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Investing in Resilience

Unlocking Pension Capital for Climate Adaptation

Martin Logan & Jesse F. Abrams

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About the Authors



Dr Jesse Abrams, Senior Impact Fellow (Climate Risk) at Green Futures Solutions, University of Exeter

Dr Jesse Abrams is one of the UK's foremost experts in physical climate risk and tipping points, whose work quantifies human-induced change on the natural environment. As an Earth system scientist in Exeter's Green Futures Solutions team, Jesse's work increasingly focuses on how physical climate impacts translate into material, financial and systemic risks. In recent years, he has authored several landmark reports on climate risk – including Recalibrating Climate Risk (University of Exeter and Carbon Tracker), Planetary Solvency (University of Exeter and Institute and Faculty of Actuaries), the Global Tipping Points Report 2025 (University of Exeter), and No Time To Lose (University of Exeter and USS). In addition to his Exeter role, Jesse is an Associate Research Fellow at the Strategic Climate Risks Initiative.



Martin Logan, Sustainability Manager at Cushon by WTW

Martin Logan has been working in financial services for 10 years, and for the last 7 he has been focused on sustainability strategies in pensions. As part of the Cushon Master Trust's in-house investment team he has supported the Trustees of the Cushon Master Trust in developing their climate risk framework that prioritises portfolio resilience to climate risks alongside decarbonisation efforts. This framework led to the Scheme improving their approach to climate scenario analysis to better account for physical and transition risks facing the Scheme's portfolio, leveraging research from the University of Exeter and differentiated scenario design. Martin also led on the Scheme's investment into natural capital which was implemented to build resilience to carbon price risk.

This paper is based on research and data produced by Jesse Abrams at Green Futures Solutions. The analysis, interpretation and presentation of this research have been undertaken by Jesse and Martin. While reasonable care has been taken in preparing this publication, Cushon has not independently verified all underlying information and accepts no responsibility for any errors or omissions in the source material. This is also true of additional external sources that have been leveraged in the presentation of this report.

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Introduction

Over the last 5 years, Cushon has been supporting the industry and evolving the way that we look at climate risks, in line with the latest climate science and risk analysis. Our goal is to further the measurement and consideration of systemic climate risks in investment decision making and make investments that address these risks.

In 2020 we started with a proposition that used carbon offsets to deliver a net zero solution immediately. This was replaced with a mission to decarbonise our default investment strategy towards net zero. Our decarbonisation approach was rooted in our aims to further the transition - a bid to reduce the climate-related financial risk that our portfolio (and ultimately our members) is exposed to. Alongside this, we were the first DC Master Trust to invest in a UK Long Term Asset Fund (in 2023). Our first fund was a portfolio of transition infrastructure and climate-focused assets.

However, whilst we significantly reduced emissions in our portfolio, there were signs that the world was not decarbonising along with our portfolio. In fact, the latest climate science tells us that greenhouse gas emissions have continuously increased into 2025[1]. During this time, we reviewed how we were considering climate risk. It was no longer about simply reducing the emissions in our portfolio. After all, if we're choosing to not own a high emitting asset, that does not stop the asset from existing - it's just simply owned by someone else.

In 2024 we launched our Climate Risk Framework. A refreshed way of thinking about climate risk management that prioritised resilience to transition and physical risks alongside portfolio decarbonisation and real-world decarbonisation. This way of thinking helped us to commit to our first investment in natural capital – an investment that complements all three facets of our climate risk framework:

- Portfolio resilience: This investment partly delivers returns from high-quality carbon credits, providing a partial hedge for carbon price risk that is expected to impact other areas of the portfolio.
- Real-world decarbonisation: Projects such as afforestation, peatland restoration and mangrove plantations will actively remove carbon emissions from the atmosphere.
- Portfolio decarbonisation: This investment supports wider emission trajectories of the portfolio by reinforcing carbon pricing signals (through generating and selling high-quality credits).

The work around our climate risk framework underpinned a key problem that persists across industries and markets. There remains a broader lack of understanding of the risks that portfolios and economies are exposed to, limiting the ability to build resilience to them. From our perspective

[1] https://wmo.int/publication-series/state-of-global-climate/state-of-global-climate-2025

at Cushon, we believe we have a duty to further understand these risks so that we can better invest in resilience and the future for our members. For our Trustees, it is part of their fiduciary duty to consider these long-term systemic financial risks. Climate risks are still often misunderstood and underestimated, but work is emerging that highlights differentiated ways of measuring climate risks.

As such, across the last few years we have partnered with climate data providers who are challenging the way that financial institutions think about climate risk. Instead of only linear equilibrium modelling based on structured scenarios, we are incorporating non-linear disequilibrium modelling that incorporates realistic narratives of the global economy.

Using differentiated non-linear climate risk measurement, we aim to better consider the tail risks and get a better understanding of the extent of the problem. This paper explores some of the ways that climate risk measurement can be improved, and how severe the impacts of physical climate risk might be.

It is not enough to measure and reflect on the possible climate risks we may be exposed to. Where relevant, the data should be leveraged to embed resilience and adaptation measures across portfolios, through infrastructure upgrades and hazard management.

Cushon are signatories to the Mansion House Accord and members of the Sterling 20. Through these initiatives we have an ambition to channel capital to UK projects (subject to fiduciary and Consumer Duty) including infrastructure, aligned with the UK government's modern industrial strategy. We have already done this through our investments in renewable infrastructure and UK venture capital. Many other institutional investors are also signatories/members of these initiatives, making them significant frameworks that could support investment into resilience.

Policy considerations discussed in this paper can help adaptation investments be better rewarded, and institutional investors may already be able to deploy capital towards these projects. This is a significant moment where we can act, and we encourage policymakers and industry actors to start to consider these risks so that we can manage financial risk through better protecting the world in which we will all retire.

Background

Recent years have seen growing debate and scepticism about the pace, cost and delivery of climate policy. Increasing politicisation of this topic has contributed to policy change and uncertainty in some jurisdictions, most notably in the US. In the UK, the previous political consensus on climate has fractured, for example, with the conservative party announcing plans to repeal the UK's Climate Change Act[2], drawing criticism from climate scientists[3].

In this new political environment, the financial risks of climate to investors remain relevant. Political uncertainty does not reduce the underlying physical risks association with climate change and the Inevitable Policy Response (IPR) notes that, despite climate policy reversals, global climate policymaking remains active and the anticipated spillover effects have been more limited than many expected[4].

Scepticism ignores many of the potential financial benefits that come with transitioning to a low-carbon economy. Investing in certain adaptation and climate technologies can provide meaningful returns for investors, and for asset owners. These investments seek to provide partial risk mitigation for the systemic risks posed by climate change and a better protected world for their members. They may also be better insulated from shocks to energy prices, which we have seen as a result of increased conflict and geopolitical tensions in the last 5 years.

In preparation of this report, Cushon has worked with the University of Exeter's Green Futures Solutions initiative to analyse the potential impacts we might see in the UK. The report aims to highlight the need to take action to help adapt the UK to the physical impacts of climate change. To do this, this paper:

- Highlights the impacts of climate change that we are already seeing today
- Discusses how these impacts are likely to magnify and grow
- Assesses current approaches to physical risk assessments, with a closer look at the UK
- Discusses examples of industry actors who are creating solutions for physical risk resilience.

