UK Climate Risk Independent Assessment (CCRA4)

Technical Report

Chapter 4: Economy

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4.1 Chapter Summary

This chapter assesses how climate change poses complex, systemic risks to the UK economy, affecting everything from macroeconomic stability and public finances to business assets, labour productivity, and household resilience. It finds that most economic risks now require critical action, with mounting threats from extreme weather, disrupted supply chains, financial instability, and rising adaptation costs. The chapter highlights widening inequalities as lower-income households face greater exposure, while also identifying emerging opportunities for UK firms in adaptation goods, services, and green finance. Despite growing awareness, the report stresses that investment in data, modelling, and coordinated policy is essential to build a climate-resilient economy.

Headlines

- The impact of climate change on the economy is complex, multifaceted, and requires future research.
- Climate change is a systemic threat to the UK economy with multiple risks already rated as “critical”.
- Macroeconomic stability is at risk: climate shocks to growth, inflation and trade require critical action.
- The financial system faces growing disruption from physical risks and contagion, critical action needed.
- Public finances will be squeezed across tax, spend and borrowing, evidence gaps mean critical investigation is needed.
- Business assets and supply chains, domestic and global, are exposed to escalating climate hazards.
- Rising heat and poorer air quality are eroding labour productivity and availability, critical investigation needed.
- Household finances face higher costs and widening vulnerabilities; urgency lower than other risks but still rising.
- A fast-growing market for adaptation goods and services offers the UK opportunities, if strategy and data gaps are closed.

E1 – Risks to UK macroeconomic performance and stability

Climate change poses systemic risks to the UK’s overall economic stability. Increasing climate shocks, such as floods, droughts, and food and energy price volatility, can disrupt trade, investment, and inflation, amplifying fiscal pressures. Key evidence gaps include the lack of integrated models linking global climate events to UK macroeconomic indicators and limited understanding of how monetary and fiscal policies interact with climate shocks. Key messages are that critical action is needed to safeguard macroeconomic stability, climate risks can trigger inflationary pressures and capital volatility, and that more integrated modelling and economic foresight are essential for resilient policy design.

E2 – Risks to domestic and overseas physical assets of UK businesses

UK businesses face escalating risks to their physical and overseas assets from extreme weather, floods and rising sea levels. These can lead to infrastructure losses, production halts, and higher insurance costs. The exposure of UK firms' overseas assets in climate-vulnerable regions further increases financial instability. Key messages are that climate hazards can cause billions in asset damages annually, businesses need stronger resilience planning, and climate-risk disclosures and that adaptation investment is lagging growing physical exposure.

E3 – Risks to domestic and international supply chains and resource inputs of UK businesses

UK supply chains are highly globalised and increasingly vulnerable to climate disruption. Extreme weather, port flooding, and global climate shocks threaten logistics and commodity flows. Key sectors at risk include food, pharmaceuticals and manufacturing. The evidence base remains weak, particularly around dependencies on climate-vulnerable regions and infrastructure resilience. The key messages are that critical investigation is needed to understand systemic vulnerabilities, globalised supply chains amplify UK exposure to overseas climate risks, and that domestic infrastructure resilience, especially ports and transport, is inadequate.

E4 – Risks to the productivity and availability of labour in the UK

Heatwaves and poor air quality increasingly reduce worker productivity and raise health costs. Outdoor sectors (construction, agriculture, logistics) are particularly exposed. Evidence suggests that climate-related heat stress could cost the UK over £1 billion annually by 2050 in lost output. Adaptation of buildings and work patterns is limited. The key messages are that labour productivity losses from heat will rise sharply post-2050, workplace adaptation (ventilation, flexible hours) is underdeveloped, and that research gaps persist around heat exposure data and regional vulnerability.

E5 – Risks to the financial institutions and the financial system

Banks and insurers face systemic threats from climate shocks that could destabilise asset valuations and trigger cascading financial losses. Flood damage, portfolio repricing, and investor uncertainty could collectively affect up to 1% of UK GDP. London's dominance in financial services magnifies exposure. The key messages are that critical action is required to strengthen financial resilience, and climate stress testing must become integral to risk management frameworks.

E6 – Risks to public finances

Public finances are vulnerable to rising adaptation and disaster-recovery costs, as well as declining tax revenues due to economic disruption. Major public infrastructure spending is at risk of being reactive rather than preventative. The scale of potential fiscal exposure is estimated at tens of billions of pounds. The key messages are that climate shocks can erode fiscal stability and crowd out investment, current public budgeting lacks a climate-risk accounting framework, and that critical investigation is needed into long-term adaptation funding models.

E7 – Risks to household finances

Climate change impacts household finances through higher food and energy prices, flood damages, and insurance losses. Food price shocks alone could add £275–£860 annually per household by the 2050s. Low-income households are disproportionately affected, widening inequality and financial vulnerability. The key messages are that household finance risks require further investigation, particularly distributional impacts, climate-related costs will exacerbate household debt and inequality, and that stronger social safety nets and insurance reforms are needed.

E8 – Opportunities to the UK businesses [and financial institutions] from delivering adaptation goods and services

Climate adaptation and transition present new market opportunities. UK firms can gain competitive advantage through innovation in resilient infrastructure, insurance products, and adaptation services. Exporting adaptation expertise could generate substantial growth. However, evidence on readiness and investment scale is limited. The key messages are that climate adaptation will create new markets and innovation potential, public-private collaboration can accelerate green finance and technology diffusion, and that investment in skills, data, and adaptation R&D will determine success.

Cross-cutting conclusions

Climate change is now a systemic economic risk, requiring coordinated adaptation across all levels of government and business. The urgency of most economic risks has increased since CCRA3, except for household finances. Major evidence gaps persist around cross-sectoral interactions, regional exposure, and modelling capability. Overall priority actions should be to develop integrated UK climate-economic models, enhance financial sector stress testing, strengthen public and private adaptation investment, and expand data collection and cross-disciplinary research.

Table 4.1: List of risks and urgency scores for the Economy by country. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the urgency scores are calculated is provided in the Methods Chapter. Where insufficient evidence is available to provide urgency scores at an individual country level, a single score is provided at the UK level in a merged box.

ID	Risk		Present	2030	2050	2080	Urgency
E1	Risks to UK macroeconomic performance and stability	**UK**	+++ (H)	++ (H)	++ (VH)	++ (VH)	CAN
		England	++ (H)	++ (H)	++ (VH)	++ (VH)	CAN
		Northern Ireland	+++ (H)	++ (H)	++ (VH)	++ (VH)	CAN
		Scotland	+++ (H)	++ (H)	++ (VH)	++ (VH)	CAN
		Wales	+++ (H)	++ (H)	++ (VH)	++ (VH)	CAN
E2	Risks to domestic and overseas physical assets of UK businesses	**UK**	++ (VH)	++ (VH)	++ (VH)	++ (VH)	CAN
		England	++ (H)	++ (H)	++ (VH)	++ (VH)	CAN
		Northern Ireland	++ (H)	++ (H)	++ (VH)	++ (VH)	CAN

		Scotland	++ (VH)	++ (VH)	++ (VH)	++ (VH)	CAN
		Wales	++ (H)	++ (H)	++ (VH)	++ (VH)	CAN
E3	Risks to domestic and international supply chains and resource inputs of UK businesses	**UK**	++ (H)	+ (H)	+ (VH)	+ (VH)	CI
		England	++ (H)	+ (H)	+ (VH)	+ (VH)	CI
		Northern Ireland	++ (H)	+ (H)	+ (VH)	+ (VH)	CI
		Scotland	++ (H)	+ (H)	+ (VH)	+ (VH)	CI
		Wales	++ (H)	+ (H)	+ (VH)	+ (VH)	CI
E4	Risks to the productivity and availability of labour in the UK	**UK**	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
		England	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
		Northern Ireland	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
		Scotland	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
		Wales	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
E5	Risks to the financial institutions and the financial system	**UK**	++ (M)	++ (H)	++ (VH)	++ (VH)	CAN
		England	++ (M)	++ (H)	++ (VH)	++ (VH)	CAN
		Northern Ireland	++ (M)	++ (H)	++ (VH)	++ (VH)	CAN
		Scotland	++ (M)	++ (H)	++ (VH)	++ (VH)	CAN
		Wales	++ (M)	++ (H)	++ (VH)	++ (VH)	CAN
E6	Risks to public finances	**UK**	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
		England	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
		Northern Ireland	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
		Scotland	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
		Wales	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
E7	Risks to household finances	**UK**	++ (M)	+ (M)	+ (H)	+ (H)	CI
		England	++ (M)	+ (M)	+ (H)	+ (H)	CI

		Northern Ireland	++ (M)	+ (M)	+ (H)	+ (H)	CI
		Scotland	++ (M)	+ (M)	+ (H)	+ (H)	CI
		Wales	++ (M)	+ (M)	+ (H)	+ (H)	CI
E8	Opportunities to UK businesses from delivering adaptation goods and services	**UK**	++ (M)	++ (H)	+ (VH)	+ (VH)	CI
		England	++ (M)	++ (H)	+ (VH)	+ (VH)	CI
		Northern Ireland	++ (M)	++ (H)	+ (VH)	+ (VH)	CI
		Scotland	++ (M)	++ (H)	+ (VH)	+ (VH)	CI
		Wales	++ (M)	++ (H)	+ (VH)	+ (VH)	CI

Note that for the economy chapter the guidance is to use two different risk classifications within the same chapter. One for risks E1, E5 and E6 and another for the remaining risks. The table below shows the distinction.

Table 4.2: The distinction in the two different types of risk classifications used across this chapter.

	Very high magnitude	High magnitude	Medium magnitude	Low magnitude
Economics E2, E3, E4, E7 and E8	£ billions of damages (economic) or foregone opportunities and/or	£ hundreds of millions (economic) or foregone opportunities and/or	£ tens of millions damage (economic) or foregone opportunities and/or	Less than £10 million damage (economic) or foregone opportunities and/or
	At least 0.05% of GDP	0.005%-0.05% of GDP	0.001%-0.005% of GDP	< 0.001% of GDP
Macroeconomic E1, E5, E6	1% of UK GDP or £ tens of billions of damages	0.25%-1% of UK GDP £ billions of damages (economic) or foregone opportunities	0.05-0.25% of UK GDP £ hundreds of millions damages (economic) or foregone opportunities	Less than 0.05% of UK GDP Less than £100 million damage (economic) or foregone opportunities

This means Table 4.1 needs to be interpreted carefully. For context, nominal GDP was estimated to be £2.851 trillion. Where there is inconsistency in the above table, percentages were used. The following analysis is further complicated by the fact that the estimates for the UK regions (Scotland, Wales and Northern Ireland) are set to be one category lower than for England. This makes comparisons across tables and within tables harder to interpret.

The scores above are based on the following assumption: “If there is no planned and announced adaptation, or if adaptation is happening but we don't have good monitoring and evaluation/projections of effectiveness, then we retain the confidence from the score without adaptation i.e. we are following the precautionary principle.”

4.2 Risks to Economy

4.2.1 Risks to UK macroeconomic performance and stability – E1

Scope: This risk covers systemic economic effects of climate change at the UK level, including changes in GDP, inflation, productivity. Subcomponents include climate shocks to productivity and investment, impacts on monetary and fiscal policy and domestic ripple effects from global economic volatility.

Headlines

- Critical action needed.
- The risk is expected to increase over time due to rising frequency of climate-related shocks (e.g., floods, droughts, global food and energy price volatility); increased likelihood of systemic disruptions to trade, investment, and inflation pathways; amplification through interdependencies between macroeconomic variables and climate-linked fiscal pressures.
- Key evidence gaps include limited empirical modelling of how climate risks affect UK macroeconomic indicators (e.g., GDP, inflation, exchange rates); scarcity of integrated models linking global and domestic climate shocks to the UK economy; lack of assessment of the interaction between climate risks and monetary or fiscal policy responses**;** inadequate quantification of long-term macroeconomic impacts under high warming scenarios.
- There was no comparable risk in CCRA3 although some related risks were embedded within broader economic themes.

Table 4.3: Urgency scores for E1 Risks to UK macroeconomic performance and stability. Key to the magnitude scores: very light purple (L), light purple (M), purple (H), dark purple (VH). Key to the magnitude scores and confidence levels: L = Low, M = Medium, H = High, VH = Very High Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

ID	Risk		Present	2030	2050	2080	Urgency
E1	Risks to UK macroeconomic performance and stability	**UK**	+++ (H)	++ (H)	++ (VH)	++ (VH)	CAN
		England	++ (H)	++ (H)	++ (VH)	++ (VH)	CAN
		Northern Ireland	+++ (H)	++ (H)	++ (VH)	++ (VH)	CAN
		Scotland	+++ (H)	++ (H)	++ (VH)	++ (VH)	CAN
		Wales	+++ (H)	++ (H)	++ (VH)	++ (VH)	CAN

Note that Table 4.3 above uses the macroeconomic categorisation. The analysis is complicated by the wide range of estimates in the literature for current and future economic damages.

4.2.1.1 Evidence relevant to the entire United Kingdom

Current and future drivers of risk

The links between climate change and the macroeconomy are very complex. On the one hand, one needs to recognise that the full impacts of climatic factors on the macroeconomy reflect the economic outcomes for each sector, which need to be carefully accounted for. While it is evident that climate factors directly affect agricultural output, for example, through their influence on temperatures and water availability, shifts in weather patterns also have more subtle impacts on other economic sectors, indirectly affecting manufacturing, energy production, and transportation, for example, due to reductions in labour productivity, or disruptions in supply chains. On the other hand, the macroeconomy is more than the simple sum of the individual sectors, and a comprehensive evaluation of the overall risks posed by climate change needs to account for systemic factors, such as the resilience of the physical and financial infrastructure and financial institutions that underpin the economy, including the interconnectedness with international trading partners and public finances. Similarly, one needs to account for the degree to which climate hazards are correlated across space and time, and the nature of the policy responses to both climate shocks and longer-term patterns. Localised floods in one part of the country, for example, may have limited impacts on aggregate output if supply chains and public services are able to continue working. The existence of resilient energy and transportation networks, and access to resources via international trade as needed are key to reduce the risk from idiosyncratic shocks. The same shock, however, may become devastating if failures cascade through national systems, and access to international suppliers is limited.

To put some structure on our assessment, we follow the taxonomy of risks developed by the Bank of England (e.g., Table 1 in Batten, 2018), which also highlights the channels through which the risks affect the economy. The first distinction is between physical risks, defined as "those risks that arise from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability of exposure of human and natural systems, including their ability to adapt" (Batten et al., 2016), and transition risks, that instead are risks that arise from the transition to a low-carbon economy. This section only considers physical risks.

Physical risks can be further divided according to their source, and a useful distinction is between climate change risks from extreme weather events and risks that emerge because of gradual (slow onset) climate change. Extreme weather events, such as floods, droughts and heat waves, tend to manifest as economic shocks, i.e. unpredictable events that produce significant, swift changes in the economy and tend to be short-lived. Gradual climate change, on the other hand, may have predictable, albeit usually highly uncertain effects on the economy over a much longer time horizon meaning there are large confidence intervals around the predicted effect. All risk types may be mitigated by reducing the degree of exposure to known hazards, for example, by building more resilient infrastructures or via different types of adaptation, such as developing drought-resilient crops.

The economic risks more generally associated with extreme weather events can be thought of as direct risks and are linked to the direct loss of production, for example in agriculture, as well as with the damages that events such as floods may cause to building and infrastructure, leading to indirect effects in other sectors such as construction, manufacturing, energy and transport, to name a few. On the other hand, reconstruction efforts for example, may benefit some sectors such as construction. In addition, extreme weather events may lead to loss of labour supply and other inputs, or to an increase in their prices across the economy, including sectors downstream from those directly affected by the extreme event.

From an economist's point of view, there is little doubt that an extreme weather event represents a negative shock in the short term. Whether disasters have a positive or negative impact in the medium run (e.g., 2 to 10 years), however, is less clear-cut since investment in reconstruction (if any) forms part of GDP. Other positive impacts of the recovery from extreme events might arise if the reconstruction phase leads to 'building back better', whereby the new assets that replace the lost ones are more modern and productive. On the other hand, investment in adaptation measures post-disaster may crowd out investment in more productive investment and reduce growth potential in the longer run (for example, rebuilding existing flood defences instead of investing in new flood defences or other productive avenues such as R&D in new technologies). Similarly, an inflow of workers brought about by the reconstruction could lead to longer-run benefits, whereas outmigration following the disaster may lead to worse long-run outcomes for the affected region or the country.

The increased frequency and unpredictability of extreme weather events may also lead to losses on the demand side, due to drops in investment as uncertainty rises, or reductions in consumption, as the result of the increased risk of wealth losses (e.g., flooding of residential properties and/or increases in insurance premia).

The risks from gradual climate change (e.g., sea level rise) and those associated with the transition to a low-carbon economy, instead, are better thought of as the diversion of resources towards mitigation and adaptation expenses, potentially at the cost of investment in productive capital and consumption. Again, whenever resources are used for mitigation or adaption, the opportunity cost is that the same resources are not being used potentially more productively elsewhere in the economy.

In what follows, our focus is mostly on assessing Macroeconomic risks for the UK economy by reviewing the evidence on the impact of climate change hazards on the level of economic activity, as measured by Gross Domestic Product (GDP), as well as its rate of growth over time. We also review the available evidence of the impact of climate change on inflation, since moderate price rises at the aggregate level are generally seen as reducing uncertainty, being conducive to higher investment, and allowing for greater macroeconomic stability. While there will also be wealth effects there is little data that allows us to examine this aspect of the macroeconomy, although one might expect that poor people and regions with less resilience (weaker institutions, less savings, fewer assets) will generally bear the brunt.

Assessment of current magnitude of risk

The section starts with an overview of the current literature before going into more detail of the individual studies. First, at the global level the costs imposed by climate change are already significant, even at the current level of warming. The range of estimates is very large, however, making it hard to estimate the actual level of risk with any precision. For the UK, as for any developed country with a functioning financial system located in a temperate climatic zone, the literature suggests that the impacts ought to be lower than for warmer and more vulnerable countries. These caveats notwithstanding, the evidence is mounting that even the lower bound of climate-related impacts on UK GDP are, in terms of current risk, likely to exceed the threshold set for 'High' within this report, i.e. 0.25% of annual GDP.

Second, growing evidence from developed economies suggests that both the rate of inflation and its volatility are increasingly driven by global extreme weather events, via both domestic and foreign supply shocks, suggesting that the macroeconomic stability of the UK may be more at risk from climate-driven shocks than commonly appreciated (Breeden, 2025).

Finally, the two previous points taken together indicate that the macroeconomic risks linked to climate change are likely to have been underestimated both at the global level and for the UK. From this point of view, there appears to be a significant shift in the cost-benefit analysis in favour of significant mitigation and rapid adaptation efforts, even purely based on macroeconomic risks (see also, Glanemann et al., 2020).

Turning to the literature, there are a number of studies exploring the links between climate change, notably temperature change, and global aggregate economic costs. Much of this literature, and therefore our understanding of the damages from climate change, has been shaped by results derived from Integrated Assessment Models (IAMs) and structural models, mostly computable general equilibrium models (CGE).

IAMs often represent mitigation vs adaptation trade-offs and the costs of inaction in stylised aggregated form, but they typically do not capture all real-world complexities, uncertainties, and local dynamics. On the other hand, CGE models can be used in different ways, but typically take sector impacts and assess these in an economy wide analysis. Broadly speaking, in this literature researchers do not attempt to separate climate-related costs that could be felt in market sectors such as agriculture, energy services, labour supply and productivity, etc., from non-market impacts such as health effects including mortality and damages to ecosystems, for example. While IAMs tend to include market and non-market impacts, CGE models only include market impacts (but can look at welfare effects on top). Furthermore, most of these studies (IAMs in particular) take an aggregate perspective and do not provide results for individual countries, often restricting themselves to large trading blocs such as the U.S., the EU, and China. Consequently, much of this body of knowledge provides information that is informative *per se*, but does not speak directly to the risk to macroeconomic performance and stability in the UK.

IPCC (2022), which is part of the IPCC Sixth Assessment Report, provides a detailed overview of this literature. The assessment concludes that, at the global level, there exists a wide range of estimates but the lack of direct comparability between methodologies prevents the identification of a robust range of estimates with high confidence. IPCC (2022) argues, however, that certain patterns emerge. First, most IAMs and structural models find that global aggregate economic impacts are found to increase with temperature: across a range of scenarios and methodologies, the damages from climate change start at modest levels and increase over time along with the increase in warming. Second, models with regional disaggregation suggest that the impacts as a percentage of GDP are smaller for richer countries at higher latitudes, and larger for poorer, hotter countries, including some evidence that colder regions might benefit from lower levels of warming. A possible lesson from this literature on the level of risk posed by climate change to the UK macroeconomic position, therefore, would seem to be limited at current levels of warming.

A similar, if more nuanced, picture emerges from sources that more directly try to evaluate the impact of climate change on the macroeconomic performance of the UK by monetising and compiling sectoral impacts. One of the few attempts to systematically evaluate the impact of climate change across economic sectors specifically for the UK is offered by the monetary evaluation of risks developed by Watkiss et al. (2021). Tracking their estimates across the risks (and opportunities) discussed in CCRA3 (2010-2020), it is possible to come up with a total amount of economic losses in the range of £2-10 billion per year, equivalent to between 0.05-0.35% of current GDP. It is safe to assume that this is a lower bound of the impacts, given the cautious approach adopted by the authors and the paucity of the existing quantitative evidence for many of the impacts.

Feyen et al. (2020), who report on the results of the modelling analysis of the PESETA IV study, also estimate impacts at the lower end of the range of estimates available in the literature in terms of the percentage of GDP. Their study is significant because while they focus on the broader economic losses in much of their work, they also explicitly include estimates of welfare loss from climate impacts net off human mortality. Their conclusions emphasise a significant North-South divide with southern regions in Europe impacted more, due to extreme heat, water scarcity, drought, forest fires and agriculture losses. Although not related to the current risk it is worth noting here that the for the UK (and Ireland) the authors estimate that the losses from a 1.5 °C increase are modest, not exceeding 0.1% of GDP. They also emphasise, however, that the assessment does not evaluate the full economic impacts of climate change, because of the limited coverage of impacts in their models.

The COACCH report (2021), uses a Computable General Equilibrium approach to estimate the impacts of climate change on 8 aggregate economic sectors at the NUTS2 (Nomenclature of Territorial Units for Statistics) level. The results for the SSP2-RCP2.6 concentration pathway, which reflects levels of warming comparable to the current ones which is why we include it in this section, alongside considerable efforts at both mitigation and adaptation, suggest that for the UK the loss in GDP would be relatively small, remaining around 0.5% of GDP in the low-capital mobility scenario, even in 2050. Their results, however, are extremely sensitive to the degree of mobility of capital in their model. Assuming that capital may be easily reallocated across NUTS2 regions, for example, brings the economic losses over 2% of GDP in 2050 for the UK.

Rising et al. (2022) provide an estimate of the total climate change risk for the UK by analysing nine key impact channels, including market costs from agriculture, livestock and fisheries, energy supply and demand and labour productivity, as well as losses from droughts and flooding and coastal impacts. While these sectors do not cover the whole macroeconomic risks from climate change, their work provides yet another set of estimates for our purposes. The total damages accruing via these channels sum up to a modest 0.18% of GDP per annum between 2011 and 2030 and equivalent to 1.1% of GDP for the whole period. These damages mark the lower bound of a trajectory projected to worsen to 3.3% of GDP by 2050 and 7.4% by 2100 if current policies persist.

Rising et al. (2022) provide one of the most comprehensive estimates of the economic costs of climate change to the UK. The study synthesises results from multiple sector-specific models, covering agriculture, flooding, health, ecosystems, energy and trade, each using different data sources and assumptions. While these impact channels are expressed in consistent GDP-equivalent terms, the analysis does not fully integrate feedbacks or interdependencies between sectors. Moreover, missing risks and catastrophic damages are added as meta-estimates derived from separate global studies, reinforcing the compositional nature of the framework. As a result, the report represents a systematic but partly piecemeal synthesis so can be considered more as a structured aggregation of diverse evidence rather than a unified macroeconomic assessment of climate impacts. From a macroeconomic perspective, these contributions do not account for the risk from systemic, cascading failures across the economy and miss the role of international links whereby multiple countries are hit by climate shocks at the same time and spatial smoothing of the impacts becomes much more costly.

To capture some of these aspects, we need to turn our attention to the recent and rapidly expanding literature that tackles the problem of estimating the macroeconomic cost of climate change from an econometric point of view, to provide an alternative evaluation of the impacts. Unlike the IAM modelling approach discussed above, which is largely theoretical and scenario-based, econometric approaches enable the estimation of the historical impact of climate change on GDP levels, GDP growth rates and price stability empirically, i.e., they rely on observed relationships between climate variables (like temperature and precipitation) and economic outcomes using historical data. This literature tends to provide estimates of the impacts of climate change on GDP, GDP per capita and GDP growth that are significantly larger than the literature discussed above and provides unique information on inflation rates. By their nature, however, these contributions cannot provide definite evidence on the channels that operate. Not being structural, they do not identify all the parameters and elasticities in the model, only the actual outcomes. These channels are assumed and modelled (and calibrated) in IAMs and CGEs so that the total outcome is the sum of all channels. Moreover, the growth-focused contributions tend to focus on long-run impacts and on cross-country averages rather than short-run, country-specific results. Hence, we can say that econometric models provide valuable evidence on how historical climate variability has influenced economic performance, but still face important limitations when used to predict future climate impacts. Their estimates rely on past temperature fluctuations that may not represent the magnitude or complexity of long-term climate change. Moreover, they often neglect adaptive behaviour, structural economic change, and non-linear damage processes. Spatial aggregation and data limitations introduce further uncertainty, while omitted variables and institutional confounders can bias causal inference. As a result, while useful, they offer an incomplete and potentially misleading picture of how national economies will respond to future climate conditions.

With these caveats in mind, turning to the early contribution by Dell et al. (2012), they find that higher temperatures within a country reduce not just the level of GDP, but also its growth rate. This effect is found, however, only for poor countries. The authors estimate that a 1 °C rise in temperature in a given year reduces output per capita by about 1.3 percentage points (from agriculture and industrial output) and economic growth by 1.1 percentage points in poor countries, whereas they find no discernible effect for rich countries.

Burke et al. (2015) allow for non-linearities in the damage function, and find evidence that economic activity in all regions is coupled to the global climate and show that global losses are approximately linear in global mean temperature, with median losses many times larger than leading models indicate. Using their benchmark model, they predict that climate change would reduce global output by 23% by 2100 relative to a world without climate change, and lead to temporary increases in GDP for some colder and wealthier countries. Care should be taken when interpreting these results given concerns over the damage functions and how wealth and adaptation capacity may influence outcomes. The model used in Burke et al. (2015) model suggests the UK might experience relatively smaller negative effects (or even modest positive effect for a limited warming) compared to hotter countries. That said, they do not provide a strong or explicit point estimate for UK GDP loss by 2100 so the country-level projections are secondary and uncertain. Moreover, the model’s assumptions and empirical basis carry substantial caveats, especially when extrapolating beyond historical temperature ranges.

