the red and orange lines), the economic costs of climate change are extremely high. Reducing GHG emissions (mitigation), in line with the Paris Goals, can reduce these costs significantly (the green line). However, even with global mitigation, the benefits to the UK only arise after 2040, due to lags in the climate system. This means the economic costs of climate change over the next 20 years are already locked-in. Only adaptation can reduce down the economic costs of climate change over the next two decades.



Net aggregate economic costs of climate change for different warming scenarios (RCP2.6, 4.5 and 6.0). The green and red lines are broadly equivalent to 2°C to 4°C of warming globally. Values are central estimates from an economic model (a CGE). Source COACCH project (Bosello et al[v]). These values exclude non-market impacts (health and ecosystem services) and major tipping points.

Clearly there is a wide range of the estimates of the economic costs of climate change in the UK, and this therefore influences the economically optimal level of adaptation. This is not just related to scenario and model uncertainty, it is also determined by the method of analysis used and the assumptions made, with plausible future economic costs (for the UK) that vary by over an order of magnitude even by mid-century.

Estimates of the costs of adaptation

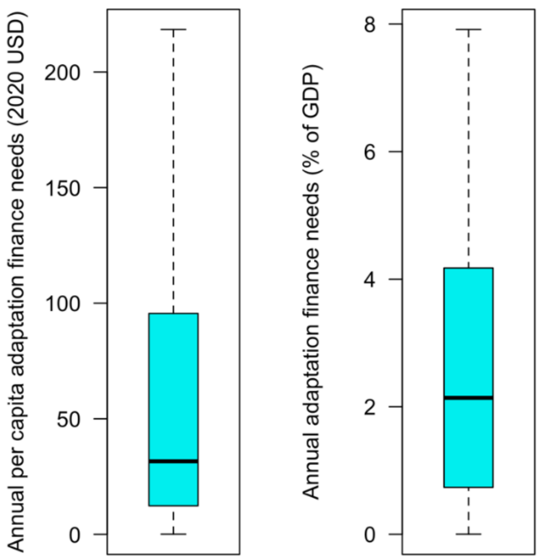
Following from the discussion of challenges above, considerable care must be taken in reporting any estimates of the costs of adaptation.

This section looks at a number of evidence lines to explore the potential cost of adaptation.

Transfer of international cost estimates

There has been significant progress by developing countries in assessing the costs of adaptation in recent years, with many more developing country Parties now assessing adaptation costs, and reporting these in Nationally Determined Contributions (NDCs), National Adaptation Plans (NAPs) and other communications. At the time of this report, 76 developing countries have reported adaptation costs in their NDCs or NAPs. These have used sector, programme, project, or activity-based costing as the primary method for estimating costs. This has the advantage of focusing on the short-term costs (to 2030) but cost estimates are not based on an economic analysis, and also there are incentives for developing countries to highlight high costs, in relation to potential adaptation finance needs.

The total costs of adaptation estimated by various countries in NDCs and NAPs are very different. Annual adaptation costs vary from USD 0.2 million to USD 13 billion per year for individual countries. Some of this variation is reduced by comparing population/economic size. Annual adaptation finance needs as a percentage of GDP range from 0.7% to 4.2% (interquartile range) with the median estimate of 2.3%. When adjusted for population, the result shows that developing countries' estimated costs of adaptation range from 10 to 95 USD per capita (interquartile range) with the median estimate of 30 USD per capita for the 2021-2030 period, for those countries that have reported adaptation costs. Values range with income, for example, the analysis above found the average per capita value was 63 USD in upper middle-income countries (UMCs).



For those developing countries reporting costs, costs per capita and as a percentage of GDP. Source, Chapagain and Watkiss, 2022[vi].

The costs indicated in these political documents should be interpreted with care for various reasons: (i) their level of precision varies considerably; (ii) NDC implementation periods vary; (iii) estimates are partial (covering only limited numbers of sectors); and (iv) there is no clear differentiation of the adaptation deficit versus the adaptation gap (Pauw et al. 2020). As a result, there is a large variation in estimated costs among countries. There are also obvious incentives for countries to report high adaptation costs. Nevertheless, they provide a useful benchmark for exploring possible adaptation costs. The average values have been used to estimate the possible costs of adaptation to the UK, based on a transfer on a per capita and GDP basis. The values are shown in the table below for the UK, based on National Office of Statistics data for population and GDP.