Whilst this paper focuses on the physical impacts of climate change and the role of investment in adaptation in the UK, it is important to highlight that there are other facets to climate risk which are not discussed as a part of this paper. For one, investments in climate solutions and the funding of the transition to a global low-carbon economy globally are needed to help to reduce the likelihood of high warming. Additionally, the impacts of physical risks will be broad and not solved

[2] https://www.legislation.gov.uk/ukpga/2008/27/contents
[3] https://www.sciencemediacentre.org/expert-reaction-to-conservatives-saying-theyll-repeal-the-climate-change-act-2008/
[4] https://ipr.transitionmonitor.com/cms/wp-content/uploads/2026/06/20260626_Q4-2025-Q1-and-Q2-2026-QFT.pdf

by just considering adaptation investment in the UK, the focus of this paper. This report is aiming to draw attention to one area that could warrant further exploration and additional investment.

It is important to acknowledge that protecting vital infrastructure and UK businesses will require significant upfront investment, but investment now has the potential to reduce future costs caused by natural disasters. To contribute towards the investment required there is significant capital that can be deployed by pension providers. By 2030, it's expected that c.£50bn will be invested in UK private markets under the Mansion House Accord[5]. This has the potential to facilitate ongoing and further investments required across future decades to build resilience within the UK.

There are various policy considerations which will help to unlock pension capital for adaptation and transition investments, but we also think the Government has the capability to move the dial, for example through the suggestions later in this paper to support the financial case and availability of adaptation investments. Part of the commitments of the Mansion House Accord could also facilitate this.

[5] https://www.gov.uk/government/news/pension-schemes-back-british-growth?utm

Physical Risks & Adaptation

For years now, many economic models used by policymakers and investors may have been significantly underestimating certain projected impacts of climate change[6]. These underestimates have been well documented and discussed as the use of scenario analysis (climate risk stress testing) has become a regulatory requirement for financial services[7]. Whilst there has been an improvement in recent years, there is still a concern that scenarios are being used as evidence to suggest that the impacts of climate change will be relatively modest. There is a need to pay closer attention to the scientific consensus.

The UK is already experiencing changes in weather patterns attributable to climate change, with warmer and wetter winters leading to increased flooding. These weather events have been happening whilst we are still at an average of 1.4°C warming since pre-industrial levels. We are also likely to see worse winters as warming increases.

This has been documented by recent research from the University of Newcastle and Willis Research Network, which also found that future projections of UK rainfall and flooding extremes are underestimates and risk exposure may be higher than current models imply. This is due to storms being able to carry increasingly more moisture as warming increases, a trend that is now detectable for the UK.[8]

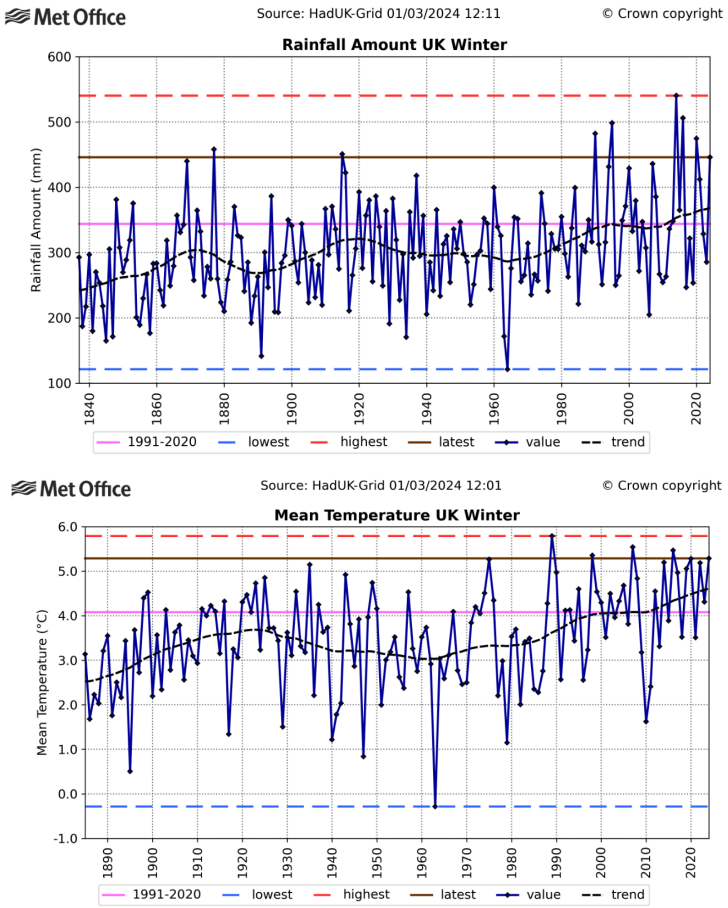


Figure 1: Mean Rainfall and Temperatures for UK winters (Source: Met Office)

As highlighted by the Climate Change Committee's (CCC) recent letter to government[9], the UK should be prepared to cope with weather extremes resulting from at least 2°C of warming by 2050.

[6] https://www.lse.ac.uk/granthaminstitute/news/economic-models-significantly-underestimate-climate-change-risks/#:~:text=Policymakers%20are%20being%20misinformed%20by,today%20(4%20June%202018).
[7] https://actuaries.org.uk/media/qeydewmk/the-emperor-s-new-climate-scenarios.pdf
[8] https://www.wtwco.com/en-kw/insights/2026/03/a-climate-signal-is-emerging-in-uk-winter-rainfall-and-models-may-be-underestimating-it
[9] https://www.theccc.org.uk/wp-content/uploads/2025/10/CCC-letter-to-Minister-Hardy-15-October-2025.pdf

Given an earlier report from the CCC, that highlighted inadequate preparations for climate change at current warming, there is a clear need for significant investment in effective adaptation provisions. This has been further reinforced by the latest independent assessment of UK climate risk by the CCC, which calls for a new approach to adaptation with measurable targets to help define what "well-adapted" would mean for the UK[10].

We are seeing an increasing number of institutions begin to plan for higher levels of global warming based on "current policy projections" which puts the world on track for about 2.6°C of warming by 2100[11]:

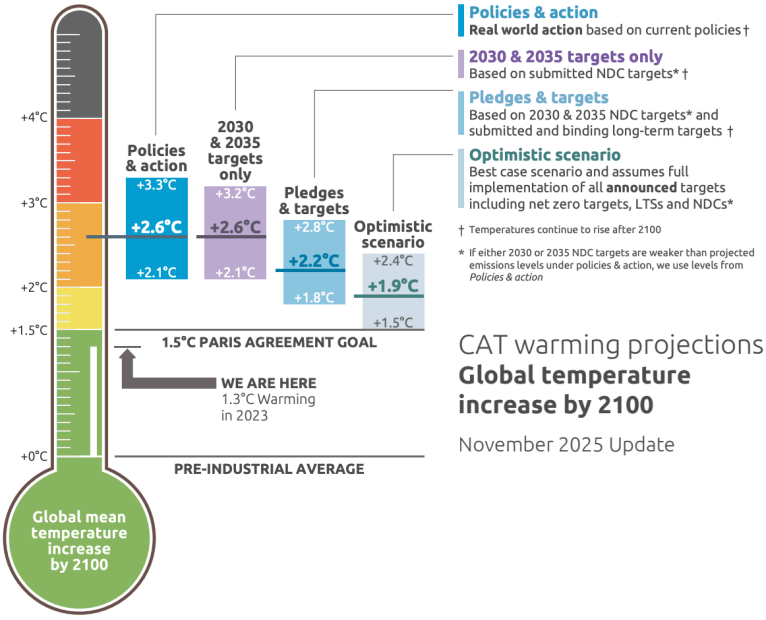


Figure 2 Climate Action Tracker as at November 2025

As noted below, some institutions expect warming to reach these levels (or higher) in a shorter timeframe:

- The global consulting firm Wood Mackenzie have published research projecting 2.6°C of warming by 2060
- Verisk Maplecroft (a risk and analytics consultancy) have warned of a tripling of corporate climate risk by 2050 based on their intermediate scenario that projects global temperatures climbing 2.7°C above preindustrial levels.
- The World Meteorological Organisation reported that a year above 2°C is now plausible before 2030

Further to this, the Institute and Faculty of Actuaries recently published a report, called Parasol Lost, which indicates that the rate of warming has been increasing in recent years[12]. This was later supported by a peer reviewed paper by Foster & Rahmstorf that highlights a significant

[10] https://www.theccc.org.uk/publication/a-well-adapted-uk/
[11] We note this trajectory has decreased from 2.7°C to 2.6°C in the latest estimates. This is largely due to methodological updates rather than significant new policy action.
[12] https://actuaries.org.uk/media/isvotyer/parasol-lost.pdf

acceleration in warming over the last 10+ years than during any previous decade[13]. In part this is due to a loss of aerosol cooling that the planet was unintendedly benefitting from. Pollution generated particulates in the atmosphere have been reflecting sunlight and fostering cloud formation and providing an "aerosol cooling effect". However, in recent years, efforts to improve air quality (by removing sulphur from coal and oil burning) have altered atmospheric circulation and reduced the aerosol cooling effect leading to accelerated warming. This has been substantiated by a variety of publications including Wang et al.[14], Yang et al.[15], and Roldan-Gomez et al.[16].

This report also highlights that the planet may be more sensitive to global warming than was previously thought. This is an important consideration because even if we significantly reduced emissions today so that they balanced with natural carbon sinks, there would still be a period of warming as a result of emissions already in the atmosphere. This is measured by Equilibrium Climate Sensitivity (ECS), which gauges the eventual global temperature increase after the Earth has stabilised following a doubling of atmospheric CO_2. A higher ECS implies more warming for a certain amount of greenhouse gases.

This would have significant implications on the projections highlighted in Figure 2, with the higher end of temperature ranges becoming more likely and equally concerning, a minimum of 2°C of warming becoming almost certain.

With the awareness of passing 1.5°C being imminent, and the need to prepare for 2°C of warming above pre-industrial levels, we have been exploring what the potential impact might be on the UK from acute and chronic natural disasters at these temperatures. We partnered with the University of Exeter's Green Futures Solutions to perform granular risk assessments that consider hazard impacts on populations, infrastructure and ultimately UK GDP.

The Missing Picture from Mainstream Analysis

Climate models and their limitations

To put our analysis into context, Green Futures Solutions have first analysed the outputs from the most widely used models across financial services; the Network for Greening the Financial System (NGFS). NGFS was widely adopted because it was launched by a group of central banks and was therefore seen as apolitical and supported by peer validation. It was launched as climate risk became a core financial stability issue and provided scenario analysis frameworks, not just principles. Given the uptake, policymakers have also largely focused on these models. NGFS has provided an important starting point for the industry and helped with the widespread adoption of

[13] https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2025GL118804
[14] https://www.pnas.org/doi/10.1073/pnas.2534130123
[15] https://egusphere.copernicus.org/preprints/2025/egusphere-2025-840/
[16] https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2026GL122424

climate risk analysis. However, like all climate models, they are just a subset of plausible outcomes and there are concerns that these models perhaps understate some of the potential impacts.

Climate economic models, such as those used by NGFS, are made up of several modelling components. They are a combination of:

- Socio-economic pathways
- Energy system models
- Emission pathways
- Climate system models
- Impact and damage models
- Financial-economic models.

These components are often brought together in a series of models that includes integrated assessment models (IAMs), climate models, and simplified/sectoral damage modules. Use of IAMs in climate modelling has been criticised as they are sometimes viewed as oversimplified systems for a complex problem, and assumptions used are not always transparent which can obscure biases.

These models are also criticised for adopting insufficiently specified damage functions that can create misleading impact analyses. These are functions that translate climate change outcomes (traditionally relying on changes in temperature) into economic losses (usually in terms of GDP loss compared to a “no climate change” baseline). Typically, they are calibrated using historical weather-economic regressions, expert judgment and extrapolations. We have taken a specific interest in the damage functions used as we are focusing on the impacts of physical risks.

Different damage functions can lead to a wide range of outcomes depending on the assumptions behind the modelling. To highlight this, Table 1 shows a comparison of potential global GDP losses under various damage functions across different pieces of literature. This clearly shows a vast difference across studies:

Table 1: Comparison of GDP loss in damage functions (Source: Green Futures Solutions)

Study	Type of Damage Function	Projected GDP impact of ~2°C global warming	Projected GDP impact of ~3°C global warming
Nordhaus and Boyer (2000)	Enumeration	1%	2%
Weitzman (2012)	Enumeration	1%	3%
Dell et al. (2012)	Econometric	4%	22%
Tol (2014)	Meta-analysis	1%	2%
Nordhaus (2014)	Enumeration	1%	2%
Dietz and Stern (2015)	Enumeration	2%	13%
Burke et al. (2015)	Econometric	8%	14%
Howard and Sterner (2017)	Meta-analysis	3%	8%
Kompas et al. (2018)	CGE	1%	2%
Kalkuhl and Wenz (2020)	Econometric	2%	5%
Howard and Sylvan (2020)	Survey	3%	8%
Kahn et al. (2021)	Econometric	3%	8%
Waidelich et al. (2024)	Econometric	4%	8%
Bilal and Känzig (2024)	Econometric	19%	44%

NGFS damage function based on Kotz et al. (2024)[17]	Econometric	14%	33%

There is an observable trend to these impacts. Over time as human understanding of the impacts of climate change has improved, the projected losses have increased. The industry has welcomed attempts to include a broader range of damages, as it helps to give a clearer picture of the risks that we are facing.

However there remain concerns that the analysis highlighting greater impacts has not yet been internalised by policymakers. Whilst NGFS models, the most widely used, have adopted a damage function that models higher damages, the concern is that the outputs from these models are not being considered by policymakers. This is indicated by various comments and claims that suggest that the economic damage from climate change is small relative to intervention costs. If you consider the median of damage functions across 2000-2020, it is understandable how these conclusions could have been drawn.

If we look at NGFS in particular, prior to using the Kotz et al. (2024) damage functions, their previous models leveraged the Kalkuhl and Wenz (2020) damage functions. There is a considerable distance between the two and it is easy to dismiss the impacts of global warming under an estimated 3% impact to GDP. At an estimated 14% of global damages, the more up to date damage functions may give a better estimate of the impacts of climate change, but this estimate still does not take into account some important considerations.

It is important to note that these assessments are still linear in nature (as they are typically gradual functions of temperature), so may understate the systemic impacts of climate change. These models can present smoother outcomes, as they fail to reflect the impacts of tail risks and ignore the impacts of 'tipping points' and other nonlinearities in the climate.