Kahn et al. (2021) study the long-term impact of climate change on economic activity across a panel of 174 countries between 1960 and 2014 and find that per-capita real output growth is affected by persistent changes in temperature away from its historical norm. They estimate that an increase in temperature of 0.01 °C above the norm for a long period of time reduces per-capita income growth by 0.05 percentage points per year. Moreover, they show that their empirical findings apply to both rich and poor, and hot and cold countries, although there is significant heterogeneity across countries and climate change scenarios. For the UK, they estimate a loss in per-capita GDP of 0.34% in 2030, 1.16% in 2050, and 3.97% by 2100 along the RCP8.5 scenario. In the much more stringent RCP2.6 scenario, the impact on UK GDP is predicted to be small and positive. Again, care is needed with interpretation of the results as these are just selected predictions from a panel estimation.

Several recent contributions reach conclusions similar to Kahn et al. (2021), suggesting that the effects of climate change on GDP and growth may be larger than previously thought. IPCC (2022) also note that the most recent literature finds significantly larger impacts than older contributions.

The work of Nath et al. (2024) tries to make sense of the large differences in economic impacts found in the econometric literature by investigating whether the effects of temperature shocks on GDP are permanent, i.e., whether there is a growth impact besides the impact on the level of GDP. They show that shocks to temperatures have remarkably persistent, although not permanent, effects on GDP in both hot and cold countries. Their projections to the end of the century suggest that a 3.7 °C increase in temperature by 2099 would reduce global GDP by 7-12%, relative to a scenario with no warming, and there is no reason to suggest that the UK would fare dramatically differently from this global sample of countries.

Bilal and Känzing (2024) focus on changes in global mean temperatures to capture the comprehensive impact of climate change, rather than on country-level, local temperature shocks. They argue that global temperature shocks better predict the large and persistent rises in the frequency of the extreme climatic events that cause most of the economic damage: extreme temperature, droughts, extreme wind and extreme precipitation. Despite mapping global temperature shocks to world GDP in a conservative framework that assumes persistence of level effects rather than growth effects, their results are much larger than those documented elsewhere in the literature. Indeed, their model shows that a 1 °C global temperature shock leads to a gradual decline in world GDP that peaks at 12% after 6 years and does not revert to the mean even after 10 years. Their results have significant implications for macroeconomic stability and lead them to an estimate of output losses of 30-50% of global GDP in 2100 from a 2 °C increase in global temperature by the end of the century. Importantly, their findings also imply that, since climate change is slow and persistent, the negative economic effects accumulate over time. In a counterfactual experiment, they calculate that, in the absence of the warming observed between 1960 and 2019, world GDP would have been 18% higher than it is today. Their large estimated impact that damages from climate change are “six times larger than previously thought” is because global temperature shocks better capture extreme events, spillovers, and systemic effects than local temperature shocks used in prior work, but it is important to note that their estimates are based on mode-based projections, not observed historical losses.

The work of Bilal and Känzing (2024), with its focus on global temperature as a predictor of extreme weather events, provides a link to yet another strand of the literature which, rather than estimating the impact of temperature shocks, looks directly at the impact of extreme weather events on GDP, growth and inflation. As mentioned in the previous section, while there is little doubt that in the short-run the impact of climate-change-driven extreme weather events are expected to have negative impacts on GDP, the longer-run consequences of extreme weather events are less clear-cut.

Hsiang and Jina (2014), for example, analyse the impact of tropical cyclones across different countries during the period 1950-2008 to empirically assess claims about the likelihood of positive vs negative growth effects of extreme weather events. They reject the hypothesis that disasters stimulate growth and that short-run losses are compensated by migration or a transfer of wealth. Instead, they find robust evidence that GDP declines relative to the pre-disaster trend and does not recover within twenty years. This effect is found in both rich and poor countries and can be traced to small but highly persistent reductions in growth rates lasting more than a decade. This result is extremely concerning given the expectation that extreme weather events will become more frequent (and intense) in the coming years so that these negative-growth shocks will accumulate over time. Although the UK does not have tropical cyclones, the point is that it shows how the economies respond to shocks.

Usman et al. (2024) study the dynamic, medium-run macroeconomic effects of heatwaves, droughts, and floods across 1160 NUTS3 EU regions. They find that while each specific type of extreme weather event has different impacts, they all have significant medium-term impacts on growth. They show that while summer heatwaves and droughts lower medium-run output everywhere, the impact of floods depends on regional income levels. High-income regions show evidence of significant reconstruction activity, whereas less wealthy regions do not. Also, population tends to decline in affected regions and adaptation often occurs only post-event. In general, total factor productivity is also shown to decline following a disaster, suggesting that adaptation capital may be less productive that the capital lost during the disaster.

Ehlers et al. (2025) complement the work of Usman et al. (2024) by looking at the macroeconomic impacts of natural disasters (extreme weather events) across eight North and South American countries over the period 2000-2023. They conclude that the average annual cost of climate-related natural disasters ranged between 0.05% of GDP in Colombia and just over 0.3% of GDP in the US in the first quarter of the twenty-first century. Although the UK is likely to have different disasters these studies provide a range of GDP damages that are informative as it includes estimates for other developed countries such as the US.

Von Peter et al. (2024) examine the process of macroeconomic recovery following natural disasters using a global panel covering more than 200 countries between 1960 and 2011 and find that major disasters (defined as those where reported direct economic losses exceed 0.1% of the affected country's GDP) reduce growth by between 1 and 2 percentage points on impact and over time produce output costs of 2% to 4% of GDP. They also show that it is the uninsured losses that drive the macroeconomic cost. Insured losses are less consequential and can even stimulate growth as insurance payments help fund the reconstruction without crowding out productive investment elsewhere in the economy.

The impacts of climate change induced extreme weather events on inflation have also been the subject of a significant literature over the past two decades (see Botzen et al., 2019, for a review). For example, Parker (2018) found that disasters have little impact on inflation in advanced economies, whereas in emerging economies they can have large impacts that persist for many years. Droughts are shown to have the worst impacts in emerging and developing countries by increasing food price inflation for many years after the start of the drought. More recently, Peersman (2022) shows that weather-driven food price shocks have a strong impact on consumer prices volatility in the Euro area.

Cevik and Jalles (2023) investigate the effect of climate shocks on both inflation and real GDP growth in a panel of 173 countries over the period 1970-2020 and show that both inflation and output growth respond significantly to climate shocks. Among the advanced economies, temperature shocks are shown to have significant and positive effects on headline inflation (peaking at ~1% in the third year following the shock) and, most notably, on food inflation, where the effect is twice as large.

Ficarra and Mari (2025) focus on the impact of floods on economic output and prices at the sectoral level for local authorities in England. They find significant differences across sectors and estimate that a one standard deviation increase in the number of floods (i.e. 17 more floods per year) reduces local GDP by more than 1% in the first year, 3% after three years and that local GDP is still 2% lower than in the absence of the increase five years after the event. Similarly, headline inflation increases by 50 basis points within one year of the shock.

Assessment of future magnitude of risk

<u>2030s, central warming scenario:</u>

The central warming scenario for the 2030s is for 1.5 °C global relative to pre-industrial, which represents a modest increase in temperature compared to recent years. Therefore, although one might expect that climate hazards are unlikely to change dramatically in this scenario, barring a sudden shift and the emergence of unexpected tipping points (e.g., destabilisation of the Greenland and West Antarctic ice sheets or changes to the ocean and atmospheric circulation systems), there is some evidence that large tail risks become more frequent. There will be a continuing trend for warmer and wetter winters, drier and hotter summers, continuing sea-level rise and higher river and surface flooding risks and hence larger tail risks (a larger magnitude of extreme event). The vulnerability of the UK critically depends on adaptation efforts over the coming decade. Chapter 1 provides much more detail on the state of the climate.

The latest two progress reports presented to Parliament by the CCC (CCC, 2024; 2025) emphasise that the current National Adaptation Plan (NAP3) is inadequate and that progress towards adaptation is inadequate.

As a consequence, the assessment made above for the current level of risks is broadly applicable to this scenario, with the caveat that the cumulative growth impacts of the more frequent and stronger extreme weather events are likely to exert a significant negative impact on the growth rate of GDP. Even the lower bound of the confidence interval is likely to exceed the threshold for “High” impacts set for this risk by the mid-2030s.

<u>2050s, central and high warming scenarios:</u>

The hazards and exposures are going to be significantly increased by the mid-2050s for both scenarios (central and high warming). Even the most cautious estimates of GDP losses for these scenarios projects damages that greatly exceed 1% of GDP. Tol (2024), for example, in his meta-analysis reports a range of losses between 1.72 and 3.69% for 2.5 °C warming but relates to global aggregates and distributions across studies.

<u>2080s, central and high warming scenarios:</u>

At temperatures exceeding 2.5 °C in the central scenario and reaching 3.5 °C in the high -warming scenario, damages to GDP are projected to increase significantly. For the UK, the Office for Budget Responsibility (OBR) (2024), for example presents an estimated impact of 5% of GDP by 2070 along a scenario that keeps temperature within 3 °C. The OBR cites Tol’s meta-analysis to show that for a 4 °C warming, the average long-run global GDP loss is around –4.2%, with a broad range from –23% to +6%. OBR (2024) compare these estimates to existing UK-specific estimates: e.g., Grantham estimates of –7.4% GDP loss by 2100 under ~3.9 °C warming, including a "catastrophic risk" term, and Bank of England stress testing scenarios estimating –7.8% GDP loss by 2050 under 3.3 °C warming. However, they explicitly note they do not attempt to calibrate catastrophic risk channels beyond what existing literature (including Tol's) shows, acknowledging that some extreme outcomes may lie outside their calibrated scenarios.

Level of preparedness for risk

The risk to macroeconomic performance and stability is included in the CCRA4 for the first time. This inclusion is suggestive that the importance of systems thinking around the way the economy might be impacted by climate change has only recently emerged. Although interesting, it is beyond the scope of this section to look at what determines UK resilience.

Macroeconomic risk or systemic economic risk is not explicitly addressed in the UK National Adaptation Plan (NAP) or in any of the devolved administrations' NAPs, including the links of the UK macroeconomic performance and stability with climate risks and risks of political instability and societal collapse at the international level.

The Bank of England and the OBR have only recently published their first assessments of the implications of climate change for the conduct of monetary and fiscal policy. In their recent July report, the OBR (2025) argue that there are significant long-term fiscal risks from climate change damage (and the transition to net zero) and suggests that the UK is not well prepared in terms of the potential size of the risk and the potential burden imposed on the government.

The Climate Change Committee has been clear that the level of adaptation contained in the NAP3 is insufficient, and its two most recent reports to Parliament have been scathing about the insufficient progress made on adaptation in the UK both in the public sector and elsewhere. Indeed, the April 2025 report of the CCC states that "The UK's preparations for climate change are inadequate" and that the government has not yet changed its approach to tackling climate change risks that is currently considered inadequate.

The Treasury, via its Green Book guidance, is working on embedding climate change risk (and adaptation) in policymaking which is a necessary component of developing UK's preparedness.

Based on this evidence, we would assess the level of preparedness for the systemic nature of macroeconomic risk as currently limited and although frameworks are partially in place, the delivery, and resilience capacity may not yet match the scale of the risks identified in this report.

Assessment of the evidence base and evidence gaps

At the global level, the evidence base is evolving. The range of methodologies used to assess the consequences of climate change on natural systems and human societies is broad. Given the range of methods, measures and estimates, estimating confidence intervals for the estimated impact on GDP is a challenge. The evidence is less abundant for the UK, especially as the UK is no longer included in European assessments. Despite one or two pieces of evidence specific to the UK discussed above, there is a clear evidence gap in terms of robust estimates of macroeconomic risk from climate change at the UK level. The evidence base is even scarcer for the individual nations within the UK, for which only the downscaled projections of Rising et al. (2022) are available.

For this reason, we present the same magnitude and confidence levels for all countries within the UK.

4.2.1.2 England

Table.4.4: Urgency scores for E1 Risks to UK macroeconomic performance and stability, for England. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

England								
E1 Risks to UK macroeconomic performance and stability.								
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (H)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
With adaptation	++ (H)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
Urgency scores	MAN	MAN		CAN			MAN	
Overall urgency score	CAN							

4.2.1.3 Northern Ireland

Table 4.5: Urgency scores for E1 Risks to UK macroeconomic performance and stability, for Northern Ireland. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Northern Ireland								
E1 Risks to UK macroeconomic performance and stability.								
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	+++ (H)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
With adaptation	+++ (H)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)

Urgency scores	MAN	MAN		CAN			MAN	
Overall urgency score	CAN							

4.2.1.4 Scotland

Table 4.6: Urgency scores for E1 Risks to UK macroeconomic performance and stability, for Scotland. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Scotland								
E1	Risks to UK macroeconomic performance and stability.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	+++ (H)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
With adaptation	+++ (H)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
Urgency scores	MAN	MAN		CAN			MAN	
Overall urgency score	CAN							

4.2.1.5 Wales

Table 4.7: Urgency scores for E1 Risks to UK macroeconomic performance and stability, for Wales. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Wales				
E1	Risks to UK macroeconomic performance and stability.			
	Present	2030	2050	2080

		Central	High	Central	High	Low	Central	High
No adaptation	+++ (H)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
With adaptation	+++ (H)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
Urgency scores	MAN	MAN		CAN			MAN	
Overall urgency score	CAN							

4.2.2 Risks to domestic and overseas physical assets of UK businesses – E2

Scope: Encompasses risks to tangible business assets located in the UK and abroad, including business infrastructure, equipment, and property. Subcomponents include damage from physical climate hazards (e.g., floods, heatwaves), disruption to business operations and cross-border risks to UK-owned assets overseas.

Headlines

- Critical action needed.
- The risk is expected to increase **over time** due to the rising frequency and intensity of physical climate hazards (e.g., flooding, sea-level rise, extreme heat); accumulation of climate exposure in asset-intensive sectors like manufacturing, logistics and retail; increasing global climate impacts on UK-owned overseas assets and supply chain nodes.
- Key evidence gaps identified include insufficient data on the location and climate vulnerability of UK business assets, especially overseas; lack of integration between geospatial hazard maps and business asset registers; limited data on the impact of hazards other than flooding.
- In CCRA3 the risk to physical assets wasn't examined directly but instead considered more general risks (e.g., to both physical assets and business operations) for the three specific hazards, flooding, coastal change and water scarcity. As a result, it is not possible to state precisely how Risk E2 has changed since CCRA3.

Table 4.8: Urgency scores for E2 risks to domestic and overseas physical assets of UK businesses. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

ID	Risk		Present	2030	2050	2080	Urgency
E2	Risks to domestic and overseas physical assets of UK businesses	**UK**	++ (VH)	++ (VH)	++ (VH)	++ (VH)	CAN
		England	++ (H)	++ (H)	++ (VH)	++ (VH)	CAN
		Northern Ireland	++ (H)	++ (H)	++ (VH)	++ (VH)	CAN
		Scotland	++ (VH)	++ (VH)	++ (VH)	++ (VH)	CAN
		Wales	++ (H)	++ (H)	++ (VH)	++ (VH)	CAN

4.2.2.1 Evidence relevant to the entire United Kingdom

Current and future drivers of risk

Climate change presents a multifaceted and escalating threat to the physical assets of UK businesses due to a mix of hazard, exposure and vulnerability trends. The hazard risks manifest in various forms, ranging from acute events such as flooding and storms to chronic stresses such as sea level rise. Fixed assets in geographically exposed areas are particularly at risk, while factors such as how such assets have been built or designed, or how they are being used, can add to their vulnerability.

One of the most pressing concerns is the increased frequency and severity of flooding, a growing hazard as outlined in Chapter 1 (State of the Science). Businesses situated in flood-prone areas of the UK, such as the Thames Valley, Hull, and Cumbria, face repeated exposure to riverine (fluvial), surface water (pluvial), and coastal flooding. The siting of industrial estates and commercial properties in these areas often dates back decades and has led to what researchers describe as a “lock-in” to physical climate risk. Mathews et al. (2021) illustrate how such locational inertia hampers adaptation and reveal that over 40% of England’s business-critical infrastructure is at risk of flood-related disruptions.

Heatwaves represent another growing hazard, particularly for sectors that depend on stable temperature environments. Manufacturing plants, food storage facilities, and data centres will require additional cooling to reduce risks to operational continuity and worker safety. Storms and high wind events further compound the vulnerability of physical assets. In urban and peri-urban settings, buildings suffer from roof damage, window failures, and debris impact. Sea level rise adds a more gradual but no less severe pressure, especially for coastal businesses. The industrial zones along the South West and East Anglian coasts, including ports in Bristol and Felixstowe, are exposed to saline intrusion, storm surges, and eventual asset submergence. Arnell et al. (2021) quantify how rising seas will increasingly exceed the design thresholds of existing coastal defences, placing fixed assets at long-term risk unless major adaptation investments are made.

Even without direct damage to physical assets, the value of firms’ assets may fall in the face of increased climate hazards and exposure. At risk assets may face a lower expected asset life due to physical assets located in high-risk areas depreciating faster, and may become costlier to operate due to higher insurance premiums, which could in turn reduce asset values. Finally, such assets may also experience reduced marketability if they become more difficult to sell or less valuable.

Exposure risks are not distributed evenly. For instance, businesses in London and the Thames Estuary region benefit from the Thames Barrier, which offers some degree of protection against storm surges. In contrast, businesses based in towns such as Doncaster and Carlisle and Dumfries have faced repeated flooding over the past two decades, exposing shortcomings in infrastructure resilience.

Climate impacts overseas are a concern for UK supply chains (see Section 4.2.3 E3) but also for UK-owned businesses that have physical infrastructure and critical assets based overseas. Indeed, those physically located in climate-exposed regions of the world are facing growing exposure and vulnerability to climate impacts. Assets located in low-elevation coastal zones in Asia and Africa may be particularly exposed, as are those in storm-prone regions of the southern USA, the Caribbean and South East Asia. However, since the geographical spread of UK owned assets is wide, while climate exposure risks vary substantially by country and region, summarising the risk faced by UK owned physical assets overseas is not straightforward.

Assessment of current magnitude of risk

Of the climate risks faced by UK firms' physical assets, the risk of flooding from rivers, the sea and surface water has the largest evidence base.

The Environment Agency (2024) reports that the total number of properties (residential and non-residential) in England in areas at high risk of flooding from rivers and the sea increased by 88% from the previous National Flood Risk Assessment in 2018. Of these properties, 44% are likely to flood to depths of 30cm or higher. Total properties in areas at risk of flooding from surface water increased by 43% relative to the 2018 assessment, while 3 times as many properties are at high risk of surface water flooding compared to 2018. Of these, 17% are likely to flood to depths of 30cm or more. The Environment Agency (2024) therefore indicates that the risk of surface water flooding – where heavy rainfall overwhelms drainage systems and the ability of the ground to absorb water - affects a greater number of properties than river and sea flooding but the resultant floods are likely to be shallower.

Table 4.9 provides the number of non-residential properties in England, Scotland and Wales at risk of flooding from rivers and the sea, and from surface water for the most recent year available (2023 or 2024 for England and Wales, and 2018 for Scotland) (Environment Agency, 2024; Natural Resources Wales, 2024; Scottish Environmental Protection Agency (SEPA), 2018). We see that across the three countries over 88,000 non-residential properties are facing a high risk of flooding from the rivers and sea, with over 80,000 facing a high risk of flooding from surface water. It should be noted that the risk level used by Scotland to denote 'high risk' is a 10% (1 in 10 year) risk of flooding, while England and Wales use a lower 3.3% (1 in 30 year) risk of flooding. While Northern Ireland doesn't report the number of non-residential properties at risk of flooding for different risk levels, the 2018 Northern Ireland Flood Risk Assessment does estimate the potential damages to non-residential properties from floods. More specifically, the annualised average damages to non-residential properties due to flooding from rivers and the sea are estimated to be £8.8 million for Northern Ireland, while damages from surface water flooding are £24.1 million.

Table 4.9: Non-Residential properties in England, Scotland and Wales in areas at risk of flooding from rivers and the sea, and from surface water flooding.

Flood Risk Band*	Non-residential properties in areas at risk of flooding from rivers and sea	Non-residential properties in areas at risk of flooding from surface water
ENGLAND:		
High	73,400	71,800
Medium	168,900	87,100
Low	217,800	385,200
SCOTLAND:		
High	6,300	4,600
Medium	17,400	16,000
WALES:		
High	8,932	3,870
Medium	4,602	2,182

Low	8,446	7,574

*For England and Wales, high risk indicates that each year an area has a chance of flooding of greater than 3.3%, medium risk means an area has a chance of flooding between 1% and 3.3%, and low risk means that an area has a chance of flooding of between 0.1% and 1%. For Scotland, high risk refers to a chance of flooding of 10% or greater, while medium risk refers to a risk greater than 0.5%. Non-residential properties include businesses as well as other properties such as schools and hospitals. Source: Flood and Coastal Erosion Risk Management Report 1st April 2023 to 31st March 2024 (Environment Agency, 2024); Natural Resources Wales, Flood Risk Management Annual Report 2023/24; Scottish National Flood Risk Assessment 2018 (SEPA, 2018). For England, the figures are for December 2023 (rivers and sea flooding) and January 2024 (surface water); for Wales the figures are for 2024; for Scotland 2018.

Sayers et al. (2020) model the impacts of floods on non-residential properties and estimate the expected annual direct flood damage to such properties to be £670 million for the UK as a whole, comprised of damages of £463 million in England, £114 million in Scotland, £51 million in Wales and £42 million in Northern Ireland.

Other evidence also suggests the financial impact of extreme weather, including flooding, on UK business is substantial. The Association of British Insurers reports that in the first quarter of 2025 its members paid out £109 million to businesses for weather-related damage and business interruption (ABI, 2025). Similarly, the autumn storms of 2023 resulted in claims of £155 million by UK businesses, averaging £28,900 per claim (ABI, 2023).

Limited quantitative evidence is available for climate risks faced by UK owned business assets other than flooding. The ONS Business Insights Report (3 October 2024) asked 10,444 firms which types of climate risk they have been impacted by over the previous 12 months, with 8.8% reporting being affected by flooding, 11.3% by storms and 5.9% by increased temperature or heat. When asked how severe weather had affected them, 24.9% of the firms surveyed (excluding those with fewer than 10 workers) stated they had experienced weather-related damage to 'physical infrastructure'. These impacts differ by industry, with 29.8% of firms experiencing physical damage from severe weather in Construction, and 27.3% in Manufacturing. Unfortunately, the absence of this data for previous years means it is not possible to observe trends over time.

The European Central Bank's Climate-related risk and financial stability review (2021) doesn't specifically model the UK but shows that flood risk is the greatest physical climate risk facing businesses in northern European countries. Their analysis of 1.1 million firms in the Euro area indicates that 10-15% face 'high present/projected exposure or increasing exposure'. This report indicates that firms in northern European countries face very low or zero risk of physical damage from water stress, heat stress or wildfires. The impact of storms is not reported.

In terms of the risks faced by UK owned assets overseas, a large body of international evidence estimates the impact of physical climate risk on indicators relating to firm performance. These studies reveal the variety of different climate risks that are present and show how these differ by location, thereby illustrating the extent of the risks to which UK owned overseas assets are exposed. These findings imply that since the UK itself faces a relatively low risk of climate impacts by global standards, the international geographical dispersion of UK business assets will increase the climate risks that they face. This impact on the UK is likely to be further compounded by the fact that it acts as a major global hub for overseas asset management. However, the international evidence on climate impacts also indicates that the precise risks faced by UK assets overseas cannot be accurately estimated without knowing the exact geolocation of each such asset.

Huynh et al. (2020) for instance, focus on the US and estimate the impact of drought intensity and duration on firms' costs of raising equity capital. They show that firms affected by severe drought conditions face increased risks and increased financing costs, equivalent to an increased cost of equity capital of $20 million. This impact was reduced for firms with greater geographical dispersion and with large cash holdings, but was larger for firms in water dependent industries. Ai and Gao (2023) also focus on the US but consider the impact on firms of exposure to a wide range of climate impacts including hurricanes, droughts, lightning and wildfires. They show the importance of such impacts to firm risks. By considering a range of climate impacts, they show that geographical diversification increases the risks to firms as it makes it more likely a firm will be exposed to one such risk. This contrasts with the Huynh et al (2020) study of one risk (droughts) which they found to be mitigated by geographical dispersion.

Bressan et al. (2024) argue that climate physical risks are very real for businesses but tend to be underestimated leading to an underinvestment in adaptation and mitigation and, in turn, to higher risks. They show that both acute and chronic risks are important as is the need to know the precise geolocation of firms' productive assets in order to quantify them accurately. Indeed, they show that proxying the latter using firms' HQ locations, as has been done in previous work, can underestimate losses by up to 70% in their analysis of tropical cyclone risk in Mexico. Other studies that show the scale of the physical climate risks faced by firms and the challenges of identifying them include Pankratz et al. (2023), S&P Global (2023), Ranger et al. (2022), Fiedler et al. (2021), Kling et al. (2021), Siamak and Abdullah-Al (2021), Po-Hsuan et al. (2018), Balvers et al. (2017), and Barrot and Sauvagnat (2016).

An accurate assessment of the climate risk faced by UK-owned business assets overseas would require a modelling exercise in which the precise geographical locations in which major UK owned business assets are located are mapped to the various climate risks at those locations. To date, this exercise has not been undertaken. However, the geographical spread of the UK's outward FDI stock illustrates the wide range of climate risks that such assets are likely to be exposed to. While approximately 50% (by value) of UK FDI stock is based in Europe, 34% is in the Americas, with 10% in Asia (ONS, n.d.).

The above evidence base, with particular emphasis on the analysis of Sayers et al. (2020), suggests that the present-day physical damages to UK firms' business assets from climate change are likely to be in the hundreds of millions of pounds which equates to a magnitude score of 'High'. Since the majority of the above evidence base relates specifically to flooding there is little guidance as to the impact of climate risks other than flooding, for instance drought, wind or extreme heat, on firms' physical assets. However, evidence does suggest that floods are likely to be the largest climate impact faced by UK firms (European Central Bank, 2021) and hence we continue to assess the impact as being in the hundreds of millions of pounds with a magnitude score of 'High'. Nevertheless, the lack of evidence on non-flooding climate impacts means we reduce our confidence in this magnitude to Medium.

Assessment of future magnitude of risk

<u>2030s, central warming scenario:</u>

Sayers et al. (2020) did not produce forecasts for 2030 but did predict the present-day economic impacts to increase steadily by 2050 and 2080 (as discussed below for those scenarios) by amounts that indicate that damages in 2030 remain in the hundreds of millions of pounds. Again, the lack of evidence on non-flooding climate risks means we continue to assess the 2030s impact as being High but with only a Medium confidence score.

<u>2050s, central and high warming scenarios:</u>

Sayers et al. (2020) estimate expected annual damages to non-residential properties from all sources of flooding to be £542m by 2050 for their 2 °C warming scenario, (consistent with the 2050s Central scenario) in the presence of adaptation planned at the time of writing in 2020. However, Watkiss et al. (2021) extends the analysis of Sayers et al. (2020) by allowing economic growth to increase the value of physical assets at risk and for 2050s predicts damages to be in the billions of pounds.

Forecasts of the future impacts of climate physical impacts on business assets are largely missing from the academic literature. However, the grey literature includes some attempts to predict these future impacts. Note that the Task Force on Climate-related Financial Disclosure (TCFD), discussed in more detail below, should begin to provide evidence of the climate impact on firms but, at the time of writing, such evidence is not available in a comprehensive form that is of direct use in this study.