Transfer of the Costs of Adaptation from NDCs and NAPs to the UK based on per capita and GDP estimates. Transfer for upper middle income and all developing countries shown. Transferring values from Chapagain and Watkiss 2022.

		upper middle income			**All developing countries**		
Per capita	**low**	**medium**	**high**		**low**	**medium**	**high**
	0.671	4.226	8.721		0.671	2.012	6.373
GDP							
	2.32	25.49	64.88		16.22	48.66	97.31

This would imply a central value of £4.2 billion/year this decade based on a per capita basis, but £25 billion/year when based on the size of the economy.

There is relatively little information on the costs of adaptation in high income countries. There has been some analysis for the USA and some partial studies in Canada and Australia (See OECD, 2016).

Adaptation investment needs in the EU are estimated to range between EUR 35 billion and 500 billion annually, the large variation reflecting different underlying assumptions and methodological approaches[vii].

Recent analysis in France (IC4E, 2022) has, interestingly, estimated values[viii]. This identified a first set of 18 national budgetary decisions – representing an additional cumulative amount of at least €2.3 billion/year – that should be taken now to prepare, strengthen or operationalize adaptation actions.

Importantly, this includes the costs of the processes and plans needed, as well as early technical options. This highlights the need to move away from a narrow cost-curve perspective for adaptation, and the importance (and costs) of broader enabling activities.

Costs of Adaptation for France. I4CE, 2022.

