Institute and Faculty of Actuaries

Examining the impact of today's challenges on longevity

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# Longevity Bulletin

## Issue 17: The climate change issue



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# Contents

# Introduction by the Editor

Before introducing the theme of this *Longevity Bulletin*, I would like to take a moment to thank Matthew Edwards for his stewardship of this publication over many years and all the hard work that this entailed.

Turning to the current issue, the effects of the changing global climate are becoming increasingly obvious, with more frequent extreme weather driving worrying news headlines covering floods and storms, droughts and wildfires, and mounting evidence of melting ice caps and glaciers. On a more mundane level, European holiday bookings are shifting away from the traditional month of August, as beachgoers seek to avoid the worst of the intensifying summer heat.

In financial terms, a greater degree of focus has thus far been placed on modelling the consequences of climate change for investment portfolios and operational resiliency. For general (P&C) insurance, there has been a related effort to understand the potential losses from extreme weather and associated events such as drought and floods. By contrast, for pensions - as well as both life and health insurance - there has been less focus on the liability side of the balance sheet, despite the potentially profound impacts that climate change could have on future mortality and morbidity.

Now, with growing regulatory scrutiny and increasing demand, attention is rightly turning to understanding the implications of climate change in this context. Actuaries have much to contribute in this area, working together with other experts to synthesise a broad array of data sources and insight. By integrating climatological, epidemiological, and demographic knowledge, sophisticated models reflecting the environmental, social, and biological variables impacted by climate change that will influence mortality can be constructed.

This is a crucial area, because the consequences of climate change often emerge over extended time horizons, necessitating a long-term outlook. Scenario analysis - involving various emissions trajectories, environmental changes, and broader food supply and adaptation considerations - can help stakeholders to appreciate the potential scope of future risks, and hence develop effective mitigation strategies.

This edition of the *Longevity Bulletin* illustrates the breadth and sophistication of actuarial engagement with climate change and longevity. Maynard Kuona and Sophie Gong discuss how changing temperatures can affect mortality. Steven Baxter and Jill Jamieson demonstrate how scenario modelling can be an effective tool to explore broader impacts and implications of climate change beyond temperature, and Scott Hamilton and Richard Marshall explain how comprehensive climate-driven scenarios can best be constructed. Importantly, we also include a wider contextual view highlighting the necessity for collaboration between experts across a range of disciplines, with Esther McNamara and Sage Jeffries showcasing the International Longevity Centre's Global Healthy Ageing and Prevention Index.

Finally, as the Climate Scorpion group reminds us, not all climate-related risks are immediate or obviously evident. Secondary consequences, such as migration due to resource scarcity, economic disruption and social instability, can all influence mortality patterns too. Adopting a holistic systems-based approach, mapping the causal pathways that link climate variables to demographic shifts and, ultimately, to the health and mortality outcomes relevant to insurance and pension provision is therefore crucial in capturing all the complex interactions at play.

I hope that the articles in this edition of the *Longevity Bulletin* will spark new ideas and fresh thinking amongst the longevity community, leading to a better understanding of the implications of climate change for future mortality outcomes.

**Michael Anderson**
Editor

# Foreword by the President of the IFoA

Climate change represents a unique challenge to our society, our financial systems, and the global economy. Evidence of how the global climate is changing at an unprecedented rate is clear, as is the increasing frequency with which extreme weather-related events appear in the news. It is therefore becoming ever more important to understand properly the ramifications of climate change, in order to support robust risk management in the face of this far-reaching and fast-moving phenomenon.

This need may be easy to see, but modelling the impact of climate change is hard. It requires working with large amounts of data to understand and quantify the dynamics of complex systems with feedback loops that magnify effects in non-linear ways. The rapid nature of the change we are experiencing, as well as the fact that global average temperatures are on a trajectory to levels that humanity has not yet experienced, means that significant expert judgement will be required. Past data, no matter how plentiful, will not necessarily be a reliable guide to the future. What is more, clear communication of the technical topics involved, as well as useful, actionable and modelling-based advice is required if the effort is to have any value.

Actuaries have much to offer in all these areas: modelling complex systems based on large quantities of imperfect data is just the sort of problem that that we are good at. Taking a long-term view, looking past short-term noise and deeply understanding the true nature of risks is fundamental to our approach, and clearly communicating technical topics is something of a speciality in traditional actuarial roles. Not only do actuaries have these important skills to offer, but most importantly we bring with them a highly regarded professionalism. We have a code of ethical conduct which we must follow, and we are required to act in the public interest. In a field which can sometimes become contentious, even slightly fraught, perhaps actuaries can bring our trustworthiness to the table to help inspire the confidence in the analysis that is needed if we are to find an effective way forward.

Whilst actuaries have an obligation to contribute towards helping meet the challenges of this growing crisis, climate change also presents us with a unique opportunity to take a leading role in an important new area of work for the profession. I hope that the articles in this edition of the *Longevity Bulletin* will stimulate new thinking on this important topic. Projecting future mortality outcomes is something that our profession has been doing for centuries, and is one of our most recognised areas of expertise. We can, and indeed should, remain at the forefront of innovation in this area, bringing our skills to bear to improve understanding of the relationship between climate change and mortality, and what this means for life insurance, pensions, investment, and broader sustainability issues. We have the technical ability, we have the communication skills, and we have the professional oversight that means people can rely on what we say.

I look forward to the exciting, impactful developments that will no doubt follow as actuaries increasingly turn to focus on meeting this important challenge.

**Paul Sweeting**
President, Institute and Faculty of Actuaries

# Life expectancy along the climate pathway: modelling mortality in a warming world

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## Introduction

As global average temperatures continue to increase, life insurers will need to consider if, when, and how this could affect life expectancies, and how annuity liabilities may shift in response. This article examines how the impacts of climate change-driven temperature variations on mortality risk can be modelled for the UK population.

In published climate change pathway data available from institutions such as the Intergovernmental Panel on Climate Change (IPCC) (2025) and World Bank (Climate Change Knowledge Portal (CCKP), 2025), the UK is projected to experience a continuing increase in average temperatures until at least 2100. Based on Met Office weather station data, there has also already been broadly a 1°C increase in average temperatures in the UK over the period of 1981–2020 (Met Office, 2025).

Extremely hot and cold days both give rise to 'excess deaths'[1], with cold days historically resulting in significantly more 'excess deaths' in the UK than hot days, driven by the relative frequency of such days in the UK. To understand how annuitant longevity may change over the expected lifetime of a typical annuity portfolio that includes deferred annuities (e.g., over the next 80 years or so) as a result of changes in temperature, we must not only understand how mortality is impacted by temperature, but also how both average temperatures and the distribution of extreme temperature days could themselves change over time.

Using historical UK mortality and weather data, with a relative risk model based on that published by Hajat et al. (2014) and then expanded by Gasparrini et al. (2015), we can isolate the temperature-driven component of mortality risk. We can then investigate how mortality rates interact with ambient temperatures by both age band and region under various climate scenarios, and hence project life expectancies by age band, time period, and climate scenario.

With this model we can also explore the potential impacts of climate change mitigation measures, such as government policy, which seek to reduce temperature-related mortality risk.

A key conclusion from this analysis is that the expected reduction in mortality rates due to the projected decrease in the number of cold days will likely have a greater overall impact on mortality – particularly for the over 50s – than the projected increase in mortality from more frequent hotter days. We might expect, therefore, that climate-driven temperature increases alone – excluding other climate change risks and governmental mitigation measures – could potentially have a beneficial (although minimal) impact on the life expectancy of over-50s in the UK.

To develop this model further – and to take the broader view discussed by Jill Jamieson and Steven Baxter elsewhere within this *Bulletin* – other physical factors such as air quality, extreme weather events, and food shortages could also be incorporated (along with their various interdependencies). Further development of and allowance for non-physical risk elements – such as additional nuances around mitigation measures and governmental/industrial policy – would allow for even more flexibility and sophistication in the model.

Note that this analysis was originally performed in 2020–21, and has not been updated since (e.g., to allow for newer/more recent data). Indeed, the data used in respect of mortality improvements, deaths, and weather has been curtailed to around 2019–20.

1 | 'Excess deaths' refer to the number of deaths that occur above and beyond what would be expected based on historical data and trends.

## The relative risk model

After considering the approaches by Seklecka et al. (2017) and Hanewald (2011), it was determined that the relative risk model proposed by Hajat et al. (2014) and then expanded by Gasparrini et al. (2015) would be most appropriate for the analysis we intended to carry out. Gasparrini et al. looked in their analysis at the relative mortality risk according to ambient daily temperatures for various regions in the world, and also released an R package alongside Vicedo-Cabrera et al. (2019) to allow for the calibration of such models. Note that the Gasparrini approach models the immediate response to temperature changes, along with a lagged response where the impact of temperature on mortality is modelled for up to 21 days after the event of interest. In our modelling, however, we look only at the immediate mortality response, as the lagged relative risk falls away quickly.

The daily average temperature for any given day is calculated as the mid-point between the maximum and minimum temperatures recorded/observed on that day. The minimum mortality temperature (MMT) is defined as the temperature corresponding to the lowest observed levels of mortality, measured using daily data. Relative risk at a given age $x$ and given temperature $\theta$ – $RR_x(\theta)$ – is defined as a ratio of mortality rates (for age $x$) at temperature $\theta$, compared with those at the MMT. Therefore, $RR_x(\theta)$ represents the proportionate increase in mortality rates at age $x$ due to the difference between the MMT and $\theta$. Where $\theta$ equals the MMT, the $RR_x(\theta)$ – i.e., $RR_x(MMT)$ – therefore equals 100%, as can be seen in *Figure 1.*

Across England and Wales, our analysis of weather and death data indicated that the MMT was c.17°C. For a particular climate scenario, the average relative risk a given age $x$ in a given year $t$ can be defined as:

$$RR_{x,t} := \frac{1}{n_t}\sum_{\theta} n_{t,\theta} RR_x(\theta)$$

where:

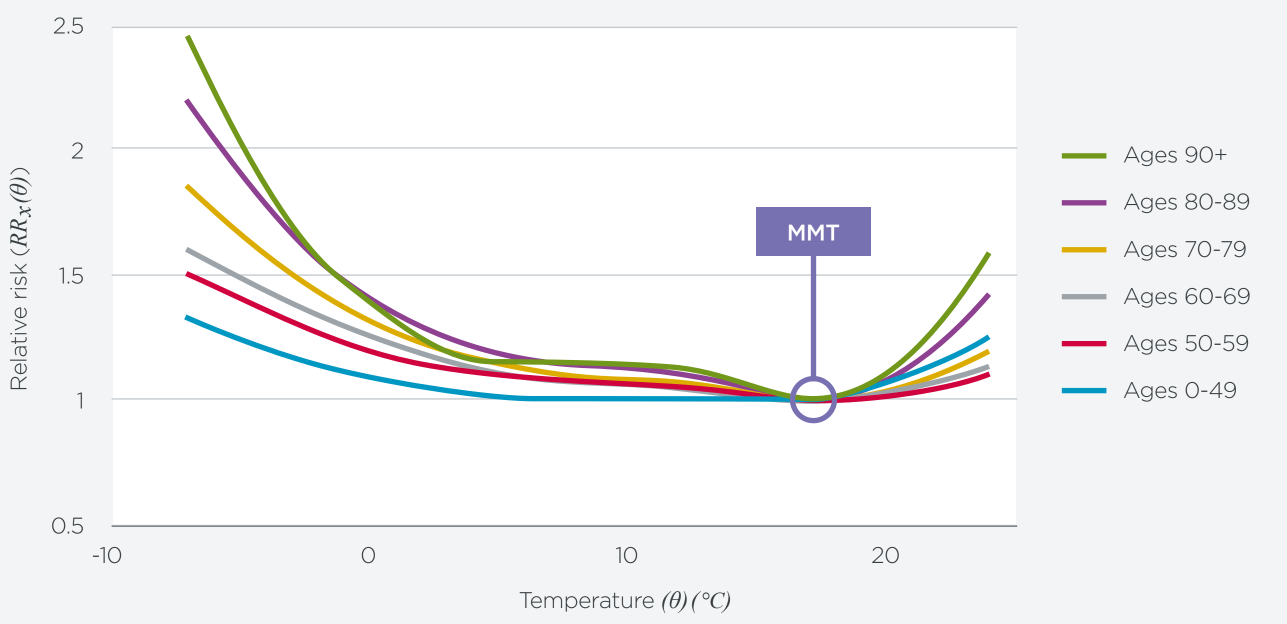
$RR_x(\theta)$ is the relative risk at age $x$ and given temperature $\theta$, i.e., a ratio reflecting the impact on mortality rates at age $x$, given that the average daily temperature is $\theta$;

$n_{t,\theta}$ is the number of days with daily mean temperature $\theta$ in the year $t$; and

$n_t$ is the total number of days in year $t$.

The MMT for individual regions and age groups can be identified or observed on the basis of historical weather and mortality data. As the temperature deviates from the MMT, the relative risk curves (and therefore mortality rates) increase in both directions/at both ends. The proportionate change in mortality rates compared to rates at the MMT is the relative risk of that age group and temperature, where the $RR_x(\theta)$ at the MMT – i.e., $RR_x(MMT)$ – is taken to be 1.

***Figure 1:*** **Relative risk by age (based on national England and Wales data)**



Thus, a relative risk curve for an age group and region can be constructed using historical data between (for example, and in this case) 1981 and 2019. It is assumed that the relative risk curve for an age group is invariant over time within that age group, as is largely supported by our analysis of the historical data.

We observe from the fitted relative risk curves that the relative mortality risks at extreme temperatures increase more rapidly at older ages than at younger ages, which is as expected. For all ages, mortality increases most rapidly above 20°C and below 5°C.

Once the choice of base scenario is made (which in this case was Shared Socioeconomic Pathway 2 (SSP2) - see CCKP, 2025), and the relative risk curve is established for each age group, it is then possible to derive life expectancies for both the base as well as for a range of climate scenarios. In each scenario, the total expected deaths at age $x$ during time period $t$ $(D_{x,t})$ are calculated as the number of expected deaths at the MMT for that age and period $(D^{BM}_{x,t})$, plus the 'excess' expected deaths related to temperature $(D^{\theta}_{x,t})$ for that age and period. This is equivalent to the product of the corresponding (central) exposed to risk $(E^{c}_{x,t})$, the base mortality rate at the MMT $(BM_{x,t})$, and the relative risk of mortality for that age and time $(RR_{x,t})$. The force of mortality can then be calculated as $BM_{x,t}$ multiplied by $RR_{x,t}$:

$$D_{x,t} = D^{BM}_{x,t} + D^{\theta}_{x,t} = E^{c}_{x,t} BM_{x,t} RR_{x,t}$$

The relative risk is conditional on the climate scenario under consideration. Suppose we consider a comparison with an alternative stressed climate scenario with corresponding relative risk curve $RR^{*}_{x,t}$. Projections of the relative risk $(RR_{x,t})$ by age and year under different climate scenarios are therefore generated – as well as of $p_{x,t}$ (i.e., probability of survival to time $t$ of a life now aged $x$) – under the base scenario. Life expectancy is then calculated based on these projected mortality rates, and the results (shown in *Table 1)* are a projection of these by age and time, and per climate scenario modelled.

## Relative risk calibration

Since both mortality rates and weather vary by locale, regional death and weather data are therefore needed to determine the relative risk curve for each age band across different temperature ranges. In the United Kingdom, mortality statistics for England and Wales are compiled by the Office for National Statistics, whilst separate statistical authorities – i.e., the National Records of Scotland, and the Northern Ireland Statistics and Research Agency – gather data for Scotland and Northern Ireland, respectively. For this investigation we chose to focus on England and Wales, simply to reduce the complexity of, and additional complications arising from, combining data from multiple sources. The data used covered the period 1970 to 2020, and was only available grouped by age. We chose to further group data into larger, 10-year age bands to ensure that there is sufficient data within each band for a robust calibration. The 10-year age bands begin at 50, with the final age band including all deaths above the age of 90 inclusive. As death data containing both timing and cause of death was not available, all-cause mortality data was used instead. As such, there is a degree of 'noise' in the data, due to the inclusion of deaths that are not expected to be related to temperature (e.g., those due to accidents). Ideally, the analysis would only include deaths that are clearly temperature-related. This, however, would rely on the availability of death data by both cause and timing, and also for judgement to be applied as to whether certain causes of death are temperature-related or not.