Moody's (2020) model the impact of floods on annual aggregate insured losses across Northern European countries, predicting them to increase by between 35% and 80% by 2050 for the various Representative Concentration Pathway scenarios (which don't map directly to our scenarios used in CCRA4). Flood losses are defined as insured damage to property structures and contents, as well as losses due to business interruption.

Although a global analysis, with perhaps limited direct applicability to the UK, S&P Global (2023) examine the costs of physical climate impacts to firms in the S&P 500 and S&P Global 1200 by 2050. Their scenario is consistent with the 2050 High scenario and indicates that these physical impacts will equal on average 3.3% per annum of the value of real assets held by S&P Global 1200 companies (an increase of 28% from 2023). The largest impacts stem from extreme heat, then fluvial floods, followed by drought.

No other studies specifically estimate a scenario consistent with the 2050s High scenario, but the evidence above continues to point to a high or very high magnitude of risk from flooding. When factoring in the potential risks from non-flooding climate impacts, we therefore assess the 2050s impact as being Very High (above £1 billion), with a Medium confidence score.

<u>2080s, central and high warming scenarios:</u>

Sayers et al. (2020) estimate expected annual damages to non-residential properties from all sources of flooding to be £579m by 2080 for their 2 °C warming scenario (consistent with the 2080s Central scenario) in the presence of adaptation planned at the time of writing in 2020. This rises to £699m by 2080 for their 4 °C warming scenario, (consistent with the 2080s High scenario). Watkiss et al. (2021) predict the impact of flood damages in 2080s to be above £1 billion by allowing for the growing value of assets at risk from flooding.

Moody's (2020) model future flood impacts on annual aggregate insured losses across Northern European countries for 2090 as well as 2050. These impacts are predicted to increase by between 35% and 276% by 2090, though again the climate scenarios used don't map directly to our scenarios used in CCRA4.

S&P Global (2023) examine the costs of physical climate impacts to firms in the S&P 500 and S&P Global 1200 by 2090, in addition to their 2050 analysis. Their scenario is consistent with the 2080 High scenario and indicates that these physical impacts rise to 6.0% of the value of real assets. Again, the largest impacts stem from extreme heat, then fluvial floods, followed by drought.

The evidence above continues to point to a high or very high magnitude of risk for the 2080s central and high scenarios. Since the majority of evidence continues to relate to flooding, we assess the overall climate impact on UK firms' physical assets to be above £1 billion, and hence Very High, by the 2080s. Our confidence in this assessment remains at Medium.

Level of preparedness for risk

We first consider governmental adaptation, primarily designed to reduce the losses that arise from damage to physical assets (and households). We then outline efforts largely within the private sector to improve the resilience of business assets in the UK.

The majority of governmental climate adaptation in the UK is devolved, with separate policies implemented in England, Scotland, Wales and Northern Ireland. In England, the government published the Third National Adaptation Programme (NAP3) in 2023 as its primary strategy for managing climate risks over the period to 2028. It set out objectives across priority areas such as flooding, overheating, water scarcity, and biodiversity loss. NAP3 also outlines the Flood and Coastal Erosion Risk Management 2021-27 Plan which announced investment of £5.2 billion to enable the government, the Environment Agency and local partners to protect England from floods and coastal erosion by 2027. In February 2025 the Labour government pledged to increase this by £250 million. Spending to date has been high under this programme and the 2025 spending review announced a continued capital programme for floods with £4.2 billion to be spent over three years, from 2026-27 to 2028-29. Supporting NAP3 is the Fourth Strategy for Climate Adaptation Reporting, designed to improve transparency by requiring public bodies and infrastructure operators to report on their climate risks and adaptation responses.

Northern Ireland's Climate Change Adaptation Programme (NICCAP2)**,** covering 2019 to 2024, outlines a sectoral approach to resilience, including measures in health, agriculture, and infrastructure. While the CCC (2023) notes that adaptation planning in Northern Ireland is 'still in its infancy' NICCAP3, the successor to NICCAP2, is being developed at the time of writing.

In Scotland, the government introduced its National Flood Resilience Strategy in 2024. This strategy aims to embed flood resilience not only in infrastructure but also in how land is used and how communities are supported. Natural flood management techniques, such as restoring wetlands, planting trees, and rewilding landscapes, are prioritised alongside better early warning systems and local risk planning. In principle, this represents a shift towards sustainable, long-term resilience, aligned with both scientific recommendations and Scotland's broader climate commitments.

In Wales, Natural Resources Wales (NRW) has developed a detailed Flood Risk Management Plan, with updates in 2024 reinforcing the importance of nature-based and community-focused interventions. NRW has taken a relatively progressive stance, with strong emphasis on ecosystem restoration and local collaboration.

While some studies have outlined the limitations of the above adaptation measures (CCC, 2024; Henderson et al., 2025), these measures undoubtedly provide the UK with a degree of preparedness for future flood events in particular. In their absence the degree of flood risk exposure would be considerably greater. While few studies have directly attempted to quantify the benefits of the UK's flood adaptation measures, Sayers et al. (2020) is an exception. They estimate, for instance, that by 2050, under a scenario consistent with the 2050 Central scenario, damages to non-residential property in England would be £630 million in the absence of the then current adaptation measures, compared to £542 million with such measures, a difference of £88 million. Given the flood adaptation investment made and pledged since 2020, this difference may well have increased.

In terms of non-governmental adaptation, the 2023 Recommendations of the Task Force on Climate-related Financial Disclosure (TCFD), the net zero Transition Plan Taskforce (TPT), and the Climate Adaptation Research and Innovation Framework (CARIF) are promising developments. The TCFD promotes identification, assessment, and management of climate risks through transparent reporting—though it doesn't itself make firms more resilient. These disclosures aim to enhance accountability, attract climate-conscious investors, and drive innovation by revealing new opportunities. As part of their climate disclosures, the Climate Financial Risk Forum (2023) recommends that firms should quantify and report the exposure of their assets vulnerable to physical risk, physical risk heatmaps, and the anticipated financial impacts based on scenario analysis. Like the TCFD, the TPT supports adaptation by embedding climate resilience into corporate strategy. CARIF helps UK businesses, especially SMEs, prepare for climate risks by aligning research with practical needs and improving access to data, tools, and innovation. Its success, however, depends on sustained funding, coordination, and the translation of research into action.

Initiatives such as the above emphasise the need for businesses to invest in a combination of engineering upgrades, nature-based solutions, and financial innovations to mitigate exposure to flooding, heat stress, and other environmental hazards. Building retrofits, such as the installation of flood barriers, improved drainage systems, raised electrical infrastructure, and enhanced ventilation, are becoming more common, particularly in sectors with high fixed capital exposure. These efforts are complemented by nature-based interventions like green roofs, permeable surfaces, and urban greening projects, which help to manage surface water and reduce the urban heat island effect. Together, these strategies indicate a growing recognition that climate resilience is both a risk management necessity and a long-term investment in asset value preservation.

Business networks such as Resilience First have played a central role in driving corporate engagement with climate resilience, providing a platform for knowledge exchange, scenario exercises, and coordination with local authorities. Through initiatives like the Resilience Rising partnership and annual resilience programmes, Resilience First has worked with major UK firms including HSBC, Zurich, and AstraZeneca to conduct climate-focused exercises that build operational readiness for heatwaves, flooding, and supply chain disruption. These business-led forums encourage firms to adopt structured approaches to resilience planning, linking asset-level adaptation measures with organisational continuity strategies. Evidence from the London Climate Resilience Review reinforces the need for such cross-sector collaboration. The Review, which made over fifty recommendations for enhancing the city's climate preparedness, highlights the importance of private-sector engagement in implementing local adaptation measures, particularly in the retrofitting of commercial property and the adoption of green infrastructure.

Despite significant progress, challenges remain. The uptake of climate adaptation measures is uneven, with small and medium-sized enterprises often constrained by financial or informational barriers. Indeed, ONS Business Insights (Wave 117, October 2024) reports that only 3.7% of businesses have assessed the risks associated with flooding, while 3.9% have assessed the risks from temperature increases. Notably, 74.6% of firms report that they have not assessed any of the risks to their business associated with climate change. The survey also indicates that only 10.3% of firms have taken action to adapt to flooding, while 9.0% have done so to adapt to temperature increases. Since systemic interdependencies in infrastructure (e.g., energy) and supply chains mean that even well-protected assets can be disrupted by failures elsewhere in the system, this evidence suggests that there is still a way to go before UK business assets are resilient to a changing climate.

Assessment on the evidence base and evidence gaps

The evidence used to assess this risk is a mix of academic literature and so-called 'grey' literature from large firms and institutions. The literature actually quantifying the climate risks to firms' physical assets is limited and primarily relates to flood risk. It also typically focuses on the UK as a whole (or even Northern Europe) with practically no risk assessments for the devolved nations other than Sayers et al. (2020).

4.2.2.2 England

Evaluation of urgency score

For England, the risks represent those facing the UK as a whole as described in the 'Assessment of current/future magnitudes of risk' sections above. In addition, specifically for England, Sayers et al. (2020) quantify the risk magnitudes due to flooding, both with and without the planned adaptation at that time, as being in the hundreds of millions of pounds. They do so for the present day, 2050s and 2080s. While these impacts relate to flooding only, there is little guidance as to the impact of climate risks others than flooding on firms' physical assets. However, as stated above, since evidence does suggest that floods are likely to be the largest climate impact faced by UK firms (European Central Bank, 2021) we continue to assess the current and 2030s impact as being in the hundreds of millions of pounds with a magnitude score of 'High'. Nevertheless, the lack of evidence on non-flooding climate impacts means we reduce our confidence in this magnitude to Medium. For the 2050s and 2080s our judgement is that these flood and non-flood impacts could exceed £1 billion. While Sayers et al. (2020) estimate flood impacts in England to be in the hundreds of millions of pounds by 2050 and 2080, Watkiss et al. (2021) estimate them to be above £1 billion due to economic growth raising the value of assets at risk (an issue not considered by Sayers et al., 2020). This fact, combined with likely impact of non-flood risks, means we estimate overall impacts to be over £1 billion for the 2050s and 2080s hence the score of Very High. Our confidence levels for 2050s and 2080s remain at Medium.

Table 4.10: Urgency scores E2 risks to domestic and overseas physical assets of UK businesses, for England. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

England								
E2	Risks to domestic and overseas physical assets of UK businesses.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (H)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
With adaptation	++ (H)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)

Urgency scores	MAN	MAN		CAN			MAN	
Overall urgency score	CAN							

4.2.2.3 Northern Ireland

Evaluation of urgency score

In terms of specific evidence for Northern Ireland, Sayers et al. (2020) predict flood damages in the tens of millions of pounds for the present day, 2050s and 2080s both with and without the planned adaptation known in 2020. Watkiss et al. (2021) raise these to hundreds of millions of pounds for the 2050s and 2080s. Based on this evidence, and the lack of evidence on non-flood impacts, our assessment is that the magnitude will be High for the current period and the 2030s and Very High for the 2050s and 2080s. Confidence is Medium throughout.

Table 4.11: Urgency scores E2 risks to domestic and overseas physical assets of UK businesses, for Northern Ireland. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Northern Ireland								
E2	Risks to domestic and overseas physical assets of UK businesses.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (H)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
With adaptation	++ (H)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
Urgency scores	MAN	MAN		CAN			MAN	
Overall urgency score	CAN							

4.2.2.4 Scotland

Evaluation of urgency score

For Scotland, Sayers et al. (2020) predict flood damages just above £100 million for the present day. For the 2050s and 2080s this falls below £100 million with adaptation, however Watkiss et al. (2021) raise these to hundreds of millions of pounds. Based on this evidence, and the lack of evidence on non-flood impacts, our assessment is that with adaptation the magnitude will be Very High for the current period and all future periods. Confidence is Medium throughout.

Table 4.12: Urgency scores E2 risks to domestic and overseas physical assets of UK businesses, for Scotland. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Scotland								
E2 Risks to domestic and overseas physical assets of UK businesses.								
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
With adaptation	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
Urgency scores	CAN	CAN		CAN			MAN	
Overall urgency score	CAN							

4.2.2.5 Wales

Evaluation of urgency score

Similar to Northern Ireland, Sayers et al. (2020) predict flood damages in the tens of millions of pounds for Wales for the present day, 2050s and 2080s both with and without the planned adaptation known in 2020. Watkiss et al. (2021) raise these to hundreds of millions of pounds for the 2050s and 2080s. Based on this evidence, and the lack of evidence on non-flood impacts, our assessment is that with adaptation the magnitude will be High for the current period and the 2030s and Very High for the 2050s and 2080s. Confidence is Medium throughout.

Table 4.13: Urgency scores E2 risks to domestic and overseas physical assets of UK businesses, for Wales. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Wales

E2	Risks to domestic and overseas physical assets of UK businesses.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (H)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
With adaptation	++ (H)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
Urgency scores	MAN	MAN		CAN			MAN	
Overall urgency score	CAN							

4.2.3 Risks to domestic and international supply chains and resource inputs of UK businesses – E3

Scope: Focuses on the vulnerability of UK supply chains to climate impacts, particularly where they are global, complex, or concentrated. Subcomponents include physical disruption to transport, storage and production, international trade risks from climate events abroad and sectoral exposure (e.g., food, energy, manufacturing).

Headlines

- Critical investigation is needed due to the combination of high risk and low confidence.
- The risk is expected to remain high due to climate hazards in the UK and globally, particularly in key production regions and transport hubs; increased complexity and globalisation of supply chains, which amplifies exposure to regional climate shocks; potential for systemic cascading effects if multiple nodes are simultaneously impacted by climate events (e.g., droughts, floods, heatwaves).
- Key evidence limitations include lack of comprehensive mapping of UK supply chain dependencies, especially on climate-vulnerable countries or regions; insufficient data on climate vulnerability of logistics infrastructure (ports, freight, cold chains); poor understanding of how supply chain climate risks interact with other disruptions (e.g., geopolitical instability, pandemics); limited information on private-sector adaptation measures and resilience investments by UK firms.
- While supply chain risks were acknowledged in CCRA3, they were not analysed as a standalone economic risk.

Table 4.14: Urgency scores for E3 risks to domestic and international supply chains and resource inputs of UK businesses. Key to the magnitude scores: very light purple (L), light purple (M), purple (H), dark purple (VH). Key to the magnitude scores and confidence levels: L = Low, M = Medium, H = High, VH = Very High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

ID	Risk		Present	2030	2050	2080	Urgency
E3	Risks to domestic and international supply chains and resource inputs of UK businesses	**UK**	++ (H)	+ (H)	+ (VH)	+ (VH)	CI
		England	++ (H)	+ (H)	+ (VH)	+ (VH)	CI
		Northern Ireland	++ (H)	+ (H)	+ (VH)	+ (VH)	CI
		Scotland	++ (H)	+ (H)	+ (VH)	+ (VH)	CI
		Wales	++ (H)	+ (H)	+ (VH)	+ (VH)	CI

4.2.3.1 Evidence relevant to the entire United Kingdom

Current and future drivers of risk

Supply chains are exposed to risks that affect the natural and built environments, infrastructure, people, and business operations. Climate risks can arise at different points, cause disruptions to critical infrastructure (e.g., transport or energy) and cascade to other stages of the supply chain with implications for businesses and consumers (CCC, 2022).

Extreme weather events (EWEs) are perceived to be the largest climate hazard to supply chains due to their damaging impact on critical infrastructure. Seasonal and annual changes in mean temperature present additional threats (IPCC, 2023, Infrastructure Chapter). These damages increase maintenance and replacement costs of physical assets, indirectly adding to supply chain costs. In the UK, some strategic infrastructure is in low-lying coastal areas or along single-corridor road and rail links, thereby increasing exposure to climate risk (Mulholland and Feyen, 2021).

UK supply chains are highly globalised, with two thirds of trade manufacturing dependent on simultaneous flows of exports and imports (HM Government, 2024). Moreover, a fifth of the economic value of the UK global supply chains originates in countries and regions at ‘medium’ to ‘very high’ levels of increased climate risk (CCC, 2022). Therefore, overseas climate risks feed directly into the risk to UK supply chains with knock on effects on production and exports by UK businesses (Breinlich et al., 2023) as well as price stability and inflation for the UK economy as a whole.

The exposure of supply chains to international climate shocks is not limited to direct trade links but can be indirectly channelled through changes in the price of key commodities. Global supply chains amplify the effects of climate change in one country, such as disruptions to industrial output, storage facilities and transport networks, by propagating these effects to other countries and regions through trade links and port-to-port shipping delays (Sun et al., 2024; Pankratz and Schiller, 2024).

<u>Risks to Maritime Transport:</u>

Maritime transport, which accounts for 80% of world trade by volume, is particularly exposed to climate associated risks. The global maritime transport network is shaped around a few strategic trade routes and so-called maritime chokepoints (narrow, strategic passages with high volumes of traffic) some of which face high levels of climate-related risks. For example, the Panama Canal, which facilitates about 5% of global annual trade, is at high risk from floods and droughts and medium risks from haze and fog. The Suez Canal, a key connection between Asia and Europe that handles approximately 12% of maritime trade, is at high risk from storms and medium risks from haze and fog (Ranger et al., 2025).

In the case of the UK, 95% of all trade, by volume, is transported by sea (Department of Transport, 2022). In addition to dependencies on global maritime chokepoints, UK supply chains are exposed to climate-risks to ports and coastal infrastructure. Ports are uniquely vulnerable to climate risks given their costal locations and reliance on complex logistics networks. EWEs, like hurricanes, typhoons and storms, can cause physical damage to ports’ infrastructure and major disruptions to their operations (Verschuur et al., 2023a). Moreover, sea level rise and increased risks of coastal flooding may significantly hinder ports’ capacity, creating potential bottlenecks, congestions and delays that would further increase supply chain costs.

<u>Sectoral Variation:</u>

The vulnerability of UK supply chains to climate shocks, both at the domestic and international levels, varies across sectors. Dependence on a few mega-suppliers, single transport routes or highly specialised supply chains (e.g., for semiconductors), can lead to severe disruptions for downstream stakeholders due to spiking prices or reduction in supply. Specific supply chains like food, pharmaceuticals, critical materials and semiconductors are at particular risk from climate shocks (EU CRA, 2024; DEFRA, 2023).

UK food supply chains are significantly exposed to domestic and international climate risks that may cascade to industries such as food processing and beverages. In recent years, weather conditions in the UK have been some of the most extreme on record, with direct implications for the domestic production of food (Kendon et al., 2023; Met Office, 2024; DEFRA, 2024). Domestic food production is also affected by the risks to biodiversity, soil health and water (DEFRA, 2024; Environment Agency, 2023). The exposure of UK food supply chains to climate change is heightened by the reliance on food imports. In fact, the UK imports almost half of the food it consumes, and half of these imports consists of non-indigenous food items that would be difficult to produce domestically in a cost-effective way. The imports of certain food products are highly concentrated geographically (e.g., rice, citrus fruits or bananas). Moreover, around 16% of food imports originate from countries with low climate readiness (CCC, 2022; Energy & Climate Intelligence Unit, 2023; CCC, 2025). The resilience of the food supply chain is also affected by the dependencies on regionally concentrated providers of agricultural inputs (e.g., phosphatic and potassic fertilisers, animal feed additives) and inputs needed at the processing stage of the supply chain (e.g., CO_2, cardboard, sunflower oil). The prevalent model of 'Just in Time' where a low level of stock is maintained at any given time further limits the resilience of food supply chains (DEFRA, 2024).

In sectors where suppliers produce highly specialised and unique inputs, the disruptions caused by climate change can be more severe and more long-lasting (WTO, 2022). For example, in the semiconductor industry, many components are produced in the Asia-Pacific region, where the probability of disruptive hurricanes is expected to increase (IPCC, 2022, WGII AR6 Ch. 10.4.6.3.5). For example, in December 2021 a typhoon in Malaysia disrupted local semiconductor production and severely damaged Klang, Southeast Asia's second-largest port, where advanced microchips from Taiwan are routinely shipped for packaging and re-exporting. The packaging breakdown contributed to global semiconductor shortages (Leslie, 2022). Semiconductors are embedded in a wide range of products and disruptions to their production and trade will therefore have cascading effects through most sectors of the economy.

Another sector with significant exposure to climate risks, domestically and internationally, is pharmaceuticals. In the UK, the pharmaceutical sector is the third largest for goods exports and the fifth largest for goods imports (ONS, 2024). The pharmaceutical industry relies on global supply chains for its production and distribution, for instance between 60–80% of active pharmaceutical ingredients are manufactured in India or China (European parliament, 2020). The production process in the pharmaceutical industry is intensive in the usage of water and is often characterised by specialised processes and a dependence on specific physical assets (European Medicines Agency, 2020). Water quality, flooding and water scarcity are important risks facing this industry worldwide (World Wildlife Fund, 2021). Moreover, many medical products (e.g., insulin) require specific temperature-controlled storage and transportation. Increases in temperature and unexpected delays in distribution can cause temperature excursions (Cervest, n.d.). Given the critical nature of this industry to the UK, the implications of disruptions to supply chains are not limited to the cost of the industry but also have health ramifications (which relates to Risks to Health and Social Care Delivery, H6).

Assessment of current magnitude of risk

There is a lack of evidence on the frequency and magnitude of climate-related supply chain disruptions in the UK. There is also a lack of evidence on the direct and indirect losses to businesses from climate-related disruptions to their supply chains. Most of the evidence is based on self-reporting by large firms and may not be specific to the UK context. Nevertheless, the available evidence suggests a risk magnitude of high.

Surveyed businesses consider that adverse weather and natural disasters are risk factors of growing concern over the upcoming years (BCI, 2022, 2023). Disruptions to critical infrastructure can result in substantial costs for downstream supply chains. There are several examples from recent years where EWEs resulted in significant disruptions to the transport network in the UK (e.g., Storm Arwen in 2021, the heatwave in 2022 and Storm Babet in 2023) (Kendon et al., 2022, 2023). For instance, during Storm Arwen, Network Rail was forced to close lines for freight and commuter services in NE England due to severe wind and snow, with impacts further cascading through regional networks (BBC News, 2021). During the July 2022 heatwave, physical deformation of key transportation infrastructure (e.g., railway lines, tarmac) led to temporary closures of several airports (including Luton) and speed restrictions along time-sensitive supply routes for 'Just in Time' components (Transport Focus, 2022). Similar impacts were seen during Storm Babet, where exceptional rainfall flooded key logistics corridors in eastern Scotland and Yorkshire, further highlighting chronic drainage and signalling vulnerabilities (Network Rail, 2023).

Climate change is also expected to increase incidence of EWEs with a potential to disrupt the operations of domestic ports. For example, the port of Dover temporarily closed because of Storm Eunice in February 2022 (Kendon et al., 2022). The port of Dover is a key entry point for food imports, particularly perishable products, and as such disruptions there and in the neighbouring Folkstone-Calais freight shuttle will have significant implications for food distribution in the UK (Zurek et al., 2022). Most third-round Adaptation Reporting Power submissions by UK ports (including Dover, London, ABP and Peel) identify increased storm surge and significant wave heights, shifts in wind speed and direction, and accelerated coastal erosion as their primary current sectoral risks. These risks are already known to drive an average of 2-3 days of annual downtime per port, including recurrent damage to infrastructure (Coyle et al., 2023).

UK supply chains are also vulnerable to disruptions in international ports. Ranger et al. (2025) point out that the trade risk associated with these disruptions is estimated at $2.5 billion per year. However, this estimation must be interpreted with care since disruptions at ports rarely result in a trade loss but often lead to delays (Ranger et al., 2025). The magnitude of the trade risk will vary by sector and supply chain. For example, Ranger et al. (2025) present a case study of the implications of international supply chain shocks to the supply of grains in the UK and show that weather-driven variations translate into moderate fluctuations in consumer prices in the UK of around 10%. Their study shows that the UK grain system is relatively more resilient in comparison with the global system. This resilience is driven by existing supply diversification and domestic wheat production. Although these price fluctuations are considered moderate, they can have significant implications in terms of food security, income inequalities and health outcomes as experienced in the recent cost-of-living crisis (DEFRA, 2024).

Assessment of future magnitude of risk

Risks to UK supply chains maintain a high level of uncertainty due to the unpredictability of future EWEs (IPCC, 2023). Across all future horizons, the narrative evidence suggests a high risk magnitude, punctuated by the possibility of very high impacts when multiple hazards coincide or international tipping points are crossed.

Tipping points, particularly those affecting ecosystems and ecosystems services, pose significant risks that are propagated internationally through global supply chains (Marsden et al., 2024). For example, large scale loss in the Amazon could heavily impact important trade routes such as the Panama Canal (de Bolle, 2024). Ecosystem tipping points also increase the exposure of the global food system to the risks of synchronised agricultural losses in major food-producing areas (Gaupp et al., 2019; Ranger et al., 2023).

Water risk exposure in the pharmaceutical sector is predicted to increase (World Wildlife Fund, 2021). The regional dependence on China and India for certain products and inputs, increases future risks of supply shortages. Both countries face escalating climate hazards that will negatively impact production sites and disrupt transportation networks (Adaptation Without Borders, 2023; EU CRA, 2024). At the same time, climate change may lead to the proliferation of new and existing infectious diseases resulting in an increased demand for antibiotics and vaccines. Moreover, chronic diseases are becoming more prevalent with an aging population, further increasing the damages and health risks associated with medicine shortages (EFPIA, 2022; EU CRA, 2024).

<u>2030s, central warming scenario:</u>

Moving toward the 2030s, in a global climate roughly 1.5 °C warmer, the same hazards that trouble firms today are expected to intensify (BCI, 2023). Future climate risks are further projected to increase for sectors associated with the twin transition. For example, heat related water stress is expected to affect around 40% of semiconductor plants by 2030 (Lepawsky, 2024).

<u>2050s, central and high warming scenarios:</u>

Rising temperatures also have implications for supply chains with losses ranging between 0.1% and 1.5% of global GDP by 2060 under different climate scenarios (Sun et al., 2024). More extreme high temperatures are particularly challenging for the cold chain and can lead to the failure of refrigeration (Fallon et al., 2022; Davie et al., 2023).

Projected higher flood risks jeopardise the resilience of infrastructure systems, like transport, electricity and water with a potential of cascading impacts between infrastructure systems. For example, by 2050 around half of railway and road kilometres in the UK will be at risk of flooding, compared with a third currently (Environment Agency, 2024). Costal infrastructure faces increased risks from climate change in all scenarios. Storm surges, of a given magnitude, are projected to affect larger areas of land in future compared to previous years because of dynamic sea level rises (Bulgin et al., 2023).

<u>2080s, central and high warming scenarios:</u>

Existing evidence on the risks of future damage to ports and future disruptions to ports operations tend to focus on high-end warming scenarios. For example, Izaguirre et al. (2021) model operational risks across 2,013 ports worldwide by 2100 under the high-end emissions pathway and show that the number of key ports that are at high risk from multiple climate hazards could almost double from 385 to 691 key ports globally. These risks will cascade through global trade networks (Verschuur et al., 2023a).