Chantiers et propositions associées (Projects and associated proposals)	Budget (en M€/an)
Piloter et animer les politiques d'adaptation aux niveaux national, régional et local (Piloting/Steering and coordinating/leading adaptation policies at national, regional and local levels)	
Se doter de réelles capacités d'animation et de pilotage de la politique d'adaptation aux niveaux national, régional et local. (Develop real capacities to lead and steer the adaptation policy at the national, regional and local levels)	116
Créer un dispositif de mutualisation des moyens pour le développement et l'animation des services climatiques (Create a mechanism for pooling resources for the development and facilitation of climate services)	10
Protéger durablement la ressource en eau (Sustainable protection of water resources)	
Augmenter et maintenir dans la durée les moyens dont disposent les agences de l'eau pour leur action en faveur du grand cycle de l'eau et de la biodiversité (Increase and maintain in the long term the means available to the water agencies for their action in favor of the large water cycle and biodiversity)	300
Anticiper et prévenir les effets du changement climatique sur la santé (Anticipating and preventing the health effects of climate change)	
Financer un programme national de santé publique pour anticiper et prévenir les risques climatiques (recherche, campagnes de prévention, renforcement de la veille sanitaire) (Fund a national public health program to anticipate and prevent climate risks (research, prevention campaigns, strengthening of health monitoring)	2.52
Renforcer les politiques de sécurité civile pour suivre une extension des risques (Strengthen civil security policies to keep up with the exapnsion of risks)	
Revoir à la hausse les crédits de la sécurité civile pour accompagner l'extension du risque de feu de forêt et de végétation – accompagner l'investissement des SDIS (Increase the civil security credits to support the extension of the risk of forest and vegetation fires – support SDIS investment)	115
Pérenniser le niveau de prévention des risques naturels malgré un climat qui change (Sustain the level of natural hazard prevention despite/in a changing climate)	
Prévoir des moyens supplémentaires (enveloppes d'actions et capacités d'animation) pour rehausser le niveau d'effort de prévention des risques d'inondation pour à minima maintenir le niveau de risque actuel malgré les évolutions du climat (Provide additional resources (action envelopes and coordination capacities) to increase the level of effort for flood risk prevention in order to at least maintain the current level of risk despite climate change)	125
Repenser les villes pour lutter contre l'effet d'ilot de chaleur urbain (Rethinking cities to combat the urban heat island effect)	
Equiper les programmes de renouvellement urbain existant de moyens d'ingénierie leur permettant d'intégrer l'adaptation à la conception des opérations qu'ils soutiennent (Equip existing urban renewal programs with engineering resources that allow them to integrate adaptation into the design of the operations they support)	18
Pérenniser une enveloppe annuelle de soutien à l'extension des bonnes pratiques d'adaptation en ville (Sustain an annual support envelope for the extension of good adaptation practices in the city)	500
Tenir compte du climat futur lors de la construction et la rénovation des bâtiments (Take into account the future climate in the construction and renovation of buildings)	
Renforcer les moyens d'animation, de sensibilisation et de recherche appliquée en matière d'adaptation des bâtiments notamment aux vagues de chaleurs (Strengthen the means of animation, awareness and applied research on adaptation of buildings, particular to heat waves)	31.3
Prendre en charge le surcoût pour renforcer les exigences en matière de constructions durables et adaptés aux chaleurs futures dans la construction des bâtiments d'enseignement et de recherche. (Support the additional cost to strengthen the requirements for sustainable and future heat resistant construction in the construction of educational and research buildings.)	500
Garantir la résilience des réseaux et infrastructures d'importance vitale : transport, eau, énergie (Guarantee the resilience of networks and infrastructures of vital importance: transport, water, energy)	
Doter les gestionnaires d'infrastructures et leurs autorités régulatrices des moyens de connaître leurs vulnérabilités et de piloter l'adaptation, notamment au sein de la gestion patrimoniale des réseaux (Provide infrastructure managers and their regulatory authorities with the means to understand their vulnerabilities and to manage adaptation, particularly within the framework of network asset management)	15
Mettre en place et animer une instance de coordination des gestionnaires d'infrastructures (Set up and lead a coordination body for infrastructure managers)	1.7
Prévoir une première enveloppe pour financer des actions ciblées pour traiter les points critiques de vulnérabilité sur les réseaux de transport (Provide an initial envelope to finance targeted actions to address critical vulnerability points on transport networks)	325
Accompagner la recomposition des territoires littoraux face à la montée du niveau de la mer (Supporting the recomposition of coastal territories in the face of rising sea levels)	
Doter les collectivités des moyens d'objectiver leurs vulnérabilités, d'élaborer et d'animer une stratégie d'adaptation de leur littoral (Provide communities with the means to assess their vulnerabilities and to develop and implement/lead an adaptation strategy for their coastline)	15
Créer un fonds d'aide à la recomposition du littoral (Create a fund to assist in the recomposition of the coastline)	150
Agir pour des forêts résilientes et un maintien des services qu'elles rendent (Acting for resilient forests and maintaining the services they provide)	
Financer la mise en œuvre des actions de la feuille de route pour l'adaptation de la forêt française au changement climatique (veille sanitaire, interface recherche-gestion, expérimentation, animation et concertation) (To finance the implementation of the actions of the roadmap for the adaptation of French forests to climate change (health monitoring, research-management interface, experimentation, coordination and consultation))	25
Accompagner la diversification et la transition des économies de montagne (Supporting the diversification and transition of mountain economies)	

Pérenniser le fond "Avenir Montagne Ingénierie" et renforcer les moyens d'animation pour répondre aux besoins d'accompagnement des territoires de montagne en matière d'adaptation (Sustain the "Avenir Montagne Ingénierie" fund and strengthen the means of animation to meet the needs of mountain territories in terms of adaptation)	16.7
Pérenniser la part état du fond "Avenir Montagne investissement", inciter les Régions à faire de même (pour aboutir à un total de 150 M€/an) et flécher les investissements vers les projets contribuants à l'adaptation (To perpetuate the state share of the "Avenir Montagne Investissement" fund, to encourage the Regions to do the same (to achieve a total of €150 million/year) and channel investments towards projects contributing to adaptation)	75
Hypothèses communes (Common assumptions)	
Total	**2.34 Mds€/an**

Related to this, many countries internationally and now in Europe (France again) have undertaken climate budget tagging exercises. These look at how much is currently being spent in the government budget (and sometimes in private sector) on climate (adaptation and resilience, though can also look at mitigation). These can then be extended to look forward, to start looking at the potential increase in climate related expenditures. It might be useful to start trying to build up an estimate of current public financial flows on adaptation, as part of this PFM analysis.