Climate tipping points are critical thresholds in the Earth's systems which, if passed, could lead to persistent changes in the state of the climate system. These changes can have impacts globally, affecting food systems, economic growth and national security. This is because they could accelerate catastrophic risks across the planet and in some cases, cause further global warming. The Global Tipping Points Report 2025[18] highlights the potential for further warming as a result of crossing some of these thresholds:

[17] We note that Kotz et al. was retracted and republished. Damages were overstated due to some outliers in specific regions. Revised damages were slightly lower than the original calculations which NGFS used for the damages shown. The damages in the NGFS function would therefore be less (but still expected to be higher). NGFS have advised that they are not revising their estimates but updating methodology more broadly in 2026 that will consider the revised damages. NGFS have commented on this via this article: https://www.ngfs.net/en/press-release/statement-regarding-physical-risk-estimates-phase-v-ngfs-long-term-scenarios

[18] https://global-tipping-points.org/

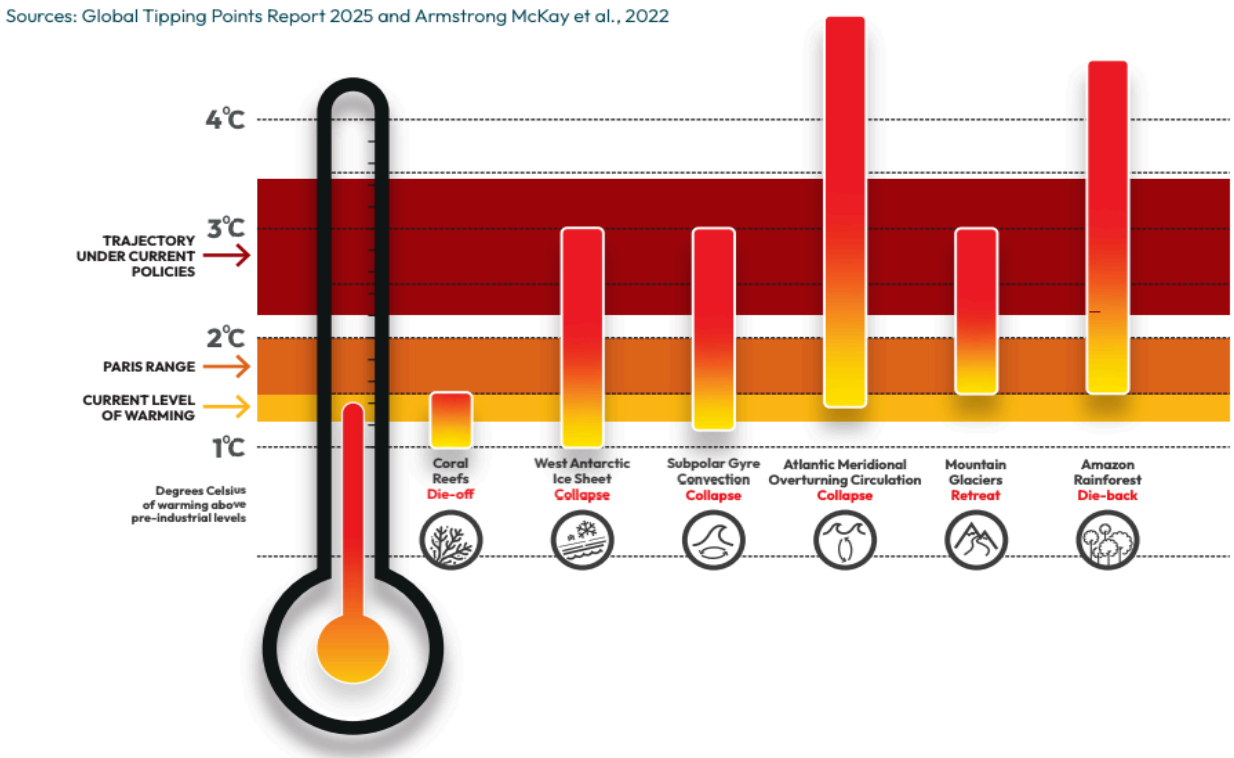


Figure 3 Risks of Earth system tipping points increase with global warming

Many of these tipping points become increasingly likely as we breach the 1.5°C-2°C warming marks (shown in Figure 3). Once crossed, tipping points are irreversible. It would be akin to a shock like the Global Financial Crisis, with the difference that no government would be able to bail the environment out to restore the previous state of the Earth's system. The Global Tipping Points Report calls for governments to pay due attention to these risks, especially considering the imminent threat of ice sheet and ocean current collapse.

It is very hard to model the impacts of tipping points, as studies often rely on a standard temperature-to-GDP relationship that would not hold under the far-reaching changes induced by tipping of certain elements of the Earth's system. There is limited literature on this topic, and the outcomes can be very diverse, this is demonstrated by the studies discussed below:

- A recent meta-analysis attempted to summarise the economic impacts of eight tipping points (Dietz et al. 2021[19]). This study concluded that damages could be ~25% higher (measured as the Social Cost of Carbon, or marginal damage to the economy) as a result of tipping points. This is predominantly driven by the amplifying of global temperature increases due to permafrost collapse and ocean methane hydrate release.
- A study by Anthoff et al. 2016[20] concluded that there could be a positive impact on GDP as a result of the collapse of the Atlantic Meridional Overturning Circulation (AMOC). Due to the connection of temperature to GDP, and cooling expected as a result of this tipping event, they concluded that this would counteract warming in the northern hemisphere, where global GDP is concentrated. This is counter to estimates by physical scientists of potential

[19] https://www.pnas.org/doi/abs/10.1073/pnas.2103081118
[20] https://www.aeaweb.org/articles?id=10.1257/aer.p20161102

agricultural collapse in an AMOC collapse scenario, due to shifts in atmostpheric circulation that will lead to decreased rainfall and significantly lower temperatures affecting crop yields.

- In contrast to the above Cai, Lenton, & Lontzek (2016)[21] concluded that AMOC collapse could lead to a 15% increase in GDP damage. Their methodology, whilst still relying on the same temperature-to-GDP relationship, incorporated interacting tipping points into stochastic models. Considering interaction is important, as the large impacts of one tipping element is likely to trigger another.

Impact studies for all major tipping elements is an area of research that desperately needs more attention. We encourage industry actors and governments to push for more research in this area to better capture these risks in core models.

If we do begin to consider tipping points in the analysis of damage estimates (by drawing on expert knowledge and the limited available literature), we can start to see a broader range of potential outcomes that the UK needs to be prepared for:

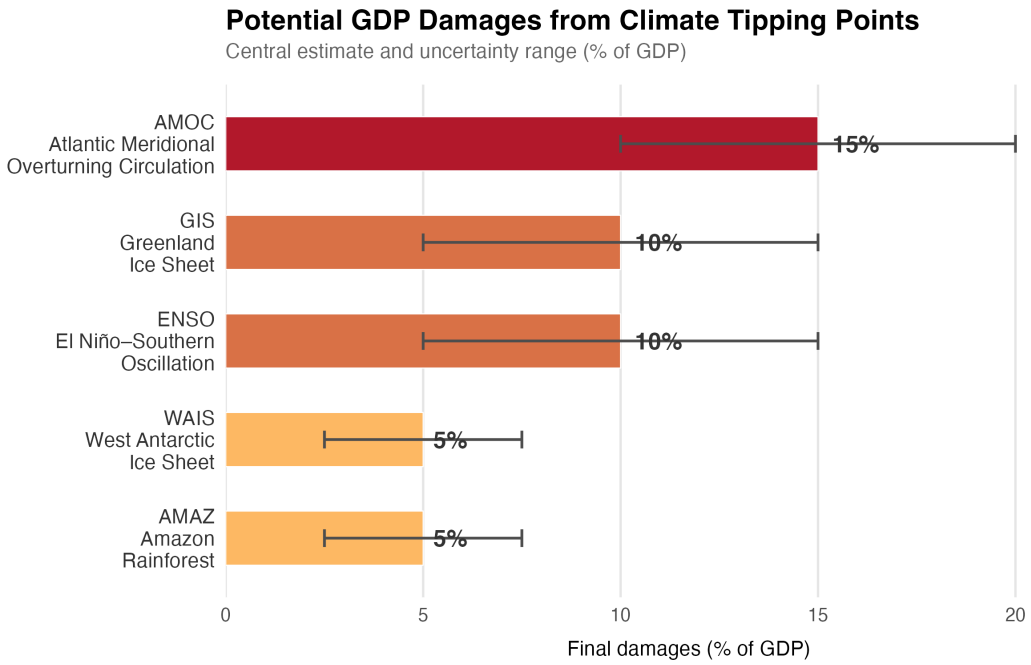


Figure 4: Estimates of GDP impacts from climate tipping points; ranges show uncertainty bounds (Source: Cai, Lenton & Lontzek (2016))

We can also consider the impacts of these tipping points more qualitatively. Below we highlight some of the impacts that could be observed as a result of crossing tipping points (source: Green Futures Solutions):

- **AMOC weakening/shutdown** could lead to up to 7°C cooling in UK average temperatures, reduced summer rainfall exacerbating drought, and increased winter storms penetrating further inland. Globally, changes in the AMOC will lead to shifts of the intertropical convergence zone (ITCZ), which will impact global atmostpheric circulation patterms.

[21] https://www.nature.com/articles/nclimate2964

- **Antarctic ice sheet instability** could lead to up to ~1m additional Antarctic contribution to sea level rise by 2100 which translates to a high-end UK sea level rise of up to 2m by 2100 with major implications for coastal flood defences.
- **Greenland ice sheet retreat** would have direct sea level contribution for the UK. Greenland meltwater will have feedback effects of the AMOC through freshwater input which will weaken the density driven deepwater formation that drives the AMOC.
- **Permafrost thaw** would lead to an additional 0.13-0.27°C of global warming by 2100 bringing forward in time the impacts of warming.
- **Amazon dieback** would lead to a large release of carbon to the atmosphere resulting in about 0.3°C additional global warming. Amazon dieback may also affect circulation patterns with impacts such as a shift towards stronger and less predictable El Niño events (warmer and drier periods) and colder UK winters.
- **Boreal forest dieback** would have an unknown net effect of the UK due to competing carbon-sink loss (causing warming effects) vs albedo increase (reflecting more solar radiation back to space causing cooling effects).
- **Jet stream changes** which could happen as a result of arctic sea ice loss, AMOC collapse, destabilisation due to warming, or other mechanisms could result in more blocking patterns which would lead to an increased probability of UK extremes. The unprecedented rain experienced in the UK at the start of 2026, and the UK summer heatwaves of 2026, are examples of these blocking events. These are driven by shifts of the jet stream leading to a "blocked" weather pattern.

Further to this, a study published in early 2026 (Ripple et al., 2026[22]) argues that Earth system components could be at a higher risk than we think of reaching crucial tipping points. If this is the case, the study suggests irreversible destabilisation that would send our planet on a "hothouse Earth" trajectory. The paper defines this as a scenario in which long-term temperatures are about 5°C higher than pre-industrial temperatures.

The above shows that tipping points are a crucial piece of the picture when considering the impacts of climate change, and their lack of consideration in mainstream analysis may be leading governments to underestimate the problems facing the planet. Even without their consideration there are concerns that societies are ill-prepared to counteract the damages caused at lower levels of warming.

A closer look at the UK

It can be hard to put these figures into context on a more granular level, but Green Futures Solutions have modelled some of the more specific impacts that might be observed in the UK as a result of various hazards. These hazards have been considered through two distinct channels:

[22] https://www.cell.com/one-earth/fulltext/S2590-3322(25)00391-4?_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS2590332225003914%3Fshowall%3Dtrue

- Chronic physical risk effects characterised by more gradual, long-term shifts such as rising sea levels
- Acute physical risk effects characterised by rapid-onset high-intensity events (such as more frequent and intense heatwaves).

As the planet warms, both effects will increase, as the probability distributions of extreme events shift and morph due to changes in temperatures. This is best visualised below, which shows changes in temperature distributions as the mean and variance of global temperatures change:

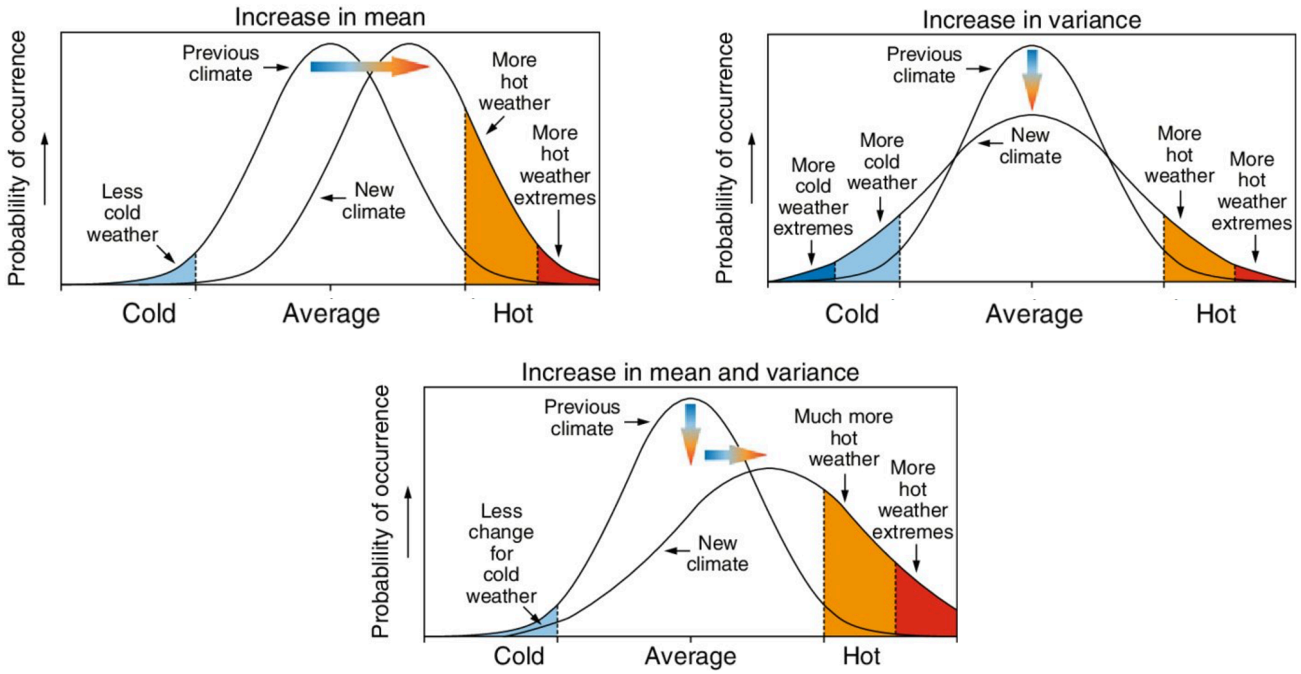


Figure 5 Potential changes in temperature distributions between present and future climate and their effects on extreme values of distributions (Source: Green Futures Solutions)