The mortality dataset is split by sex, so it was possible to examine whether there is any significant variation in the relative risk exposure between males and females. Whilst the analysis showed that there is a small deviation between sexes in the temperature extremes (where females are more susceptible to extreme cold and heat in the 50–89 age group), the differences were deemed overall insufficient to warrant modelling distinct temperature effects by sex.

Historical temperature data was gathered from the 21 British Atmospheric Data Centre (BADC) weather stations located across England and Wales. On days where weather was particularly localised to an individual weather station area, an average across that area was taken. Average daily temperatures were calculated as the mid-point between the maximum and minimum temperatures recorded in that location on that day.

Socioeconomic data were gathered to explore whether temperature-related mortality differed for different socioeconomic groups, with the Index of Multiple Deprivation (IMD) used as a proxy for socioeconomic status (ONS, 2022). We combined IMD deciles 1–4, 5–7, and 8–10 to represent 'Low', 'Medium', and 'High' socioeconomic groups, respectively, and found that IMD decile groupings had no material impact on the resulting relative rsk curves. We did observe, however, that lower-IMD populations had the flattest relative risk curves at lower temperatures, meaning that these groups' mortality was less sensitive to colder days. Our initial hypothesis, however, was that higher socioeconomic groups would have the flattest relative risk curves, given their increased access to resources (e.g., heating and air-conditioning) which can reduce the temperature-sensitivity of mortality rates. However, we also expect this to be confounded with other effects – in particular, differences in the distribution of ages within each IMD decile. To explore the socioeconomic impact more granularly, smaller age bands could be used together with IMD deciles to remove this potential age effect and isolate the 'true' socioeconomic effects, although this would also of course be subject to the relevant data being available.

## Temperature projection

Alongside historical weather data, projections of the distribution of extreme temperatures – both in time and location – are required to model future temperature-driven changes in mortality. For the relative risk framework developed so far within this example, the desired input is a series of average daily temperatures covering the next c.80 years under each climate scenario, which can then be used to calculate the relative risk under each pathway.

The World Bank publishes – via the Intergovernmental Panel on Climate Change – various data, including country-specific average temperatures, numbers of frost/summer days, and Shared Socioeconomic Pathways (SSPs), which represent future climate scenarios (CCKP, 2025). They explore how socioeconomic factors may change between now and 2100, including a consideration of factors such as population, economic growth, education, urbanisation, and the rate of technological development. The pathways represent a range of potential futures absent of (governmental or industrial) climate policy, with varying intensities of emission reductions and temperature shifts. The World Bank/IPCC SSP climate scenarios categorise possible future outcomes using the following temperature projections, expressed in terms of degrees of warming compared to pre-industrial temperatures:

| | |
|---|---|
| **SSP1–1.9:** | +1.5°C by 2050 |
| **SSP1–2.6:** | +1.8°C by 2100 |
| **SSP2–4.5:** | +2.7°C by 2100 |
| **SSP3–7.0:** | +3.6°C by 2100 |
| **SSP5–8.5:** | +4.4°C by 2100 |

The World Bank data used for this analysis is country-specific – meaning that this investigation can be replicated internationally – and the data is accessible via a Creative Commons Attribution license.

We considered the following approaches for estimating future temperature distributions:

1. Rolling forward the temperature distributions in historic years along a mean temperature increase pathway, whilst keeping their underlying distribution shapes unchanged
2. Further modifying the distributions achieved in (1) to reflect changes in the expected number of days at each average temperature
3. Using the output of a climate model to generate daily future temperatures.

We chose to use the second approach with World Bank projections as a starting point, since the first approach would not capture changes in extreme temperature distributions along climate pathways (which would lead to unrealistic outcomes), and building a climate projection model was considered too onerous for this analysis. As the analysis was completed in 2020–21, temperature distributions from 2019 were used as a starting point, and extended along mean temperature climate pathways; the shape of the temperature curve of an average year was kept consistent, but shifted upwards each year as projected average temperatures increased over time. As climate change progresses, it's clear that not only will mean temperatures change, but that the distributions of daily temperatures themselves will also shift, which is relevant for mortality projections. Thus, the daily temperature distributions were adjusted as follows, to both align with the World Bank projections of extreme cold and hot days whilst maintaining the projected mean temperatures:

- Temperatures above the projected mean temperatures are scaled using the 'hot days coefficient'
- Temperatures below the projected mean temperatures are scaled using the 'cold days coefficient
- An additional, overall adjustment is then applied to the resulting scaled temperature distributions, in order to maintain mean temperatures in line with the World Bank projections.

The 'hot days' and 'cold days' coefficients are scaling parameters that are applied to the temperature distributions both above and below the projected mean temperatures, so as to adjust the shape of the distributions to ensure that the temperature extremes in the World Bank projections are captured in the adjusted distributions.

The output of this analysis is thus a set of temperature distribution projections along each climate pathway. Each individual temperature distribution projection is then used to adjust the mortality rates within each projection year, in line with changes in the relative risks due to the projected temperature changes.

## Mitigation measures

We could reasonably expect that the UK government may take policy decisions which could reduce mortality risk associated with temperature changes – in particular, to address any extremes that might occur. Our model, therefore, incorporates a means of adjusting the relative risk curves by a constant proportion, to reflect the impact of such policy changes. We have also embedded some flexibility within the model, whereby the relative risk can be assumed to be modified by a percentage of the full relative risk either below (a 'cold adaptation') or above (a 'heat adaptation') the MMT (or both). The approach we have taken to modelling mitigation factors is flexible in that it assumes that the impact of mitigation effects can be estimated independently of the temperature model itself. Nuance in the effect of mitigation measures can be reflected by incorporating the impacts of time, age, and temperature (either above or below the MMT) into the relationship which defines the allowance for the mitigation effects within (i.e., the flattening of) the relative risk curves.

## Results

To generate our resulting sample life expectancies, we have used a sample mortality base table comprising UK industry standard CMI SAPS S3PxA tables, combined with mortality improvements in line with the Core CMI_2020 model (with a 1.5% p.a. long-term rate of improvement) for both males and females as the base scenario.[2]

Results were determined for multiple age groups, and a sample of these is presented in *Table 1*, which compares future life expectancies under opposite ends of the IPCC's climate scenario range, as well as a bespoke climate scenario that is broadly equivalent to SSP5-8.5. We will further explore mitigation impacts on this bespoke scenario later in this article.

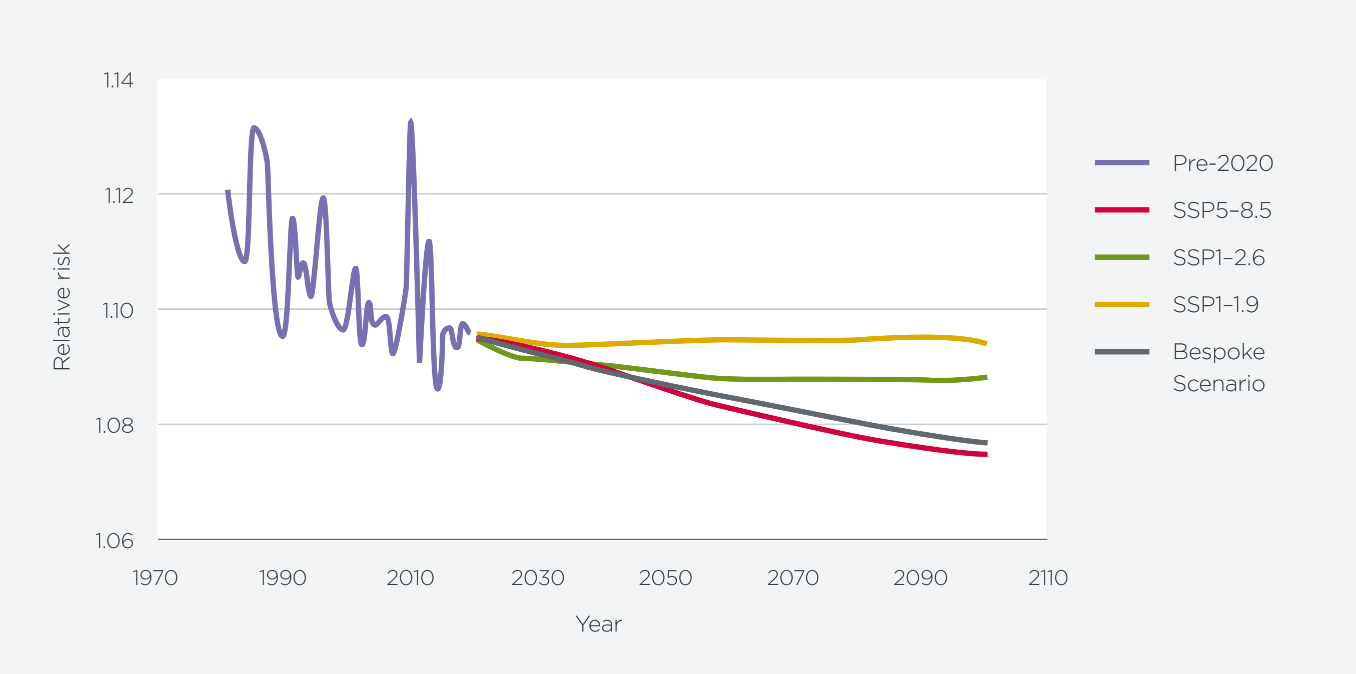
Overall, we see very small differences in projected future life expectancies across each of these scenarios. The increased risk associated with more hot days is much smaller than the impact of fewer cold days; so, while these forces work in opposite directions, it is in fact the reduction in cold days that is driving the overall change in relative risk. This can be seen by comparing the relative risk curves on the following page.

***Table 1:* Cohort life expectancies as at 2022, but with allowance for the projection of future mortality improvements beyond 2022 under each scenario**

| Male Age in 2022 | SSP5-8.5 (+4.4°C by 2100) | SSP1-2.6 (+1.8°C by 2100) | SSP1-1.9 (+1.5°C by 2050) | Bespoke Scenario (+3.9°C by 2100) | SSP1-2.6 vs SSP5-8.5 | SSP1-1.9 vs SSP5-8.5 | Bespoke Scenario vs SSP5-8.5 |
|---|---|---|---|---|---|---|---|
| 50 | 36y 7.6m | 36y 7.4m | 36y 7.0m | 36y 7.6m | -0.04% | -0.13% | 0.00% |
| 55 | 31y 7.5m | 31y 7.4m | 31y 7.0m | 31y 7.5m | -0.03% | -0.12% | 0.00% |
| 60 | 26y 10.0m | 26y 10.0m | 26y 9.6m | 26y 10.0m | -0.02% | -0.11% | 0.00% |
| 65 | 22y 1.4m | 22y 1.4m | 22y 1.2m | 22y 1.4m | -0.01% | -0.10% | 0.00% |
| 70 | 17y 7.9m | 17y 7.9m | 17y 7.7m | 17y 7.9m | 0.01% | -0.08% | 0.00% |
| 75 | 13y 6.9m | 13y 6.9m | 13y 6.8m | 13y 6.9m | 0.04% | -0.06% | 0.00% |
| 80 | 9y 10.0m | 9y 10.1m | 9y 9.9m | 9y 10.0m | 0.08% | -0.04% | 0.00% |
| 85 | 6y 8.8m | 6y 8.8m | 6y 8.7m | 6y 8.8m | 0.10% | -0.02% | 0.00% |

2 | This reflected the latest available version of the CMI Mortality Projections Model at the time our analysis was performed – i.e., during 2020-21.

***Figure 2:*** **Relative risk projection (deaths at ages 70 to 79)**




Looking further into the future when we consider deferred annuitant lives, the results and conclusions – as shown in *Table 2* – remain broadly similar:

***Table 2:*** **Cohort life expectancies as at 2040, but with allowance for the projection of future mortality improvements beyond 2040 under each scenario**

| Male Age in 2040 | SSP5-8.5 | SSP1-2.6 | SSP1-1.9 | Bespoke Scenario | SSP1-2.6 vs SSP5-8.5 | SSP1-1.9 vs SSP5-8.5 | Bespoke Scenario vs SSP5-8.5 |
|---|---|---|---|---|---|---|---|
| 60 | 28y 5.8m | 28y 5.5m | 28y 5.1m | 28y 5.8m | -0.08% | -0.21% | 0.00% |
| 65 | 23y 6.6m | 23y 6.4m | 23y 6.0m | 23y 6.6m | -0.08% | -0.22% | 0.00% |
| 70 | 18y 10.6m | 18y 10.5m | 18y 10.1m | 18y 10.6m | -0.08% | -0.24% | 0.00% |
| 75 | 14y 7.2m | 14y 7.1m | 14y 6.8m | 14y 7.2m | -0.07% | -0.25% | 0.00% |
| 80 | 10y 9.3m | 10y 9.3m | 10y 9.0m | 10y 9.3m | -0.07% | -0.25% | 0.00% |
| 85 | 7y 6.0m | 7y 6.0m | 7y 5.8m | 7y 6.0m | -0.07% | -0.24% | 0.00% |

We now consider the incorporation of mitigation measures within the bespoke scenario, which act to reduce the relative risk curve for both hot and cold temperatures by a specific percentage (as discussed). *Figure 3* on the following page compares the impact on projected deaths of relative risk multipliers of 90%, 80% and 70%, respectively (and assuming that these underlying mitigations take 10 years to implement).

***Figure 3:*** **Relative risk projection (deaths at ages 70 to 79, with adaptation)**

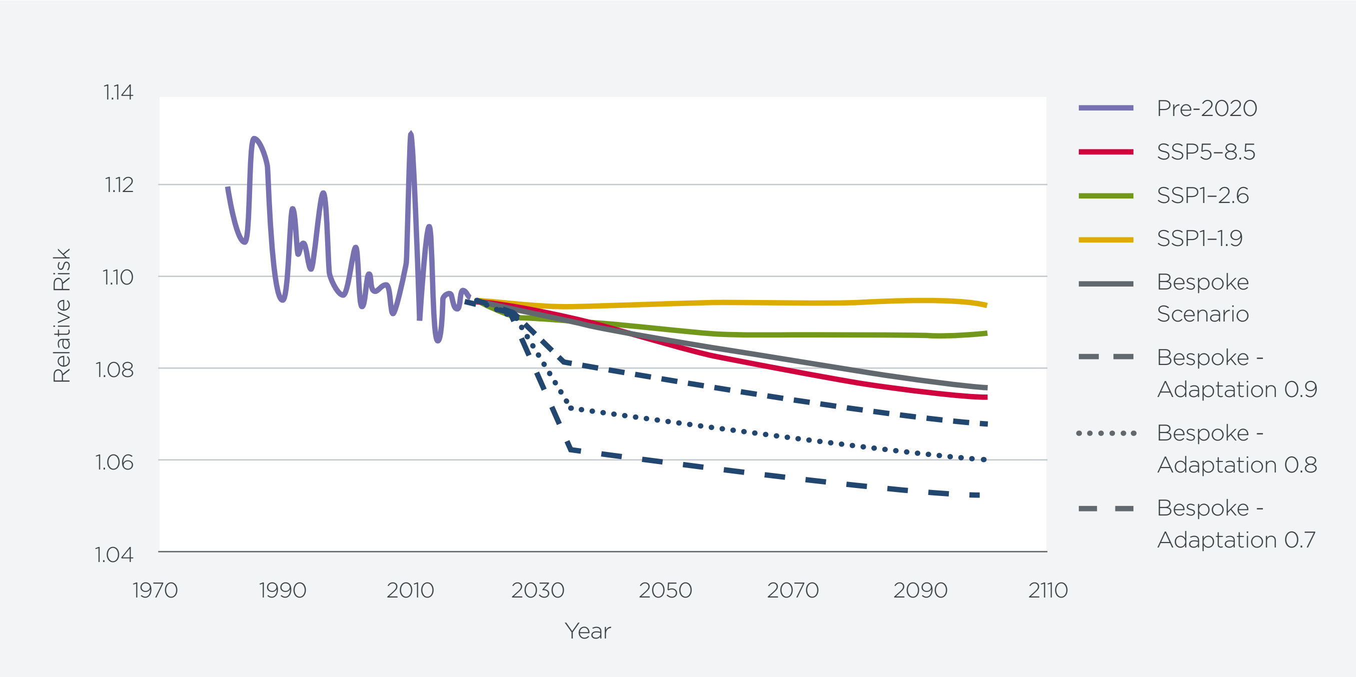



*Table 3* below shows the impact of the assumed mitigations/relative risk multiplier adaptations on future life expectancies in each scenario.