UK Sector estimates

Moving to the UK, this review has undertaken a rapid review of the potential adaptation costs for CCRA3 risks. Note that there are also some potential costs associated with fully realising opportunities. The analysis is presented below. These should be considered indicative only. It is critical that these are not considered as a cumulative set of adaptation costs, because they are not based on the same frameworks or assumptions, i.e., they are based on different objectives and thus trade-offs between costs and residual damage (and further, only costs and not residual damage are reported).

Natural environment. This is one of the most challenging, yet most important areas and there is very little robust information on the economic costs, or on adaptation costs. There is some data on the baseline finance gap for UK nature to deliver nature-based outcomes and targets (EFTEC[ix]) which indicates this could be £44 billion to £97 billion over the next 10 years – with a central estimate of £56 billion. Similar work has also been undertaken by Defra as part of the impact assessment for the Environmental Targets, which are largely aligned to the 25 Year Environmental Plan (Defra, 2022[x]; IFC, 2020[xi]). The latter costed the additional costs to deliver the set of targets related to restoring protected sites to favourable condition, increasing species abundance, reducing the risk of species extinction and creation/restoration of wildlife-rich habitats outside of protected sites. This reports that total spend on biodiversity in England was £646 million in the 2019/20 financial year, but that the total needed to achieve the biodiversity targets might be approximately £1 billion per year (note the Defra IA reports that the average annual additional costs of achieving the species targets, beyond what is included in the counterfactual, are estimated to be £207m (between 2023-2042), and the average annual additional cost to reach the wider habitats outside of protected sites target is estimated to be approximately £55m (between 2023-2042) (Defra, 2022[xii]). However, this analysis did not consider the impact of climate on the achievability of the targets. Initial work to investigate this (Watkiss, Hunt and Berry, 2022) indicated delivering the targets under a changing climate might potentially increase costs by 20% and would add approximately £200 million to the annual costs of achieving the targets.

There are also potentially high adaptation costs for the agriculture and forestry sector, though there are many low regret options (climate smart agriculture) (Posthumus et al. (2015[xiii]) SRUC, 2013). These could be assessed and aggregated to derive possible adaptation costs. There has been some analysis on the costs and benefits of restoring peatlands and enhancing carbon storage (Moxey and Moran, 2014; Bright, 2017, Watkiss et al., 2019, Glenk and Martin-Ortega 2018[xiv]).

CCRA3 also had a number of risks associated with pests and diseases. The Environmental Audit Committee (2019) identified that expenditure on GB biosecurity is ca. £220 million per year, but invasive species only receive 0.4% of that sum (£0.9m), but these would be expected to increase with climate change. There has also been some analysis of costs and CBA for pest monitoring by SRUC (2013[xv]).

There is information in general on the costs and benefits of river basin management plans for England's water environment, as published in the Impact Assessment (Defra, 2015[xvi]), which include possible options that might have high relevance for addressing increasing climate related risks to freshwater. There are also some costs on adaptation for the fisheries sector, both in terms of enhanced monitoring and fisheries adaptive management, but also more specific actions such as increasing marine protected areas (Watkiss et al, 2019).

Infrastructure. The CCRA3 identified a large number of individual and cascading risks for infrastructure. There is some information in individual areas, but this has not been collated in this review.

There is a general need for climate proofing of new infrastructure, given the long life-times involved. Previous work for the CCC (Watkiss et al., 2019) looked at the future national infrastructure investment profile to see how potentially large these needs might be. In the UK, the National Infrastructure Delivery Plan (NIDP) 2016–2021 set out Government commitments to £483 billion of investment in over 600 infrastructure projects / programmes to 2020-21 and beyond, of which £297 billion was planned by 2020-21 (National Infrastructure and Projects Authority, 2016). Around 50% of the infrastructure Pipeline to 2020-21 was anticipated to be financed and delivered by the private sector. The average annual investment excluding social infrastructure was around £48 billion. Based on evidence from climate proofing studies, and the typical uplifts associated with climate proofing (from Hallegatte et al., 2017[xvii] ADB, 2014[xviii]) the analysis estimated the annual adaptation cost of building climate resilience in this NIDP economic project pipeline could be £0.2 billion to £4.8 billion/year, with a central estimate of around £1 billion/year.