To put this analysis into context Green Futures Solutions have considered how this has been explored by NGFS. In 2025, NGFS released the latest phase of their climate scenarios (phase V). This set of scenarios incorporated the Kotz et al. (2024) damage function discussed above. They have implemented acute risks stochastically and modelled chronic risks as fixed supply and demand shocks that have been calibrated to match the damage function. The chart below shows the projected losses under current policies, versus a counterfactual no-climate-change benchmark:

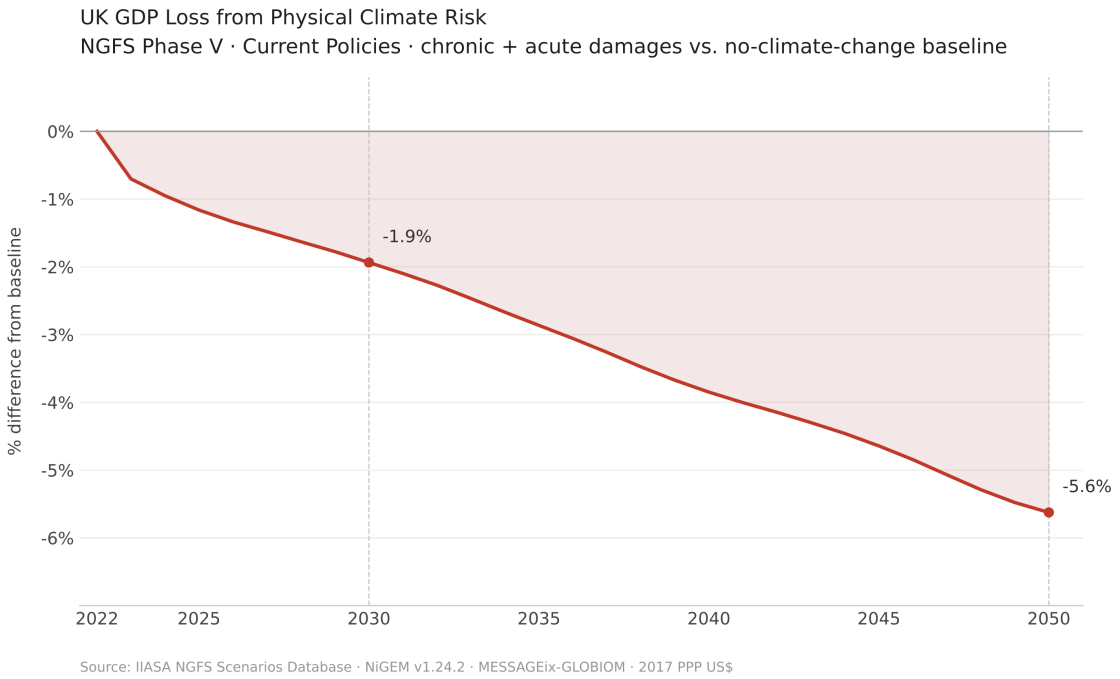


Figure 6 UK GDP loss from Physical Climate Risk under NGFS Phase V (Current Policies)

This demonstrates just one possible scenario and trajectory that physical risks may materialise. Whilst there have been probabilistic elements to the modelling, we believe it is important to consider a range of outcomes to give a clearer view of how these risks could impact the UK and to try and consider some of the compounding effects of chronic and acute effects. NGFS itself acknowledges that the compounding of risks (both physical and transition) may produce more severe outcomes than any individual scenario captures.

For analysis in this report, Green Futures Solutions drew on emerging Earth system and damage function research to construct upper-bound physical risk estimates for the UK economy that better reflect the conditions under which financial institutions may actually be stress-tested in the coming decade.

For this analysis the UK was split into 1km^2 grid cells and integrated infrastructure vulnerabilities and building loss estimates to get a realistic estimate of potential economic losses that could be observed in the UK under various hazards. A few hazards have been modelled given their specific relevance to the UK at higher levels of warming. These include coastal flooding, river flooding, wildfires, heat stress (the physiological strain on humans, livestock, and crops when temperature and humidity exceed the body's or organism's capacity to thermoregulate), and drought. In similar grid cells, GDP attribution data was used to give estimates for GDP contribution by location. Damages are then applied to the GDP contribution within a grid cell.

The approach considered annual UK GDP damage estimates using both median (1 in 2) and 90th percentile (1 in 10) exceedance probabilities at critical levels of global warming. By considering impacts at different levels of warming, the analysis is detached from a specific trajectory to create

a less selective risk assessment. As we have discussed earlier, these levels of warming are imminent for 1.5°C and likely by 2050 for 2°C.

We also believe this approach gives a clearer picture of the range of impacts and the consideration of extremes is necessary given the discussion above on means and variance. It is also worth noting that this modelling is still unable to consider the impacts of compounding hazards, and the UK faces multiple concurrent climate hazards. In practice annual impacts will frequently outpace the median, therefore the 90th percentile estimates provide a better basis for stress testing than the median alone.

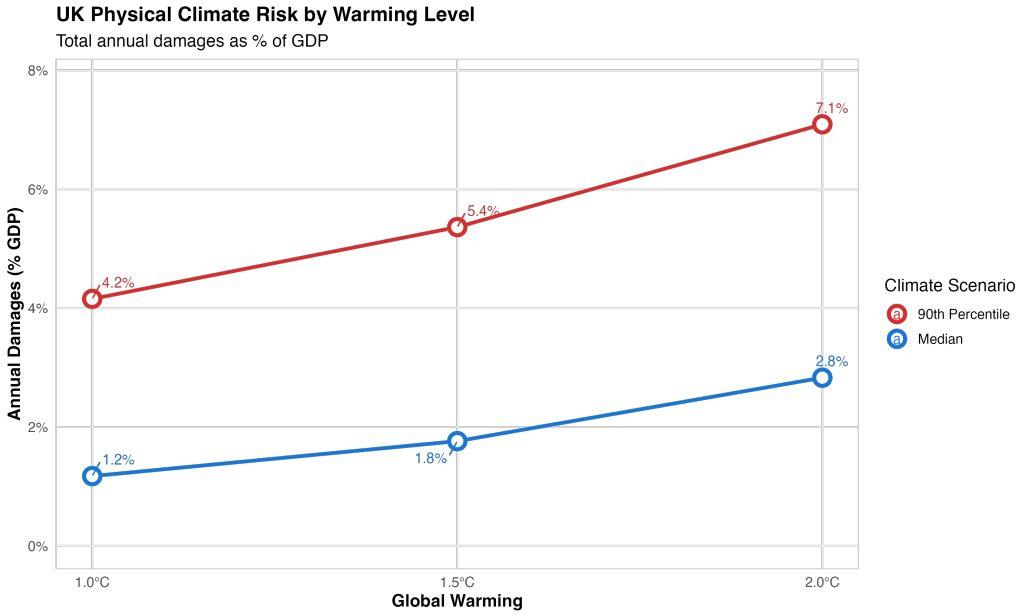


Figure 7 UK physical climate risk by warming level (Source: Green Futures Solutions)

The damages at 1°C are broadly the levels of damage that have been observed due to warming over the last decade. Green Futures Solutions notes this is supported by research from LSE's Grantham Research Institute in 2022 that calculated that the cost of climate change damages was currently 1.1% of UK GDP for any given year, reaching 3.3% by 2050 (~2°C) and 7.4% by 2100[23]. The results show that the median "expected" damages rise moderately, however the tails – and associated tail damages – become significantly heavier with rising global mean temperature.