***Table 3:*** **Cohort life expectancies as at 2022, but with allowance for the projection of future mortality improvements beyond 2022 under each scenario**

| Male Age in 2022 | Bespoke Scenario | Bespoke - Adaptation 0.9 | Bespoke - Adaptation 0.8 | Bespoke - Adaptation 0.7 | Adaptation 0.9 vs Bespoke Scenario | Adaptation 0.8 vs Bespoke Scenario | Adaptation 0.7 vs Bespoke Scenario |
|---|---|---|---|---|---|---|---|
| 50 | 36y 7.6m | 36y 8.4m | 36y 9.3m | 36y 10.2m | 0.20% | 0.41% | 0.61% |
| 55 | 31y 7.5m | 31y 8.4m | 31y 9.2m | 31y 10.1m | 0.23% | 0.45% | 0.68% |
| 60 | 26y 10.0m | 26y 10.8m | 26y 11.6m | 27y 0.5m | 0.25% | 0.51% | 0.76% |
| 65 | 22y 1.4m | 22y 2.2m | 22y 2.9m | 22y 3.6m | 0.28% | 0.56% | 0.84% |
| 70 | 17y 7.9m | 17y 8.5m | 17y 9.2m | 17y 9.8m | 0.30% | 0.60% | 0.89% |
| 75 | 13y 6.9m | 13y 7.4m | 13y 7.8m | 13y 8.3m | 0.29% | 0.59% | 0.88% |
| 80 | 9y 10.0m | 9y 10.3m | 9y 10.6m | 9y 10.9m | 0.25% | 0.50% | 0.75% |
| 85 | 6y 8.8m | 6y 8.9m | 6y 9.1m | 6y 9.2m | 0.18% | 0.35% | 0.53% |

This analysis demonstrates that temperature mitigation measures may potentially have significant impacts on future life expectancies.

In summary, for annuities in payment within current life insurance portfolios, the effects of climate change-driven changes in temperature alone are likely to be too gradual to have any noticeable impact on mortality (in the UK, at least). However, temperature mitigation measures – which may possibly only be intended to address the impacts of extreme temperature outcomes – may have a more significant impact on life expectancy.

There are, however, other non-SSP climate change scenarios which could lead to very different impacts on UK weather. For example, scenarios which include the overturning of tipping points which could plunge UK winter temperatures downwards, such as the collapse of the Atlantic Meridional Overturning Circulation (as discussed by the Climate Scorpion group elsewhere within this *Bulletin*). These scenarios were not considered within this analysis, but could be explored in a future extension of this work.

In our analysis, we have seen that where climate-driven governmental policy decisions are brought in within a relatively short time frame (i.e., within c.10 years), these have the potential to drive more impactful changes in life expectancy (alongside, of course, any other policies that may have a more direct impact). As such, whilst modelling policy effects is not straightforward, impacts from emerging non-health government policy should be considered when assessing the short to medium-term trajectory of mortality improvements (relative to current assumptions).

## Limitations and further development

Various limitations are present within our modelling due to data constraints – for example:

- The model only allows for the effects of temperature, and does not consider other physical climate risks (e.g., air quality impacts) or transition risks (e.g., economic impacts leading to changes in healthcare provision)
- England and Wales data has been used as a proxy for the UK as a whole, but temperature-related deaths in Scotland and Northern Ireland may display a different pattern of experience, and so could affect the results of/conclusions from our analysis were they to be allowed for
- All-cause mortality data was used, which will include noise from non-temperature related deaths
- 10-year age band groupings were used in the data to ensure credible model fitting; smaller age bands could be explored for more granular analysis
- Representative (localised) weather station data were used as a proxy for (larger) geographic regions
- The model only allows for mean temperature projection, and does not take into account the uncertainty in the climate projections themselves
- Temperature projections are only available to 2100.

Other limitations include:

- A simplistic and subjective approach to incorporating mitigation factors was used (in the form of a fixed percentage reduction across the relative risk curves); for further development, a more sophisticated approach could be taken to allow for these mitigations
- The use of change in life expectancies as a proxy for the impact on a life insurer's annuity liabilities (bearing in mind that, in practice, the precise business mix, financial conditions to determine the discount rate, and nature and form of any inflation-linked benefits would also have an impact on these liabilities)
- The absence of any assessment of asset impacts from climate change risks
- The adoption of a (currently) UK-specific framework, which may not be applicable for use in other countries or regions.

These all offer opportunities for further model development and refinement in future.

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# An introduction to a driver-based framework for modelling climate-related mortality and morbidity impacts

Scott Hamilton, Senior Risk Actuary at WTW
Dr Richard Marshall, Director at WTW

## Introduction

How will climate change affect general population health and mortality? What about insured populations? With increasing regulatory focus on climate change, insurers and reinsurers face such complex questions as these, spanning meteorological, medical, and behavioural sciences, which are not amenable to typical extrapolative modelling approaches. In this article, we introduce the use of driver-based modelling to relate climate scenarios to their potential morbidity and mortality effects.

Viewed simplistically, **extrapolative modelling** identifies trends in historical data and extends these to project future outcomes. However, such approaches fail to account for causes of change, and discontinuities in the relationships between those causes and the outcomes of interest. Both the direct impacts of climate change on weather patterns and extreme events, and the desire to limit any harmful effects of these, are evolving phenomena which have not materially contributed to historical changes in mortality or morbidity rates, and so extrapolation of past trends cannot hope to reflect the impact of such changes.

Contrastingly, **driver-based modelling** uses granular (ideally mechanistic) relationships between particular drivers and (often cause-specific) morbidity and mortality rates. An insightful example of the use of such links in the context of climate change is the influence of climate concerns on dietary choices: consumption of red and processed meat has been linked to increased risk of certain diseases and increased mortality risk, so a change in consumption as a result of climate change mitigation policies might be expected to influence population morbidity and mortality rates (Abete et al., 2014; Papier et al., 2021).

There are obvious challenges to using driver-based modelling to quantify the impacts of climate change – in particular, what are the drivers to model, and how do we specify the pathways for those drivers in different climate scenarios? For results to be meaningful, driver-specific scenarios which are somehow qualitatively (and ideally quantitatively) consistent with published climate scenarios must be developed.

Unless otherwise stated, references to mortality rates or death in this article are intended to be interchangeable with morbidity rates or incidence of disease, and vice versa.

## Published climate scenarios

Before one can model their impact, one has first to select suitable climate scenarios for modelling. Many scenarios are available, varying in origin, emphasis (e.g., from single climate variables to qualitative narratives), intended target audience, and purpose. Typically, scenarios are published without associated probabilities of occurrence; they are not predictions, but illustrations of potential future trajectories. Actuaries using such scenarios will need to exercise judgement to determine whether the scenarios represent best-estimate, optimistic, or pessimistic views of the future. Some of the publicly available scenarios are set out below:

**Representative Concentration Pathways (RCPs)** describe future concentrations of greenhouse gases up to the year 2100. There now exist a total of seven such scenarios: RCP1.9, RCP2.6, RCP3.4, RCP4.5, RCP6, RCP7, and RCP8.5. RCPs are now being considered in tandem with **Shared Socioeconomic Pathways (SSPs)**, which provide narratives of the extent to which both adaptation to and mitigation of climate change might occur up until the year 2100 (IPCC, 2023).

The **Network for Greening the Financial System (NGFS)** also produce their own climate scenarios (NGFS, 2024). These are characterised by potential future evolutions of 'physical' risk – i.e., climate change itself – and 'transition' risks (i.e., climate policy responses and technological trends). They include trajectories for quantities such as damages from tropical cyclones, labour productivity, unemployment rates, fossil fuel revenues, and investment in low-carbon electricity.

The **International Energy Agency (IEA)** produces scenarios (IEA, 2024) using its Global Energy and Climate (GEC) Model: the Stated Policies Scenario (STEPS), the Announced Pledges Scenario (APS), and the Net Zero Emissions by 2050 Scenario (NZE). The model covers 27 regions with 'bottom-up' modelling for energy demand, transformation, and supply, to allow for possible trajectories of the energy system to be produced.

Other institutions – such as universities, or those which are part of (or commissioned by) governments – also produce climate scenarios.

Published climate scenarios might be thought of as being either vague or specific along two dimensions: a physical dimension – relating to specific, measurable climate variables – and a social dimension (concerning sociopolitical actions which might manifest particular climate-related outcomes).

Published scenarios specify environmental, social, and/or economic measures at the macro-level, but may leave open to interpretation the specifics about how the trajectories of specific drivers of mortality and morbidity may be realised, including those characterised by changes in both people's behaviours and their local environments. Characterisation of the driver-specific scenarios by actuaries and other interested stakeholders may involve developing a narrative which is consistent with the macro-level scenario, prior to a quantitative consistency check.

## Modelling overview

Our goal of developing tangible assumptions might be achieved by:

1. Establishing narratives consistent with **published macro-level climate scenarios**
2. **Selecting drivers** believed to both materially affect mortality and be influenced by climate change
3. Producing **driver-specific scenarios** aligned to our narratives
4. Ascertaining **links between the selected drivers and mortality**, measured using relative risks (RRs) or hazard ratios (HRs), and based on published academic research
5. Combining the scenarios and links to calculate the **impact on mortality** (e.g., in terms of future rates of improvement).

***Figure 1:*** **Comparison of physical and social dimensions of different published climate scenarios**

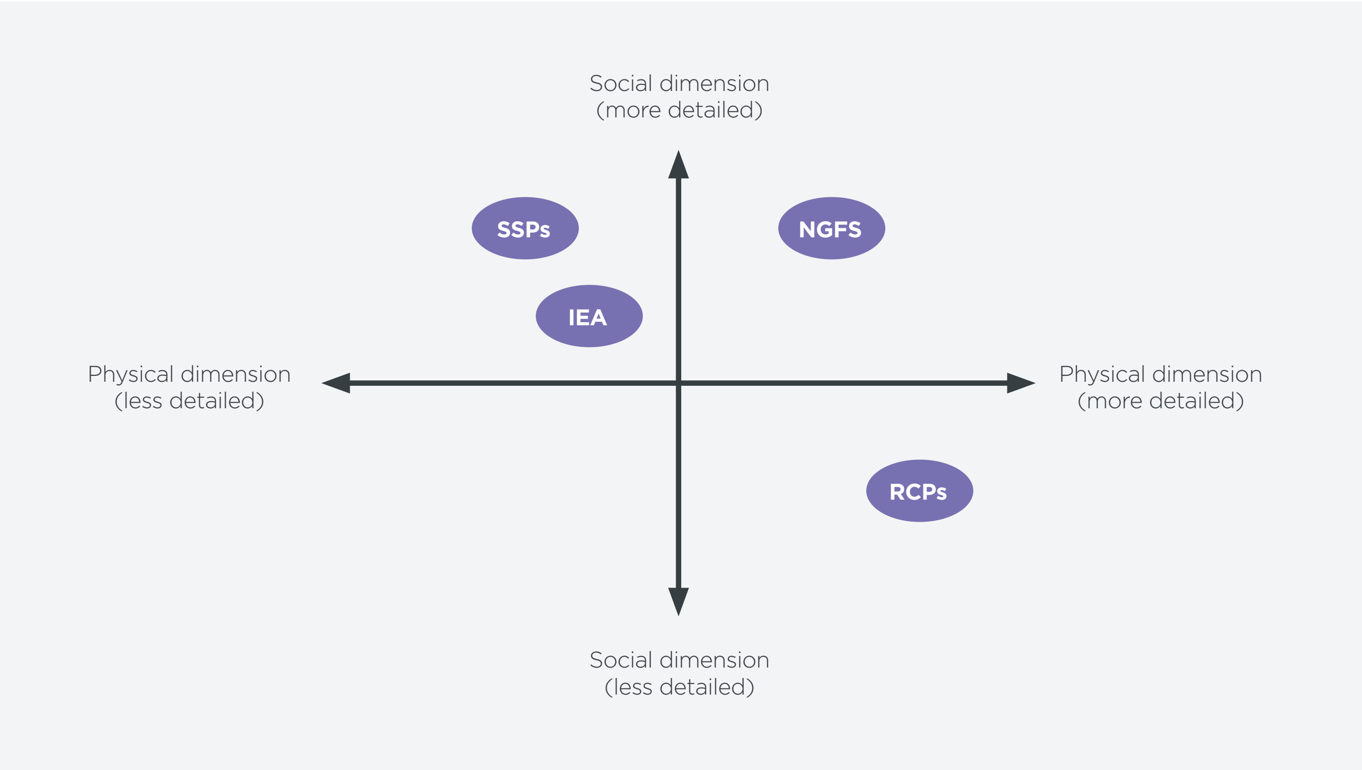
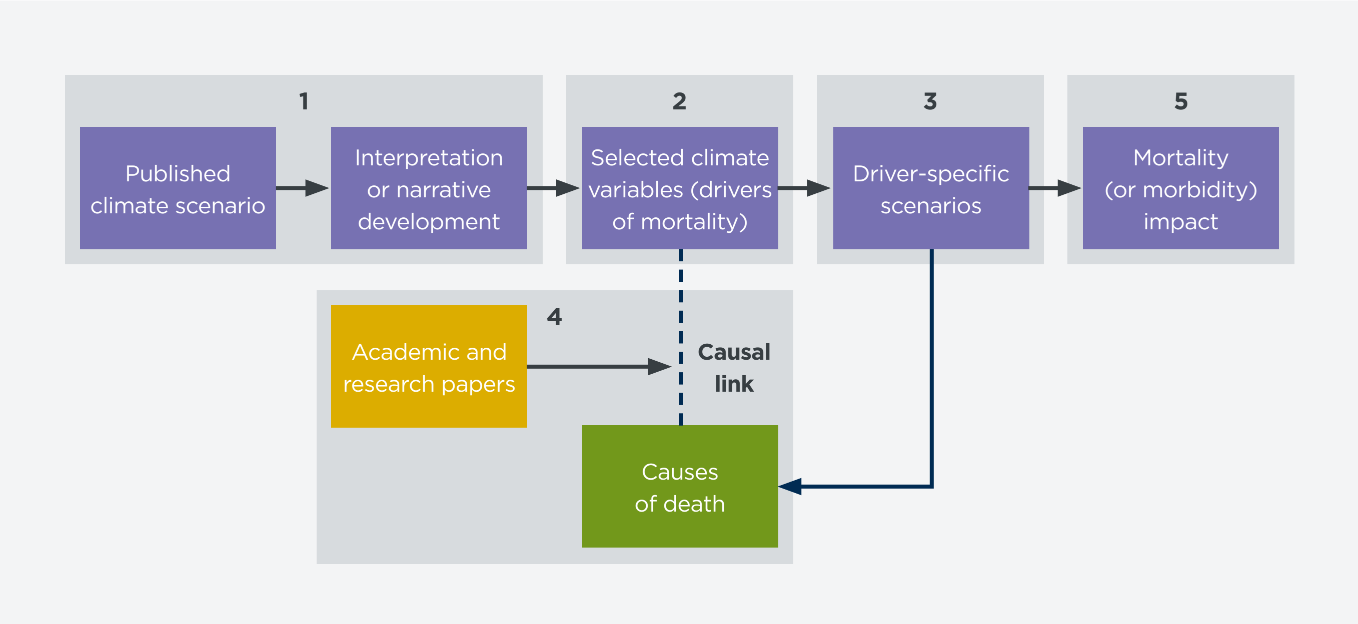


*Figure 2:* **Development of driver-specific scenarios linked to effects of climate change**




This process, which allows us to move from a (potentially nebulous) climate scenario to usable assumptions for insurers and other industry stakeholders, is summarised in *Figure 2*.

In selecting drivers, both the quantity and quality of evidence relating each driver to mortality risk must be assessed. At best, links based on poor evidence will leave significant uncertainty around their resulting impacts; at worst, the results could be misleading. Appraisal of studies evidencing the links should include consideration of the study population (and its similarity to the population being modelled, i.e., 'heterogeneity'), methodology, setting, definitions (e.g., diagnostic standards for disease), confidence intervals around results, and reporting standards.

The calculation of the resulting mortality impacts will combine the RRs/HRs with the driver trajectory, potentially allowing for a lag period between a change in a driver and its impact; a population previously exposed to a cause of excess mortality risk may have higher mortality rates for a period even after exposure has ceased, a phenomenon well-understood in the context of smoking cessation, for example.