There are more studies in the water sector. As an example, Water UK (2016) assessed a twin track approach of demand management coupled with appropriate development of new resources and potential transfers as being the most suitable strategy for providing drought resilience in the future. They estimated that total costs per annum for all potential future scenarios (under the business and usual base demand management strategy) to maintain resilience at existing levels in England and Wales are between £50 million and £500 million per annum in demand management and new water resource options. If resilience to 'severe drought' is adopted, this increases to between £60 million and £600 million and for resilience to extreme drought, between £80 million and £800 million per annum. There are other estimates, and these include higher costs if more drought contingency is included.

There are some estimates of costs of adaptation for bridges Nemry and Demirel (2012), some indicative estimates for the costs of adaptation to the railways (RSSB, 2016[xix]) and for roads (Atkins, 2013[xx]) as well as case studies for many of the categories in CCRA3, but further work is needed to compiled estimates.

Health and Well-being. There is considerable information available on flood adaptation costs. In terms of current spending, the Defra (2021) flood and coastal erosion investment plan sets out that the amount invested in the new 6-year investment programme in England will be doubled to £5.2 billion for 2021 to 2027. Of this, it was anticipated that between £310 and £610 million of Partnership Funding contributions would come from local communities and the private sector. Overall, current flood funding is below estimated needs. The Environment Agency's Long-term Investment Strategy (2019) estimates that the overall economic optimum level of investment[1] corresponds to a long-term annual average of over £1 billion/year (£1000 million to £1340 million). This was higher than estimated in LTIS 2014, which estimated investment needs of £850 to 900 million/year in the period 2024 to 2053. However, these costs are low, in that they assume a high benefit cost return. Academic studies that are based on acceptable levels of risk estimate much higher flood related adaptation costs for the UK.

There are additional adaptation costs for the public sector, in terms of the anticipated scale-up needed for public health warnings to heat, and the increased response from the health sector (resource costs). There are also additional adaptation costs for health buildings, notably hospitals and care homes, to address over-heating risks. These costs are high, e.g., the costs of retrofitting the existing portfolio of hospitals.

There are also the costs of addressing over-heating in the public and commercial building stock. This includes new houses and retrofits. There are estimated costs of mechanical (AC) vs. passive methods of space cooling in new houses and retrofits (Wood Plc, 2019). An indication of costs can be generated by combining costs of a package of measures for new build (£1000 - 3,000 per house), with house building levels (200,000 to 300,00 new homes a year), which would mean £0.2 – 0.9 billion/year. For retrofit, costs are much higher. The CCC has also provided an indicative estimate for climate proofing building stock which estimates that installing moderate cost measures might have total investment costs of £4-5 billion overall by 2050. This can be compared to the impact costs of increased air conditioning (which can be considered an impact or adaptation), which is estimated to be very high in terms of annual costs (See CCRA3 valuation report).