Given the focus on shorter term timeframes, we have not included the consideration of tipping points in these assessments. Although some tipping point thresholds, such as warm water coral reef die-off may be crossed soon (or may have already been crossed), the effects of these are more locally concentrated. Not many scientific estimates indicate that large global scale tipping points, such as AMOC collapse and Amazon dieback, will be crossed in the next 10 years (although there is significant uncertainty surrounding tipping points).

[23] https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2022/05/Climate-costs-UK-policy-brief.pdf

Some estimates point to AMOC tipping as soon as the middle of the 21st century, which would be applicable for this analysis. As mentioned above, more research is needed in this area in order to be incorporated in risk assessments. If tipping points were to be crossed as we approach 2°C (which some studies suggest is plausible – see Figure 3), there is the potential for these impacts to be much greater, as shown in Figure 4.

A closer look at the East of England

In section 1.2, we discussed the importance of considering the tail of damages for stress testing, however we recognise that this figure may overestimate damage for the whole of the UK as it sums the upper tail of each hazard independently. However, many of the impacts modelled are positively correlated – for example, hot, dry summers drive drought, heat mortality, wildfire and infrastructure stress in tandem. When considering physical impacts at different points across the UK, it is worth considering how different parts of the UK may be disproportionately exposed to the clustering risks of multiple hazards and impacts.

The map below shows how different parts of the UK are exposed to multiple climate driven impacts at 2°C of warming, and how certain areas are particularly exposed to multiple compounding risks. For example, East Anglia is particularly exposed to climate hazards due to its low-lying topography that increases flood risk, and it also being one of the driest regions in the UK making it exposed to heat and drought events.

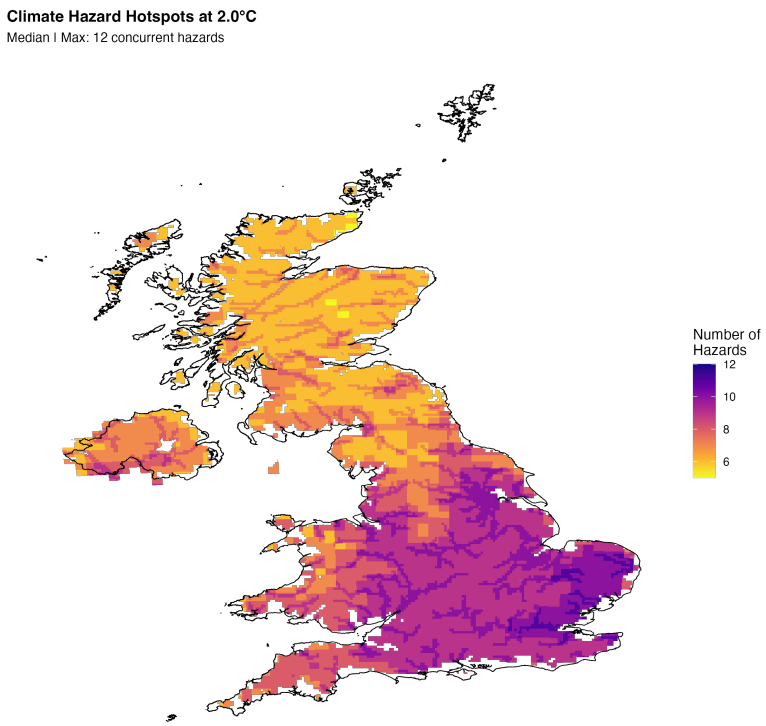


Figure 8: UK exposure to climate driven impacts at 2°C wamring relative to pre-industrial temperatues (source: Green Futures Solutions)

Some of the exposed zones in East Anglia are also home to key infrastructure such as ports (in Felixstowe) and energy infrastructure. The impact of compounding hazards in this region may have outsized impacts across the rest of the UK. Especially considering that East Anglia is one of the UK's most important agricultural regions due to its large arable farms. In 2024 East Anglia contributed the following percentages of England's crop production[24]:

- Wheat: c.28%
- Barley: c.24%
- Oilseed rape: c21%
- Sugar beet: c.64%
- Potatoes: c.33%
- Field vegetables: c.31%

Therefore, the impacts of multiple hazards in this region extend beyond infrastructure to food security, rural employment and supply chains. Investment in adaptation measures in this region would be varied with some areas explored in the table below:

Table 2: Adaptation investment examples for the East of England

Adaptation investment	Examples	Impacts
Coastal and flood protections	Maintain and upgrade coastal defences such as embankments	Provides protections for large areas of the Fens which are below sea level. May protect high-value areas
	Sustainable drainage and river management such as re-naturalising river floodplains upstream	Reduces frequency and duration of flooding caused by flat terrain being persistently flooded once it occurs.
Nature-based solutions	Coastal realignment by allowing low-value lands to flood or creating saltmarsh buffers	Reduces pressure on key areas and potential to protect under sea-level rises.
	Re-wetting of peat soils and fenland restoration	Reduces subsidence and flood vulnerability.
Infrastructure resilience	Protection of critical assets by hardening ports at Felixstowe, or flood-proofing substations	Focusing on assets of systemic importance can reduce cascading economic impacts.
	Investment in energy-water-drainage interdependencies, such as back-up power for pumping stations or decentralised energy systems	As drainage relies on power, and power relies on cooling and water, the energy supplied to these regions could be protected to avoid systemic failure risk.

[24] https://www.gov.uk/government/statistics/agricultural-facts-england-regional-profiles/agricultural-facts-east-of-england-region?utm

Adapting Adaptation to Make it More Investible

The analysis presented in this paper suggests that in addition to mitigation investments, the UK needs to prepare for increased impacts from climate hazards and invest in climate adaptation to reduce the potential impacts. We have outlined some potential avenues above, but we are aware that these opportunities may not be investible or scalable to attract significant private capital.

The UK encountered a similar problem with the advent of low carbon power infrastructure, where the government required support from the private sector to develop solar, wind, tidal and geothermal energy projects. The primary mechanism that has increased investment in renewable energy is the Government's Contracts for Difference (CfD) scheme[25].

CfD's work by guaranteeing a set price for electricity that generators of energy receive per unit of power output. As the wholesale price of electricity fluctuates, the generator is either paid a subsidy up to the set price or pays back any surplus above the set price to the scheme. This provides certainty over the price received for energy created, which incentivises generators to develop renewable electricity, and provides stable returns for investors in these projects.