Level of preparedness for risk

According to the latest CCC report on progress in adapting to climate change (CCC, 2025), there is insufficient progress in identifying and managing supply chain risks and the set of policies in place remain partial despite an improvement since 2023. The committee was unable to evaluate the delivery and implementation of adaptation actions aimed at minimising the disruption to food and feed supply chains and considered that the current set of policies and plans is insufficient to achieve progress. The committee notes an improvement in the policies and plans aimed at identifying and managing supply chain risks for businesses. These improvements are associated with the publication of a set of strategies aimed at strengthening the resilience of UK supply chains, notably the 2021 Integrated Review of Security, Defence, Development and Foreign Policy which places strong and resilient supply chains at the core of economic and security policy (HM Government, 2021).

The committee considered that adaptation action associated with the resilience of critical infrastructure is insufficient or partial. Of particular concern from the perspective of supply chain risk, is the insufficient progress on the delivery and implementation of action aimed at improving the reliability of port operations. Having said that, certain ports are taking action to increase their levels of preparedness. For example, as part of Dover Harbour Board's fourth-round Adaptation Reporting submission, the harbour has begun implementing automated tidal flood gates and expanding dock drainage systems across both Eastern and Western Docks to mitigate storm surge impacts (Dover Harbour Board, 2025). Further measures outlined in the ARP4 report include deployment of a real-time flood monitoring and alert system and commencement of quay-wall heightening works, with full completion of these medium-term actions scheduled by 2028.

In the business sector the level of preparedness varies. 60% of large manufacturers and 43% of SMEs have diversified their supply chains; 40% have increased sourcing from within the UK and more than 80% regard supplier diversification as a core mitigation step (Make UK, 2022; Make UK and Infor, 2023). In addition to these strategies, some UK businesses are planning to move away from the predominant 'Just in Time' supply chain model to a 'Just in Case' model where businesses hold some stock as a buffer against supply chain disruption (SAP, 2022). However, technological preparedness lags strategic intent: 82% of manufacturers say supply chain monitoring is critical, yet one quarter still conduct no tracking of upstream risks (Make UK and Infor, 2023).

Overall, the evidence paints a picture of partial preparedness: government frameworks and intelligence capacity are advancing, and many firms have begun to diversify and reshore. Current government policies, including Powering Up Britain, seek to mitigate these threats, but adaptation efforts are lagging behind the scale of the challenge. Stronger action is needed to safeguard businesses from long-term climate-related disruptions (CCC, 2023d). On this basis the magnitude of the risk is unchanged.

Assessment on the evidence base and evidence gaps

The UK has a moderate evidence base, strong on physical hazards and headline business sentiment, weak on quantified economic losses, devolved-nation coverage, and the real-world performance of adaptation measures. Filling those gaps is critical for national level risk management and for tracking progress toward resilient supply chains. For example, the UK Food Security Report is increasingly focusing on the implications of climate change and changing weather patterns, but it does not provide businesses in the food supply chain with the data and information required to manage their climate-related risks (DEFRA, 2024). As noted by the CCC, the limited availability of good quality data at the national level is a barrier to the effective assessment of progress on adaptation action (CCC, 2025).

The ambition of the UK Critical Imports and Supply Chains strategy is "making the UK government a centre of excellence for supply chain analysis and risk assessment". The strategy aims to improve the UK's response to supply chain shocks and to enable businesses to assess the resilience of their supply chain by increasing the availability of data and conducting scenario 'stress testing'. This could mark a step-change in closing the current evidence gap. Greater coordination between different government bodies and departments should also enhance the availability of good quality indicators specific to climate risks that are comparable across critical supply chains.

4.2.3.2 England

Evaluation of urgency score

Climate change is already affecting supply chains in England, with damages running into the hundreds of millions of pounds. Businesses are vulnerable to disruptions in critical infrastructure, particularly transport and energy networks. Flooding, storms, and coastal erosion threaten key transport routes, while electricity and fuel supplies are at risk from climate hazards (Environment Agency, 2024). Risks to critical infrastructure in England are predicted to increase, in frequency and magnitude, under future climate scenarios. For example, future risks of adverse weather events and natural disasters such as wildfires and floods are projected to expose the transport network to severe and major future risks (Perry et al., 2022; National Highways, 2024).

Table 4.15: Urgency scores for E3 Risks to domestic and international supply chains and resource inputs of UK businesses for England. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

England								
E3	Risks to domestic and international supply chains and resource inputs of UK businesses.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (H)	+ (H)	+ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (H)	+ (H)	+ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
Urgency scores	MAN	CI		CI			FI	
Overall urgency score	CI							

4.2.3.3 Northern Ireland

Evaluation of urgency score

Northern Ireland's supply chains are largely dependent on road freight, which faces increasing risks from climate-related hazards such as flooding, coastal erosion, and rising temperatures. These disruptions threaten businesses, yet little research has been conducted on their full impact (CCC, 2023c). Sectors reliant on imports are particularly exposed to international supply chain shocks, while freight transport itself remains highly vulnerable. Despite the risks, adaptation measures are lacking, and the government has yet to develop a targeted strategy to mitigate climate-related supply chain disruptions. The CCC highlights that available business support focuses on general supply chain management rather than specific climate resilience measures (CCC, 2023c). Without urgent action, supply chain vulnerabilities will continue into the 2030s and beyond. The absence of government-led adaptation plans means projected risks remain high, with little certainty about future resilience strategies. As climate threats intensify in the coming decades, disruptions to transport and logistics will put increasing pressure on businesses. Future adaptation efforts must address these gaps by integrating climate resilience into national and sector-specific supply chain policies. Without proactive strategies, businesses will face growing financial risks from supply chain instability linked to climate change.

Table 4.16: Urgency scores for E3 Risks to domestic and international supply chains and resource inputs of UK businesses for Northern Ireland. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by CAN = Critical Action

Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Northern Ireland								
E3	Risks to domestic and international supply chains and resource inputs of UK businesses.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (H)	+ (H)	+ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (H)	+ (H)	+ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
Urgency scores	MAN	CI		CI			FI	
Overall urgency score	CI							

4.2.3.4 Scotland

Evaluation of urgency score

Scotland's supply chains rely heavily on road transport, with 90% of freight moved by road (Logistics UK, 2021). This dependence makes businesses vulnerable to climate-related disruptions such as flooding, landslides, and coastal erosion (Transport Scotland, 2023). Rail transport faces additional threats from rising temperatures and unstable ground conditions (Network Rail, 2024). Energy infrastructure is another major risk factor, as disruptions to power supplies can ripple through supply chains, affecting transport and business operations. There is little research on the specific economic impact of climate-driven supply chain disruptions in Scotland, though industry experts suggest that the costs could be substantial (CCC, 2022, 2023). The construction sector, which depends on imported raw materials, is particularly exposed to international supply chain instability (Scottish Parliament, 2022).

Scottish Enterprise provides general guidance on supply chain resilience, but specific adaptation measures for climate risks remain limited. The government's Food Security Unit will monitor risks but is not designed to implement adaptation strategies. Over the next few decades, climate-driven disruptions to transport infrastructure and international supply chains will pose increasingly severe challenges. Without proactive measures, businesses will continue to face significant risks, especially in sectors reliant on imports and freight logistics. Greater investment in adaptation is needed to protect Scotland's economy from escalating climate threats.

Table 4.17: Urgency scores for E3 Risks to domestic and international supply chains and resource inputs of UK businesses for Scotland. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical

Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Scotland								
E3	Risks to domestic and international supply chains and resource inputs of UK businesses.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (H)	+ (H)	+ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (H)	+ (H)	+ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
Urgency scores	MAN	CI		CI			FI	
Overall urgency score	CI							

4.2.3.5 Wales

Evaluation of urgency score

Supply chains in Wales are under pressure from climate risks, particularly those affecting transport networks and energy infrastructure. The wholesale and retail trade sector, which accounts for over 30% of private sector turnover, is highly exposed to climate-related supply disruptions (HM Government, 2022b). Welsh SMEs, which represent a larger share of private sector turnover than in England, may struggle to implement resilience measures due to limited resources. Key threats include flooding, rising temperatures, and coastal erosion, all of which are expected to cause growing disruptions (CCC, 2023c). There is little research specific to Wales' supply chains, particularly concerning food security and business adaptation strategies. While the Refreshed Manufacturing Plan for Wales recognises the importance of supply chain resilience, it does not directly address climate change risks. A planned mapping exercise could help identify vulnerabilities, though it remains unclear how effective this will be. Looking ahead, climate-related disruptions to transport and imports are expected to continue, increasing financial risks for businesses. Without targeted adaptation policies, supply chain risks will persist through the 2050s and beyond. Addressing these challenges requires a stronger focus on climate-specific resilience measures, as the current policy framework does not sufficiently support businesses in preparing for long-term climate threats.

Table 4.18: Urgency scores for E3 Risks to domestic and international supply chains and resource inputs of UK businesses for Wales. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Wales

E3	Risks to domestic and international supply chains and resource inputs of UK businesses.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (H)	+ (H)	+ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (H)	+ (H)	+ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
Urgency scores	MAN	CI		CI			FI	
Overall urgency score	CI							

4.2.4 Risks to the productivity and availability of labour in the UK – E4

The supply of labour and the performance of employees in the work environment can be sensitive to prevailing temperature. In particular, evidence suggests that elevated temperatures, particularly if sustained, can impact workplace absence due to heat stress and heat-induced illness, for example, and the productivity of workers, in both manual and non-manual tasks.

Scope: Considers direct and indirect climate impacts on workforce health, productivity, and availability. Subcomponents include health effects (e.g., heat stress, respiratory issues), reduced productivity, absenteeism, and presenteeism and sectoral variation in vulnerability (e.g., agriculture, construction). The focus is on temperature impacts, though it is acknowledged that there may be effects through other channels, for example mental health or transport disruption issues arising from flooding.

Headlines

- Critical investigation needed.
- This risk is expected to increase in the future, particularly due to higher temperatures and more frequent heatwaves affecting outdoor and manual workers; deteriorating air quality and rising incidence of climate-sensitive diseases, reducing workforce health and productivity; regional and sectoral disparities (e.g., agriculture, construction) where climate impacts are likely to be most acute; longer-term demographic and health system pressures exacerbated by climate change.
- Several evidence gaps limit assessment and policy planning such as limited UK-specific data on heat stress and labour productivity impacts; weak integration of health data with economic productivity modelling; lack of regional breakdowns of exposure and vulnerability; inadequate studies on cumulative and chronic effects of climate on labour availability (e.g., through illness, migration, or occupational disruption).

Table 4.19: Urgency scores for E4 Risks to the productivity and availability of labour in the UK. Key to the magnitude scores and confidence levels: L = Low, M = Medium, H = High, VH = Very High. Key to the urgency scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

ID	Risk		Present	2030	2050	2080	Urgency
E4	Risks to the productivity and availability of labour in the UK	**UK**	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
		England	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
		Northern Ireland	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
		Scotland	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
		Wales	++ (H)	++ (H)	+ (VH)	+ (VH)	CI

4.2.4.1 Evidence relevant to the entire United Kingdom

Current and future drivers of risk

There are multiple pathways from temperature to labour supply and productivity.

The relation between temperature and labour productivity requires an understanding of both effects on labour supply (measured in hours, days, for example) and output or performance per unit of labour. Recent studies by economists and others have in most cases studied these separately.

Two things are worth making explicit. First, micro-level empirical evidence is scant, and most of the best quality evidence that does exist does not relate directly to the United Kingdom. While there is value in including evidence from elsewhere, appropriate caution needs to be exercised with respect to importing those results.

Second, while most of the evidence – and probably also the popular discussion – focusses on possible productivity losses due to increased frequency of hot weather, since the UK is a temperate country, a fuller analysis would require accounting for any offsetting effect that might be seen from less cold winter conditions. The evidence base on the latter is much less developed. The temperature to performance relationship sometimes built into forecasting models typically peaks at around 20 to 22 °C. Performance is expected to decline with departure from that 'sweet spot' temperature in either direction. See, for example, Figure 1 below, which reproduces Figure 1 from page 2 of the Vivid Economics (2017) report cited above (the report in turn draws on Seppanen, Fisk and Le, 2006).

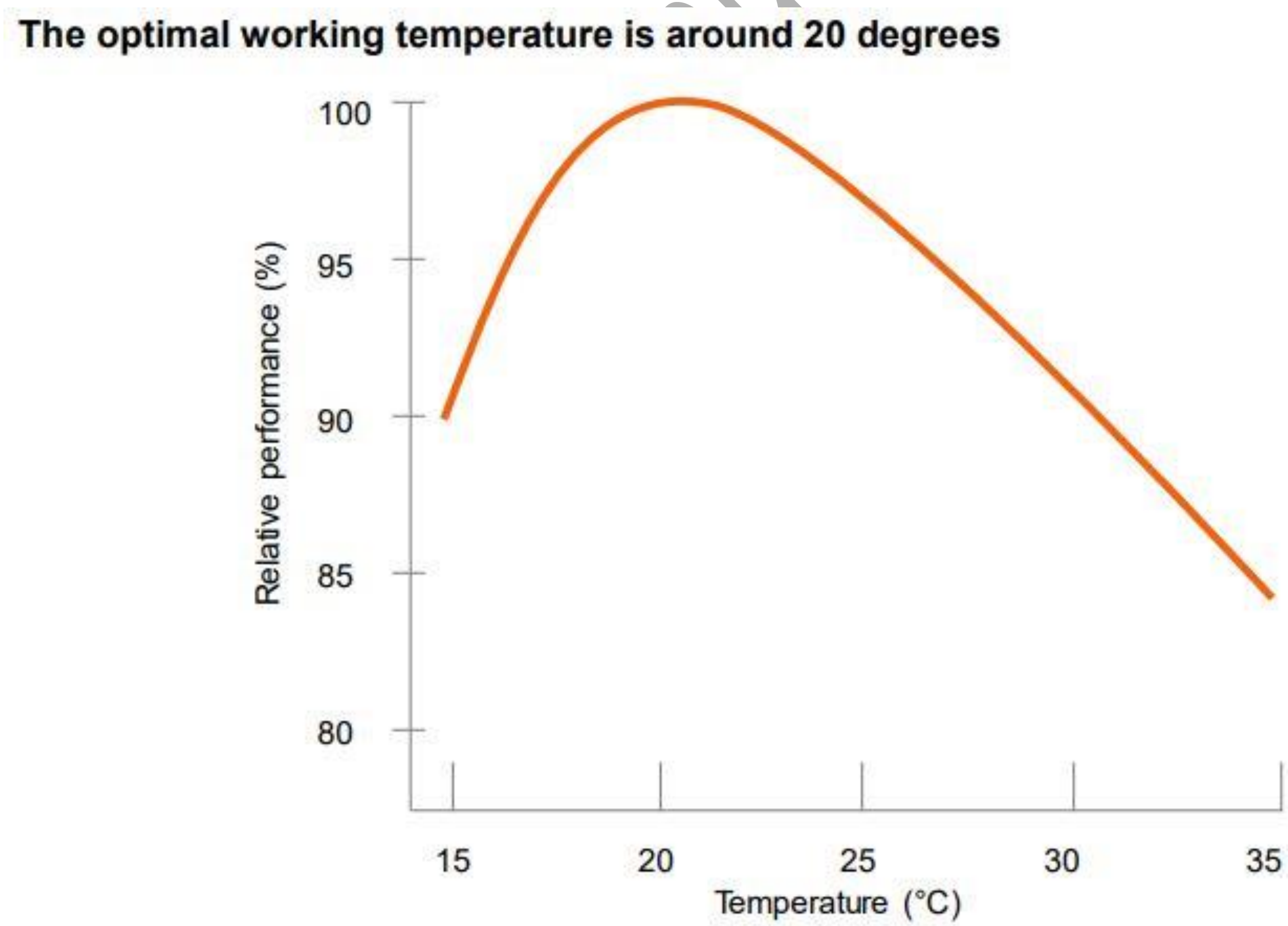

Figure 1: The optimal working temperature is 20-22 °C, with productivity declining with departure in either direction from that temperature. Source: Figure 1 of Vivid Economics report, 2017.

For many hotter locations, such as Mumbai, most working days are located beyond the turning point, such that any increase in projected temperatures can plausibly be expected to diminish performance. In a city such as London, in contrast, temperature on most working days locates us on the upward sloping portion of curve where higher temperature would be expected to improve performance (average daily maximum temperature only exceeds 20 °C in two months of the year, July and August, in London, and no months of the year in Glasgow). As such, modelling should involve balancing productivity improvements across most of the working year against the potential for losses on a smaller number of hot days. This would require a very granular analysis, extrapolated to the macro-economy, which existing analyses do not achieve. It is also worth making explicit that while this might apply quite cleanly to those working outside, the impact on indoor work will depend on how well temperature is controlled in the workplace. Workplace (Health Safety and Welfare) Regulations 1992 require employers provide a reasonable indoor temperature. While heating is almost universally available current penetration of air conditioning (AC) is much more sporadic, so the plot above might be expected to be quite flat to the left of the peak, declining thereafter. More research is needed to characterise this further.

Temperature can affect workplace performance per unit of time worked through physiological strain and cognitive impairment. The human body works constantly to maintain a stable internal temperature, and at elevated ambient levels, particularly above the mid-20s Centigrade, this system becomes less efficient. When external temperatures rise above core body temperature, especially in humid conditions, the ability to cool through sweating diminishes.

Such physiological stresses can directly reduce work capacity. This is likely to be particularly important in physical labour settings, and where work takes place primarily outside, like agriculture, construction and logistics. Tasks take longer, error rates increase, and accident risks rise. Work indoors may be protected contemporaneously for elevated outdoor temperatures by climate control, though workers may still “import” the effects of temperature with them from outside, so understanding lagged effects of exposure is important but understudied.

Cognitive functions and mental state can also be compromised. Research shows that high temperatures reduce attention span, working memory, and decision-making speed. For example, Graff Zivin, Hsiang and Neidell (2018) investigate the impact of temperature on human capital by analysing how heat affects cognitive performance, arriving at mixed results. Using data from the National Longitudinal Survey of Youth (NLSY79), they find that exposure to daily temperatures above 26 °C significantly reduces mathematics test scores, indicating immediate cognitive impairments. Reading performance, however, is unaffected. Despite these short-term effects, the study finds no evidence that long-term exposure to heat impacts the accumulation of human capital, suggesting that individuals and institutions may adapt to mitigate lasting consequences of high temperatures on cognitive development. See also the literature review provided by Rony and Alamgir (2023), who explore the link between high temperatures and mental health and show that chronic heat stress can lead to increased stress, anxiety, and cognitive impairment.

Taken together these and related studies point to a more complex relationship between temperature and performance than we are sometimes led to believe.

Assessment of current magnitude of risk

A reasonably robust body of empirical work, often using panel data and at different levels of aggregation, has demonstrated that high temperatures, beyond some point, reduce both the quantity and quality of work across a wide range of settings. Most of the study settings have been outside the UK, often in locations where higher temperatures are more common, and the applicability of such results to cooler northern environs requires caution.

A subset of the most pertinent of these are outlined here, though this is not exhaustive. Since Chapter 6 of CCRA3 had a different focus, it did not engage in detail with the academic economic research that existed at that time as it explicitly related to labour productivity as it existed in 2020. Kopp et al. (2016) offers a good overview of the important literature prior to 2016, with particular reference to the United States.

One early and frequently cited study by Seppenan et al. (2006) review previous literature by ergonomists and others finding that, for a range of typical office tasks, task productivity improves up to a threshold of around 20 to 25 °C, then declines. Declines are approximately 2% per degree. Similarly, Niemelä et al. (2002) found that Indian call centre productivity declines by 1.8% per degree above 22 °C. Although based in warmer settings, these findings are relevant for the UK as average temperatures rise. Somanathan et al. (2021) observed productivity losses of up to 4% per degree above 27 °C in manual manufacturing, though not in automated environments, with mixed evidence on the benefits of basic climate control. Adhvaryu et al. (2020) also reported lower efficiency on hotter days, driven by reduced on-task focus rather than absenteeism.

In high-tech manufacturing, Chen et al. (2023) analysed over 35,000 shifts in a Chinese silicon wafer producer and found that a 10 °C increase in outdoor wet-bulb temperature cut productivity by 8.3%, despite advanced climate control—suggesting technological adaptation alone may not prevent losses. Firm-level data across temperature-sensitive industries show similar patterns: productivity peaks around 25 °C and drops rapidly beyond 30 °C, with output over 8% below optimum (Zhang et al., 2022).

In service settings, LoPalo (2020) found that fieldworkers completed 13.6% fewer interviews per hour on the hottest, most humid days—implying comparable risks for social or customer-facing jobs common in the UK. Heat also impairs cognitive performance: Park (2022) showed that New York students scored significantly lower in exams on days above 24 °C, suggesting analogous risks for UK knowledge-based professions. Longer-term, Park et al. (2020) found that each 1 °F (0.55 °C) hotter school year without air conditioning reduced learning by about 1%, implying that persistent heat may weaken future human capital and skilled labour supply.

Heat also influences labour supply. Graff Zivin and Neidell (2014) found that high temperatures reduce time spent on high-effort tasks by up to an hour per day, with time reallocated to low-productivity or leisure activities. Somanathan et al. (2021) observed that prolonged high temperatures increase worker absenteeism, a mechanism likely to operate in the UK through health impacts. High temperatures are linked to various health risks (European Environment Agency, 2024), including indirect effects such as childcare disruptions when schools close during heatwaves.

Evidence from Australia (Ireland, Johnston and Knott, 2024) shows high temperatures significantly reduce attendance and hours worked, especially in cooler regions and sectors such as finance. Absences were not compensated later, suggesting lasting productivity losses. Though UK temperatures rarely exceed 38 °C, similar patterns during heatwaves could still disrupt work attendance, commuting, and output, highlighting the limits of indoor climate control alone.

As already observed, while most research focusses on productivity losses at the hot end of the temperature distribution it is also important to be aware of the change in frequency of very cold days. Cook and Heyes (2020), for example, use a large Canadian data set to provide rigorous evidence of loss of cognitive performance among adults on very cold days, even when working indoors in rooms with high-quality climate control.

Consistent with this, Heal and Park (2013), who examine the general labour productivity relationship using country-level data from 1950-2005, find that hotter-than-average years lead to lower output in hot countries, but higher in cold countries (such as the UK), with each 1 °C variation in annual average temperature associated with a 3 to 4% increase in labour productivity.

Robinson et al. (2025) investigate how extreme heat affects labour supply, productivity, and worker health across the UK, including England, Scotland, Wales, and Northern Ireland. Drawing on a representative survey of over 2,000 UK workers conducted after the July 2024 heat episode, the study finds that a 1 °C temperature anomaly above the 1961–1990 July average increased the likelihood of workers reducing their hours by 9.9% and their effort by 9.5%. Advanced heat alerts mitigated these effects, lowering the probabilities to 6.2% and 6.7%, respectively. Despite these adaptations, nearly a third of respondents reported heat-related health issues, such as headaches and dizziness. Employers' measures, like adjusting work environments and hydration policies, partially alleviated these impacts. The study estimates that a 1 °C anomaly could result in a loss of 106.6 million working hours across the UK, with adaptation strategies potentially recovering up to 66.7 million hours.

Other studies project that rising temperatures due to climate change may have significant impacts on labour supply in the UK, particularly in sectors with high physical demands (see, for example, Dasgupta et al., 2021). Expanding on this, Dasgupta et al. (2024) emphasise the risks of heat stress, showing that without adaptation, cumulative work hours lost will grow sharply. Policy-oriented insights by Dasgupta and Robinson (2023) call for urgent research into mitigation and adaptation strategies, stressing the socioeconomic costs of inaction and the need for robust frameworks to protect vulnerable workers.

The International Labour Organization (ILO 2019) has reported similar trends globally. They project that that by 2030, the equivalent of 2% of total working hours worldwide could be lost due to heat stress. Construction is likely to be particularly affected, projected to experience a significant loss of working hours due to heat, with an estimated 19% reduction by 2030.

In the UK, heat-related absence data remain sparse, but anecdotal and sector-specific reports are mounting. The Chartered Institute of Personnel and Development (CIPD, 2020) found that only a minority of UK employers collect health and safety data related to temperature exposure. Among those that do, most rely on self-reporting or do not link the labour organise data to productivity losses.

Assessing the current magnitude of risk requires making assumptions about the temperature-labour supply and temperature-productivity relationships, motivated by the research reported above, with the current temperature distribution for the United Kingdom, or a setting with similar characteristics.

In a study of European countries Garcia-Leon et al. (2021) build a sectoral model to estimate productivity damages due to hot days using data from 1981 to 2010 and find it to be 0.3-0.5% of European GDP. The largest effects are, unsurprisingly, found in the countries of southern Europe. For the United Kingdom the estimate is approximately 0%.

Dasgupta et al. (2021) and Dasgupta and Robinson (2023) propose that, apart from extreme heat events, increasing average temperatures could reduce individual labour supply, though effects to now are small, and positive effects on supply could be seen in cooler northern counties and Scotland. The multi-model study of Dasgupta et al. (2021) evaluates the combined effects of climate change on labour productivity and supply globally. They do so by examining micro-survey data from diverse sources, combining it with empirical exposure-response functions (ERFs) and climate projections to arrive at forecasts mapping climate scenarios to productivity outcomes, including for the UK. The study finds that under a 3.0 °C warming scenario, effective labour (which is a metric that combines hours worked and hourly-productivity, both sensitive to temperature) is projected to decline by as much 18.3 percentage points globally for low-exposure sectors, and by 32.8 percentage points in high-exposure sectors. Importantly for our purposes, Europe sees relatively minor average reductions, just 1.0 percentage point at 3.0 °C for low-exposure work, but southern Europe may experience declines up to 28.5 points. For the UK, which predominantly falls into low-exposure categories, modest reductions are anticipated, yet productivity losses remain a concern, especially during heatwaves. The findings stress the need for regional adaptation strategies to mitigate economic impacts. The study also highlights that reliance on global ERFs may obscure local vulnerabilities, underscoring the value of region-specific policy planning.

In a report prepared by Vivid Economics (2017) for the UK Department for International Development the authors seek to quantify the economic impact of heat on labour productivity in five countries, in addition to evaluating the value-for-money of adaptation strategies. Based on a literature review they adopt a 'consensus' threshold level of wet-bulb temperature at which labour productivity would decline, of 26 °C, though acknowledging likely variation in that depending on work type. They estimate that current hot temperatures in the five target countries already impose meaningful loss of effective labour supply and project that these losses could rise substantially in future.

Zhang and Shindell (2021) estimate that climate change-induced extreme heat led to approximately $1.7 billion in annual labour productivity losses in the U.S. between 2006 and 2016. Under a high-emissions scenario these losses could escalate to $51–119 billion annually by the 2100s, equating to about 0.3% of U.S. GDP. Implementing GHG mitigation strategies could prevent 600–2,600 million hours of lost labour per year by the 2100s, translating to savings of $20–78 billion, highlighting the potentially substantial economic benefits of climate change mitigation efforts.

In a systematic review of prior empirical research, the analysis of Zhao et al. (2021) points to possible global economic losses due to heat-related labour productivity losses. These could range from 0.31 – 2.6% of GDP by 2100 though it is worth noting that as with most of these studies effects are primarily or fully driven by projected experiences in hotter regions.

A 2024 study by the Office for National Statistics presented an experimental methodology to estimate the scale of lost output from hot days in the Great Britain (not Northern Ireland due to data constraints). Hot days are days when maximum temperature exceeds 28 °C at a location and data is geographically highly granular, estimates are made for built-up areas with populations over 5000. Combining the frequency of hot days at a location with estimates of the temperature-productivity relationship derived from Costa et al. (2016), they estimated productivity losses (Gross Value Added) due to hot days in the UK to be £1.2 billion per year or approximately 0.0% (Office for National Statistics, 2024).