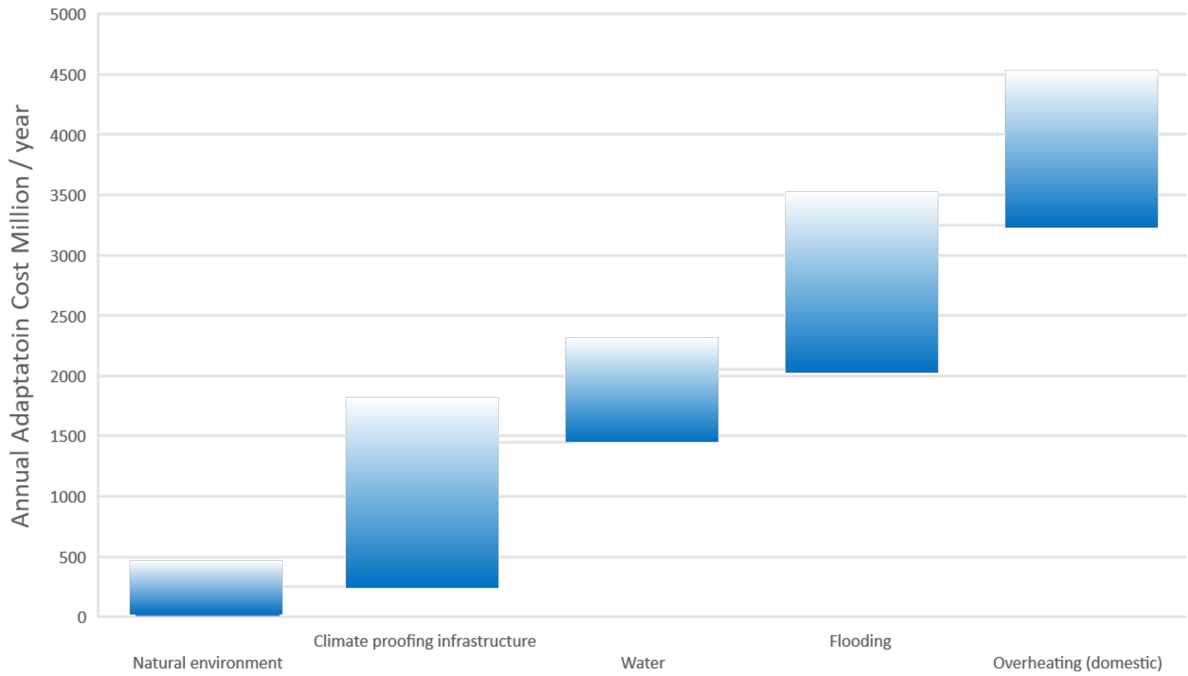
While there is no good aggregate data, studies of individual hospitals, prisons and schools indicate potential high adaptation costs, for both retrofit as well as new buildings.

Business. The main costs identified for business in CCRA3 are associated with flooding, and thus largely captured in the LTIS numbers, or associated with water and thus in the earlier water costs. There will be costs associated with addressing risks with business supply/supply chains, but these are not well characterised. There are some case studies on the costs of adaptation for addressing labour productivity impacts.

International. There is very little information on the costs of adaptation (in the UK/by the UK) to address international risks.

Total. Taken together, this initial review indicates adaptation costs / investment needs for a small selection of (albeit important) risks might be around £5 billion /year (very approximately) this decade. However, these costs are likely to increase very significantly after 2030. Expanding to all 61 risks in the CCRA3, it would seem plausible that the costs of adaptation this decade could be £10 billion/year, if this includes proactive adaptation.

[1] LTIS sets out the total national level of investment if we invest in all the places where the benefits are greater than the costs. This is called the economic optimum level of investment for FCERM. In some places this means that the ratio of benefits to costs is only slightly higher than 1. Across the whole LTIS 2014 baseline investment profile the overall ratio is about 5:1. https://www.gov.uk/government/publications/flood-and-coastal-risk-management-in-england-long-term-investment/long-term-investment-scenarios-ltis-2019



Indicative costs of adaptation for a selection of major CCRA3 risks.

This would require significant public sources of adaptation finance (floods, health, natural environment) but also significant private/household sources of finance (overheating in properties, water).