## Modelling example

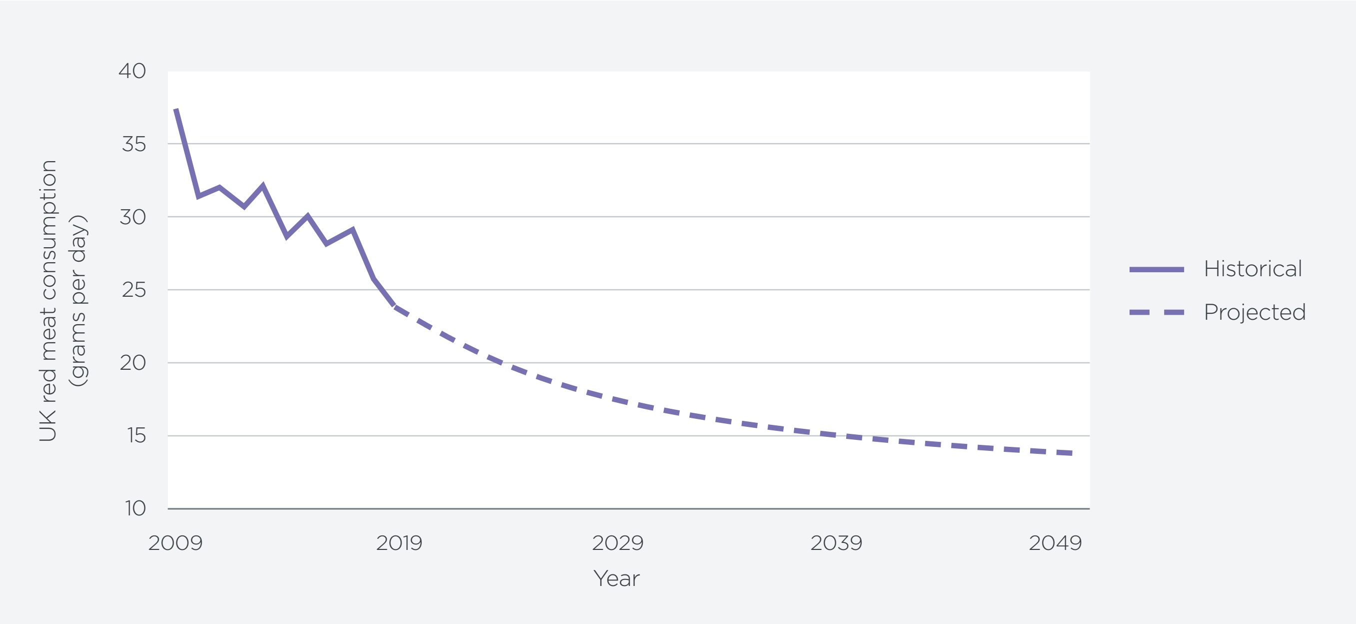
Here, we provide a tangible and quantitative – but simplified – run-through of the process outlined above. It is not intended to be rigorous, but rather to showcase the high-level process carried out. For instance, it assumes no lag period (i.e., no time between the change in behaviour and the manifestation of the change in morbidity risk), results are not split granularly by sex or age, and no consideration is given to any offsetting of the change in the risk implied by the model.

1. **Published scenario:** The published scenario, *Land use: policies for a net zero UK*, was produced by the Climate Change Committee (CCC, 2020). It assesses the farming and land use changes required to meet a 2050 target of net zero greenhouse gas emissions, and quotes a need for per capita beef, lamb, and dairy consumption to fall by 20% by 2050. CCC (2022) also recommended a 20% reduction in meat and dairy consumption by 2030, and a 35% reduction by 2050. It is the effect of this latter recommendation – specifically in relation to red meat – which we model here.

2. **Selected driver:** Consumption of red meat – measured in grams per day – in the UK, with historical data from 2008/09 to 2018/19 (Stewart et al., 2021).

3. **Driver-specific scenarios:** Starting from the most recent data point for red meat consumption, we can extrapolate out to 2050 in a manner consistent with the stated assumed reductions in consumption by 2030 and 2050, with these reductions applying relative to the year in which they were stated by the CCC, i.e., 2022. The results illustrated in *Figure 3* only change slightly if the historical data is smoothed.

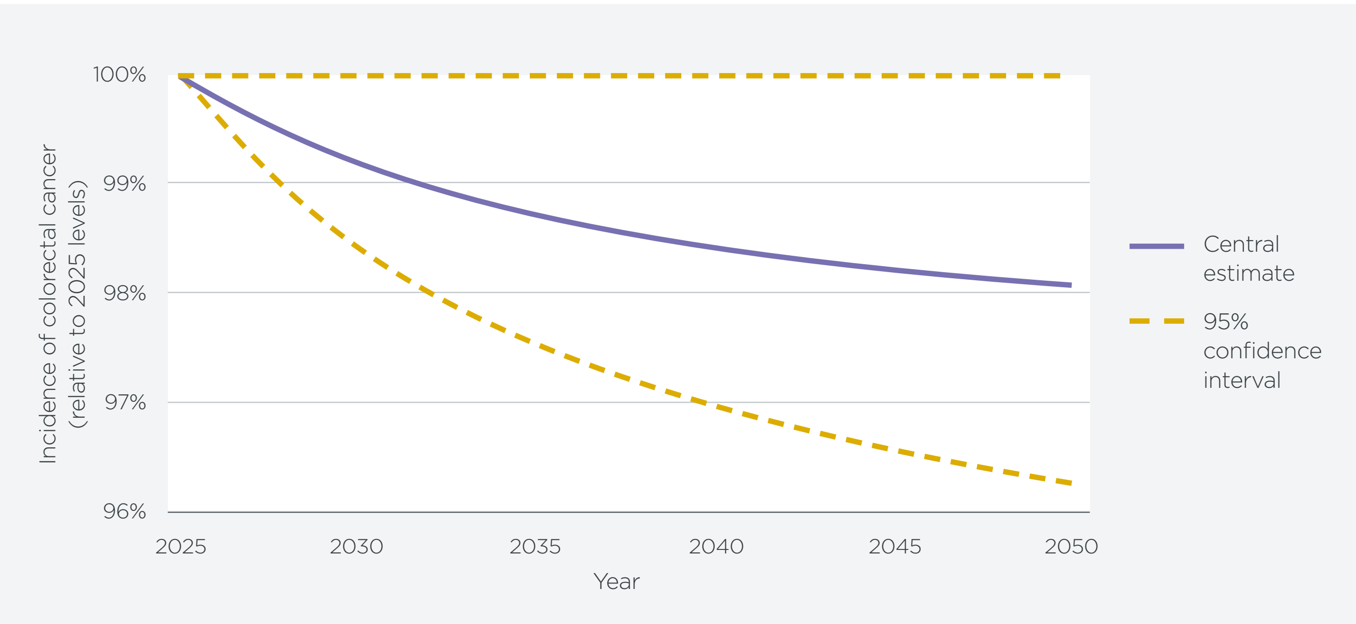
***Figure 3:*** **Historical and projected consumption of red meat in the UK**




4. **Link between driver and morbidity:** Here we utilise a study by Bradbury et al. (2020), which examined the effect of diet on colorectal cancer incidence. The authors quote an adjusted hazard ratio of 1.19 – with a 95% confidence interval of [1.00, 1.41] – for every 50 gram-per-day increment in red meat consumption. Analyses were stratified by age, sex, geographical region, and socioeconomic status. The historical data for meat consumption includes processed red meat within the red meat category, whereas the paper distinguishes between 'red meat' and 'processed meat', and so there may be a slight definitional inconsistency. However, the central estimate for the hazard ratio for colorectal cancer incidence in the case of red and processed meat was very similar, at 1.18.

5. **Morbidity impact:** Using the projected consumption of red meat and the hazard ratio for colorectal cancer incidence, *Figure 4* shows the projected change in incidence rates for colorectal cancer, presented versus the modelled 2025 levels.

***Figure 4:*** **Projected change in colorectal incidence rates relative to 2025 levels**



## The importance of behaviour

Our example highlights a crucial but often underappreciated consideration in the modelling of mortality impacts of climate change – the behaviour of individuals. A portion of the population may be inclined to engage in actions to reduce personal contributions to greenhouse gas emissions – or in some other way aim to mitigate or respond to the effects of climate change – and such actions may improve those individuals' own health. Further examples include:

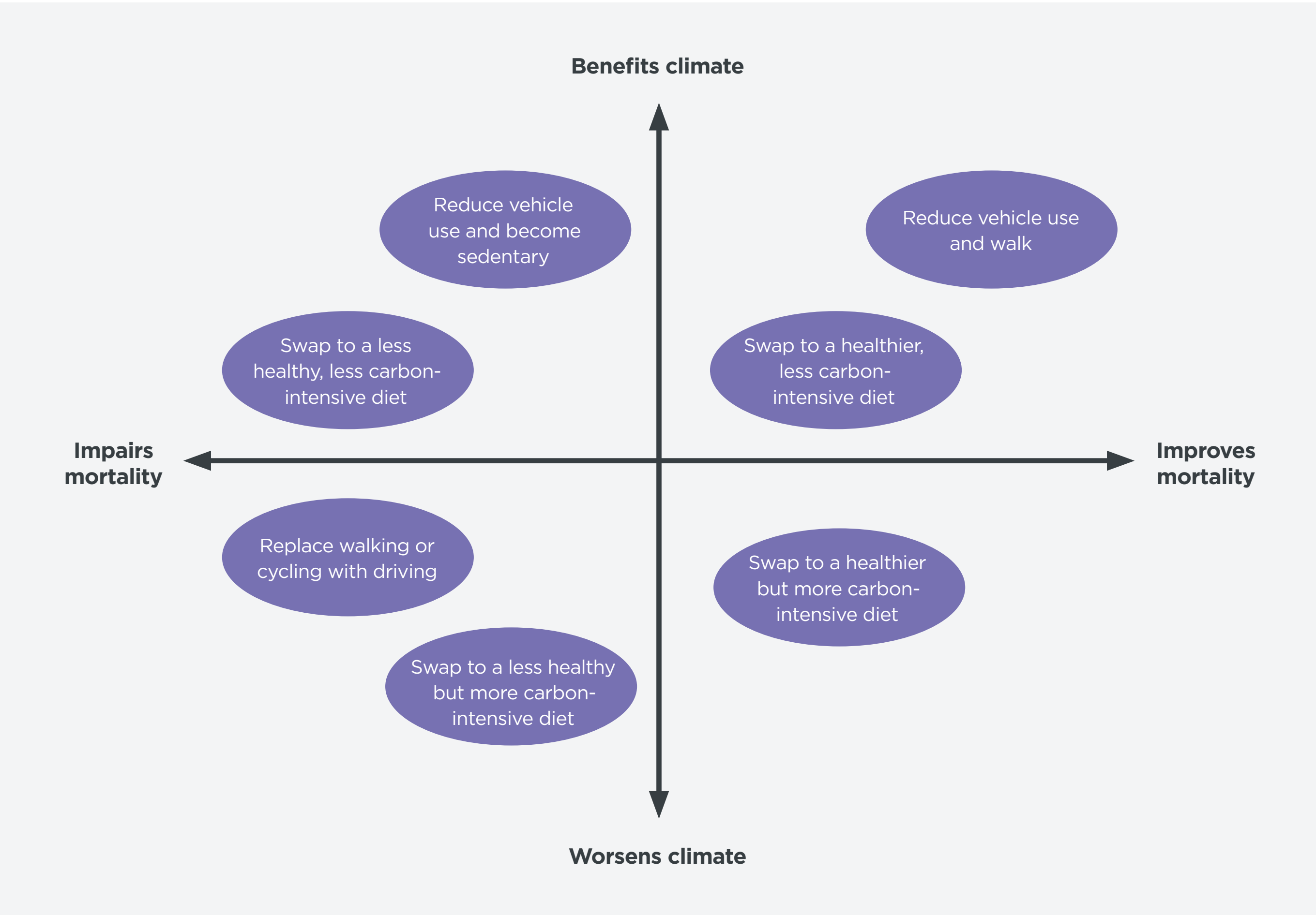
- Reducing use of vehicles powered directly or indirectly by fossil fuels in favour of walking or cycling; increasing physical exercise reduces the risk of heart disease, stroke, and diabetes
- Reducing food waste, both through buying and consuming less food; reduced calorific intake may reduce obesity risk
- Reducing alcohol consumption – aimed at lessening negative environmental contributions from its production – can confer a reduced risk of liver disease
- Increased vaccination uptake in the face of novel tropical diseases may confer protective effects against additional diseases, or increase the likelihood that individuals take up vaccines for existing prevalent diseases (such as influenza).

Conversely, it is also possible that individuals engage in climate-related actions which result in a worsening of their own mortality or morbidity risk, such as:

- Sedentary behaviour, stemming from an unwillingness to spend time outdoors – due to extreme weather or pollution – or replacing the use of vehicles not with exercise, but with simply remaining inactive at home
- Poorer eating, drinking, and sleeping habits, perhaps induced by anxiety around the perceived severity of climate change, and/or the inability to make an impactful individual contribution to mitigate its effects.

Of course, behavioural decisions which act to worsen the effects of climate change are also possible, and these could either improve or impair mortality. It may be useful to consider the positioning of these scenarios on the following axes, as shown in *Figure 5*:

***Figure 5:*** **Scenarios for behavioural changes, and their impacts on both mortality and climate**



In some geographies – arguably, including the UK – it is possible that climate-focused behavioural changes of this sort may have a greater mortality impact than the more typical 'direct' drivers – such as more extremes in hot and cold temperatures, precipitation, flooding, air pollution, new diseases, and droughts – whose impact on mortality in the UK we consider to be at most modest over the next few decades. However, the opposite might be true elsewhere – e.g., it might be that the Sahel region in Africa experiences increasingly high temperatures, or that Bangladesh sees ever-worsening flooding. Of course, the behavioural and direct impacts are linked: changes in the behaviour of populations over the coming decades will impact the extent to which the negative impacts of the direct drivers manifest, and vice versa. Actuaries should take time to carefully consider the materiality of, and relationship between, these direct and behavioural effects in various locales.

We have described here behavioural changes which are motivated by an attempt to mitigate climate change, and which also entail a mortality benefit. However, the motivation might occur in the opposite direction: for example, an individual may seek to reduce their risk of, say, cardiovascular mortality – and it may be for precisely this reason that they reduce their consumption of red meat, which then in turn entails a climate benefit.

An unrelated motivation could also be at play: for instance, concern for the wellbeing of animals – rather than for human health or the environment – driving a dietary change. Appreciating the source and direction of the behavioural motivation could therefore become an important factor when considering what constitutes a feasible range of driver-specific scenarios to include in the modelling process, and whether scenarios should even be thought of as being climate-related at all.

Changes in the behaviour of individuals are often inextricably tied to the actions of government. Policy announcements and implementations can have radical short-term implications on the daily actions and characteristics of the population, from purchasing habits to smoking rates. This highlights the importance of considering behavioural scenarios based around and in the context of government climate policy. For example, which dietary changes might the introduction of a meat tax – or a ban on plastic food packaging – lead to, and what might the resulting mortality impacts look like?

On the other hand, individuals might exhibit resistance – whether consciously or not – to changing their behaviour. The extent to which this is the case will depend on a multitude of factors from genetic, psychological, cultural, and environmental perspectives. Some may lack knowledge of which behavioural changes are at their disposal to mitigate climate change, whilst others may not even have the desire to act in the first place. Individuals may display attitudes which are principally against 'being told what to do' by government, or characterised by a more general aversion to change. Insured lives, however – being typically more affluent – might be more willing, able, or prone to behavioural change (Grandin et al., 2022). For example, they may be more educated on the climate implications of certain actions, or may have the time and discretionary income to assess and implement various mitigation techniques. The extent to which age is a factor affecting climate-related risk perceptions and behaviours is mixed (Poortinga et al., 2023; Ágoston et al., 2024).

## Modelling considerations

There are many hurdles to overcome when engaging in driver-based modelling, and consideration should be given to difficulties relating to:

- Selection of drivers: this is not a fixed choice – actuaries and other stakeholders may have differing views on which drivers underlie future changes in mortality and morbidity, and indeed which of these drivers are the most material. The availability of data on individual drivers may influence the selection
- Aggregation across drivers, avoiding double-counting but capturing interactions, e.g., offsets and interdependencies
- Accounting for lags in the manifestation of reduced mortality risk
- Evolution of risk/driver-mortality relationships over time, e.g., the U-shaped relationship between temperature and mortality might evolve over time, influenced by physical effects and evolving societal actions or norms
- Distinguishing between association and causation in driver-mortality relationships
- Consistency of the model calibration with the target population.

We encourage thinking which goes beyond local considerations when setting up scenarios of the type discussed in this article. This could include, for instance, the potential impacts of climate change on the type and magnitude of migration - e.g., due to food insecurity, extreme droughts, or flooding - and the resulting benefits and drawbacks for local and national economies, particularly in respect of healthcare provision.