The nature of available evidence, just described, means that we cannot provide a clear mapping from published research to an assessment of current impacts. However, an informed reading of the evidence base makes likely that temperature variations in the UK impose labour productivity and labour supply burdens when compared to a benchmark in which temperature was maintained at a constant 20 to 22 °C. The threshold loss for categorisation as "High" is that impacts due to additional hot days will exceed £100s of millions per annum. The offsetting gains due to less frequent cold days are expected to be relatively small, though the evidence here is scant.

Assessment of future magnitude of risk

Assessment of future magnitudes for this risk requires combining a projection about future temperature patterns with a projection about the impact of temperature on labour supply and productivity in the future.

Two important caveats are worth making explicit here.

First, as already noted our understanding of temperature-human impacts in this area are imperfect, as is our understanding of the scope for adaptation of various kinds to mitigate any such impacts.

Second, as the time being considered moves further into the future we can project with less confidence what “work” will look like. Even as soon as the 2030s, just 10 years away, it is not easy to project how AI, robotics, etc., will support, displace or change work patterns, the types of jobs that people do and how they do them. The pattern of substitution between technology and human labour is difficult to predict. Additionally, organisational changes such as hybrid work and tele-commuting may increasingly mean that the geography of work shifts substantially, so to the evolution of the “offshoring” or work via micro-work platforms such as Amazon Mechanical Turk, though some sorts of work – for example manual – are likely to be less prone to such change.

By the 2050s and 2080s the labour market, patterns and the geography of work can be expected to be comprehensively different to the current day, making forecasting temperature impact to be highly speculative.

Costa et al. (2016) integrate urban climate modelling with sector-specific productivity loss functions to estimate potential economic losses in a panel of European cities like London, Antwerp and Bilbao. Findings indicate that, without adaptation, heat-induced productivity losses could range from 0.4% to 9.5% of Gross Value Added (GVA) by 2081–2100, though London is at the bottom end of that range (0.4). With regard to Great Britain, GVA losses due to hot days are estimated to be £1.2 billion as an annual average (1998-2021) though with much higher impacts in the hottest years. Of course, as they acknowledge, adaptation measures could significantly mitigate these losses.

Over a longer horizon a further question, as yet unstudied, is the extent to which climatic conditions might have longer run influence on quantitative and qualitative aspects of labour supply through individual choice, for example retirement decisions, with associated withdrawal from the labour force of older workers.

<u>2030s, central warming scenario:</u>

The threshold loss for categorisation as “High” is £100s of millions. The research summarised here, and the wider literature, read in the round, makes it plausible that current extreme temperature days will exceed that threshold for the 2030s, under all warming scenarios.

<u>2050s, central and high warming scenarios:</u>

The threshold loss for categorisation as “Very High” is £1 billion per annum or 0.03% of GDP. While a “best guess” would be that the effects of extreme temperature would easily exceed that threshold, the confidence in this projection is reduced by the level of uncertainty with respect to the “future of work” issues outlined above.

<u>2080s, central and high warming scenarios:</u>

The threshold loss for categorisation as “Very High” is £1 billion per annum or 0.03% of GDP. While a “best guess” would be that the effects of extreme temperature would easily exceed that threshold, the confidence in this projection is reduced by the level of uncertainty with respect to the “future of work” issues outlined above.

Level of Preparedness for Risk

Certain sectors where outside work predominates (agriculture, construction, etc.) face particular challenges, however for a large majority of workers, those that work indoors, the primary protection against the effects of increased temperatures on health, function and productivity are the buildings within which they work. Robinson, Howarth and Dasgupta (2024) argue that UK workplaces are not well-adapted for warmer conditions. However, a systematic audit of workplaces and the scope for adaptation has not been conducted, and the scope for effective adaptation will involve not just physical infrastructure but also changes in the organisation of work, such as working from home and changes in the temporal allocation of work tasks during the day and during the year. Some of these adjustments may be made by employers in response to changes in temperature patterns, while others may plausibly happen independent of those changes.

It is also worth noting that adaptive responses will not only be choices of employers. For example, heat-induced sleep disturbance can be expected to affect next day workplace productivity and is primarily mitigated by adjustments at the employee’s home. In addition to climate-protection in workplaces the characteristics of the homes in which people live can also be expected to be an important predictor of the health, and therefore labour supply and performance impacts, of workers.

CCC (2022) argue that the current stock of homes is ill-prepared for future heat events. Consistent with this, measured data from the Energy Follow Up Survey (EFUS) and the English Household Survey, using datasets that include half-hourly temperature measurements from a carefully constructed sample of 2,600 homes found that over-heating was a common problem on hot days, particularly in flats (rather than houses) and smaller dwellings (less than 50 square-metres). Interestingly, overheating risk was 50% higher in more energy efficient dwellings, those with Energy Performance Certificate (EPC) ratings A to C. Overheating has similarly been shown to be a problem in UK schools, hospitals and prisons.

The CCC (2022) report also presents a range of possible passive and active adaptive approaches, such as internal and external shading of windows, changes to mechanical and natural ventilation, and the use of green roofs.

While evidence as to the preparedness of the current UK building stock to higher future temperature is far from complete, the extent to which buildings can be adapted, and the role that government intervention could or should play in encouraging any such adaption is not obvious. In the absence of a market failure preventing it, though Dasgupta and Robinson (2023) suggest the possibility of asymmetries of information might lead to misaligned incentives, we would expect employers to have a strong incentive to develop their workspaces, for example by retrofitting climate-control to office spaces where it does not currently feature, to ensure that the workers they employ remain productive. Furthermore, given the rapidly evolving nature of work already outlined, it may be that in many sectors the adaptations will not be primarily to physical structures but rather to work patterns, for example the temporal pattern of work within days and between days across the seasons. Naturally, the considerations in buildings with public sector or governmental operation, schools, prisons, etc., are different.

Assessment on the evidence base and evidence gaps

The evidence base, with respect to current impacts, and impacts in the comparatively short term, is strong enough to allow us to assert that impacts exceed the 0.03% of GDP threshold for the risk to be categorised as “Very High”.

With respect to longer term projections, those for the 2050s and the 2080s, the most important knowledge gaps are with respect to how the nature of work will evolve over the next 30 to 50 years. While it is likely that “work” in 2080 will bear little relation to its 2025 counterpart, the form that it will be likely to take is highly contested. Projections of the economy that do not account for that are unlikely to generate useful information.

4.2.4.2 England

It is important to note that the available evidence base doesn't allow us to provide differentiated risk magnitudes for each UK nation. While the risk of extreme heat may be lower in, for example, Northern Ireland than England, it is not possible to map such differences into nation-specific productivity impacts with any precision. Furthermore, since the risk magnitude categories are relatively broad, our view is that it is unlikely that relatively small differences in productivity impacts, even if they could be accurately predicted, would lead to differences in risk magnitude categories. Nevertheless, our risk magnitudes in the UK nation tables below are our assessments of the risk magnitude for the UK as a whole and from which it should not be inferred that the risk magnitude is necessarily equal in each UK nation.

Table 4.20: Urgency scores for E4 Risks to the productivity and availability of labour in the UK for England. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

England								
E4	Risks to the productivity and availability of labour in the UK.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (H)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (H)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
Urgency scores	MAN	MAN		CI			FI	
Overall urgency score	CI							

4.2.4.3 Northern Ireland

For interpretation, please see caveat in 4.2.4.2 above.

Table 4.21 Urgency scores for E4 Risks to the productivity and availability of labour in the UK for Northern Ireland. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Northern Ireland	
E4	Risks to the productivity and availability of labour in the UK.

	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (H)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (H)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
Urgency scores	MAN	MAN		CI			FI	
Overall urgency score	CI							

4.2.4.4 Scotland

For interpretation, please see caveat in 4.2.4.2 above.

Table 4.22: Urgency scores for E4 Risks to the productivity and availability of labour in the UK for Scotland. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Scotland								
E4	Risks to the productivity and availability of labour in the UK.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (H)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (H)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
Urgency scores	MAN	MAN		CI			FI	
Overall urgency score	CI							

4.2.4.5 Wales

For interpretation, please see caveat in 4.2.4.2 above.

Table 4.23: Urgency scores for E4 Risks to the productivity and availability of labour in the UK for Wales. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Wales								
E4	Risks to the productivity and availability of labour in the UK.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (H)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (H)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
Urgency scores	MAN	MAN		CI			FI	
Overall urgency score	CI							

4.2.5 Risks to the financial institutions and the financial system – E5

Scope: Assesses financial system exposure to climate risk, including the impact on stability, lending, and investment practices. Subcomponents include physical risk to financial assets, systemic contagion and macro-financial feedback loops and regulatory and risk disclosure gaps. The private financial sector includes commercial banks, pension funds, asset managers, insurance and re-insurance companies, and institutional investors. Public financial institutions include the Bank of England, export credit agencies, domestic and international development banks, disaster and stability funds. Finally, financial markets include equities and bonds, derivatives and other financial instruments.

Headlines

- Critical action needed.
- This risk is projected to increase, with potential for significant disruption to financial markets and institutions due to increased physical risk to assets and operations (e.g., through extreme weather events).
- Several critical evidence gaps are identified such as limited data on climate exposure of financial portfolios**,** especially for smaller institutions and private capital markets; gaps in forward-looking scenario analysis and modelling of financial contagion and systemic risks; underdeveloped understanding of the effectiveness of current regulatory and market responses**,** including the real-world impact of disclosure frameworks (e.g., TCFD); need for integration between financial risk assessment and real economy climate impacts (e.g., supply chain shocks or labour loss affecting creditworthiness).
- In CCRA3, financial system risks were recognised but not given standalone treatment.

Table 4.24: Urgency scores for E5 risks to the financial institutions and the financial system. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

ID	Risk		Present	2030	2050	2080	Urgency
E5	Risks to the financial institutions and the financial system	**UK**	++ (M)	++ (H)	++ (VH)	++ (VH)	CAN
		England	++ (M)	++ (H)	++ (VH)	++ (VH)	CAN
		Northern Ireland	++ (M)	++ (H)	++ (VH)	++ (VH)	CAN
		Scotland	++ (M)	++ (H)	++ (VH)	++ (VH)	CAN
		Wales	++ (M)	++ (H)	++ (VH)	++ (VH)	CAN

Note that Table 4.24 above uses the macroeconomic categorisation. The analysis is complicated by the wide range of estimates in the literature for current and future economic damages. Given the remit of CCRA4 this section focuses only on the impact of physical risks on the financial sector although there is clear overlap between physical and transition risks, where the latter are dealt with elsewhere but are noted when relevant and help to contextualise the physical risk.

4.2.5.1 Evidence relevant to the entire United Kingdom

Current and future drivers of risk

Climate change presents a complex challenge for the UK's financial institutions and more generally for the stability of the financial system. The current drivers of climate risk such as more frequent floods and heatwaves have the potential to influence how banks lend, how insurers underwrite and invest, and how asset managers allocate capital. In the future, these drivers are expected to intensify. Physical risks will grow as global temperatures rise, and extreme weather events become more frequent.

The UK's financial services sector is a significant component of the national economy. The financial and insurance services sector contributed £208.2 billion to the UK economy in 2023, accounting for 8.8% of total economic output. When including related professional services such as legal, accounting, and consultancy, the combined sector contributed £243.7 billion, representing 12% of the UK's Gross Value Added (GVA). In the first quarter of 2024, the financial services sector employed approximately 1.17 million people, accounting for 3.1% of all UK jobs. When including related professional services, total employment in the sector reached over 2.4 million people in 2022, representing 7.5% of total UK employment. In 2023, the UK had a trade surplus of £73.2 billion with exports of financial services of £91.8 billion being greater than imports of £18.6 billion (House of Commons Library 2024). These numbers are important when it comes to the magnitude scores provided later in this section.

The UK financial system consists of various segments, each with its own vulnerabilities (Schoenmaker and Schramade, 2019). First, banks are primarily concerned with credit risk, as borrowers in high-risk sectors or locations prone to natural disasters may face higher default rates. Operational risks may arise if severe weather disrupts day-to-day activities. Second, insurers absorb the immediate costs of physical damages through claims. Rising loss frequencies and severities force insurers to increase premiums or withdraw coverage, potentially creating a protection gap. Third, capital markets represented by equity and bond markets reflect investor sentiment, which is increasingly influenced by Environmental, Social and Governance (ESG) considerations. Companies failing to adapt may see their stock prices impacted as investors price in potential climate liabilities. Finally, the UK has a number of active reinsurers such as Lloyds of London, Munich Re, Swiss Re, Chaucer Group and others who are among the most exposed financial institutions as their core business is to absorb tail risks from primary insurers.

Insurance, as the other big player in the financial sector also has a complex relationship with climate shocks. On the one hand there is a significant insurance gap (under insured) (Banerjee et al., 2023), but on the other hand, an increased frequency of climate shocks could generate higher claims, raising premiums, which in turn will reduce demand for insurance as it becomes unaffordable (Tesselaar et al., 2020b). The second order effect is insurance companies withdrawing coverage as we have seen recently in the US with respect to wildfires in California (Hill, 2023).

Overall, the EEA (2024) highlights the limited evidence at the European level which, not surprisingly, also holds for the UK. This section does not consider those climate shocks that may occur outside of the UK but may cascade into UK financial markets though trade and value chains (Anisimov and Magan, 2023) as these are discussed in risk E3.

Banks face climate risks primarily through credit exposure (e.g., mortgages on flood-exposed properties) and must manage both the gradual erosion of asset quality from climate trends and the possibility of sharp shocks from extreme events. More specifically, the banking sector is susceptible to:

1. Credit Risk: Increased physical risks from climate change could lead to higher default rates among borrowers, especially those in vulnerable sectors.
2. Operational Risk: Banks may face operational disruptions due to extreme weather events affecting infrastructure and supply chains.
3. Market Risk: Shifts in asset values could impact banks' investment portfolios.
4. Reputational Risk: Failure to adequately address climate risks may damage banks' reputations and stakeholder trust.

Similarly, insurers are on the frontline of absorbing climate impacts and will likely experience rising claims and volatile investment conditions, requiring them to adapt their pricing models, withdraw from unmanageable risks, and support broader resilience efforts. Asset managers are also exposed via the value of securities and assets they manage, and their success will depend on anticipating climate-related market shifts and fulfilling their duty to protect client investments. Indeed, market anticipation is itself a form of risk and has the perverse outcome of bringing risks forward (before they happen). The anticipatory action of financial system could have a larger and earlier impact than is currently estimated and may also transfer a greater level of risk to the public sector. All three sectors (banks, insurers, and asset managers) are intertwined, weaknesses in one can transmit to others, underscoring that climate risk is a systemic issue, not just an isolated concern for individual firms.

The systemic implications mean that a wait-and-see approach has its own risk. If climate risks are not addressed until they fully materialise, the financial losses and economic dislocation could be far greater, potentially overwhelming risk buffers and necessitating difficult interventions. The `tragedy of the horizon' is that by the time the risks are evident in financial outcomes, it may be too late to avoid severe damage (Bank of England, 2021).

On the liability side, unless global emissions trajectories improve markedly, we might see a rise in litigation, including cases that directly implicate financial actors (for example, lawsuits against pension funds for investing in polluting firms which are seen as responsible for more extreme weather events). How the judiciary responds will influence the risk landscape although one may predict that a few high-profile judgments could greatly amplify liability risk. This is an area where physical risks and transition risks overlap.

The Grantham Institute (2022) article describes the drivers of risks to the financial sector as:

1. Rising physical climate risks, such as more frequent flooding and extreme weather, that will directly threaten the insurability and affordability of property and assets.
2. Insurance companies facing increasing claims costs, pushing premiums higher and, in some cases, risking the affordability of coverage for homes and businesses.
3. Without effective climate resilience strategies, more assets are expected to become “uninsurable”, particularly in high-risk flood-prone areas.

The possibility that assets may become stranded is also highlighted by the Grantham Institute (2022). Although this risk is more commonly associated with transition risks, even such assets can make up a significant proportion of the UK’s financial portfolios, especially within infrastructure and real estate. Physical climate impacts, combined with potential regulatory shifts towards low-carbon investments, increase the likelihood that high-emission and vulnerable assets (e.g., coastal properties) will lose value. Investment funds and pension schemes would need to reevaluate their portfolios accordingly. While these shifts are ongoing or yet to take place, gaps remain in incorporating climate scenario analysis into broader financial decision-making, leaving some investments exposed to future climate risks.

In a broader context, globally, the UK is highly exposed to physical climate risks because of its central role in international finance. Events like the 2011 Thailand floods demonstrated how interconnected global supply chains can have immediate financial impacts on UK insurers and investors (and is touched on in the supply chain section of Chapter 4, 4.2.3). The Grantham report suggests that such interdependencies make the UK vulnerable to international climate shocks, necessitating robust risk management strategies in global finance.

Assessment of current magnitude of risk

The current magnitude of risk was assessed based on evidence and is presented in a qualitative, narrative style. At a fundamental level there is limited new evidence since 2021 that quantifies the individual impact of physical climate change on the UK financial sector whether that is current or projecting into the future.

Table 4.24 presents a current magnitude score of Medium reflecting economic damage to the financial sector of 0.05-0.25% of GDP or hundreds of millions of economic damages. In this section the current magnitude of the risk from physical climate change is discussed.

The Bank of England (2025) suggests that the current magnitude of climate-related risk on the UK financial system is material but not (yet) system-threatening in the near term. In its 2025 climate disclosure, the Bank of England's own scenario work implies capital hits that are "material" but smaller than those in regular solvency stress tests, and UK banks would have enough capital to absorb such losses at current capital levels. That points to resilience now, even as risks grow over time. At the current time (2025/6), the official line is that climate risk is real and growing, with pockets of under-pricing that could trigger sharp adjustments. However, UK banks currently appear able to absorb modelled climate losses. Supervisors are tightening expectations, embedding climate into stress testing, and pushing firms to quantify and capitalise properly because the tail can get big fast if transition is delayed or disorderly, or if physical risks accelerate.

The Grantham institute (2022) looks at the economic risks and expresses them as a percentage of GDP and the current estimate of the physical risk from climate change is around 1.1% of GDP although banks and asset managers are largely unaffected. To date, there have been no significant liability losses to UK financial institutions.

The Bank of England (2022) note in relation to climate risks that "*…these risks are challenging to quantify, which could limit financial institutions' abilities to mitigate against these risks into the future.*" (Bank of England, 2024, page 1). The way that scenario analyses are undertaken in the Climate Biennial Exploratory Scenario (CBES) is to use different transition scenarios to generate their results. More specifically, the Bank of England (2022) presented a report on the risks to UK banks and insurers from climate change. The exercise explored three scenarios over a 30-year horizon depending on whether the UK takes: Early Action (EA), Late Action (LA), and No Additional Action (NAA). Note that we are tasked with providing cost estimates with and without planned adaptation, so these projections are only illustrative. The scenarios include the current period so are left in this section for ease of exposition. The report presented some key findings:

1. Projected Credit Losses: Banks' projected climate-related credit losses were 30% higher in the LA scenario compared to the EA scenario. In the LA scenario, loss rates were projected to more than double due to climate risks, equating to an additional approximately £110 billion in losses over the period. This provides us with some of the first estimates of damage from climate change to the financial sector.
2. Impact on Profitability: Climate risks are expected to create a drag on the profitability of UK banks, particularly if not managed effectively. The overall costs are anticipated to be lowest with early, well-managed action to reduce greenhouse gas emissions, but such actions are highly uncertain at the current time.
3. Risk Management Enhancements: The Climate Biennial Exploratory Scenario (CBES) has driven improvements in banks' climate risk management although the Bank of England notes that UK banks still need to do much more to understand and manage their exposure to climate risks.

The CBES frames physical risk primarily via the NAA scenario, where governments fail to act sufficiently on climate, so warming and physical impacts intensify. Bank of England (2022) show that under NAA, global warming reaches ~3.3 °C (relative to preindustrial) by scenario end. Precipitation and extreme weather events increase, leading to deterioration of infrastructure, ecosystem stress, flooding, etc. Physical risks include higher claims (insurance losses), asset damage, valuation losses, and reduced productivity due to climate stresses.

Although not a direct cost estimate, it is useful to compare cost estimates for the UK with those from the EEA (2024) who, in a similar exercise, review the current literature on the risks of financial shocks and the risk to financial stability from climate change in the EU. The EEA (2024) conclude, using a similar scale, that the magnitude was low to moderate. However, the same report when taking a system level approach (where they consider the links between physical risk and transition risks) finds the magnitude of the risks faced by the EU to be high (critical) from 2021-2040 and very high (catastrophic) in the medium term. In each case their confidence in their magnitude score was either low or medium. The UK findings are broadly consistent.

Assessment of future magnitude of risk

The future magnitude of risk is based on the following categories laid out in Appendix B3. The narrative of the evidence focused on the time periods and warming scenarios laid out below.

<u>2030s, central warming scenario:</u>

The overall estimate is that the magnitude will be high with medium confidence, meaning 0.25%-1% of UK GDP and/or £ billions of economic damages or foregone opportunities.

It is predicted that there will be rising physical losses as warming continues. The annual damage from climate change is on track to grow toward ~3% equivalent of GDP by mid-century under current global policy trends (Grantham institute, 2022). By the 2030s, a noticeable uptick in climate-related insurance claims and loan losses (e.g., more frequent floods, subsidence, crop failures) is expected. UK general insurers already project significantly higher claims; for instance, stress-test results show ~50% higher annualised losses by 2050 under severe physical risk scenarios (Bank of England, 2022), implying an ongoing climb in the 2030s.

Climate litigation and liability claims are expected to become more common by the 2030s, but quantifiable losses remain small in this decade. Litigation risk is tied to the physical impact of climate change on the litigator who wants compensation for their physical losses. The trend is upward with over 2,400 climate lawsuits being filed worldwide, more than doubling since 2015 (University of Oxford, 2024). This increases the legal risk for carbon-intensive companies and more importantly for this section, the insurers of these companies form part of the financial sector. Even so, for the UK financial system in the 2030s, liability risk likely remains immaterial in terms of GDP impact (although there are no robust numerical estimates yet). Regulators are monitoring high-risk sectors (like directors' liability insurance), but any large payouts or settlements (if they occur) are more likely in subsequent decades once precedents are established.

<u>2050s, central and high warming scenarios:</u>

The overall estimate is that the magnitude will be very high will medium confidence, meaning 1% of UK GDP or £ tens of billions of damages.

As previously noted above, the Bank of England (2022) reported on the risks to UK banks and insurers from climate change exploring three scenarios over a 30-year horizon: for banks, the projected climate-related credit losses were 30% higher in the late action scenario compared to the early action scenario. In the late action scenario, loss rates were projected to more than double, due to climate risks, equating to an additional approximately £110 billion in losses over the period. This provides us with some of the first projections of damage from climate change to the financial sector, but it is important to note that the actions also relate to how the UK deals with the transition so are not purely physical risks that are being projected.

Likewise, the Bank of England's Climate Biennial Exploratory Scenario (CBES) 2021 assessed the financial risks posed by climate change to major UK banks and insurers. The exercise estimated that, under certain scenarios, the financial sector could face losses of up to £330 billion, primarily due to credit losses from increased exposure to vulnerable sectors and households. These losses are projected over a 30-year horizon and assume no changes to the balance sheets of banks and insurers during this period.

By the 2050s, physical climate impacts are projected to accelerate. Under a "current policies" scenario (assuming the world continues on its present path with ~3 °C+ of warming by 2100), UK climate damages are estimated at roughly 3.3% of GDP per year by the 2050s (Grantham Institute, 2024), equivalent to on the order of £70–80 billion annually in today's terms (although this includes productivity impacts and more frequent extreme weather events). In a more pessimistic scenario with higher warming, the Bank of England projects even larger hits: ~7.8% of GDP lost by 2050 under a severe physical-risk scenario (around 3.3 °C warming by mid-century) (OBR, 2024). Insurers would face escalating claims (the Bank of England's stress test suggested UK general insurance losses could be ~50% higher by 2050 in such a scenario (Bank of England, 2022), and banks would see more loan defaults in climate-exposed regions. These figures underscore that physical risk could cost on the order of tens to hundreds of billions of pounds per year by the 2050s if climate change remains unabated.

As climate damage becomes more apparent by the 2050s, the likelihood of successful high-value climate lawsuits increases as a result of the physical damage the litigators experience. While difficult to forecast, analysts warn of multi-trillion-pound liabilities in play. For instance, a scientific assessment published in *Science* estimated that a major emitter like Chevron could face liability on the order of $8.5 trillion for its historical emissions under adverse legal judgments (University of Oxford, 2024) the payment of which is likely to fall on company insurers. By the 2050s, if courts hold companies accountable for climate harms, we could see cumulative damages in the trillions of pounds globally. The UK insurance sector (which provides coverage for directors & officers liability and other corporate liability lines) could be responsible for a portion of these claims. Thus, liability risk, currently small, could become material by the 2050s, though exact estimates in % of GDP are not available. Notably, Lloyd's of London which covers liability lawsuits, wrote about $7.5 billion in premiums in 2018 (Band of England, 2022), indicating the scale of exposure that might need to absorb such claims. Overall, liability risk by 2050 remains hard to predict and potentially significant, but highly uncertain and scenario-dependent.

<u>2080s, central and high warming scenarios:</u>

The overall estimate is that the magnitude will be very high will medium confidence meaning 1% of UK GDP or £ tens of billions of damages.

For the financial sector, the late-century outlook means much higher default rates, insurance losses, and market volatility driven by potential climate change extremes. By the 2080s, properties in high-risk floodplains might be uninsurable, and extreme weather events (storms, heatwaves) could cause damage amounts several times higher than today's worst events, challenging the solvency of insurers and the stability of banks in absence of adaptation. It is worth noting that aggressive mitigation can drastically reduce these damages; achieving global net zero by mid-century keeps end-century UK GDP loss to around 2.4% instead of 7%+ (Grantham Institute, 2022).

By the 2080s, the liability losses as a result of physical risks are potentially very high (though highly uncertain). If climate change continues unabated by the 2080s, liability risk could become highly significant. As damages accumulate, there may be a strong basis for holding companies and governments legally accountable for climate-related losses. We could envision a wave of litigation in the 2050s–2080s resulting in large-scale compensation payouts. While exact figures are unknown, the notion of trillions in climate liability is no longer implausible (University of Oxford, 2024). This could take the form of class-action lawsuits by affected communities, or governments seeking redress from polluters for adaptation costs. For UK financial institutions, this means that insurers could face substantial claim payouts (far beyond current liability insurance reserves), and banks/investors might be indirectly impacted if the companies they lend to or invest in incur crippling legal penalties. In summary, by the 2080s liability risk could rival physical risk as a source of losses, but it remains the least charted and most contingent risk category.

Level of preparedness for risk

In this section we restrict our narrative to briefly describing the evidence gathered on government and non-government actions already taken that are relevant to the financial sector risk. Recommendations for future action are beyond the scope of this report. The current preparedness levels have improved but more is needed to impact the risk levels shown in this chapter.