The introduction of CfDs allowed for scalable investment and has significantly increased the UK's capacity of renewable energy, as demonstrated below. Renewable electricity investment rose sharply with annual real investment increasing from c.£8-10bn pre-CfD to c.£15-20bn per year in the 2020s:

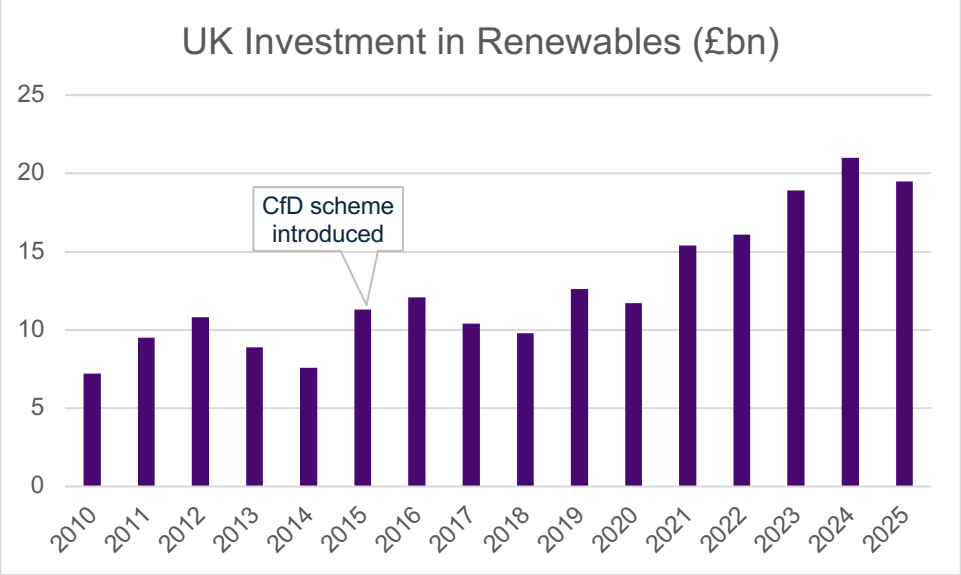


Figure 9: UK investment in renewables from 2010-2025 based on BEIS/DESNZ energy investment and energy trends data, rebased to 2024 prices with ONS CPI. 2025 data reflects provisional reporting and pipeline assumptions from DESNZ

[25] https://www.gov.uk/government/collections/contracts-for-difference

In the context of adaptation investments, there is not enough being done to appropriately incentivise investors to support any of the adaptation investments highlighted in Figure 9. This is something we believe needs to change if the UK government is seeking support from private finance. There was still a lag to increase investment in renewables following the introduction of the CfD scheme, and as discussed in Section 1, the UK will not be able to wait 10 years before it's starts to feel the impacts of climate change, in fact we are already feeling those impacts in a tangible way.

A comparable adaptation CfD scheme, may be linked to avoided damages, wherein investors into adaptation schemes are rewarded for mitigating damages to key infrastructure on an ongoing basis.

Rebalance Earth is a natural capital asset manager that invests in the restoration of landscapes and seascapes that build natural resilience to hazards. They define nature as an infrastructure asset which should be maintained so that it can continue to provide services to the economy. This is one such manager seeking to make adaptation more investible.

In a recent letter to Defra, the EA and HMT, Rebalance Earth set out how nature-based solutions could be scaled to build flood and drought resilience across the UK. We are supportive of the suggested Outcome Purchase Agreements (OPA's) that could be introduced by government to incentivise investment into nature-based solutions.

The OPA would work similarly to a CfD, but instead of being indexed to an electricity price, they would be indexed to a measurable risk or loss metric. This may be based in expected annual damages from flooding, heat-related mortality or hospital admissions, infrastructure downtime hours or insurance losses/uninsured losses.

There are existing, comparable instruments to OPA's that operate in a similar way to finance aspects of resilience in insurance markets. Catastrophe bonds, and broader insurance-linked securities (ILS), are risk-linked securities that insurers/reinsurers use to transfer the risk of natural disasters to investors. Investors receive a premium for taking on the risk of catastrophes, and risk losing capital if specific natural disasters occur. The difference for OPAs is that they would seek to incentivise risk reduction, rather than creating incentives for bearing the risk.

The government would be required to set counterfactuals for a baseline risk trajectory, not dissimilar to vaccination programmes, existing flood defences and national security. Then contracts could be auctioned where an acceptable strike outcome level is achieved for developers/investors. If realised outcomes are then worse than the strike, then there would be no payment to holders of the agreements. If outcomes are better, then the government would pay the difference, up to the strike price.

Agreements for 15-20 years would incentivise investors to maintain adaptation investments and provide continuous resilience in the face of increasing hazards across the UK. The government benefits via reduced disaster relief and lesser infrastructure repair.

There are other measures outlined by Rebalance Earth which we also believe could greatly support the widespread adoption of adaptation investment. These include:

- Water utility reform which would see the introduction of a capital value model that enables nature-based infrastructure to enter utility investment pipelines (instead of just pipes and treatment plants)
- Resilient housing & planning that embeds natural flood management as a core planning requirement for new builds. Reduced flood risk now would be cheaper than retrofitting later. This could be linked to lower insurance premiums and better mortgage terms.
- Similar to the Outcome Purchase Agreements, a UK corporate resilience buyers market could allow businesses to pay for verified resilience outcomes and better protect their operations from natural disasters. Resilience credits could be blended with biodiversity and carbon co-benefits.

We note there is significant need for cross-industry collaboration given the broad dependencies that all businesses have on nature. We believe policy intervention is crucial to facilitate this collaboration.

We recognise initiatives such as the Big Nature Impact Fund, that has received a cornerstone investment from Defra[26], serve as important catalysts to facilitate increased investment in nature based solutions. However, this does not focus on the need for adaptation nor is it made for the institutional scale of asset owners such as DC Master Trusts.

If adaptation investments became scalable then they would be well suited for long-term investment portfolios. In the same way that many pension schemes now house renewable infrastructure within their portfolios, allocations to adaptation could help to reduce the impacts that nations are already seeing from climate change, and protect against some of the further impacts that are still to come.

[26] https://finance.earth/wp-content/uploads/2026/05/UK-BNIF-First-Close-Press-Release_FINAL.pdf

Conclusions

The analysis presented in this paper has highlighted that we are already facing the impacts of climate change, and steady changes in our weather systems are likely to precede more shock events in the coming years. If current emissions trajectories continue, the UK is likely to encounter increasingly severe events as a result of global warming. The country is not prepared for this in a variety of ways.

The scale of the problem is not fully understood, and it is unclear how increasing tail events, including climate driven extremes and climate tipping points, could change our Earth's systems for the worse. This may be even more disastrous if our planet is more sensitive to emissions than previously thought. Literature is limited and sometimes contradictory. We encourage further research in these areas, including targeted impact assessments, fostered by governments and financial services.

The UK is not investing at a large enough scale to protect its infrastructure. Signatories of the Mansion House Accord are committed to investing in the UK, but that does not necessarily include investing in adaptation measures for existing UK assets. If the impacts of climate hazards are to be believed, asset owners should seek to get ahead of this and invest in resilience as well as new transition opportunities. Part of the commitments of the Mansion House Accord could facilitate this.

The UK also does not have the framework to facilitate these investments at the scale and pace that is required. This is a national problem, that requires government intervention and guidance to direct private sector cashflow where it is needed. Investments in adaptation could be better rewarded in the same way that renewable investment has been previously. Further investment could be facilitated with additional opportunities like the Big Nature Impact Fund that are created for DC investment at scale. With more of these measures, Trustees will be more able to take action to protect against the physical risks of climate change, and, aligned with their fiduciary duty, invest to protect the world that pension scheme members will retire into.

With clearer research, financial commitments and policy frameworks, we believe the UK can better prepare for the physical impacts of climate change that are beginning to materialise.

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