## Conclusion

Driver-based modelling allows actuaries to in some way account for causes of changes in variables of interest, a vital feature in the context of a keen regulatory focus on climate change. The behaviour of individuals, as well as the direct physical effects they may experience, ought to be given a material amount of thought.

Whilst there are potential difficulties with the implementation of driver-based modelling, it arguably wins out over the typical alternative approach of extrapolating past mortality and morbidity trends with no regard for what may actually drive future changes. The considerations and methodologies outlined in this article can be used to form views on the magnitude of changes in disease incidence and mortality rates in different climate scenarios, and models can be frequently updated to account for new data, regulation, or (re)insurer-specific needs.

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## Scott Hamilton

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# A warming world: exploring the visible and invisible longevity impacts of climate change through scenario modelling

Steven Baxter, Head of Longevity Innovation at Club Vita
Jill Jamieson, Head of UK Pensions at Club Vita

## Introduction

Around the world we are witnessing evidence of the bleak reality and direct impacts of climate change, from catastrophic flooding in Libya to the devastating wildfires that swept across Los Angeles. This increase in extreme weather events poses an obvious financial risk to general (P&C) insurers, due to the greater volume of property damage and business continuity claims ('acts of god' clauses aside). However, the impact of climate change is much broader than just the weather. It has the potential to impact human health, mortality, financial institutions, and the wider economy, posing the key questions:

- What will the impact of climate change on life insurers and pension funds be?
- How do we quantify it?

## Traditional models

Regulators are placing increasing pressure on both insurers and pension funds to account for the risks associated with climate change.

The insurance sector was the first to face requirements to include quantifications of the potential financial impacts of climate change – since 2019, the Prudential Regulation Authority (PRA) has expected all UK (re)insurers to "embed consideration of financial risks of climate change in their governance arrangements", including the use of "(long term) scenario analysis" (PRA, 2019). Their more recent climate change adaptation report (PRA, 2025) for insurers highlighted that "further improvement is still required as, in general, scenario analysis capabilities are not sufficiently well developed to support effective strategic and business decision-making".

In the UK pension sector, the Pensions Regulator (2022) has issued guidance explicitly requiring pension funds to take "proper account of climate change", including performing analyses on and having considered both the risks and opportunities it poses.

Across both sectors, actuaries are being asked to embed climate scenario analyses in their valuation calculations. There are well-established models for assessing the impact of climate change on assets, which often rely on the foundations laid in the seminal work of the Club of Rome's *The limits to growth* (The Club of Rome, 2025). But what about the liabilities of pension funds and life (re)insurers?

In our experience, liability analyses generally focus on the impacts most readily quantifiable by current actuarial and statistical modelling techniques. These often start with the work of Gasparrini et al. (2015), which explores the sensitivity of mortality to temperature changes, but also demand further thought on questions such as:

- Does extreme heat have a lasting effect on mortality?
- Are heatwaves worse than single, isolated days of extreme heat?
- Is there an age relationship to the temperature-driven excess mortality?

In principle, the answer to all of these questions is 'yes', but the results are sensitive to how each of those questions are answered, and the impact also varies by geographical location.

(This temperature-focused approach is explored elsewhere in this *Bulletin* by Maynard Kuona and Sophie Gong.)

## Beyond the temperature extremes

As first highlighted by Allen et al. (2011), it is however also important for actuaries to consider the indirect impacts that climate change may have on human health, mortality, and the economy – after all, the effects of this wide-ranging phenomenon cover much more than just temperature and extreme weather. This thematic was reiterated in the International Actuarial Association (IAA) paper *Importance of climate-related risks for actuaries* (IAA, 2020).

The broader, indirect impacts of climate change include but are not limited to:

- **Spread of infectious (and parasitic) diseases:** Changes to the global climate can lead to more areas of the world where vector-borne diseases[1] such as Zika can thrive. Climate-related risks could also increase the prevalence of pandemics, or outbreaks of zoonotic diseases such as tuberculosis, and these threats are amplified by growing microbial resistance to current antibiotic treatments.
- **Food and water security:** Agricultural productivity and water supplies are impacted by climate change, having rippling effects on ecosystems, societies, and economies.
- **Human health impacts:** Increased air pollution (and extreme heat) can exacerbate health issues, such as cardiovascular and respiratory diseases. Stress and anxiety associated with climate change can also impact mental health.
- **Effects on health systems:** Modern healthcare systems are energy intensive. The sustainability of these systems may therefore be affected if energy usage is constrained (either as part of attempts to combat climate change, or due to impacts on infrastructure of climate change), and/or other human health impacts present a significant demand-side burden (e.g., on the NHS in the UK).
- **Lifestyle adaptations:** How will lifestyles adapt or otherwise in response to climate change – will we lead healthier lifestyles and have healthier diets? Or will resource constraints and an urgent impetus to move to low carbon economies change food supply chains? Will we see climate-induced migration?

Allowing for these indirect effects can lead to significantly different projected impacts on human health, mortality, financial institutions, and the economy. For some of these effects, there are clear benchmarks to reference. For example, historical levels of infectious disease prevalence and the COVID-19 pandemic can help in assessing the impact of vector-borne diseases. However, other effects for which we have limited data and/or are subject to a myriad of interconnected issues – such as impacts on health systems (e.g., the NHS in the UK) and lifestyle adaptations – may be more amenable to narrative-based scenario modelling instead.

## A narrative-driven approach

Gray (2018) states: "Scenarios are stories from tomorrow", helping to bring risk to life for non-experts. The goal is to combine subjective insights with objective data to create a comprehensive view of potential, plausible future outcomes that might reasonably be expected to occur together. Crafting these scenario narratives can uncover future events that may be overlooked by stochastic models (which are calibrated to past data, and therefore unable to project events that are very different to what we have seen in the past).

Constructing different scenarios is helpful in capturing a range of both tangible and plausible examples of how the world may evolve over time. Inspiration can be sought from recognised scenarios such as the quantitative Representative Concentration Pathways (RCPs) – adopted by the Intergovernmental Panel on Climate Change (IPCC) – or their subsequent evolution to Shared Socioeconomic Pathways (SSPs), designed to combine possible climate change mitigation and adaptation policies in order to derive emissions and hence climate change projections (Riahi et al., 2017). In doing so, the demographic scenarios actuaries generate can be readily linked to scenarios which are often used to underpin broader investment and climate change modelling, aligning with the expectations of the regulatory authorities.

We can illustrate this by using scenarios developed at Club Vita to provide potential pathways for longevity, depending on the global response to climate change[2]:

- **Sustained Stagnation:** Global inaction to control the impacts of climate change with limited mitigation actions and policy inertia
- **Turbulent Times:** Some adaptation, but which accelerates only when the impacts of climate change (e.g., resource constraints) become much more apparent
- **Rapid Response:** Plausibly fast (and effective) adaptation of behaviours supported by fast development of mitigation actions, largely via technology.

1 | The World Health Organization describes vector-borne diseases as 'human illnesses caused by parasites, viruses and bacteria that are transmitted by vectors such as mosquitoes, ticks and fleas' (WHO, 2024.)

2 | For readers familiar with our previous scenarios, we have changed the names of the scenarios to identify them as materially updated scenarios. 'Sustained Stagnation' is an update of our 'Head in the Sand' scenario; 'Turbulent Times' is an updated version of 'Challenging Times'; and 'Rapid Response' a refresh of our 'Green Revolution' scenario.

To develop these climate scenarios, we first created specific narratives around possible outcomes from climate change, ranging from very narrow direct impacts through to broader scenarios covering adaptation to climate change. Below we have provided an example of the narrative that sits behind Club Vita's Rapid Response climate-related longevity scenario.

Next, we analysed how the components of these scenarios will affect key drivers of mortality – a 'cause of cause of death'-based approach. Scott Hamilton and Richard Marshall explain in more detail in their article elsewhere in this *Bulletin* how a driver-based approach can be used for modelling future mortality. This enables us to calculate how the stresses of our key drivers will affect lifespans of pension fund members, illustrating both the financial and intergenerational longevity impacts of potential climate change scenarios.

A key advantage of this narrative-based approach is that it enables scenarios to be aligned with recognised climate change scenario frameworks, such as the RCPs (Met Office, 2018) and SSPs (ClimateData.ca, 2025) adopted by the IPCC, and the Network (of Central Banks and Supervisors) for Greening the Financial System (NGFS) scenarios (NGFS, 2025).

Pairing each of Club Vita's life expectancy pathways to a consistent scenario from a recognised framework - as demonstrated on the next page, using our Rapid Response scenario as an example - enables life insurers and pension funds to take a holistic approach to climate-related risk management, combining plausible investment (asset) scenarios with demographic (liability) scenarios to stress test funding plans and reserves. It is also often a more engaging approach to use with different audiences – such as board level and regulatory stakeholders – when discussing resilience to climate change.

## Club Vita's Rapid Response scenario

This scenario reflects a situation where plausibly fast and effective adaptation and mitigation happens.
It assumes:

- Increased public awareness of humanity's footprint on the environment, leading to widespread calls for change
- Rapid technological advances that lead to positive adaptation to climate change and widespread mitigation efforts
- A combination of environmental conscience, legislation, and a trend towards using less polluting forms of transport (e.g., electric vehicles and public transport)
- An increased popularity of more active modes of travel (e.g., walking or cycling), leading to better health and cleaner air
- Significant improvements in the availability and efficiency of green energy also improves air quality further
- Less reliance on processed foods and red meat due to better health education, along with a general interest in reducing greenhouse gases
- Preparation for global warming has led to pre-emptive action to ensure crop security
- The UK has invested in better protection against extreme temperatures (e.g., home insulation and air conditioning), leading to lower cold- and heat-related deaths
- Better communication systems and less traffic on the roads lead to faster and more responsive emergency services
- Improvements to diet, exercise, and air quality are reflected in lower incidences of cancer, cardiovascular disease, dementia, and respiratory diseases
- There are fewer UK temperature-related deaths through mitigations preventing the extremes of summer heatwaves, and successful adaptations to improve the year-round suitability of UK housing stock.

Note that we are not specific on the precise combination of these factors (but rather the general net outcome), and as such this scenario is likely to be consistent with a variety of ways under which a material transition occurs. The smooth projection of longevity would also be consistent with fast and orderly transition scenarios.

## Club Vita's Rapid Response scenario

This scenario would be broadly consistent with:

| | |
|---|---|
| Representative Concentration Pathway | RCP 4.5 or lower |
| Temperature rise by 2100 (vs preindustrial levels) | <2°C |
| Shared Socioeconomic Pathway | SSP1: 'Taking the Green Road' |
| Network for Greening the Financial System scenario | Net Zero 2050 / Low Demand |
| IPCC Special Report on Emissions Scenarios scenario | SRES B1 |

Please note that these are indicative alignments, and this scenario could be consistent with external reference points other than those shown above.

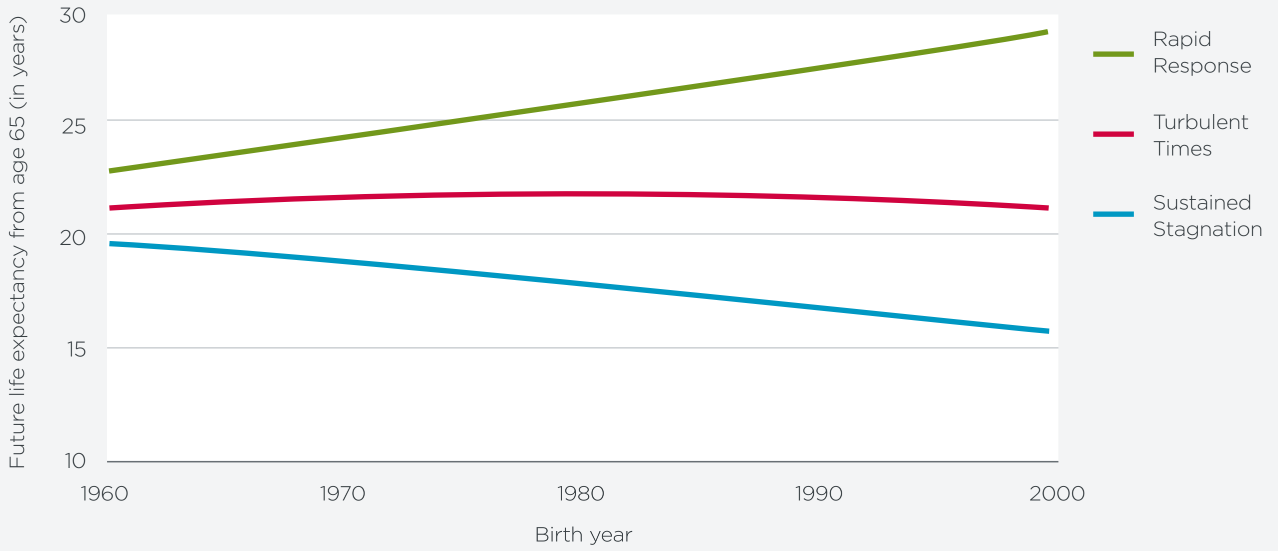
## How does future life expectancy vary under Club Vita's scenarios?

The future pathway for longevity varies markedly under our three climate-related longevity scenarios. *Figure 1* illustrates the impact on future (cohort) life expectancy from age 65.

Perhaps the most striking observation is the varying generational impact of plausible climate scenarios on cohort life expectancy. For example:

- Baby boomers (i.e., those born between 1946 and 1964) may expect up to a 3-year increase in cohort life expectancy from 65, depending on which of Club Vita's three climate-related longevity scenarios is selected.
- In contrast, the youngest generations could experience a 13-year swing in cohort life expectancy from age 65, when comparing the **Rapid Response** scenario against the **Sustained Stagnation** scenario.

***Figure 1:*** **Future cohort life expectancy from age 65**




**Note:** We have not assigned probabilities to these scenarios, and the middle ('Turbulent Times') scenario should not be taken as a view on the 'most likely' or central scenario. Nor do we suggest that this is the full range of outcomes. Unisex cohort life expectancies are weighted averages of male and female cohort life expectancies, where the weights to each gender are based upon mid-2022 population numbers for age attained in 2022 of each birth cohort using the 1838-2023 figures from ONS (2024).

Taking account of the issues raised by the Climate Scorpion group elsewhere in this *Bulletin*, however, the scenarios that may initially seem to be more extreme could in fact be well within the bounds of plausibility, and perhaps more representative of likely future paths. It may therefore be necessary to consider even more extreme cases to understand the full range of potential longevity outcomes, especially when allowing for the impacts of planetary and mortality 'tipping points' (as described in their article).

## Variations by socioeconomic grouping

We have already touched on the various generational impacts of plausible climate scenarios, and noted sensitivities by geographical location. Another important aspect to consider is how the impacts of climate change may differ across the socioeconomic spectrum.

The effects of climate change are not expected to be evenly distributed across society. To illustrate this, let's consider the broad, indirect impacts of climate change that we introduced earlier, and explore the extent to which they might vary between socioeconomic groups.

- **Spread of infectious (and parasitic) diseases:** Infectious diseases and pandemics have the potential to impact all of society. However, history tells us that groups with higher socioeconomic status are often partially insulated from their full effects.
- **Food and water security:** Agricultural productivity and water supplies affect us all to some degree, although wealthier individuals and regions are likely to have better access to clean water and nutritious food, as well as benefit from better technology, infrastructure, and resources.
- **Human health impacts:** Cardiovascular and respiratory diseases are more prevalent in groups with lower socioeconomic status, who are therefore likely to be disproportionately affected by increased air pollution and extreme heat.
- **Effects on health systems:** Different socioeconomic groups will have different levels of access to healthcare (particularly in countries such as the USA, where there is no universal healthcare system). In the UK, the sustainability of – and potential climate change-related strains on – the NHS could have a lesser effect on wealthier individuals, who may also be able to access private healthcare.
- **Lifestyle adaptations:** Wealthier countries and individuals tend to have more resources to invest in (climate change) adaptation and migration strategies. Historically, the professional socioeconomic groups have also tended to be the 'first adopters' of health changes, such as smoking cessation, switching to more sustainable/'green' diets and food sources (e.g., by reducing red meat consumption), and (non-mandatory) cancer screening.

Allowing for these socioeconomic differences under each of Club Vita's climate-related longevity scenarios will lead to different life expectancy pathways for different socioeconomic groups. Some climate scenarios could widen the socioeconomic longevity gap, and others may narrow it. As such, it is important for pension funds and life insurers to understand the socioeconomic profile of the membership being analysed – indeed, liabilities tend to be concentrated amongst the most affluent individuals, so understanding the impact of different climate change scenarios for this group is likely to be most critical.