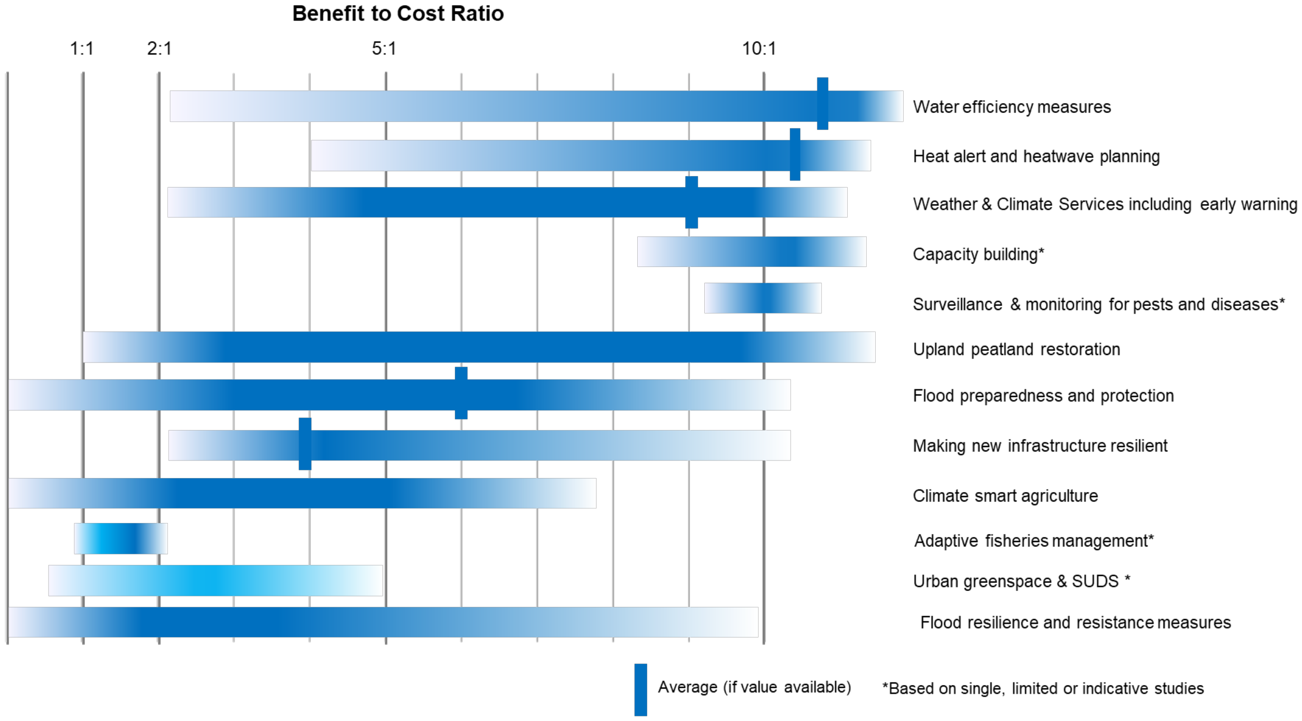
It is also worth highlighting that while the investment in mitigation is quite capex intensive, adaptation is likely to include higher opex costs (recurring, associated with ongoing operations, maintenance, etc.). The split between capex and opex is important for source of finance and for attracting finance.

Economic Costs and Benefits of Adaptation

The monetary valuation study in CCRA3 also undertook an evidence review of the costs and benefits of further adaptation action for all individual risks and opportunities, as part of Task 3b of the CCRA3 Methodology. As this review was based on the available evidence, the findings are partial, and can only be considered indicative. Furthermore, it is stressed that there are a very large number of caveats in transferring the results of existing cost-benefit studies of adaptation. This is due to the high site- and context-specificity, but also because the long time periods and high levels of uncertainty make quantification of benefits and thus economic analysis challenging.

Nonetheless, the review found an increased body of evidence, particularly since previous CCRAs, and identified potentially high economic benefits from further adaptation for many of the CCRA3 risks and opportunities. The findings for a selection of individual risks are summarised in the figure below.

This identifies that many early adaptation investments deliver high value for money. The benefit-cost ratios typically range from 2:1 to 10:1 – i.e., every £1 invested in adaptation could result in £2 to £10 in net economic benefits. The analysis also found that adaptation also often leads to important co-benefits, so as well as reducing potential losses from climate change, it often generates direct economic gains, or leads to social or environmental benefits. There are benefits from taking further adaptation action for almost every risk assessed in the CCRA report.



Benefit to Cost ratios for Adaptation for Selected CCRA3 risks.

Notes: Figure shows the indicative benefit: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.

The supporting information for this figure is included in the CCRA3 Valuation report.

Discussion and recommendations

It would be useful for the CCC/CCRA4 to develop estimates of current adaptation spend in government and more widely (climate budget tagging) and undertake a more detailed estimate of the costs of adaptation for England/UK, combining modelling and programme/project costing method. This would provide information on likely adaptation financing needs, including for the public finances and the private sectors, as well as the split between risks/sectors.

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