The UK's regulatory framework is evolving rapidly to ensure the financial system is climate resilient. The Prudential Regulation Authority (PRA) and the Bank of England have placed climate risk firmly on the supervisory agenda, essentially treating it with the same seriousness as traditional financial risks (credit, market, operational). The Financial Conduct Authority (FCA)'s efforts on disclosure and preventing greenwashing aim to harness market forces to price and manage risk properly. In the future there may be several new developments such as more refined climate stress tests (potentially regularly as part of the biennial exploratory exercises), deeper analysis of second-round and macroeconomic effects (e.g., climate's impact on migration or productivity and how that feeds into financial risk), and possibly incorporation of climate factors in capital frameworks once methodologies mature (although regulators remain cautious, the topic is on the table internationally).

Improvements in climate modelling and risk analytics (using AI to better predict risk hotspots) should provide better inputs for risk assessment and help financial institutions differentiate between companies genuinely managing their climate risks and those that are not, driving capital towards more sustainable and resilient investments. Moreover, the growth of climate finance solutions, catastrophe bonds, resilience bonds, green loans linked to sustainability targets, can distribute risk and finance adaptation, thereby reducing the concentration of risk on any single institution's balance sheet. Accurately pricing and robustly modelling climate-related risks helps the financial system reduce hazard-driven impacts in multiple ways and not doing so means that financial institutions and markets may be exposed to a range of systemic vulnerabilities that can amplify economic shocks. In addition to the physical risks, financial modelling may mitigate the risk of market mispricing (of bonds and equities) or to help avoid disorderly repricing. For example, coastal properties vulnerable to sea-level rise may be overvalued until the risk materialises at which point price corrections can be abrupt and damaging. Likewise, markets may be underestimating the impact of climate shocks on inflation, the result of which could be costly for financial institutions due to the sudden repricing of assets. Indeed, Sarah Breden states in the FT article that "Rapid repricing could occur if markets start pricing in severe physical climate risks or a disorderly transition," and that big institutions outside the banking sector "might not be resilient" to the resulting drop in sovereign bond prices (Financial Times, 10 July 2025).

In the UK, climate-related financial risk management has become a priority for regulators and the financial sector more broadly. The Bank of England, alongside the PRA and the FCA, has implemented guidelines and consultation papers detailing how financial institutions should assess, disclose, and manage climate risks (Bank of England, 2019), although disclosing and assessing does not necessarily equate to manging risks. Regulatory stress tests are increasingly demanding institutions to conduct scenario analyses that incorporate various warming pathways, ensuring they maintain adequate capital buffers and robust governance structures.

The Bank of England has implemented vulnerability assessment methods which include:

1. Scenario analysis using climate stress tests (Bank of England, 2022 Climate Biennial Exploratory Scenario).
2. Models integrating climate variables into credit risk (Moody's, S&P Global).
3. Application of Task Force on Climate-Related Financial Disclosures (TCFD) reporting by major UK financial institutions.

Regulatory and policy frameworks have been identified. The Bank of England has issued climate risk management guidelines for banks and insurers and mandatory TCFD reporting for large UK companies, including financial institutions, has been issued. The UK Green Finance Strategy (2019, 2023) provides a policy roadmap.

The UK's level of preparedness can also be gauged by referring to the HM Treasury report on "Mobilising green investment: 2023 green finance strategy" which was updated in April 2023 (HM Treasury, 2023) and was originally published under the 2016-19 May conservative government. The report aims to enhance the growth and competitiveness of the UK financial sector, positioning the UK as a global hub for green and transition finance. The strategy seeks to mobilise private capital at scale into low-carbon, climate-resilient, and nature-restoring projects, closing the investment gap needed to meet national climate and biodiversity targets. It also aims to strengthen financial stability by ensuring that climate risks are properly integrated into risk management, regulation, and disclosure across the financial system. A fourth objective is to embed nature and climate adaptation into investment and policy frameworks, recognising the interconnectedness of ecosystems and economic resilience. Finally, the strategy seeks to align international financial flows with the UK's environmental goals by promoting global standards, supporting developing markets, and reinforcing the UK's leadership in sustainable finance.

Despite its ambition and breadth, the 2023 *Green Finance Strategy* still has several important gaps that limit how effectively it prepares the UK financial sector for climate risks. Much of the strategy relies on consultations, voluntary frameworks, and future reviews rather than binding regulation, meaning implementation could be slow and uneven across institutions. Climate-related financial risks are not yet fully integrated into prudential capital frameworks, leaving uncertainty about how they will be reflected in banks' and insurers' capital requirements. The strategy also lacks a clear mechanism for monitoring systemic climate risk across the financial system, making it difficult to assess whether stability is improving as the transition progresses. Moreover, while the strategy recognises a large investment gap of around £50-60 billion per year it proposes no real solution on how to close it, relying heavily on private capital mobilisation. Finally, the UK's push to lead in global green finance risks fragmentation and inconsistency if domestic frameworks diverge from international standards such as the EU taxonomy or International Sustainability Standards Board (ISSB), potentially complicating compliance for firms and reducing the overall coherence of risk management.

Turning to the insurance sector, the "ABI Climate Change Roadmap", written in conjunction with Boston Consulting Group, outlines the UK insurance and savings sector's strategy to address climate change (ABI, 2023). Although the focus is on mitigation and adaptation, the sector plans to help customers transition by promoting eco-friendly choices in insurance claims, encouraging sustainable decisions, and engaging with the community to raise awareness about climate resilience. The thrust of the roadmap is to show that collaborative efforts with the government are required, and the sector needs adherence to environmental standards, and to push for innovative solutions to ensure the insurance sector supports the UK's climate goals while addressing customer needs.

As shown above, the UK's financial institutions and system have made progress in recognising and addressing climate-related risks, but significant gaps remain in their preparedness. The PRA has identified shortcomings in how banks and insurers assess and manage climate risks, including inadequate data on exposures and insufficient integration of climate considerations into strategic decision-making. While regulatory frameworks like the TCFD have been established, the effectiveness of these measures depends on consistent implementation and enforcement.

UK financial institutions have made measurable progress in embedding climate risk management frameworks since the PRA introduced its supervisory expectations in 2019, yet critical gaps persist in data standardisation, scenario analysis, and capital integration. The PRA's Supervisory Statement SS3/19 remains the cornerstone of climate risk governance, requiring firms to integrate climate considerations into risk frameworks, board accountability mechanisms, and strategic planning. When considered in terms of preparedness, as of January 2025, 85% of banks and 78% of insurers have established dedicated climate risk committees at the board level, a 40% increase since 2021 (PRA, 2025). However, Fagan (2025) commenting on the PRA's 2025 "Dear CEO letter" notes that only 60% of insurers link executive remuneration to climate metrics, compared to 75% of banks, signalling inconsistent incentivisation.

The 2021 CBES exercise, which modelled physical (and transition) risks under three warming pathways, catalysed improvements in scenario analysis capabilities. By 2025, 70% of large banks now run quarterly climate stress tests incorporating CBES parameters, up from 22% in 2022 (PRA, 2025a). Insurers, however, lag with only 40% embedding forward-looking climate scenarios into underwriting models, due to data limitations in attributing weather events to climate change (Costa, 2025).

The PRA identifies "hotspots" where scenario analysis remains deficient:

1. Mortgage portfolios: 30% of banks omit coastal erosion projections beyond 2040 when assessing collateral risks (PRA, 2025a).
2. Liability insurance: 65% of insurers use historical claims data rather than climate-adjusted probability distributions for pricing (FCA, 2025).

Despite progress, 80% of firms report difficulties sourcing granular climate data, particularly for Scope 3 emissions and supply chain vulnerabilities (Costa, 2025). Banks' commercial real estate valuations often rely on third-party ESG scores lacking spatial flood risk granularity, creating a £12 billion exposure gap in flood-prone regions (FCA, 2025). Insurers face similar challenges, with 55% using outdated flood maps that underestimate precipitation increases projected under RCP8.5 (Fagan, 2025).

An example of where transition risk can interact with physical risk is where the Bank of England estimates that a disorderly transition could deplete 3.2% of banking sector capital, necessitating tighter links between scenario analysis and capital planning (Bank of England, n.d.). For insurers, Solvency II reforms under "Solvency UK" require climate risk integration into Own Risk and Solvency Assessments (ORSAs). However, 45% of life insurers still exclude climate-driven mortality shocks from ORSAs, despite evidence that heatwaves could increase claims by 18% by 2035 (Costa, 2025; FCA, 2025).

UK banks and insurers stand at a pivotal juncture, balancing regulatory mandates with market realities. The PRA's 2025–6 roadmap priorities for better preparedness include:

1. Adopting the ISSB climate disclosure standards by 2026.
2. Expanding climate skills training to cover 90% of risk management staff by 2027.
3. Developing adaptation financing mechanisms, such as resilience bonds, to channel £15 billion toward flood defences and grid modernisation. This third point is the most directly linked to physical risks.

Success hinges on overcoming data fragmentation, aligning risk horizons with climate timelines, and fostering cross-sector collaboration. As climate impacts intensify, the financial sector's ability to translate supervisory expectations into operational resilience will determine its capacity to underwrite the physical risks from climate change.

Assessment on the evidence base and evidence gaps

A review of the evidence suggests that there are five main gaps that need to be looked at. First, quantitative risk estimates are limited. Existing scenario analyses tend to be relatively high level and lack granularity for specific financial products, sectors, or institutions. There is also inadequate data on the exposure of financial portfolios to climate-vulnerable sectors (e.g., mortgages in flood-prone areas).

Second, there is a lack of standardised risk assessment models. Different institutions use different methodologies, making it difficult to compare and aggregate risk exposures. There is also limited use of dynamic models that account for feedback loops between climate events and financial markets.

Third, and linked to the previous gaps, there is insufficient granularity in the data. Geospatial data on exposure (e.g., flood maps) is not always integrated with credit risk models and there is little data on indirect climate impacts (supply chain disruptions, migration).

Fourth, more information is needed on the behavioural and strategic responses of financial institutions. There is limited evidence on how banks and insurers adjust their strategies to climate risks beyond compliance (e.g., rebalancing portfolios, excluding high-risk sectors) and no robust evaluation of the effectiveness of climate risk management measures (TCFD compliance does not equal risk reduction).

Finally, cross border risk transmission has tended to be overlooked. The interconnected nature of the UK financial system means climate risks can be transmitted from international markets. There are few studies that assess how global climate impacts (e.g., Asian flood risks) could spill over into UK financial markets.

The interconnected nature of the financial sector means physical climate events that impact one sector may spillover to other sectors. The Task Force on Climate-Related Financial Disclosures (TCFD) identified climate change as a serious risk to financial market stability and the broader banking system (TCFD, 2017). The risk to the European financial system was reviewed in the European Climate Risk Assessment EEA Report 01/2020 and Alogoskoufis et al. (2021). The conclusion was that physical climate risk could be a significant source of systemic risk where there are no transition policies and with risk concentrated in certain regions. Earlier studies (Economist, 2019; South Pole Group, 2016) found the risks from physical climate change were only moderate.

The evidence for the future projections comes from a range of official and academic sources (Bank of England, OBR, Network for Greening the Financial Network, and the Grantham Institute) and reflect the potential scale of the financial impacts if climate risks are not managed. A recent report from the PRA (2025) and the Bank of England (2004)'s financial stability report argue that the impacts of climate change are expected to grow over time such that direct losses from extreme weather events (floods, storms, heatwaves) will impact property, agricultural yields, and infrastructure and have been relatively well documented in UK insurance industry reports.

The challenge with capturing the physical risks of climate change on the financial sector is nicely summarised in a recent report from the EEA (2024, page 3087) who stated in their review of the impact of physical climate change on financial markets and public finances that "…*Financial markets are very complex, including a range of markets (such as bonds, capital, money, derivatives and foreign exchange) that provide financial services and assets to participants in the real economy (such as corporations and governments).This makes it extremely difficult to assess the potential effects of climate change, as risks can be generated and cascade through the financial system, as well as through impacts on the real economy that are difficult to identify*." The report goes on to say that "*Limited reporting in Europe and abroad makes the assessment challenging, but available insights suggest the costs are likely very large*." However, the EEA (2024) also report low confidence for their near-term, medium, and long-term predictions on the grounds that although there was some literature, the pathways were complex and there is a general lack of quantification. However, confidence levels were classified as medium for their separate review of the insurance and property sector, given the literature consistently highlights property as a vulnerable sector while flood modelling studies indicate increasing insurance risk levels.

On the banking sector specifically, Ranger et al. (2022) state that "*…the impact of physical climate risks on the banking sector is highly dependent on the level of resilience of the financial sector overall (to any shock) and the vulnerability of their borrowers. For example, countries with weaker supervision and regulation and with more concentrated and less interconnected banking sectors will see greater risks, while more advanced and resilient financial sectors will be less affected*." In related research, the EEA (2024, page 313) point out that "*…the ECB has found that physical climate risks to the European banking system are underestimated, and this line of research is still in its infancy*." The Institute and Faculty of Actuaries (2022) also notes that the climate change scenarios used in financial services are underestimating risk (including physical climate risk).

At the end of the section, we include a breakdown by DAs by assuming the evidence for England/UK applies to the individual DAs despite a lack of direct evidence. Scores for each DA were a requirement of the CCRA4 remit so should be interpreted accordingly.

4.2.5.2 England

Evaluation of urgency score

The scores for the DAs are the same, but they have been reduced by a magnitude following the CCRA4 guidance document. The evidence base for the impact of physical climate change on the financial sector tends to be limited to England (given the concentration of the sector in the City of London). Other DAs have financial districts, but they tend to be far smaller. The impact on other DAs is therefore likely to be similar to England but scaled down. There is no evidence to the contrary. According to TheCityUK (2025), the GVA of the financial and related professional services sector of England is £257.5 billion (90.3%), Scotland £17.7 billion (6.2%), Wales £6.1 billion (2.1%) and Northern Ireland £4.1 billion (1.4%). If we look more closely at ONS Section K (financial & insurance activities) found at Hutton et al. (2024) we find similar results, where in 2022 in current prices, England has a GVA of £180.7 billion (85.5%), Scotland £14.0 billion (6.9%), Wales £4.6 billion (2.3%) and Northern Ireland £2.6 billion (1.3%). The financial sector is around 9% of England's total GVA.

Table 4.25: Urgency scores for E5 Risks to the financial institutions and the financial system for England. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

England				
E5	Risks to the financial institutions and the financial system.			
	Present	2030	2050	2080

		Central	High	Central	High	Low	Central	High
No adaptation	++ (M)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
With adaptation	++ (M)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
Urgency scores	MAN	MAN		CAN			MAN	
Overall urgency score	CAN							

4.2.5.3 Northern Ireland

Evaluation of urgency score

There is limited evidence on the impact of climate change on the financial sector in Northern Ireland. The impact on the Northern Ireland economy in percentage terms is likely to be similar to England (the financial sector is around 5-7% of GVA) but the overall impact is limited by the size of the sector.

Table 4.26: Urgency scores for E5 Risks to the financial institutions and the financial system for Northern Ireland. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Northern Ireland								
E5	Risks to the financial institutions and the financial system.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (M)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
With adaptation	++ (M)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
Urgency scores	MAN	MAN		CAN			MAN	
Overall urgency score	CAN							

4.2.5.4 Scotland

Evaluation of urgency score

There is limited evidence on the impact of climate change on the financial sector in Scotland. The impact on the Scotland economy in percentage terms is likely to be similar to England (the financial sector is around 7% of GVA) but the overall impact is limited by the size of the sector.

Table 4.27: Urgency scores for E5 Risks to the financial institutions and the financial system for Scotland. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Scotland								
E5	Risks to the financial institutions and the financial system.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (M)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
With adaptation	++ (M)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
Urgency scores	MAN	MAN		CAN			MAN	
Overall urgency score	CAN							

4.2.5.5 Wales

Evaluation of urgency score

There is limited evidence on the impact of climate change on the financial sector in Wales. The impact on the Wales economy in percentage terms is likely to be similar to England (the financial sector is around 6.5% of GVA) but the overall impact is limited by the size of the sector.

Table 4.28: Urgency scores for E5 Risks to the financial institutions and the financial system for Wales. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Wales

E5	Risks to the financial institutions and the financial system.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (M)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
With adaptation	++ (M)	++ (H)	++ (H)	++ (VH)	++ (VH)	++ (VH)	++ (VH)	++ (VH)
Urgency scores	MAN	MAN		CAN			MAN	
Overall urgency score	CAN							

4.2.6 Risks to Public Finances – E6

Scope: Assesses the impact of physical climate risk on the ‘fiscal triangle’ of taxation, borrowing and spending. Climate change poses significant, multifaceted risks to the UK’s public finances, affecting both government spending and revenue.

Headlines

- Critical investigation needed.
- There is little evidence that isolates solely the effects of physical risk on the public finances.
- The risk is expected to increase over time as climate change places greater pressure on all sides of the fiscal triangle of tax, borrow, and spend.
- Rising macro- and microeconomic consequences of climate change could place downward pressure on tax receipts due to restricted output, productivity, and growth.
- Climate is expected to increase demand for public spending on contingent liabilities and disaster relief.
- Key evidence gaps include the share of economic costs of climate change that will fall on the public purse, future fiscal policy, the net costs and benefits of adaptation, the pace of mitigation and adaptation and the market response to rising public debt.
- There was no comparable risk in CCRA3.

Table 4.29: Urgency scores for E6 Risk to public finances. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

ID	Risk		Present	2030	2050	2080	Urgency
E6	Risks to public finances	**UK**	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
		England	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
		Northern Ireland	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
		Scotland	++ (H)	++ (H)	+ (VH)	+ (VH)	CI
		Wales	++ (H)	++ (H)	+ (VH)	+ (VH)	CI

4.2.6.1 Evidence relevant to the entire United Kingdom

Current and future drivers of risk

Climate change presents complex and escalating risks to the UK's public finances (Agarwala et al., 2021). The health of the public finances is determined by trends over time in taxation, borrowing and spending. Each of these sides of the 'fiscal triangle' is affected both directly and indirectly by climate change (Agarwala and Zenghelis, 2020; OBR, 2021; OBR, 2024; Cevik and Jalles, 2022; Zenios, 2022; Zenios, 2024; Coalition of Finance Ministers, 2025). Potential risks include increased demands for government expenditure, decreases in tax receipts, rising public debt and rising borrowing costs. As discussed in previous sections, these risks arise from extreme weather events such as floods, storms, fires, extreme temperature, and droughts. During acute events, these can:

- reduce output and associated tax receipts;
- increase public spending on disaster relief;
- require additional borrowing to support disaster relief;
- require a re-allocation of public finances (e.g., if funds that might have been used for another purpose are diverted to disaster relief); and
- increase interest payments on index linked gilts if climate change leads to higher inflation.

Over time, the physical consequences of climate change can affect labour productivity (and associated tax receipts) (see risk E4, section 4.2.4), capital accumulation (especially if funds are diverted from productive investment to cover clean-up and recovery), and investment returns on large infrastructure investments. According to the OBR (*Fiscal Risks and Sustainability Report*, July 2025, Chapter 4: *Climate Change – Fiscal Impacts*), physical climate change affects the public finances through several interconnected channels. Lower productivity and output reduce the overall size of the UK economy, while lower tax receipts leave the government with less revenue. At the same time, higher public spending is likely to be required for disaster recovery, infrastructure repair, and addressing health impacts associated with a hotter climate. As borrowing rises to cover these pressures, interest payments compound the fiscal burden further.

Direct risks for spending obligations include costs associated with adaptation and infrastructure investment (e.g., grid upgrades, sea walls, and flood defences), and contingent liabilities such as disaster relief (Bova et al., 2019). Beyond initial disaster relief, extreme weather events can indirectly add to spending obligations. This includes direct outlays for adaptation but could spill over into other areas of public spending. For instance, Deryugina (2017) finds that US hurricanes substantially increase non-disaster government transfers (e.g., unemployment insurance and public medical payments) in affected counties for the decade following the event. The present value of this increase significantly exceeds that of direct disaster aid. Finally, increasingly urgent climate-related expenditure (both as contingent liabilities and adaptation expenditure) could crowd out other areas of public spending, for instance related to health, education, military, or policing. Thus, relevant risks include changes not only to the overall level of government spending, but to its composition as well.

In addition to impacts on spending, climate change also has significant implications for tax receipts. Revenue shortfalls are expected as a result of lost output associated with climate-driven disruptions to economic activity. These include floods, storms, droughts, and extreme weather events that interrupt commuting, shipping, tourism, agricultural production, labour productivity, and retail activity. Over the longer term, one of the greatest potential risks is the effect of climate on productivity and growth, as tax receipts scale proportionately as percentage of GDP (see risks E1, section 4.2.1, and E4, section 4.2.4).

Climate change also poses risks to the UK's sovereign debt position (Zenios, 2022; Klusak et al., 2023; Zenios, 2024). Direct effects include the potential for significant public borrowing to finance investment in net zero energy, transport, buildings, and grid infrastructure, as well as broader mitigation and adaptation investments. However, it is important to reiterate that mitigation activities such as net zero are out of scope for CCRA4, but it is worth noting that simultaneous investments in net zero activities will compound adaptation-related expansion of public borrowing. Indirect effects include rising interest rates, as climate change could make the UK a riskier borrower than it would be without climate change, leading markets to demand higher risk premia on sovereign debt (Klusak et al., 2023). One also needs to take into account the monetary response needed to address any inflationary impact of climate change. Indeed, there is a large and growing body of UK and international research demonstrating the threats of climate change to sovereign debt markets (Campiglio et al., 2018; Battiston and Monasterolo, 2019; Monasterolo, 2020; Agarwala et al., 2021; Beirne et al., 2021; Zenios, 2022; Cevik and Jalles, 2022; De Angelis et al., 2024; Calcaterra et al., 2025; Gourdel et al., 2025). In contrast, green bonds may reduce borrowing costs if investors are willing to accept lower returns in exchange for holding environmentally sustainable assets, a phenomenon referred to as the "greenium". Moreover, the UK's green bond issuances have already contributed to financing flood defences. However, whilst the UK's green debt issuances to date have been over-subscribed (indicating strong market demand for green bonds) research on the existence and magnitude of sustained "greenium" savings is in its infancy.

Across all three of tax, borrow, and spend, the net effect of climate change on the public finances is highly susceptible to frequent changes in fiscal policy, as well as legislation governing planning, agriculture, and general spending across all government departments.

Whilst E1 (4.2.1) presents the evidence on the overall impact of climate change on the economy, there is comparatively weaker evidence identifying when, and on whose shoulders, those costs will fall (de Mooij and Gaspar, 2023). Government policies, regulations, and incentive schemes will largely determine where and when the costs of climate change will fall, whether it is on businesses, households, or taxpayers (public finances), and whether the associated costs will be borne today from current flows or deferred to the future through debt. For instance, the direct costs associated with flood damages may fall on affected businesses, households, and insurers rather than the public purse. Similarly, the fiscal consequences of passive ventilation installations depend on policy decisions over whether these are funded by subsidies (from the public purse) or are required by planning legislation (shifting the costs to builders and households). The extent to which the UK government operates as a 'backstop', for instance as lender or insurer of last resort would also have significant fiscal consequences. There is potential for this to become a significant risk to the public finances, however a lack of available evidence makes this a potential priority area for future research. If financial markets and insurers withdraw from certain markets, this could potentially push more risk to the public finances (see risk E5, 4.2.5). This could be a particular issue with market anticipation, because this would bring forward these impacts in advance of them physically happening, and in turn, would put more pressure on the public finances (or else households and businesses) earlier. Ultimately, there is a three-way trade-off between meeting climate policy commitments, debt sustainability, and political constraints (de Mooij and Gaspar, 2023).

Ultimately, both the magnitude and share of the impact of physical climate change on public finances that fall on the public finances versus on other economic agents (businesses, households, or the finance sector) will be determined by policy (Mirrlees et al., 2011; Jones et al., 2013; de Mooij and Gaspar, 2023).

Assessment of current magnitude of risk

This section focuses on the impact of physical climate change on public finances and discusses whether there is evidence of the transmission channels playing out and, if so, how, and to what extent. Is there evidence for more expenditure or government consumption due to losses, has tax income fallen, and what has happened to borrowing costs. It most cases there is little direct evidence but what is available is discussed below. Since this risk, along with E1 and E5, is subject to the macroeconomic criteria for identifying risk magnitudes, we assess the current risk magnitude to be High, equivalent to damages above £1 billion.

Climate change already imposes material pressures on the UK's public finances. Physical impacts, most visibly more frequent and intense flooding, heatwaves and coastal erosion, have the potential to generate large, recurrent liabilities for government while eroding the macro-tax base. The current effect of climate on fiscal sustainability is dominated by two channels: downward pressure on tax receipts and upwards pressure on expenditure.

It is likely that climate change is already reducing UK output relative to a counterfactual without climate change (Kahn et al., 2021). Because tax receipts are a proportion of GDP (currently 37%), there is a domino effect on tax receipts. A commonly applied assumption is that revenues as a share of GDP are fixed, meaning every £1 of foregone GDP is associated with £0.37 in foregone tax revenue (OBR, 2024).

There is no comprehensive data describing annual climate-related expenditure by the UK government. Partially this is because data and reporting structures do not require such disclosure, and partially it is because of the difficulty of precisely identifying the share of expenditure that is climate specific. For instance, expenditure on road maintenance is driven by a combination of normal wear and tear, climate-related repairs and adaptation, changes in traffic volumes, and the increased weight of vehicles. Spending on flood defences is clearer cut but attributing these expenditures to climate alone would not be accurate.

Econometric evidence for the US suggests that each additional degree of warming raises government spending by roughly 0.32% (Barrage, 2020; OBR, 2021). In the US this means spending on emergency response and civil protection, health and social care operations, environment and land management services, local authority services and policing/defence support. The UK has a different hazard mix but also different consumption sensitivities in NHS operations, local authority emergency spending and the Environment Agency incident response. Applied to UK budget aggregates, this rule of thumb indicates an extra £4-5 billion of annual spending once global temperatures pass 1 °C above pre-industrial levels. The OBR's fiscal-risk framework similarly assumes that adaptation spending will add 0.3% of GDP (≈£7 billion) to annual expenditures per degree of warming, in addition to higher disaster-relief and health costs.

At present there is little evidence that physical climate risk commands a discernible premium on current UK sovereign borrowing costs. Recall that investors assess sovereign risk based on fiscal responsibility (the government's ability to service debt relative to future growth and income). Raising public spending and eroding the tax base threatens this balance. Moody's and S&P for example now include climate vulnerability and policy response in their sovereign risk models and could trigger a risk premium on gilt yields.

On the other hand, since the inaugural Green Gilt in September 2021 the UK Green Financing Programme has raised £43.4 billion (HM Treasury, 2024). Green gilts can help mitigate the effects outlined in the previous paragraph through credibility, investor diversification and pricing advantages. While evidence remains thin, several studies suggest that high quality sovereign green bonds can price 1–3 basis points below conventional benchmarks, reflecting investor demand for green bonds. Even a modest "greenium" applied to 10% of annual gilt issuance could save the Exchequer tens of millions of pounds per year. Realising this benefit, however, depends on maintaining a credible, transparent framework that links proceeds to verifiable green expenditure which is an area where further analytical work is needed.