## Conclusion

Scenario analysis is an effective approach for trying to quantify the potential impact of risk associated with climate change. It also provides a more accessible way of visualising the possible future effect of (climate) longevity risk, and is a useful tool for longevity stress testing the liability funding of a pension fund or insurer.

Even if these future longevity events do not represent a best estimate of the future against a climate change backdrop, they should not be ignored – being aware of potential blind spots is crucial.

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## Steven Baxter

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Steven developed Club Vita's longevity analytics used across the UK and North America by the majority of insurers and reinsurers taking on pension scheme assets and liabilities. A recognised thought leader, he continues to advance new approaches to modelling mortality and identifying emerging trends in later-life risks, including pensions decumulation.

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Jill is a pensions actuary and, prior to joining Club Vita, gained more than a decade of experience advising trustees and sponsors of UK defined benefit pension funds. Jill is now responsible for the strategy of services that Club Vita offer to the UK pensions market to help pension funds understand, quantify and manage longevity risk.

# Healthy people, healthy planet? The case for interlinking longevity and climate action

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Sage Jeffries, ILC Policy and Engagement Intern

## Introduction

The climate crisis and increasing longevity are two of the most transformative phenomena of our time. It is a testament to social and scientific progress that we are living longer than ever before. Yet, as more of us enjoy longer lives, the climate crisis looms large, threatening the very foundations of this progress. The relationship between planetary health and population health is rarely acknowledged in policymaking or public discourse on either topic. However, a closer examination reveals that the goals of both climate and longevity activists are more aligned than it would seem from how policymaking is structured and delivered.

For individuals to live well for longer, and to ensure that planetary resources are managed sustainably, we need a more joined-up approach to these two critical and heavily intertwined challenges.

## Why should we consider climate and longevity as interrelated?

The relationship between our environment and our health outcomes is well-established. World Health Organization's 'One Health' approach underscores the interconnectedness of human, animal, and environmental health (WHO, 2021).

What happens to our planet inevitably impacts our wellbeing. The drivers behind climate change, such as pollution and habitat destruction, lead to drivers of poor health, such as declining air and water quality, and loss of biodiversity. As temperatures rise and extreme weather events become more common, the spread of infectious diseases, such as malaria and dengue fever, will likely increase. Any pre-existing vulnerabilities – e.g., in terms of age, education, and poverty – will likely be exacerbated by climate change, leading to shortened life spans and loss of livelihoods. In particular, these diseases can have serious health consequences, and are likely to disproportionately affect vulnerable populations, such as older people, younger people, and people with existing health conditions.

However, this relationship is not one-sided. Whilst the rate of its growth is slowing, the global population is nevertheless still growing in absolute numbers – indeed, the United Nations has projected it will peak in the mid-2080s at around 10.3 billion (UN DESA, 2024). And as more countries benefit from improved healthcare and see increasingly long life spans as a result, the environment will overall also face greater strain in supporting more people for longer.

The connection between longevity and climate change is often overlooked. While policymakers may address these issues separately, the reality is that they are intrinsically linked and therefore require a joined-up, holistic approach. When we fail to link climate and longevity agendas, we miss the opportunity to simultaneously improve population health and preserve our environment for future generations.

## Why do we consider longevity and climate change in isolation?

It is a natural human instinct to break complex challenges into manageable parts. Longevity and climate change are both multifaceted, long-term issues that – often understandably – feel too big to tackle all at once. This tendency to isolate complex problems leads to fragmented solutions, where the climate crisis is typically dealt with in environmental circles, whilst ageing concerns are often tackled within public health or social policy silos.

Additionally, both population ageing and climate change are often viewed as long-term, incremental processes that do not align easily with 4- or 5-year political cycles. Climate change has been marked by global stalemates, underfunding, and a failure by many national governments to meet environmental targets. Similarly, population ageing tends to unfold gradually, making it less likely to dominate headlines or political agendas.

It is also important to distinguish between population ageing – the demographic shift towards an older age structure – and increases in longevity. While the 20th century saw broadly consistent gains in life expectancy, progress in the UK has slowed since 2010 (Mayhew, 2024), and globally particularly since the COVID-19 pandemic (Schumacher et al., 2024). Governments have often responded to these trends by simply increasing retirement ages – a move that has attracted significant political scrutiny, particularly regarding intergenerational and gender-based inequalities.

Despite their differences, the issues of both ageing and climate change have too often been deferred to future policymakers, in the hope that they will have more time and resources to act. But the reality is that the best time to adapt to these transformative forces was in the past – and the next-best time is now. By recognising the interconnections between longevity, ageing, and climate change, we can begin to create more integrated, efficient policies that respond to both challenges at once, and help build a fairer, more sustainable future for all generations.

## The Global Healthy Ageing and Prevention Index: measuring the relationship between environmental impact and ageing

ILC, the UK's leading authority on the impact of longer lives on society, has developed a Global Healthy Ageing and Prevention Index (ILC, 2021-) which ranks 153 countries across the world on six metrics of ageing well – life span, health span, work span, income, happiness, and environmental performance. The Index is a valuable tool for illustrating the intersection of longevity and environmental health.

This Index highlights how environmental factors – such as air quality and access to green spaces – are critical components of a society within which people can live long and healthy lives. However, as the Index reveals, many countries still overlook the environmental dimensions of ageing well: an oversight that is crucial to not only ensuring that longevity can serve as a credible measure and asset of planetary health, but also to preventing it from (over) burdening the planet. Whilst reliable measurements of health outcomes should in theory be possible within countries, neither disease nor environmental outcomes relating to the land, air, or sea respect international borders, and all countries have collective responsibility to protect them. The Yale Environmental Performance Index (EPI) (Yale University, 2024), which provides the dataset for the environmental performance metric on ILC's Index, "offers a scorecard that highlights leaders and laggards in environmental performance and provides practical guidance for countries" to help them achieve existing environmental policy targets. Countries and national governments have clear steps they can take to improve their environmental performance and attainment on these indices – beyond these, global cooperation is required to ensure that all countries are doing more to move the needle on climate issues, for the benefit of both current and future populations.

The Index also assesses how environmental performance influences healthy ageing, revealing stark disparities between nations. Some countries, such as North Korea, Libya, and Somalia, do not receive a score on the EPI due to lack of useable data. This data – and lack thereof – underscores an often-overlooked point: the environmental factors that harm the planet also harm our health. Pollution, poor urban planning, and lack of access to sustainable resources will not only shorten but also reduce quality of life, particularly amongst populations that are living longer but in poor health. Conversely, countries that integrate environmental sustainability into their policies – such as through green urban infrastructure, clean energy, and climate-resilient health systems – tend to rank higher in both longevity and health outcomes. Yet, as has been established, these issues are not often linked in either policy or practice.

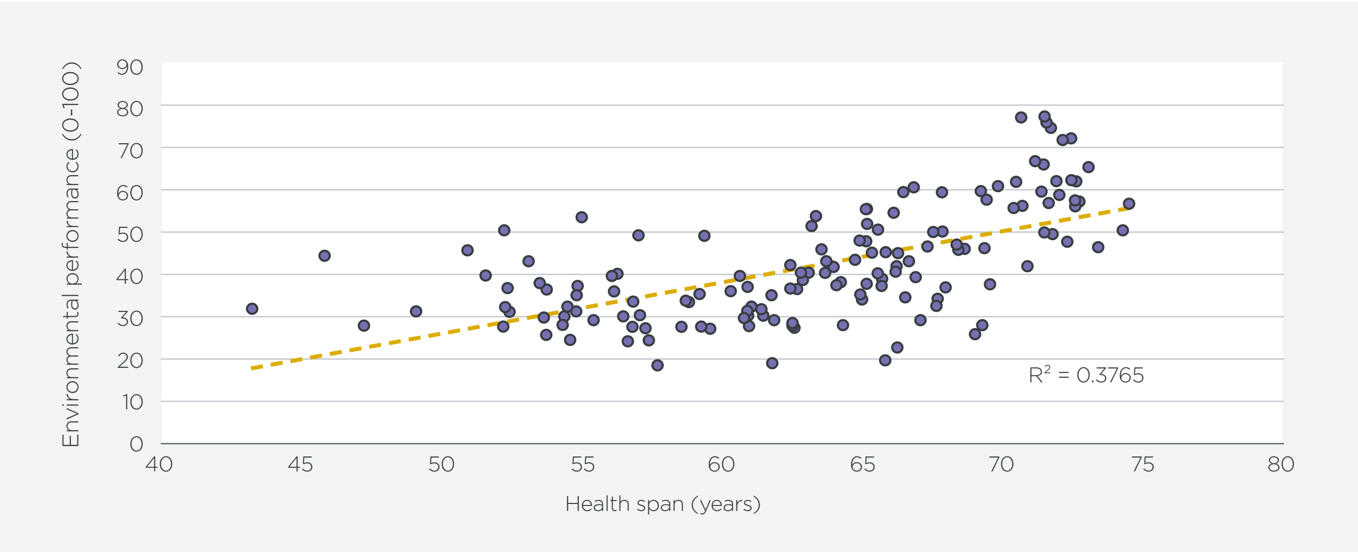
ILC's Index finds that each person around the world will spend an average of nine years of their life in poor health. In Europe and other high-income locales, people on average live longer, but also spend a greater proportion of their lives in poor health – for example, as illustrated in *Table 1,* the average proportion of the population living in poor health across the African Union is 10.88%, compared to 13.07% across the EU.

***Table 1:*** **Life and health indicators by economic bloc.** (Source: WHO, 2024.)

| Economic bloc | Life span | Health span[1] | Proportion of population living in poor health |
|---|---|---|---|
| Nordic Cooperation | 82.9 | 71.9 | 13.27% |
| G7 | 81.0 | 69.3 | 14.44% |
| EU | 81.1 | 70.5 | 13.07% |
| USMCA | 77.7 | 66.1 | 14.93% |
| OECD | 80.1 | 69.2 | 13.61% |
| APEC | 77.0 | 67.3 | 12.6% |
| CELAC | 73.7 | 64.7 | 12.21% |
| G20 | 74.3 | 64.4 | 13.32% |
| ASEAN | 71.5 | 63.2 | 11.61% |
| BRICS | 72.6 | 63.0 | 13.22% |
| African Union | 62.5 | 55.7 | 10.88% |
| Commonwealth | 67.1 | 57.9 | 13.71% |

The burden of poor health, and its impact on the economy and workforce participation, is a key focus in current UK policymaking. Extending WHO's 'One Health' approach to all policymaking across both climate and population health would deliver long-term benefits across different areas of policy and public life. Governments around the world have much to gain from thinking and acting differently on these two phenomena, finding creative ways of looking to address both simultaneously. From a longevity perspective – and considering only the fiscal implications – increases in healthy life expectancy not only reduce healthcare costs, but also mean that those who wish to do so can continue to work for longer and thereby contribute to tax revenues, whilst at the same time reducing overall social security payments that are not needed for as long a period by those who retire later.

***Figure 1:*** **Health span vs environmental performance**[1]**.** (Source: WHO, 2024, and Yale University, 2024.)




1 | Health span is the number of years an individual can expect to spend in good health. This is measured at birth in years, using health expectancy measures obtained from WHO. Environmental performance is measured using the EPI, which positions countries on a scale of 0 to 100 - where higher values correspond to higher performance. Note that this excludes countries without an environmental performance ranking, i.e., North Korea, Libya, Somalia, South Sudan, Syria, and Yemen.

*Figure 1* shows a positive correlation between health span and environmental performance, but while the top twenty countries score strongly on both metrics, there is significant variation across all countries, with health spans ranging from 43.2 years (Lesotho) to 74.4 years (Japan), and environmental performance ratings that range from as low as 18.9 (India) to 77.9 (Denmark). However, it is clear that low-income countries in particular need additional resourcing, support, and investment to improve both health and environmental outcomes.

## Examples of policies that have successfully integrated longevity and climate change

While there is much room for improvement, there are however already examples of policies where longevity and climate change agendas have been successfully intersected.

- **United Nations Sustainable Development Goals (UN SDGs)**
  The UN SDGs for cities and communities touch on the need for redesigning urban spaces with an eye toward both environmental sustainability and inclusivity for older populations (UN, 2021). For example, the concept of age-friendly cities includes features such as walkable streets, public transport, green spaces, and climate-resilient buildings – i.e., policies that support both an ageing population and a healthier environment. Cities such as Melbourne and Copenhagen have set ambitious sustainability goals whilst also ensuring that these goals are inclusive of older adults' needs (Melbourne City Council, 2020). This represents a tangible win-win where the built environment is made healthier and more sustainable for all generations.

- **Active travel policies**
  A key area where climate and longevity intersect is in the promotion of active travel. By encouraging (e.g.) walking and cycling over the use of cars and other powered vehicles, cities can reduce carbon emissions whilst simultaneously improving the health of their citizens. Policies promoting green transport infrastructure – such as cycle lanes and pedestrianised zones – help people of all ages live healthier lives, whilst also reducing environmental impact (Active Travel England, 2021). Interventions supporting active travel are one of the easier, tangible, and meaningful ways that policymakers can move the needle on physical activity, since we know that inactivity is a key driver of non-communicable diseases, and is attributable to 7.2% of deaths worldwide (Katzmarzyk et al., 2021).

- **Environmental volunteerism**
  A 2010 British attitudes survey found that 68% of those aged 55-65 are either 'very' or 'fairly' concerned about climate change (Curzon, 2020). Initiatives such as Retirees in Service to the Environment (RISE) show how older adults can still play a crucial role in climate solutions, and that environmental volunteerism not only helps the planet, but has also been shown to improve both the health and wellbeing of participants. Volunteers in this programme reported increased levels of physical activity and mental stimulation, as well as a strong sense of purpose and connection to their communities (CITRA, 2021). Such initiatives illustrate that older individuals can and do actively contribute to tackling climate change, whilst also enhancing their own quality of life.

## Building a more integrated future: where policy can connect longevity and climate change

To truly address both longevity and climate change, governments, businesses, and civil society must all embrace policies that view these issues as interconnected. This vision includes:

- **Designing age-friendly, sustainable communities**
  Cities and neighbourhoods must be designed to support healthy, active ageing, whilst also being resilient to the impacts of climate change. Urban green spaces, energy-efficient homes, and accessible public transport are essential for both climate adaptation and healthy ageing.
- **Sustainable diets for healthy ageing**
  Promoting plant-based, sustainable diets could not only lower carbon footprints, but also reduce the prevalence of age-related diseases. The food system is a major contributor to climate change, and changes in dietary habits – such as reducing meat consumption – could be a win-win for both public health and the environment.
- **Integrating climate and public health policies**
  Public health and environmental agencies need to work closely together to ensure that policies aimed at reducing climate change also consider the specific health needs of older populations. This could include strengthening health systems to deal with the increased burden of climate-related health conditions among older adults, such as improving their access to healthcare, preparing them for extreme weather events that are likely to impact their health, and addressing issues such as air quality and heat-related illnesses that disproportionately affect seniors.
- **Harnessing the longevity economy for sustainability**
  The 'longevity economy' – i.e., the economic activity generated by older adults as more of us are able to live longer – can be a significant driver of sustainable growth. By investing in green technologies, renewable energy, and age-friendly services, this 'longevity sector' can become a powerful ally in addressing climate change whilst also improving the quality of life for older people. Ethical investment of pensions savings could also be a particularly effective tool to sustain investment in climate initiatives.

## Conclusion: building a healthier, more sustainable future for all

Longevity and climate change are two of the greatest challenges of the 21st century. However, rather than treating them as separate issues, we need a joined-up, holistic approach that acknowledges and works at the intersections of these issues.

Well-designed, sustainable communities benefit people of all ages – young, old, and everyone in between – whilst also nurturing the environment. At its heart, an effective strategy for managing an ageing society is likely to also be effective for managing climate change and other environmental challenges; an opportunity to reshape our physical and social spaces to foster healthy and happy life spans, whilst also prioritising sustainability. Sustainable consumption isn't just better for the environment; it also enhances our own happiness, as evidence shows that sustainable cities promote more sustainable and happier lifestyles (Subiza-Pérez et al., 2025).

Intergenerational collaboration is the key to building a more meaningful and healthy future for both people and the environment. Sustainable choices now may indeed mean relative reductions in choice and consumption for individuals today, but will ensure significant benefit is accrued for their children and grandchildren in the future.

As we live longer lives, it is crucial that we rethink how we manage the Earth's resources to ensure that future generations have (at least) the same opportunities for longevity and wellbeing that we enjoy today. Building a sustainable world will not only safeguard the environment, but also foster healthier, more fulfilling lives for people at every stage of life. By reimagining and aligning climate and ageing policies, we can create a world that supports both long and healthy lives, as well as a thriving planet. Policies and practices that promote human health also nurture environmental health, and vice versa, creating a virtuous and sustainable cycle for both people and the planet.

## About ILC

The International Longevity Centre (ILC) is the UK's leading authority on the impact of longevity on society. We combine evidence, solutions, and networks to make change happen. Our mission is to help governments, policymakers, businesses, and employers develop and implement solutions that ensure we all live happier, healthier, and more fulfilling longer lives.

We are committed to helping forge a new vision for the 100-year life, where new technologies empower us to contribute meaningfully to society throughout our lives.

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# Climate change and longevity: are we underestimating the risk?

Institute and Faculty of Actuaries/University of Exeter Climate Scorpion group

## Introduction

The rapid pace of climate change over recent years continues to pose increasingly numerous and complex challenges, whose impacts – from increasingly common extreme weather events, such as floods, droughts and storms, to more frequent wildfires and persistently rising sea levels – are both profound and extensive.

A considerable amount of time, effort, resource, and expertise has already been invested by meteorologists and climate scientists to model how the climate may evolve as greenhouse gas levels continue to rise due to human activity. Further analysis by actuaries, financial analysts, and data scientists has then mainly explored how the changing climate might affect both physical and financial assets. However, somewhat less attention has so far been afforded to considering the possible effects of climate change on mortality.

This article explores the often complex and interrelated factors linked to climate change which can (either directly or indirectly) influence human longevity. It highlights how these factors – if ignored or not considered holistically within our models – could materially understate both the impact of climate change on life expectancy, as well as the related uncertainty.

The key message of this article is that the systemic effects of climate change – and their subsequent impact on wider planetary and human systems – must be carefully and comprehensively considered if their implications are to be effectively understood. By deepening our awareness and understanding of the connections and interdependencies between climate-related factors, we can better prepare to mitigate these risks, and hence more effectively protect both the wellbeing and future health of people all around the world.

## Key factors affecting mortality

Human health and mortality outcomes can be influenced by a wide range of different factors, key examples of which include:

- Lifestyle factors, such as diet, smoking habits, and levels of both alcohol consumption and physical activity
- Socioeconomic factors, such as occupation, housing quality and location, and levels of both education and income
- Other health-related factors, such as access to/availability and quality of healthcare, and localised pollution levels.

However, at a deeper and more fundamental level, the ability to simply meet our basic physiological needs is both critical and indeed a prerequisite for longevity – in particular, access to clean air, (healthy) food, fresh drinking water, shelter, and sleep. Many of these basic requirements are readily taken for granted throughout the UK; however, as the effects of climate change continue to both emerge and evolve, the underlying assumption of permanence with regards to these needs being easily satisfied may no longer be sustainable.

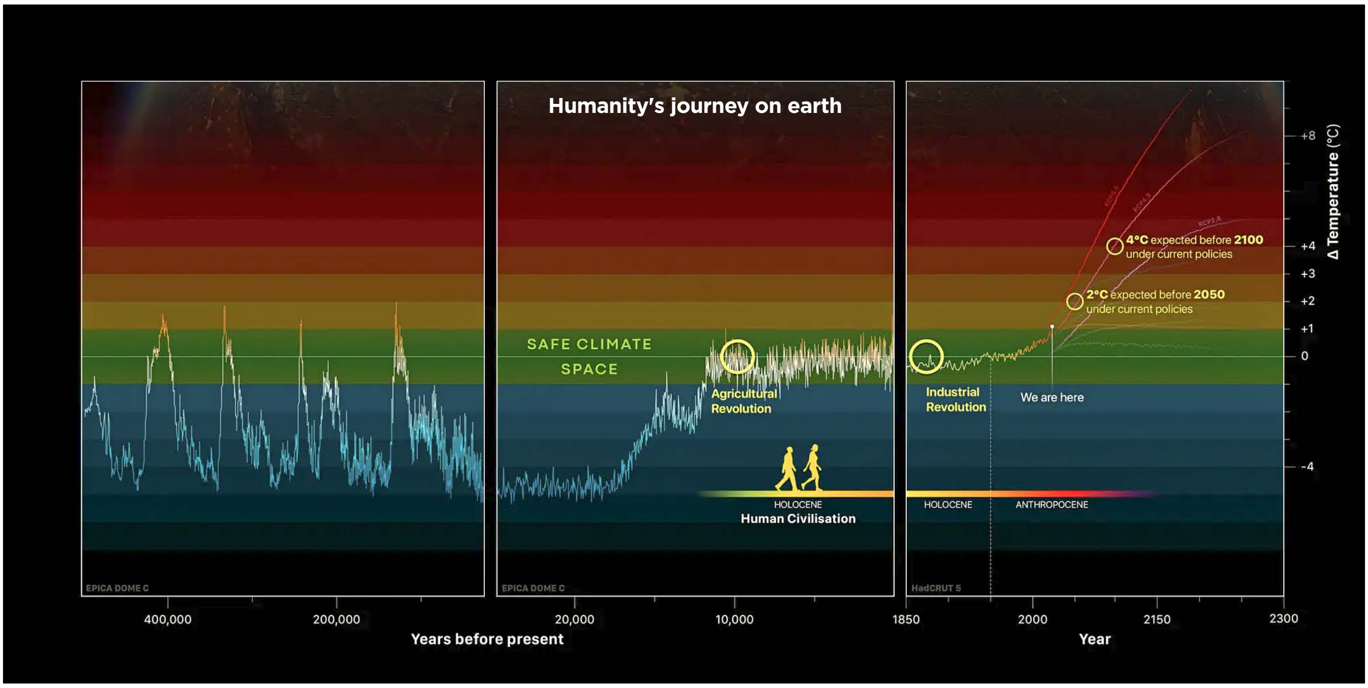
Whilst this article may be predominantly UK-focused, its overarching principles and the themes discussed could equally be applied to other countries, and on a global scale.

## Historical context: why climate change poses such a threat

During its c.4.5-billion-year existence, our planet has experienced many dramatic fluctuations in temperature, atmospheric composition, and climatic stability. From 'hot house' epochs (such as the Eocene epoch, which lasted from c.56 to c.34 million years ago) to those defined by ice ages with low temperatures and widespread glaciation (e.g., the Pleistocene epoch, which lasted from c.2.6 million to c.11,700 years ago), the Earth's ecosystems have been radically reshaped by these major changes over eons of time.

It is against this backdrop that our species – *Homo sapiens* – has thrived for roughly the past c.12,000 years, in no small part due to a hitherto unprecedented period of climatic stability on Earth. Sometimes referred to as the 'Corridor of Life' by climate scientists such as Johan Rockström (Rockström, 2024), this period has given rise to predictable seasons and moderate, relatively stable temperatures, as shown in *Figure 1*. In turn, these conditions have enabled the development of agriculture, and ultimately – by allowing

***Figure 1:*** **Change in global temperature over time** (Source: Caesar et al., 2024. Reproduced under a **Creative Commons Attribution 4.0 International licence.** You may share and adapt this work with proper credit.)




societies to plan crop cycles, harvests, and leverage the greater and more predictable resulting food supply to focus on activities beyond basic survival – the building of entire modern civilisations.

Trust et al. (2025) note that this period of remarkable and unprecedented yet clearly increasingly fragile stability of the Earth's complex systems may now be at increasing risk. Indeed, as increases in average global temperatures move conditions outside of the boundaries of (and threaten to take us even further away from) the 'Corridor of Life' – and at a pace that makes adapting to the resulting changes in weather patterns, sea levels, and temperatures themselves extremely difficult – human civilisation as we know it faces a very real threat of failure.

## Planetary solvency: measuring the viability of planetary systems

Trust et al. (2025) draw a helpful analogy between the concept of financial solvency, and all the eco-services that the Earth system provides to all its resident plants and animals. They state: "In the same way that a solvent pension scheme is one that continues to be able to provide pensions, a solvent Earth system is one that continues to provide the services we rely on, support ongoing prosperity, and a safe and just future."

Amongst others, these essential services include atmospheric and climate regulation (which act to keep conditions benign), water and nitrogen cycles, and pollination. Such services – for example, the work of pollinators and the supply of freshwater fish to ensure a significant component of our food supply – are essential not only for longevity, but also for the basic survival of all life.

The ongoing availability of these services – i.e., planetary solvency – over the past c.12,000 years or so has yielded food, freshwater, nutrients, medicines, and biodiversity in abundance, and so enabled humans to thrive. However, by repeatedly breaching Earth's physical limits – often also referred to as 'Earth System Boundaries' or Earth's 'Planetary Boundaries', and quantified extensively by many (e.g., Earth Commission (n.d.), Dasgupta (2023) and Caesar et al. (2024)) – in respect of not only sustainable temperatures, but also others such as ocean acidification limits, biodiversity, etc., we risk planetary insolvency, whereby our activities disrupt these essential services upon which we rely to the point that they become both unsustainable and unrecoverable.

Trust et al. (2025) state: "An insolvent planet is one in a state where we have degraded the Earth system to such an extent that we can no longer receive enough of the critical services we rely on to support our society and economy. For example, shortages of food and fresh water, or uninhabitable climatic conditions. Ecosystem services are often non-substitutable, meaning that once they are lost, they are unable to be replaced through another process and hence their loss undermines economic production."

Applying the same techniques actuaries have developed and honed for assessing whether financial institutions can remain solvent in the face of extreme events, it is also possible to model how close (or far) we might be from planetary insolvency, as well as consider whether or not (and to what extent) various different interventions and public policy changes might move us towards a more sustainable future. Using these techniques, we can then also investigate and model the potential subsequent impacts on human longevity.

## Implications of a warming planet for future mortality outcomes

As Maynard Kuona and Sophie Gong outline elsewhere within this *Bulletin*, extreme temperatures – whether hot or cold – are directly associated with increased levels of mortality.

However, as average global temperatures continue to rise, these extreme temperatures themselves are not the only source of increased mortality risk. Indeed, water cycles, ice sheets, and glacial systems (for example) will also be profoundly affected, and together will likely disrupt the availability of fresh water. In turn, this disruption may potentially then trigger widespread food scarcity and shortage crises in many countries, as well as increase the likelihood of forced migration and conflict as people both seek and compete over food and water.

As a significant net food importer (DEFRA, 2024), the UK would likely be materially impacted by such changing conditions, even those much further afield. Hence when considering the specific impacts of rising average global temperatures on UK mortality, it is important to also incorporate these international aspects and interdependencies into actuarial scenario and driver-based modelling approaches. These broader, global system-level considerations and dynamic interactions have not typically been included within the modelling of future UK mortality in the context of climate change, but it would be remiss of actuaries and other data and climate scientists to continue excluding them from such investigations moving forward.

## Tipping points: accelerating the impacts of climate change

Another important issue likely to both amplify and accelerate the impacts of rising average temperatures because of climate change is that of 'tipping points' within various vital planetary systems. Tipping points for such systems are critical thresholds such that – when crossed – cause said systems to undergo significant, abrupt, and often irreversible changes.

As global average temperatures continue to climb, breaches of these tipping points – which, by definition, are high impact events – also begin to increase in likelihood (Trust et al., 2024).

The University of Exeter Global Systems Institute (2023) identifies five major systems at risk of crossing their respective tipping points this century (e.g., the cryosphere, the biosphere, and both the ocean and atmosphere circulation systems) and – having identified them as being particularly high-risk tipping points – the UK Government is also currently funding research into the potential collapse of both the Greenland ice sheet and of critical North Atlantic ocean currents (Carrington, 2025).

To illustrate the potential magnitude of a tipping point breach, some modelling suggests that the collapse of key ocean currents – such as the Atlantic Meridional Overturning Circulation – could reduce the amount of global arable land suitable for growing wheat and maize by approximately 50%. Taken together with potential shocks to global food and water security such as these, it is therefore not difficult to imagine scenarios with additional food shortage-driven inflationary shocks, which would also act to drive and compound poorer nutrition – and hence mortality outcomes – more broadly.

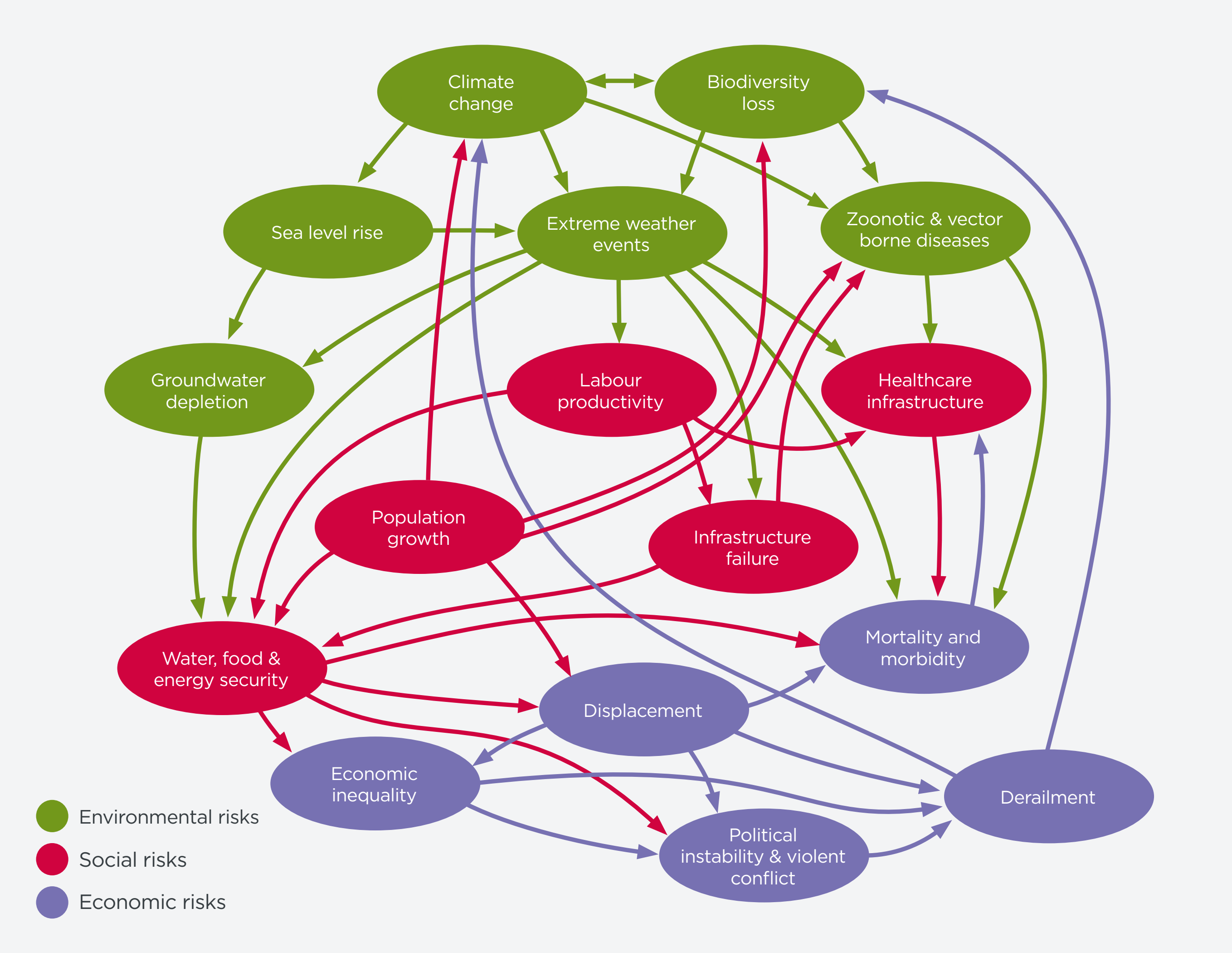
Furthermore, such systemic failures could also have significant consequences for the UK's own climate, causing a cooling effect (e.g., through a loss of warming and heat transfer from the Gulf Stream in this case), and potentially therefore more extreme winter weather patterns. In certain scenarios, the UK could even be contemplating Canadian-style winters, but – importantly – without the significant adaptations that Canada already has in place for dealing with such extreme cold (for example, enhanced housing insulation and modified transport infrastructure). This could result in significantly increased levels of winter mortality in the UK, and is in fact not a merely hypothetical scenario – indeed, the Gulf Stream could already be weakening, as evidenced by a significant North Atlantic 'warming hole' (Li and Liu, 2025).