The OBR (2021) assumes that adaptation spending amounting to 0.3% of GDP per °C will eventually pay for itself through avoided damages. The OBR's assumption that adaptation spending of 0.3% of GDP per °C of warming "pays for itself" is a stylised estimate, drawn from global studies suggesting that proactive adaptation in advanced economies yields roughly equivalent avoided damages. It reflects a mid-range cost–benefit balance informed by the OECD, IPCC, and CCC evidence base, not a UK-specific model. The OBR used it to illustrate that early and efficient adaptation is fiscally prudent but also warned that delays or underinvestment could make climate change a net fiscal burden rather than a neutral cost. International evidence is broadly consistent: Watkiss (2022) puts near-term adaptation needs for economies comparable to the UK at £4–25 billion per year, with a central UK estimate of £10 billion. The UK Climate Change Risk Assessment (CCRA3) reports economic benefit-to-cost ratios of 2:1 to 10:1 for well-chosen measures, though it does not apportion those net benefits between the public and private sectors (Watkiss et al., 2021).

Yet, the timing mismatch is critical. Bachner et al. (2019) show that even a doubling of adaptation spending as a share of GDP delivers only a 0.09% GDP gain by 2050 in Austria. In other words, adaptation investments may raise near-term spending before fiscal dividends materialise. The OBR therefore opted to leave adaptation outside its 2024 fiscal-risk quantification pending better evidence.

Since this risk, along with E1 and E5, is subject to the macroeconomic criteria for identifying risk magnitudes, we assess the current risk magnitude to be High, equivalent to damages above £1 billion. Recall that the OBR (2021) estimate of 0.3% of GDP per °C of warming is equivalent to over £8 billion based on a UK nominal GDP value in 2024/25 of around £2.7 trillion. Note also that the Third National Adaptation Programme (NAP3) published in 2023 sets out how the UK government plans to manage and invest in climate change adaptation from 2023-8 with aggregate commitments to around £10 billion. However, these are future planned expenditures on specifically on adaptation measures (flood defences, the Nature for Climate Fund, and International Climate Finance as well as various health, resilience and infrastructure programmes).

Assessment of future magnitude of risk

<u>2030s, central warming scenario:</u>

Climate change will continue to add uncertainty and volatility to the UK's fiscal position through the 2030s. Exactly where the burden falls will be determined by policy choices on planning, infrastructure, agriculture and land use: policy design can shift costs between the Exchequer and the private sector (businesses, households, landlords, insurers and the food system). Without effective adaptation, increasingly frequent and severe weather-related shocks could inflict damage running well into the tens of billions of pounds each year (Watkiss, 2022), eroding the tax base just as public spending on relief and reconstruction rises.

Cross-country evidence suggests every additional degree of warming lifts government consumption by roughly 0.32%, and UK adaptation costs are projected in the £4–25 billion range (around £10 billion a year in a central case) (Barrage, 2020; Watkiss, 2022).

While it might be argued that costs will be greater than £10 billion, our assessment based on the currently available evidence is that the risk magnitude for the 2030s remains High.

<u>2050s, central and high warming scenarios:</u>

Although direct evidence is lacking, by the 2050s the impacts of physical climate risks on the public finances could exceed £10 billion, equivalent to a Very High magnitude. However, due to a lack of direct evidence that we are likely to exceed £10 billion, our confidence falls to Low.

<u>2080s, central and high warming scenarios:</u>

As with the case for the 2050s, by the 2080s there is considerable uncertainty over government policy regarding taxation, spending, and borrowing, as well as very large uncertainty over the cost of borrowing in future.

Cumulative effects on productivity, growth, and the performance of key infrastructure are also highly uncertain. The extent to which costs fall on public finances versus businesses and households is also highly uncertain over these time scales.

The recent OBR (2005) report on Fiscal Risks and Sustainability does provide some estimates of the losses as a result of “below 3 °C” in the early 2070s and predict an 8% loss of GDP relative to a no-damage baseline which is an upward revision from 5%. The report predicts additional primary government borrowing of 2% (before interest payments) and increased public sector net debt. In the OBR’s modelling, they suggest that by the early 2070s, if the world warms to just under 3 °C above pre-industrial levels (their “below 3 °C” scenario), then the UK’s public sector net debt would be around 56 percentage points higher than in their baseline projection, solely because of the physical damage caused by climate change.

Based on expert judgement and the evidence above we believe we can justify a Very High magnitude with Low confidence.

Level of preparedness for risk

CCRA4 explicitly considers risks from climate change to the public finances (it was not covered in CCRA3, for example). This indicates a growing awareness and interest in the topic. The UK Treasury has a dedicated team working on climate and regularly engages with leading academics. The Office for Budget Responsibility and Bank of England have recently started producing projections of climate risks (Holden et al., 2024). Regular fiscal events (spending reviews and budgets) offer frequent opportunities to fine-tune fiscal policy to respond to climate and other shocks.

In the sections outlining the other economic risks in this chapter we outline the extent to which the UK government is taking action to reduce the physical impacts to the UK from climate change and how successful those actions are likely to be (see E2 in particular). These include the third National Adaptation Plan (NAP3) in England, the Climate Change Adaptation Programme (NICCAP2 and soon NICCAP3) in Northern Ireland, as well as similar initiatives from the Scottish Environmental Protection Agency and Natural Resources Wales. While such initiatives are necessary in order to reduce the physical impacts of climate change, none specifically address the risks directly to the public finances, while such activities themselves add further pressure to those finances due to the expenditure required to implement them. Our sense is that the UK is relatively unprepared to address the risks of climate change to the public finances.

Assessment of the evidence base and evidence gaps

Confidence in the overall finding that the physical impacts of climate change is already imposing costs on the public finances is Medium. It rests on consistent signals from observed fiscal aggregates, sector-specific damage assessments and macro-model simulations. However, confidence is very low in the precise apportionment of costs between the state and other economic actors and in the prospective scale and timing of adaptation liabilities. Key gaps include reliable cross-government tracking of climate-related spending, systematic evaluation of adaptation programmes, and empirical estimates of climate premia in sovereign bond markets.

Given the volatility and frequent revision of fiscal policy, and the potential for shocks (e.g., Covid-19), it is not feasible to make robust predictions about the health of the public finances as far out as the 2050s or 2080s, hence the low confidence in risk magnitudes for those periods.

We have no ability to differentiate risks for individual UK nations in any meaningful way and hence assume such risks will be evenly shared.

4.2.6.2 England

Table 4.30: Urgency scores for E6 Risk to public finances for England. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

England								
E6 Risks to public finances.								
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (H)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (H)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
Urgency scores	MAN	MAN		CI			FI	
Overall urgency score	CI							

4.2.6.3 Northern Ireland

Table 4.31: Urgency scores for E6 Risk to public finances for Northern Ireland. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Northern Ireland								
E6 Risks to public finances.								
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (H)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (H)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)

Urgency scores	MAN	MAN		CI			FI	
Overall urgency score	CI							

4.2.6.4 Scotland

Table 4.32: Urgency scores for E6 Risk to public finances for Scotland. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Scotland								
E6 Risks to public finances.								
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (H)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (H)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
Urgency scores	MAN	MAN		CI			FI	
Overall urgency score	CI							

4.2.6.5 Wales

Table 4.33: Urgency scores for E6 Risk to public finances for Wales. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Wales				
E6 Risks to public finances.				
	Present	2030	2050	2080

		Central	High	Central	High	Low	Central	High
No adaptation	++ (H)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (H)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
Urgency scores	MAN	MAN		CI			FI	
Overall urgency score	CI							

4.2.7 Risks to household finances – E7

Scope: Focuses on how climate impacts affect personal financial stability, insurance affordability, and cost of living. Subcomponents include property damage and loss of insurability, energy price fluctuations and transition costs, and uneven financial burden across income groups.

Headlines

- Further investigation needed.
- This risk is expected to increase and be at High magnitude levels due to the direct costs of higher food prices as well as financial losses from property-related impacts (e.g., flooding, heating, cooling).
- An expected decline in household energy demand as a result of warmer winter temperatures will result in reduced household costs but are not likely to outweigh the higher costs.
- There is expected to be disproportionate impact on lower-income and vulnerable households, compounding existing financial pressures.
- Several important evidence gaps are noted including: limited data on household-level financial exposure to climate risk; lack of analysis on interactions between climate shocks and cost-of-living trends; weak evidence on the behavioural response of households to physical financial shocks.
- In CCRA3, risks to household finances were not treated as a discrete risk.

Table 4.34: Urgency scores for E7 Risks to household finances. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

ID	Risk		Present	2030	2050	2080	Urgency
E7	Risks to household finances	**UK**	++ (M)	+ (M)	+ (H)	+ (H)	CI
		England	++ (M)	+ (M)	+ (H)	+ (H)	CI
		Northern Ireland	++ (M)	+ (M)	+ (H)	+ (H)	CI
		Scotland	++ (M)	+ (M)	+ (H)	+ (H)	CI
		Wales	++ (M)	+ (M)	+ (H)	+ (H)	CI

4.2.7.1 Evidence relevant to the entire United Kingdom

Current and future drivers of risk

Climate change can have a key effect at household level, including on household finances. Household finances are here considered to consist of the money (income, wealth) available to spend or save. Potential impacts of climate change risks on household finances include those on direct expenditures such as household energy use, and food and water consumption costs. For example, energy costs might be lower as a result of warmer temperatures under climate change during winter, but they might be higher as the use of air conditioning in households rises during warmer summers. Similarly, where food stuffs that are to be processed and food products are adversely impacted by climate change risks, household expenditures may be impacted. For example, an extended drought in the North American Plains like that in 2003 will negatively impact on wheat productivity and output, which might have an upward effect on global wheat prices. Consequently, food products that rely on wheat as an input are likely to have higher prices, perhaps increasing the weekly household food bill.

More indirect costs might arise from greater flood damages on household property that then needs to be repaired, as well as higher resulting insurance premia. Other impacts include those on employment and income, such as the loss of income from climate risks to health that affect individuals' ability to work, Similarly, household income may be impacted if international companies that employ UK citizens are adversely affected by extreme events such as floods in South Asia or hurricanes in North America damaging their profitability. In this case dividend payments to individuals may be lower, resulting in lower household incomes. Additionally, there may be policy costs, borne by higher income or corporation taxes related to, e.g., the costs of management of climate change-induced conflict overseas, that subsequently reduce households' disposable incomes.

The impacts on household finances can therefore be seen to be the consequence of a wide range of climate change risks described in detail throughout this national risk assessment. The current and future drivers of impacts on household expenditures are determined by the pattern of consumer trends relating to the baskets of goods and services demanded. In turn, these trends will be determined by trends in economic growth and household income, along with trends in population size and age structure, and other socio-economic factors. Drivers of climate change risks to household income include – inter alia – shifts in employment from or towards employment in sectors requiring outdoor work, where productivity may be impacted by higher summer temperatures.

A further dimension to consider in the context of risks to household finances is the distribution of impacts between households. In particular, lower income and vulnerable groups have been found to be exposed disproportionately, as a percentage of income, by climate change risks (e.g., Sayers et al., 2018). Sheng et al. (2023) highlight evidence that climate change can widen wealth inequality between income groups within the UK through increased risks to household investments (since wealth is held principally in the form of property and other at-risk physical assets at low-income levels, rather than financial assets held more by higher-income groups), food security and education attainment. Furthermore, Islam and Winkel (2017) identify three pathways through which climate change can affect wealth inequality within countries due to low-income and protected characteristics groups often having an increased exposure to climate change based on their location; a lack of resources or social protection to respond to climate change risks; and lower ability to cope and recover from climate change.

Assessment of current magnitude of risk

As identified in the previous section, there are a range of climate risks that have consequences for household finances. The most prominent of these are explored further in the following paragraphs.

As evidenced in E3 (4.2.3), current international food shocks – in combination with domestic climate-induced food shocks - can cascade through to increases in the consumer price of food. For example, it is estimated that average food bills for British households increased by £605 across the years 2022/3 as a result of a combination of food and energy shocks (Energy & Climate Intelligence Unit, 2023). Risk BE9 demonstrates that changes in energy demand are to be expected at the household level. This is a consequence of warmer mean temperatures in winter resulting in less demand for heating whilst hotter summer temperatures result in an increase in cooling demand – everything else being equal. These changes might be expected to translate into a decrease and increase in the cost of energy demand respectively, leaving the net balance of these changes uncertain, and hence so too the overall effect on annual household energy expenditures.

As described in climate risks B2 and E2, floods are one of the most important weather-related loss events in the UK and have large economic impacts, as reported in recent severe flooding events. For example, in July 2021, thunderstorms and heavy rainfall caused two serious flash floods in London that resulted in more than 1,000 homes and properties being flooded by stormwater and sewage, and more than 30 underground stations closed or partly closed. Direct damages to households result from the damage and loss of assets and contents, and the consequent diversion of disposable household income towards repair or replacement of these goods. Indirect impacts on household finances result from businesses reducing wages as a response to e.g., a loss of output.

As climate risk I9 identifies in detail, water resources in the UK are likely to be scarcer under climate change scenarios. Water resource scarcity resulting from climate change has implications for household finances since households may have to pay for costly improved provision or alternative sources of water that have higher costs than costs associated with water piped to tap. During the 2022 heatwave in the UK, for example, high demand led some water companies to supply bottled water – the cost of which might be expected ultimately to be borne at least in part by households in the form of higher charges.

Assessment of future magnitude of risk

As identified above, there is a necessary translation from the portrayal of climate change-induced changes in a range of climate change risks – including E3, BE9, BE2 and I9, highlighted above – described in physical and other metrics, and their potential consequent changes in household incomes and expenditures. Section 4.2.6.1 identifies that in practice this translation occurs currently. This section summarises the extent to which these current patterns are likely to occur in future time periods and the quantitative evidence that might allow us to assess the magnitude of these risks. The evidence base on which we rely is thin and so our confidence in the robustness of these findings is limited.

Climate change impacts on food prices are found to constitute relatively minor effects on household finances in the short-term, but with larger effects towards the middle of the century. Under an RCP8.5/SSP2 scenario, equivalent to our 2050s Central scenario, and everything else being kept constant, the annual food bill for an average household is projected to rise by 9% by the 2050s – with an uncertainty range from 0% to 28% (Watkiss et al., 2016). This equates to a cost to the average household of £275 per year (£0-860). The impact on low-income households would be higher due to a greater proportion of their average household expenditure being on food (assuming that food remains a constant proportion of total household expenditure). This could add 2% (with a range of 0-6%) to overall household costs compared to 1% for the average household (0-3%).

The costs of electricity, gas and other fuels are a major component of current household expenditure (5% of average household expenditure). A large proportion of this is for winter heating. Climate change will lead to warmer winters, which will have benefits in reducing the costs of heating. Benefits of climate change from the reduction in winter heating costs (on average) are estimated by UH HSA (2023a) to be £135/ household/year by the 2050s (with a range from +£58 to +£226 for low and high scenarios and model uncertainty). This compares to current average expenditure of around £500/household/year. Note that these estimates do not account for any potential rebound effect resulting from the fact that such a financial saving might be spent on heating to a higher ambient temperature than would be affordable. Whilst winter heating demand decreases, there will be higher summer temperatures that can be met by cooling demand from air conditioning. These costs may be broadly an order of magnitude lower than the changes in heating demand, i.e., in the range of £3-32/household/year in the 2050s (UH HSA 2023a). Lower income households allocate a higher percentage of their total expenditure to energy so the reduction in winter heating will have disproportionately large benefits for the poorest households. For cooling, the picture is more complex, because the ownership of air conditioning is strongly income dependent: the take up of air conditioning is likely to be extremely low amongst low-income groups and so the cost is likely to be felt in discomfort rather than in higher household expenditures for these groups.

Section 4.2.6.1 identifies that flood risks have impacts on household finances primarily through the necessity of spending money on repair of damaged housing and contents. Such payments are likely to be made either directly by households or indirectly via insurance pay-outs facilitated by household premium payments. Irrespective of the mechanism, household costs are projected to increase over future time periods as flood risks increase under climate change scenarios. For those households located in flood-prone areas, and assuming current levels of adaptation, expenditures are projected by Sayers et al. (2020) to increase from approximately £140/household/year currently to £200-220/household/year in 2050s under 2 °C and 4 °C scenarios, respectively, and £230-270/household/year in 2080s under 2 °C and 4 °C scenarios, respectively. Averaged across the whole UK population, these cost increases equate to approximately £7 in the 2050s and £9 in the 2080s.

Watkiss et al. (2016) indicate that water charges are currently about 2% of average household expenditure. Climate change is projected to have potentially important impacts on the supply and availability of water, whose impacts on household costs are likely to be passed on through providers' water bills. Analysis of water deficits resulting from climate change estimated costs of £11/household/year by the 2050s (for a central projection, with a range from £4-16 for 2 °C and 4 °C warming scenarios) (Watkiss et al., 2016).

Level of preparedness for risk

As highlighted above, the risks to household finances are primarily indirect and result from a number of different physical climate change risks. As a consequence, preparedness is dictated by the extent that these physical risks are managed by adaptation more broadly. We therefore first synthesise the evidence on risk preparedness for these individual risks.

With regard to food supply chain risks, the evidence reported in E3 suggests that the set of policies in place for managing supply chain risks for businesses remain partial despite an improvement since 2023 (CCC, 2025). The improvements are predominantly the result of a broad set of strategies aimed at strengthening the resilience of UK supply chains which places strong and resilient supply chains centrally in economic and security policy (HM Government, 2021). As a result of this strategic development, food businesses are responding by diversifying their supply chains and companies are more likely to switch from suppliers that have been shown to be vulnerable to repeated climate shocks, to suppliers who have demonstrably lower risks (Pankratz and Schiller, 2024). Further, some UK businesses are migrating to a business model whereby they hold larger stocks as a buffer against supply chain disruption (Yu et al., 2024). From a household perspective, preparedness is likely to become manifest in a changing basket of food products primarily incentivised as relative prices change.

Climate risk BE9 highlights the fact that requirements to limit overheating have recently been incorporated into building regulations across all UK countries apart from Northern Ireland. These requirements encourage overheating to be minimised in the design of new residential buildings, and for air conditioning to be used only if overheating cannot be eliminated passively. However, currently there is a lack of strategy and action to reduce overheating in existing buildings, through retrofit, and surrounding whether installation of air conditioning by householders can be effectively limited. The projected fall in winter heating is likely to respond more reactively to changes in ambient temperatures.

The discussion of flood risks in BE2 makes clear that there is UK-wide FCERM investment currently being implemented in the shape of defence infrastructure and warning systems (£5.44 billion over 2021-27). However, preparedness gaps remain since flood warning coverage and emergency response protocols are inconsistently implemented at local authority level. Assuming such preparedness increases it is thought likely that the associated costs will be met by introducing higher council tax bills – everything else being equal. It is also not yet known what will replace the Flood Re arrangement that the government presently has with the insurance industry after its current end-date in 2039; without continued governmental support, household insurance premia are likely to increase. At the micro-scale, household level, flood protection implementation is subject to enforcement challenges and resource shortages (Town and Country Planning Association, 2024; Borio & Kassian, 2022).

The assessment of preparedness of water resource provision given in I9 suggests that whilst all water companies recognise some level of climate risk and have begun to develop plans in the short-term, there remains a preparedness gap for the longer-term. The lack of detailed plans and investment strategies in, e.g., expanded water storage, beyond the periodic price review 5-year horizon highlights the fact that water companies are not prepared for future risks. The impression given of inadequate preparedness is reinforced since the resilience targets set by the water regulator are generally missed (Boca et al., 2022). However, assuming water company preparedness levels increase it is judged likely that the costs of such preparedness will be passed on to households to a lesser or greater extent in the form of higher water bills. Also, little attention has been given to demand management and behavioural change measures in the resilience plans of water companies.

Assessment on the evidence base and evidence gaps

As outlined in the discussion above, the evidence base for assessing households finance risks is rather limited on a broad range of identified relevant risks. This accounts for the low confidence scores given with the urgency scores in the summary Table 4.34. The following tables summarise future magnitude and confidence scores for household finances for England, Northern Ireland, Scotland and Wales. The magnitude scores are derived on the basis of the Economic descriptor. Thus, we aggregated the £/household/year findings presented above across the national household totals and then converted these totals to a percentage of the 2022 GDP totals. The central result at the UK for the 2050s was a total cost equivalent to 0.2% of GDP per annum. The results are driven by the costs of higher food that outweigh the benefits of reduced energy heating demand by a factor of two, whilst the flood and water costs are an order of magnitude lower. There is considerable uncertainty in the aggregate estimates primarily as a consequence of the fact that whilst the central cost of higher food prices is £275/household/year in the 2050s, the low cost is £0 whilst the high cost is £860/household/year. It should be noted that the risks to household finance assessed here represent the consequence of a number of climate change risks evaluated in the risk assessment, including E3, BE2, BE9 and I9. It is therefore likely that there would be a degree of double-counting if these risks were aggregated. In our assessment, and in the absence of quantitative data, we judge that because practical adaptation actions are known to exist, they are somewhat effective and so partially lower the magnitude scores.

4.2.7.2 England

Evaluation of urgency score

As noted above, at present, we do not have sufficient confidence to discriminate magnitude scores between the individual nations in the UK. Therefore, the scores presented in the table for England are the same as the UK in aggregate. Qualitatively, we judge that it is likely that the water resource constraints will be higher in England relative to the other DAs which are all further west and so likely to receive higher rainfall.

Table 4.35: Urgency scores for E7 Risk to public finances for England. Key to the magnitude scores: very light purple (L), light purple (M), purple (H), dark purple (VH). Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

England								
E7	Risks to household finances.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (M)	+ (H)	+ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (M)	+ (M)	+ (M)	+ (H)	+ (H)	+ (H)	+ (H)	+ (H)
Urgency scores	MAN	FI		CI			FI	
Overall urgency score	CI							

4.2.7.3 Northern Ireland

Evaluation of urgency score

As noted above, at present, we do not have sufficient confidence to discriminate magnitude scores between the individual nations in the UK. Therefore, the scores presented in the table for Northern Ireland are the same as the UK in aggregate. However, we would expect that with a relatively cooler climate, the energy demand benefit could be higher.

Table 4.36: Urgency scores for E7 Risk to public finances for Northern Ireland. Key to the magnitude scores: very light purple (L), light purple (M), purple (H), dark purple (VH). Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Northern Ireland	
E7	Risks to household finances.

	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (M)	+ (H)	+ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (M)	+ (M)	+ (M)	+ (H)	+ (H)	+ (H)	+ (H)	+ (H)
Urgency scores	MAN	FI		CI			FI	
Overall urgency score	CI							

4.2.7.4 Scotland

Evaluation of urgency score

As noted above, at present, we do not have sufficient confidence to discriminate magnitude scores between the individual nations in the UK. Therefore, the scores presented in the table for Scotland are the same as the UK in aggregate. However, we would expect that with a relatively cooler climate, the energy demand benefit could be higher.

Table 4.37: Urgency scores for E7 Risk to public finances for Scotland. Key to the magnitude scores: very light purple (L), light purple (M), purple (H), dark purple (VH). Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Scotland								
E7	Risks to household finances.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (M)	+ (H)	+ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (M)	+ (M)	+ (M)	+ (H)	+ (H)	+ (H)	+ (H)	+ (H)
Urgency scores	MAN	FI		CI			FI	
Overall urgency score	CI							

4.2.7.5 Wales

Evaluation of urgency score

As noted above, at present, we do not have sufficient confidence to discriminate magnitude scores between the individual nations in the UK. Therefore, the scores presented in the table for Wales are the same as the UK in aggregate.

Table 4.38: Urgency scores for E7 Risk to public finances for Wales. Key to the magnitude scores: very light purple (L), light purple (M), purple (H), dark purple (VH). Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Wales								
E7	Risks to household finances.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (M)	+ (H)	+ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (M)	+ (M)	+ (M)	+ (H)	+ (H)	+ (H)	+ (H)	+ (H)
Urgency scores	MAN	FI		CI			FI	
Overall urgency score	CI							

4.2.8 Opportunities to UK businesses [and financial institutions] from delivering adaptation goods and services – E8

Scope: Identifies potential economic gains from supplying products and services that support climate adaptation. Subcomponents include export potential in resilience infrastructure and finance, domestic market opportunities in construction, insurance, and technology and enabling conditions for scaling adaptation markets.

Headlines

- Critical investigation needed.
- While this is a positive risk (opportunity)**,** the potential benefits are expected to increase significantly in the future due to: growing global demand for climate adaptation goods and services (e.g., flood resilience technology, sustainable construction, climate insurance); the UK's comparative advantages in sectors such as finance, insurance, engineering, and environmental consulting; increasing alignment of public procurement and private investment with climate-resilient objectives.
- Evidence limitations affecting the UK’s ability to capitalise on this opportunity include: limited data on the size and growth potential of adaptation-related markets, domestically and globally; inadequate mapping of UK firms' current and future capacity to supply adaptation goods and services; lack of coordinated UK industrial or trade strategy focused on exporting adaptation expertise; absence of metrics to track the contribution of adaptation sectors to GDP, employment, and innovation.
- In CCRA3, adaptation opportunities were mentioned but they did not focus specifically on adaptation goods and services nor were they structured as a standalone risk/opportunity category.

Table 4.39: Urgency scores for E8 Opportunities to UK businesses from delivering adaptation goods and services. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

ID	Risk		Present	2030	2050	2080	Urgency
E8	Opportunities to UK businesses from delivering adaptation goods and services	**UK**	++ (M)	++ (H)	+ (VH)	+ (VH)	CI
		England	++ (M)	++ (H)	+ (VH)	+ (VH)	CI
		Northern Ireland	++ (M)	++ (H)	+ (VH)	+ (VH)	CI
		Scotland	++ (M)	++ (H)	+ (VH)	+ (VH)	CI
		Wales	++ (M)	++ (H)	+ (VH)	+ (VH)	CI

4.2.8.1 Evidence relevant to the entire United Kingdom

Current and future drivers of opportunity

There are known opportunities for businesses and financial institutions from delivering adaptation goods and services domestically and overseas. Adaptation goods and services include products, technologies, infrastructure, data, expertise, and financial solutions that will be necessary to support people, places, and systems to anticipate, absorb, and adjust to the impacts of climate change. Delivering adaptation goods and services has potential benefits for UK businesses and financial institutions in terms of revenue growth, risk reduction, reputational advantage and, significantly, export opportunity. However, the fact that many of these opportunities arise from escalating climate risks and impacts experienced elsewhere will temper the overall magnitude of their contribution to the UK economy, though these dynamics remain poorly understood.

There is strong, mostly qualitative, evidence and consensus that opportunities for UK businesses and financial institutions from delivering adaptation goods and services exist and are growing across multiple sectors, including finance, advisory services, energy, engineering, agriculture and health.

Adaptation goods and services can be provided by a wide range of actors, from SMEs and specialist consultancies to major engineering firms, insurers, and banks, highlighting the potential for UK business and financial institutions from across the UK economy to contribute to climate resilience; but this may require investments in enabling conditions to be realised (Gannon et al., 2021).

Opportunities for delivering adaptation goods and services are anticipated to increase significantly in the future, driven by rising global demand under increasing climate stress. Heightened exposure to climate impacts is anticipated to create rising needs, vulnerabilities and an increased willingness to pay for adaptation.

For UK businesses and financial institutions, this rising demand presents opportunities to deliver adaptation goods and services both domestically and internationally. These opportunities are likely to be substantial given the very high and escalating climate risk landscape, which will drive increasing demand across sectors and geographies. However, these opportunities may diminish beyond certain warming levels, as limits to adaptation are reached. They are also likely to be unevenly distributed across different sectors, geographies, time scales, value chains and actors. It should also be noted that adaptation goods and services will have to be paid for by households and businesses and so will represent a domestic cost that has to be taken into account alongside the economic opportunities and climate benefits that may also arise.

Positive export opportunities for the UK economy to sell adaptation goods and services overseas, will arise in the context of climate-related losses in other parts of the world, including among vulnerable populations, with important implications for climate justice and equity. Market opportunities under stress are also inherently limited. In many of the most climate-vulnerable settings domestically and overseas, the ability to pay for goods and services will be constrained, even as need increases. Thus, accompanying investment in adaptation action is likely to be essential, not just to reduce harm, but also to create the enabling conditions for market opportunities to be realised. Poorly tailored goods and services that prove ineffective or even maladaptive have the potential to generate liability risks or reputational harm. Moreover, global interdependencies (e.g., in supply chains, finance) mean that escalating impacts elsewhere, if left unaddressed, may generate systemic risks and undermine long-term opportunity and resilience for UK businesses and financial institutions themselves.

In this section of CCRA4, we focus on identifying opportunities for UK businesses for delivering adaptation goods and services, and we do not identify evidence on opportunities for UK businesses from climate-driven environmental and economic shifts (e.g., new fisheries benefiting from shifting species distribution). We also do not identify opportunities to deliver Net Zero pathways through opportunities to deliver adaptation goods and services, except to note potential complementarities (Howarth and Robinson, 2024; Howarth et al., 2025), but there are challenges joining these up (Howarth, 2024). In reporting evidence, this section does not make a distinction between opportunities for delivering climate-specific adaptation goods and services (which directly address climate change impacts by reducing risks or enhancing resilience) and opportunities for delivering general economic development goods and services that have climate resilience implications, since these distinctions are not currently consistently conceptualised and applied in the literature.

This section focuses primarily on identifying opportunities to UK businesses from delivering adaptation goods and services that are considered to be directly monetisable, whether through private transactions or public sector contracts, offering profitable, market-based or financially compensated opportunities that support adaptation. However, opportunities to UK businesses from delivering monetisable adaptation goods and services are closely interconnected with positive externalities because many adaptation solutions, like green infrastructure or climate-resilient crops, can provide both direct adaptation benefits to customers and broader societal and environmental advantages, such as improved air quality and biodiversity.

CCRA3 also highlighted opportunities for businesses to improve their operations, competitiveness and efficiency through adaptation, and businesses may also benefit from reputational advantages from supporting adaptation action (Lawrance et al., 2022). For example, financial institutions can strengthen their credibility and position themselves as market leaders by investing in adaptation, developing new insurance products, improving flood risk assessments, and identifying new business opportunities in climate-vulnerable emerging markets.

Below we summarise evidence of current and future drivers of opportunity by key sectors. It is not possible to split the evidence by UK country due to data limitations. However, we do identify specific opportunities that exist within each the four nations.

<u>Finance and insurance</u>

With increasing risks from climate events, there is a growing need for investments in resilient infrastructure, particularly in flood defences, transportation, and energy grids. The UK financial sector can create financial products that support these investments, offering insurance and credit solutions tailored to adaptation-related infrastructure projects. Client demand for sustainable financial products and services has surged. In response, many banks have launched tailored green financing solutions by adapting their existing offerings which could be expanded into resilience spaces to increase opportunities for adaptation finance across various sectors.

There are opportunities for the private sector to contribute to adaptation finance. The green bond market is primarily dominated by mitigation projects. It is commonly argued that adaptation is a public good and returns are less easily realised for adaptation projects. However, these opportunities can be facilitated and enhanced by having a viable pipeline of adaptation projects, with appropriate metrics (Richmond et al., 2024). Moreover, this framing may overlook the real and growing value that resilience offers to businesses. Resilience bonds and catastrophe bonds are emerging and while the overall market of these instruments is not fully known, total adaptation finance needs in middle- and low-income countries are very large ($215–387 billion per year by 2030, UNEP, 2024). The UK's expertise on these instruments could lead to opportunities to capitalise on this market, though the benefits are likely to be geographically uneven, with much of the value captured in financial centres.

Banks often take an active investment approach as well, using their balance sheets to acquire equity stakes in startups or venture firms developing climate responsive technologies. Alternatively, banks can invest indirectly through private equity funds that specialise in adaptation projects, allowing them to support adaptation, while leveraging intermediaries to manage investments.

Opportunities for the finance sector to invest in climate adaptation exist at municipal and local levels in the UK in the property, infrastructure and water sectors, addressing hazards such as water scarcity and drought, with less work focussed on heatwaves. Opportunities for financial services are further enhanced through the integration of resilience measures, particularly in the planning and design of real estate, and payments for ecosystems services leading to further incentivisation to asset owners (CCC, 2023).

<u>Advisory services</u>

There is rapidly increasing demand, both domestically and internationally, for advisory services that support responses to wide-ranging global challenges linked to climate change including food insecurity, public health threats, systemic risks and shocks, legal and governance challenges, and trade disruption. This demand spans multiple sectors and domains of expertise, including legal services, adaptation finance, climate-smart agriculture, supply chain and trade resilience, health system resilience, and cross-sector adaptation planning (CDP, 2018; CCC, 2019). Noting the UK economy is already largely services based, the UK should be well placed to respond to this rising demand.

Delivering these services engages a wide range of professional, scientific, and technical activities including consultancy, engineering, modelling, and analysis as well as information and communication services such as climate data provision, digital tools, and strategic communication. Opportunities for UK businesses include providing tailored physical climate risk assessments for public and private sector clients; adaptation strategy development, including scenario modelling and stress testing; advisory on climate-resilient infrastructure design, site selection, and nature-based solutions; climate communication services; climate-resilient investment planning and climate financing; and the development of monitoring, decision-support, and predictive modelling tools.

UK businesses specialising in digital engineering, for example, can seize opportunities for developing advanced climate data tools and smart technologies such as predictive modelling, remote sensing, and real-time monitoring to manage climate risks and investments, support early warning systems, and apply data analytics to inform urban planning and infrastructure design. Such capabilities will be needed across a wide range of climate-exposed sectors.

Sector-specific drivers of demand for advisory services are anticipated across multiple areas of the UK economy. In industrial settings, for instance, addressing heat-related risks will require advanced modelling and simulation tools to support the layout, heat risk monitoring, and cooling of equipment and assets under future temperature extremes (IMECHE Heatwaves, 2023). UK agribusinesses and food retailers will require scenario-based supply chain risk assessments and stress testing tools to respond to global disruptions in agricultural commodities or critical infrastructure (CCC, 2021). Similarly, tools to support flood risk assessments at street and building scale are being developed by UK firms to inform planning decisions and insurance pricing (Environment Agency, 2022; UKRI, 2023). Detailed weather forecasting services provided by a range of private UK-based firms offering daily forecasts, seasonal outlooks, and long-term climate projections are also increasingly used to support decision-making across sectors and harness potential opportunities arising from adaptation needs (Jenkins, 2024).

Domestically, companies are increasingly expected to identify and disclose their exposure to climate risks, including the need for adaptation. A surge in climate-related regulations has contributed to growing demand for support for compliance and strategic planning. In particular, the requirement for increasingly detailed environmental risk assessments and disclosures has created new niches for consultancy firms specialising in environmental impact assessment and compliance planning (UK Energy, 2021).

Demand for advisory services is going to continue being driven by both regulatory and voluntary reporting initiatives, such as the Task Force on Climate-related Financial Disclosures (TCFD), its forthcoming evolution through the new UK Sustainability Disclosure Requirements (SDR) and anticipated adoption of revised guidelines from the IFRS International Sustainability Standards Board. Some companies, especially in regulated sectors (e.g., water, energy, infrastructure), also have more direct obligations. For instance, in the energy sector, regulatory bodies such as Ofgem require network operators to demonstrate how they are ensuring system resilience including through measures like Black Start Response Plans, which set out how to restore power following a system failure. Beyond statutory requirements, many companies voluntarily disclose adaptation-related actions through initiatives like CDP (formerly the Carbon Disclosure Project), which collects data on companies' exposure to physical climate risks and their efforts to manage them. Similarly, growing investor interest in climate risk reflected in ESG indices and shareholder engagement is driving companies to assess their adaptive capacity and seek advisory support to strengthen climate resilience.

<u>Energy Supply and Transmission</u>

There are likely to be several adaptation-focused opportunities for UK businesses in the energy sector as climate risks increase, driven by a need for goods, services, and innovations that help energy infrastructure and systems withstand extreme weather, changing climate patterns, and associated risks. There is a need for climate resilient grid technology and resilient energy generation infrastructure to ensure the durability and stable performance of energy systems against extreme climate events (Nik et al., 2021).

Over half of major blackouts worldwide from 2011 to 2019 were triggered by extreme weather events, emphasising the importance of resilient energy infrastructure. These events are anticipated to increase in frequency and severity within the UK, creating a future driver of demand for strengthening black start capabilities, to restore an electricity grid after a total or partial blackout. For businesses, there will be opportunities to partner with power authorities, particularly through contracts with Black Start Units, which play an essential role in stabilising the grid during outages (UK Energy, 2021). Companies with expertise in energy infrastructure could capitalise on demand for alternative Black Start solutions, including optimising plant operations under non-standard conditions and navigating emissions compliance challenges (UK Energy, 2021).

<u>Engineering, manufacturing and construction</u>

Opportunities for UK businesses to deliver adaptation goods and services also arise in engineering, manufacturing and construction. As risks from both slow onset changes and extreme weather events increase, there is growing domestic and global demand for resilient infrastructure, materials, and built environments, including through the delivery of hard, soft and nature-based infrastructure, retrofitting of existing assets, and development of climate-resilient technologies.

UK businesses can lead in designing and constructing infrastructure that can withstand floods, heatwaves, and storms, including flood defences, climate-resilient transportation systems, and energy infrastructure. This includes building, reinforcing and retrofitting climate resilient buildings and urban infrastructure, including through improved insulation, ventilation, cooling systems and urban drainage systems. For example, retrofitting older buildings to withstand climate impacts such as heatwaves and flooding is a growing demand area (Howarth et al., 2024). Increasing recognition of the need to 'build back better', rather than 'like for like', when replacing aged assets to ensure that they are fit for future service, has potential to drive some of this demand (IMECHE, 2023).

Significant efforts are needed to modify the built environment and industrial infrastructure to address potential adaptation needs posed by future coastal flooding due to sea level rise. In this area, environmental engineering and restoration companies can also lead projects that rehabilitate ecosystems such as peatlands, wetlands and woodlands which act as natural buffers against climate extremes like floods, wildfires, and storms, protecting communities and critical infrastructure.

Construction, real estate, and urban planning firms have significant opportunities to provide green infrastructure solutions like green roofs, urban forests, and vertical gardens; solutions that can reduce urban temperatures, improve air quality, and lessen the risks associated with heatwaves, pollution and their interactions.

Water management under climate change also presents economic opportunities, with investments in desalination and conservation projects offering potential pipelines of work for civil engineering, environmental consultancy, and water technology firms.

The manufacturing sector plays a crucial enabling role in supporting adaptation in other sectors by producing materials, components, and technologies for adaptation. Climate change means salmon farming may need to move offshore into increasingly deeper (and cooler) waters, for example, requiring new infrastructure for deeper, rougher waters and novel in-shore facilities to reduce time at sea (England et al., 2024; Hunt et al., 2024). Expansion and adaptation in the English and Welsh wine industry meanwhile is making use of new crop protection solutions, vineyard materials and winemaking equipment (e.g., underground tanks to keep wine cool) (Gannon et al., 2023).

<u>Agriculture, fisheries, and forestry</u>

In agriculture there are opportunities for UK businesses to develop and produce new adaptation goods and services and climate smart crops and technologies, as well as associated advisory services along agricultural value chains. These include water efficient irrigation and monitoring tools, equipment for precision agriculture, improved storage capabilities, crop protection and soil husbandry, including to improve soil structure, helping retain moisture during dry spells while also reducing the risk of flooding during heavy rainfall (Khangura et al., 2023). Businesses specialising in genetics, seeds, and biotechnology can create and supply resilient crop varieties to farmers to support their adaptation to changing conditions, including overseas. As adaptation becomes a necessity, businesses that provide solutions along agricultural and food supply chains will be well-positioned for growth.

There are also opportunities for delivering goods and services to agricultural sectors that emerge as adaptation responses, as areas of the UK move within the ideal climatic range for new crops, creating further opportunities along value chains in processing, distribution, and associated advisory services. For example, expansion of vineyards in England and Wales has stimulated the development of related industries, which together make up and surround viticultural value chains, including: winemakers; input and service providers including vineyard management, establishment and advisory services, specialised equipment manufacturing, winemaking equipment and packaging material suppliers; agritourism; and distribution networks (Gannon et al., 2023).

Assessment of current magnitude of opportunity

Economic estimates of the current overall size of the UK's 'adaptation market', are very limited (see evidence gap section). Globally, the climate adaptation market size was estimated at $20.85 billion (around £15.5 billion) in 2023, but these figures include carbon dioxide removal (CDR) and other technologies illustrating the common conflation of adaptation with mitigation in market assessments (Polaris, 2024). Paul Watkiss Associates (2021) assessed the economic risks of climate change in CCRA3, as well as some of the economic opportunities, including for UK businesses. It estimated current additional demand for goods and services is in the tens of millions of pounds per year. However, this assessment was limited in scope, focusing largely on demand-side effects in a small number of sectors (e.g., infrastructure and agriculture) with only light treatment of financial institutions, investors, or enabling services (e.g., risk analytics, insurance, legal services, technology platforms). As such it did not attempt to estimate the full size of the adaptation market, nor did it address supply-side capacity or how UK firms could develop new adaptation technologies, services or intellectual property that could be exported globally. Additionally, the report does not specify a clear taxonomy of adaptation goods and services, and some of the opportunities identified such as those related to land management, and building technologies are drawn from broader CCRA3 evidence, and may reflect measures that deliver both adaptation and mitigation benefits, making it difficult to isolate the adaptation-specific commercial potential.

There are also valuations of current opportunities for specific sectors, many of which suffer from the same limitations and shortcomings as national and global data. Over the past ten years, climate investing, for example, has evolved from a niche sector into a prominent arena that draws in substantial capital from private equity and venture capital. In 2023, investments in companies providing climate solutions reached $56.5 billion and attracted a network of over 25,000 climate investors (British International Investment, 2024). There is also significant opportunity for commercial banks to expand climate-smart financial investments in developed countries' lucrative markets (Park and Kim, 2020).

Shifts in disclosure requirements also appears to have driven a spike in demand for UK-based climate and sustainability consulting services. The UK's Environmental & Sustainability (E&S) consulting market alone grew by 48% in 2022, reaching £2.9 billion, in part due to this compliance push (Environment Analyst, 2024), though we acknowledge that not all of this relates to adaptation.

Magnitude scores in Table 4.39 are based on estimates of the monetary valuations of selected climate risks and potential opportunities facing the UK commissioned to support CCRA3, which estimates opportunities for businesses from changes in demand for goods and service (Paul Watkiss Associates 2021). These estimates are supplemented by expert judgement and insights from sector-specific case studies. The medium confidence rating across the magnitude scores reflects the data gaps and limited quantification outlined above for this opportunity.

Assessment of future magnitude of opportunity

There is broad consensus, from mostly qualitative evidence, that demand for adaptation-related goods and services will grow, potentially substantially, across the sectors outlined above. Climate impacts are projected to intensify under all emissions scenarios. This is likely to result in a corresponding very high demand for businesses and financial institutions to deliver adaptation goods and services commensurate with the scale of the challenge. It is also likely to be reinforced by the prominent role ascribed to the private sector in national and international adaptation policy frameworks; rising awareness of climate risks and the need for resilient infrastructure and operations (Dookie et al., 2024); and growing regulatory and disclosure requirements. Together, these trends suggest a strong and growing commercial opportunity for UK firms to deliver adaptation goods and services both domestically and internationally.

Reflecting this growth potential (noting earlier outlined data limitations, e.g., the inclusion of CDR technologies), the global adaptation market was projected to grow by 10% a year, from $22.90 billion in 2024 to $49.24 billion by 2032 (Polaris, 2024). Meanwhile, Paul Watkiss Associates' (2021) economic analysis of monetary valuations of risks and opportunities identified in the CCRA3 Technical Report estimated opportunities for UK businesses from changes in demand for goods and services as very high (billions of pounds/year) by 2050 and to 2080 under medium (2 °C) and high (4 °C) emissions scenarios.

There are also various sector-specific estimates. Large growth is forecast for advisory services, with the Environmental & Sustainability consulting market projected to reach around £4.9 billion by 2027, with a compound annual growth rate of 10.7% (Environment Analyst, 2024), though again not all of this will relate to adaptation. Meanwhile the push for more sustainable housing is also expected to drive significant employment growth, with up to 112,000 new jobs anticipated by 2030 (Accenture, 2021), some of which will be focused on addressing adaptation needs. Projections that restoring woodland, peatland, and urban green spaces, with potential adaptation benefits, could generate around 16,000 jobs across some of the UK's most economically disadvantaged constituencies (Edgar et al., 2021) also help illustrate the magnitude of delivery effort and labour demand associated with adaptation-aligned investment, even if they provide limited insight into the value captured by businesses or investors involved in delivering these interventions.

Assessments of the future magnitude of opportunity suffer from the same data limitations as estimates of current magnitude, however, estimating future opportunities introduces additional layers of complexity and uncertainties around factors such as:

1. the timing, severity, and geographic distribution of climate impacts and their adaptation needs;
2. the pace and direction of relevant policy and regulatory change;
3. potential technological and market innovation; and
4. the scale and character of future demand, but also from the interacting and compounding nature of climate risks and opportunities.

Climate impacts are amplified and attenuated through value chains, for example, and adaptation responses undertaken within one business can redistribute risks and opportunities elsewhere in the value chain, meaning that businesses need to adapt not just to opportunities that emerge because of the changing climate, but also to how other businesses are adapting around them (Gannon et al., 2023). Business impacts and opportunities are therefore likely to emerge through cascading or systemic effects which are difficult to predict and rarely captured in existing assessments.

Moreover, adaptation is constrained by critical thresholds. The pace and magnitude of climate impacts may exceed adaptive capacity, lead to diminishing returns, significantly increase the costs of adaptation – or even make it impossible – particularly as warming accelerates and under higher emissions scenarios. These risks are further compounded by the potential to become 'locked-in' to short-term or poorly designed adaptation responses, that limit future options and could be exacerbated by poorly adapted policy responses. In addition, non-linear physical and social shifts including the crossing of tipping points, could radically reshape both adaptation needs and market opportunities over time (Dietz et al., 2021; van Ginkel et al., 2022; Shortridge et al., 2024). These uncertainties compound existing data limitations, making robust, disaggregated forecasts of future opportunity particularly challenging.

Magnitude scores for future opportunity in Table 4.39 are informed by estimates in Paul Watkiss Associates (2021), supplemented by expert judgement, qualitative data and sector specific case studies. The low confidence rating applied in the 2050s and 2080s reflects the data gaps, limited quantification and high uncertainties that surround this opportunity.

Level of preparedness for opportunity

Since E8 represents an opportunity as opposed to a risk, preparedness here is not around government or business action in managing risks, but rather how well-equipped businesses are to maximise opportunities, supported and enabled by government. Unless prevented by regulation or low adaptive capacity, businesses and financial institutions are likely to respond to climate-related demand and opportunities, supported by rising awareness of climate risks (Dookie et al., 2024). Advisory services may also benefit from AI growth. However, private sector adaptation depends on an enabling environment that stimulates and incentivises investment (Crick et al., 2018; Watkiss et al., 2019). Studies show that investment in enabling conditions, such as multi-stakeholder partnerships, can unlock adaptation goods and services (Gannon et al., 2021). Evidence of concrete actions remains limited, with scarce resources and only partial focus within institutional frameworks.

<u>National policy and strategy frameworks</u>

National frameworks increasingly consider opportunities for adaptation-related goods and services. The third National Adaptation Plan (NAP3) did not set an overarching plan to support businesses, though it recognised prospects in sectors such as climate modelling, engineering, finance, and insurance. It also noted Department for Business and Trade research into market capacity, but no updates were available at the time of writing.

Scotland's National Adaptation Plan (SNAP, 2024) aims to position the country as a hub for "innovative adaptation solutions." It commits to fostering business innovation, public–private partnerships, and developing evidence on adaptation opportunities. Key actions include:

- working with Enterprise Agencies and Business Support Partnerships to share adaptation insights;
- using the Scottish government's CivTech programme to develop innovation projects, building on the Innovate for Nature initiative; and
- expanding the Facility for Investment Ready Nature in Scotland (FIRNS) to attract private investment in natural capital.

SNAP commits to progress during 2024–29 but provides no new resourcing or measurable targets. Monitoring does not yet include indicators for business opportunities. Wales and Northern Ireland show no new policy since CCRA3. The UK's Modern Industrial Strategy (2024) omits climate adaptation, while the UK Export Finance Sustainability Strategy (2024–29) includes it under "clean green growth" but without detail. Some cities and combined authorities are mapping adaptation investment needs and testing blended finance models (e.g., ATTENUATE Project, 2025), but most local plans lack pipelines of business opportunities.

<u>Regulatory and institutional enablers</u>

Some regulations have improved private sector readiness. Mandatory climate-related financial disclosures (aligned with TCFD, from 2022) and adaptation reporting requirements have increased demand for advisory services and risk analytics. Yet TCFD still emphasises net zero risks over adaptation opportunities, and application is uneven.

<u>Access to finance</u>

The UK is well positioned to expand adaptation finance due to its financial centre status, innovation ecosystem, and enabling institutions like the UK Infrastructure Bank. Blended finance opportunities are growing (Khosla and Watkiss, 2022).

The 2023 Green Finance Strategy acknowledged adaptation finance lags mitigation, promising an action plan by end-2024, but this was not published before the July 2024 change of government. Research with the CCC continues to assess investment needs, with findings due in CCRA4 (2027).

Meanwhile, financial institutions are beginning to act. Triodos Bank's £20m loan to Oxygen Conservation for large-scale regeneration is one of the UK's largest commercial nature-based investments (Triodos, 2023). Public finance is also shifting; Scotland's agricultural reforms (2025) will tie half of farm funding to climate and nature outcomes, while the 2021 National Environment Impact Fund provided £10m to attract private investment in environmental restoration.

<u>Skills, capacity and workforce development</u>

The 2021 Green Jobs Taskforce identified new opportunities in resilient infrastructure, construction, monitoring, and adaptation finance, recognising fast-growing demand across housing, water, infrastructure, and conservation. The Taskforce has since been replaced by the Green Jobs Delivery Group, co-chaired by the Minister for Energy Security and Net Zero, but adaptation and resilience are not currently priorities in its work.

Assessment on the evidence base and evidence gaps

There is strong qualitative evidence that opportunities for UK businesses and financial institutions from delivering adaptation goods and services exist and are growing. However, as also noted in CCRA3, there is a notable absence of robust financial quantification assessing the magnitude of this opportunity, highlighting a major evidence gap in UK adaptation planning, particularly when compared with the financial opportunity analyses produced for the green transition and net zero (e.g., CBI, 2023). Where evidence does exist, it rarely isolates adaptation (as distinct from mitigation and broader sustainability opportunities), applies a UK-specific lens, or identifies opportunities for businesses and financial institutions as distinct actors. In particular, the few attempts at economic assessment that do exist do not capture the full scale of the adaptation market or the supply-side capacity for developing exportable technologies and services. There is also limited analysis of the scale of commercial opportunities: that is, adaptation goods and services that businesses and investors can develop and deliver for financial return, as distinct from adaptation measures that primarily function as public goods or generate value primarily through positive externalities that accrue to society at large rather than to those investing in them.

Key gaps of national importance include the lack of a systematic framework for quantifying commercial opportunities distinct from broader societal benefits, limited sector-specific analyses that could inform targeted industrial strategy, and insufficient understanding of how UK businesses can scale and export adaptation solutions internationally. The evidence base also fails to adequately address the complex realities of adaptation opportunities, including their uneven distribution across sectors and geographies, the ethical implications of opportunities arising from others' climate vulnerabilities, and the potential for adaptation lock-in effects. This weak evidence foundation significantly hampers the UK's ability to develop coherent industrial and trade strategies around adaptation goods and services, despite broad recognition of the sector's growth potential in the context of intensifying climate impacts. The confidence scores reported in CCRA4 across magnitude assessments are therefore consistently low, reflecting these fundamental data gaps and the fragmented nature of available evidence.

4.2.8.2 England

Evaluation of urgency score

It is important to note that the available evidence base doesn't allow us to provide differentiated opportunity magnitudes for each UK nation. While the adaptation opportunities may be lower in, for example, Northern Ireland than England, even after scaling by economy size, it is not possible to map such differences into nation-specific opportunities with any precision. Furthermore, since the risk/opportunity magnitude categories are relatively broad, our view is that it is unlikely that relatively small differences in opportunities, even if they could be accurately predicted, would lead to differences in opportunity magnitude categories. Nevertheless, our opportunity magnitudes in the UK nation tables below are our assessments of the opportunity magnitude for the UK as a whole and from which it should not be inferred that the opportunity magnitude is necessarily equal in each UK nation.

Table 4.40: Urgency scores for E8 Opportunities to UK businesses from delivering adaptation goods and services for England. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

England								
E8	Opportunities to UK businesses from delivering adaptation goods and services.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (M)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (M)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
Urgency scores	MAN	MAN		CI			FI	
Overall urgency score	CI							

4.2.8.3 Northern Ireland

Table 4.41: Urgency scores for E8 Opportunities to UK businesses from delivering adaptation goods and services for Northern Ireland. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Northern Ireland

E8	Opportunities to UK businesses from delivering adaptation goods and services.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (M)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (M)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
Urgency scores	MAN	MAN		CI			FI	
Overall urgency score	CI							

4.2.8.4 Scotland

Table 4.42: Urgency scores for E8 Opportunities to UK businesses from delivering adaptation goods and services for Scotland. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Scotland								
E8	Opportunities to UK businesses from delivering adaptation goods and services.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (M)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (M)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
Urgency scores	MAN	MAN		CI			FI	
Overall urgency score	CI							

4.2.8.5 Wales

Table 4.43: Urgency scores for E8 Opportunities to UK businesses from delivering adaptation goods and services for Wales. Key to the magnitude scores: very light purple (L) = Low, light purple (M) = Medium, purple (H) = High, dark purple (VH) = Very High. Key to the

confidence scores: + = Low, ++ = Medium, +++ High. Where urgency scores are represented by: CAN = Critical Action Needed, CI = Critical Investigation, MAN = More Action Needed, FI = Further Investigation, SCA = Sustain Current Action, WB = Watching Brief. Details of how the scores in this table were calculated are in the Methods Chapter.

Wales								
E8	Opportunities to UK businesses from delivering adaptation goods and services.							
	Present	2030		2050		2080		
		Central	High	Central	High	Low	Central	High
No adaptation	++ (M)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
With adaptation	++ (M)	++ (H)	++ (H)	+ (VH)	+ (VH)	+ (VH)	+ (VH)	+ (VH)
Urgency scores	MAN	MAN		CI			FI	
Overall urgency score	CI							

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