## Modelling in the context of the complexity of climate change

Life insurers and pension schemes alike must contend with the implications of these complex, interrelated climate change risks for the life expectancies of their policyholders and members, and all the while with the threat of significant and unpredictable step changes looming from potential tipping point breaches.

The inherent complexity, path dependency, and huge uncertainty in planetary climate systems makes it very difficult to accurately model all their interactions and interdependencies, let alone their potential subsequent impacts on mortality. A more practical approach, however, might be to instead investigate how the impact of risk events may cascade through societies using a 'causal loop' diagram, such as that illustrated in *Figure 2*.

***Figure 2:*** **Illustrative causal loop diagram** (Source: Trust et al., 2024. © Institute and Faculty of Actuaries and University of Exeter, reproduced with permission.)




As shown in *Figure 2*, each of these illustrated risks have common drivers and multiple points of interaction that could trigger and/or exacerbate each other, and so it is important for these relationships to be captured as far as is practicable within any actuarial model. These risks all have direct effects on mortality and morbidity, and cascade towards major systemic effects that feed into human impacts.

Perhaps unsurprisingly, it is the combined, compounding effects of related factors within any such system that are likely to have the most serious impacts. Therefore, failure to consider these interconnections, interdependencies, and subsequent system responses can lead to both an underestimation of risk, and an underappreciation of societal impacts, including on mortality (Trust et al. 2024).

For example, emerging and developing crises in food, water, and energy security around the world are often assumed to unanimously focus public sentiment and both political attention and resource towards a more sustainable future. However, the risk of unintentional derailment in that endeavour persists – in particular, there remains the risk that escalating demands to manage increasingly chaotic societal and climate conditions in the short-term could in fact divert effort, resources, and political will away from meaningful environmental action in the long run, thereby worsening the changes overall.

## Improving existing modelling approaches of the impacts of climate change

As emerging research both describes and highlights the increasingly extreme implications of the rapidly rising temperatures we continue to experience, the prudent risk manager should ask the question of whether existing mortality projections sufficiently capture the likely future reality, and whether current tail risk assessments (e.g., 1-in-200 shocks) adequately reflect potential future changes in mortality.

Without being able to rely on historic (mortality) data alone – which, in any case, cannot be used for projecting events under significantly different climatic conditions than observed in the past – actuaries must improve and update their approaches to estimating future outcomes. This demands both a broader and deeper understanding and consideration of the explanatory variables we use, and the science from which we draw when deciding what the key determinants and drivers of those future outcomes will be.

However, it is important to not lose sight of the fact that, as ever, data remains an important factor in modelling and understanding mortality risk, in the sense of enabling us to investigate and understand the relationships between different drivers of (or explanatory variables for) future mortality outcomes. These foundations can then be used to form the basis of coherent mortality projections – other articles within this *Bulletin* have considered a range of approaches to developing these projections, including driver-based and scenario modelling, which can be helpful in assessing the impact of a changing climate.

Regardless of the specific modelling approach chosen, a consideration of the wider planetary context is critical – in particular, a recognition and appreciation that the world which we seek to understand is not one where simple causes lead to one single or deterministic effect. This, by necessity, leads to the adoption of systems-based approaches that look to appropriately consider a broader perspective, and capture the complex interactions of climate change-triggered 'cause-and-effect' mechanisms, that can amplify each other (and often in unpredictable ways) via positive feedback loops.

Against this backdrop, it may well be the case that more extreme climate (and hence mortality) outcomes are more likely than might otherwise be projected by simpler assessments that do not take proper account of these interdependencies.

Trust et al. (2025) set out examples of more detailed systemic risk assessments of this type for the interested reader's reference.

## Conclusion

Modelling changes to Earth's systems due to climate change – and their subsequent impacts on mortality – is a formidable task due to the scale and complexity of natural processes, and whose difficulty is further compounded by the many feedback loops and interdependencies that can magnify changes in ways that are hard to both capture and predict. Translating all these possible changes into projections of and impacts on potential future mortality outcomes presents yet a further level of challenge.

A key message that we have sought to convey within this article is that both a broader and deeper view is necessary to ensure that the full implications and impact of climate-driven changes are considered when projecting mortality outcomes. In particular, a simplistic focus on temperature changes alone is unlikely to be adequate, especially if increased volatility in those temperatures (at least) is not also considered. Similarly, ignoring or failing to sufficiently allow for other factors – such as the impact on critical food sources imported from overseas, or how potential forced global migration because of climate change can have significant domestic mortality consequences – will also tend to understate the longevity risk associated with climate change.

In addition, the ever-increasing risk of climate change-driven breaches of planetary tipping points could lead to even more extreme outcomes rapidly (and more commonly) coming to pass.

Actuaries are uniquely positioned to leverage their experience of modelling relationships between real world events and longevity outcomes, and in applying considered judgement to widen the scope of analyses to also consider events that cannot be estimated from past data. This broader perspective – using some of the tools highlighted in other articles within this *Bulletin* – will be key in helping insurers, reinsurers, and pension schemes understand their exposure to, and hence manage their longevity risk arising from, climate change.

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## The authors

This article has been drafted based on the collaboration between the IFoA and the University of Exeter to develop a better understanding of climate risk, with key input from Sandy Trust, lead author of the *Planetary Solvency, Climate Scorpion* and *Emperor's New Climate Scenarios* reports. Other members of the group have included Oliver Bettis, Lucy Saye, Georgina Bedenham, Professor Timothy M. Lenton, Jesse F. Abrams, Oliver Hampshire, Sanjay Joshi, Jack Oliver and Luke Kemp. The group's latest output is the Planetary Solvency Risk Dashboard, a climate risk tool which makes it possible to visualise and assess the risks of continuing on the current path towards exceeding planetary boundaries. These include risks such as the impacts of global food and water shortages on populations, and the climate tipping points that, once triggered, could limit our ability to prevent the worst outcomes. The dashboard is available at **https://global-tipping-points.org/risk-dashboard/.**

# News from the Continuous Mortality Investigation (CMI)

## Introduction

Last year, the CMI celebrated its centenary and looked back at the key milestones during its first 100 years. These are documented in *'A jewel in our crown': the first 100 years of the CMI,* compiled by Dave Grimshaw, and freely available on the **CMI website**. Looking forward, we have carried out a subscriber survey and are considering subscribers' needs when planning our upcoming activity and outputs.

The CMI's recent activity has continued to include our regular analyses of mortality and morbidity experience, which have been accompanied by a substantial review of the CMI Model, to improve the fit to recent data across different age ranges, both during and after the pandemic. This article outlines the following:

- The release of the latest CMI Mortality Projections Model, CMI_2024
- An update on recent mortality in the general population of England and Wales
- The release of multi-factor analysis by the Self-Administered Pension Schemes (SAPS) Committee, and Index of Multiple Deprivation (IMD) analysis by the Annuities Committee
- Regular investigation work, analysing mortality and morbidity experience – including mortality of pensioners, pension annuities in payment, and term assurances – and experience of critical illness and income protection policies.

## CMI_2024

The Mortality Projections Committee (MPC) published the latest version of the CMI Mortality Projections Model, CMI_2024, alongside **Working Paper 201** in June 2025. This followed an extensive review and consultation exercise which led to the largest changes in methodology since CMI_2016.

Versions of the CMI Model from CMI_2020 to CMI_2023 reflected the COVID-19 pandemic by using 'weights' for each year of experience data, which meant that the impact on projected mortality of data for specific years was either reduced or eliminated altogether.

CMI_2024 takes a different approach, by placing full weight on each year but explicitly reflecting the pandemic with a new 'overlay' term. Mortality is modelled as the sum of 'underlying' mortality – which takes a similar approach to earlier versions of the CMI Model – and the new overlay, which is assumed to reduce over time. The overlay has a simple structure in CMI_2024, which is sufficient for the Core calibration for England and Wales; however, the CMI intends to make the overlay more flexible, to both better reflect the impact of the pandemic over time in other countries, and to allow it to be varied by age.

As the impact of the pandemic on mortality has diminished, differing trends at different ages have become clearer. In 2024, mortality in England and Wales reached a record low at older ages but remained elevated at younger ages. CMI_2024 introduces 'multiple period terms', with five in the Core version (rather than just one as in earlier versions), allowing the Model to better reflect changing trends at different ages.

There are also several lesser changes in CMI_2024, including the treatment of constraints on cohort terms, convergence periods for cohort terms at younger ages, and the methodology used to fit the Model.

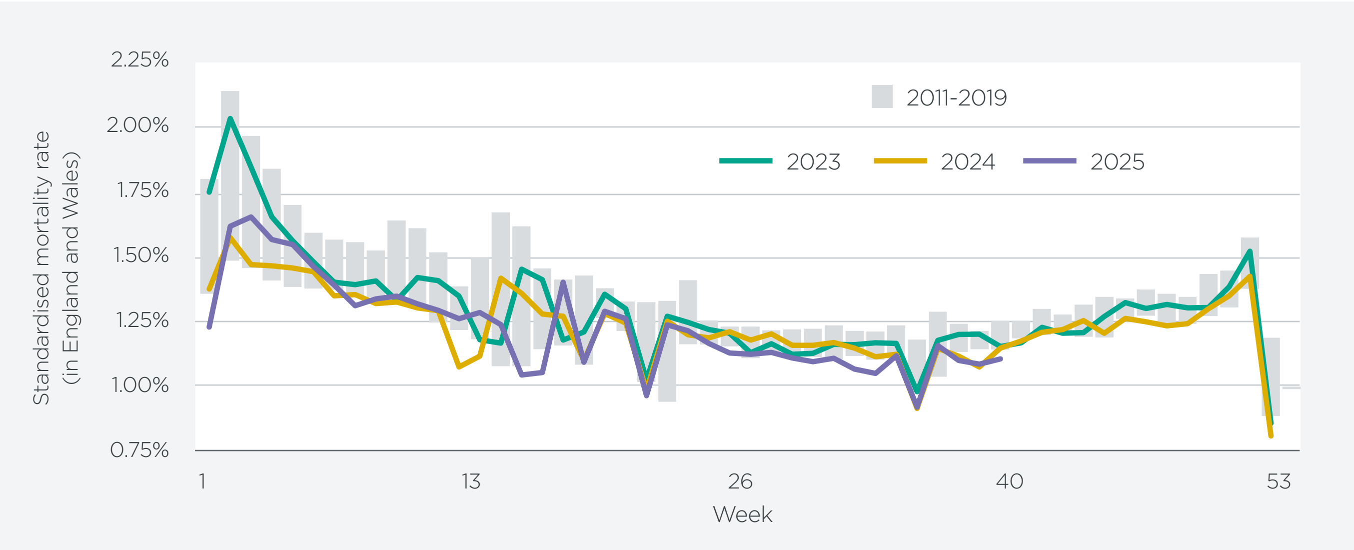
Taken together, these changes lead to CMI_2024 producing cohort life expectancies which are higher than CMI_2023 at older ages but slightly lower than CMI_2023 at younger ages.

## Mortality monitor

The MPC produces monthly updates to the **CMI mortality monitor.** The monitor for week 39 of 2025 covers data to 26 September 2025, and was published on 8 October 2025.

*Figure 1* shows how weekly standardised mortality rates in England and Wales have developed throughout 2023, 2024 and 2025, compared to the range of weekly standardised mortality rates for 2011–2019.

***Figure 1:*** **Weekly standardised mortality rates in England and Wales for 2011–2019 and 2023–2025**




Mortality to the end of week 39 of 2025 is 1.4% lower than the same period in 2024.

## Mortality experience of pensioners

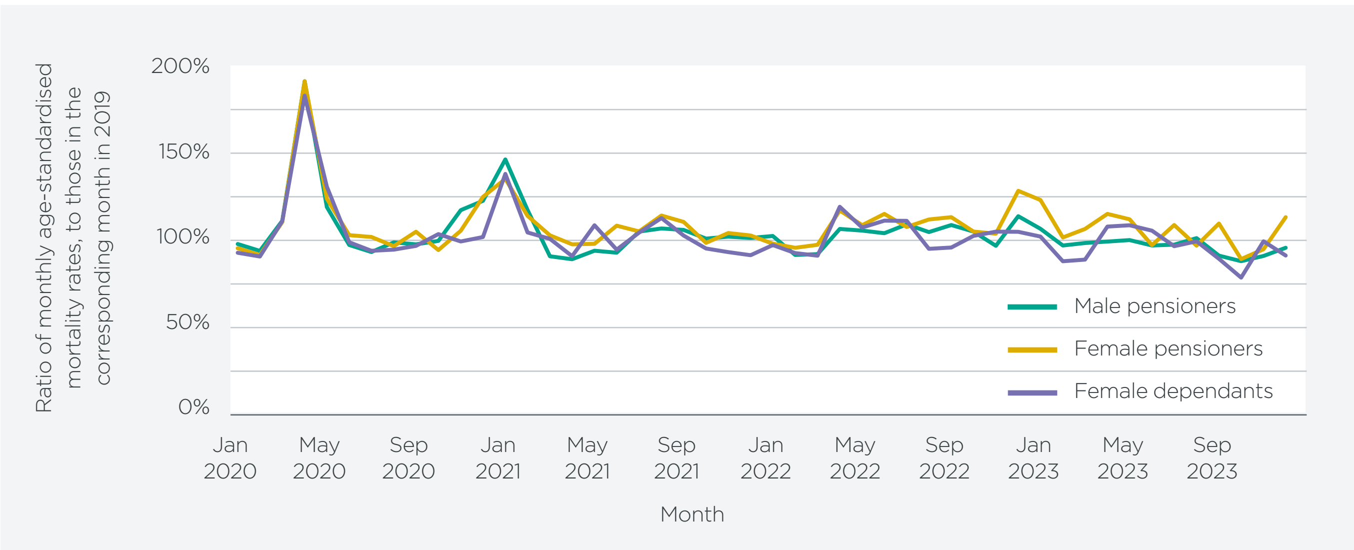
The SAPS Committee published **Working Paper 195** in December 2024. The paper investigates the mortality experience of pensioners over the period from 2016 to 2023.

The analysis shows that:

- For most subsets of the data, the mortality rates experienced by pensioners are very close to the unadjusted 'S4' Series tables, but those experienced by dependants are slightly lighter than the unadjusted S4 mortality rates. The dataset underlying this paper includes data for 2020 to 2023, whereas the S4 tables do not.
- Mortality tended to become lighter over the period to 2019 but was heavier in 2020, before becoming lighter again over the period to 2023. The improvement in experience from 2020 to 2023 is clearest for male pensioners, and least clear for female pensioners.
- Mortality experience of the 'IMD dataset' continues to be heavier than the experience of the 'total dataset'.
- Mortality shows sharp peaks in April 2020 and January 2021, corresponding broadly to the first and second waves of the COVID-19 pandemic. However, the increase in mortality between 2019 and 2020 appears to be lower for the SAPS dataset than in the general population.

*Figure 2* shows the ratio of monthly age-standardised mortality rates from 2020 to 2023, to those in the corresponding month in 2019.

***Figure 2:*** **Ratio of 2020 to 2023 monthly age-standardised mortality rates to 2019**



## Multi-factor analysis of pensioner experience

The SAPS Committee published **Working Paper 194** in October 2024. The paper presents an analysis of the mortality experience of the SAPS dataset by a range of different factors, including pension amount, IMD decile, region, and industry, as well as by combinations of these factors.

When considering each factor in isolation, we observe that:

- Mortality experience becomes lighter as pension amount band increases for most groups - a trend that is clearest for male pensioners, and least clear for female pensioners
- For all pensioner types, mortality experience clearly becomes lighter as IMD decile increases (i.e., as the deprivation level decreases)
- Mortality experience varies both by industry (typically being lightest for the Government/Civil Service and Financials industries) and by region (typically being heaviest in Scotland, and lightest in the Southeast and Southwest of England).

When considering factors in combination, or the results of a Generalised Linear Model (GLM) analysis, we observe more nuanced patterns.

## Experience of pension annuities in payment in 2023

The Annuities Committee published **Working Paper 198** in May 2025. The paper describes the experience of pension annuities in payment in 2023, including some comparisons to experience in 2022 – results by calendar year are also considered for 2015 to 2023.

The analyses show that:

- For males, experience in 2023 is overall lighter than the projected '16' Series tables on a lives-weighted basis, with a downward shape by age band – lives-weighted experience is 8% heavier than the projected '16' Series tables at age band 65–69, and falling to be 3% lighter than the projected rates for age band 90–94
- For females, experience in 2023 is also overall lighter than the projected '16' Series tables, on a lives-weighted basis – experience is 5% heavier than the projected '16' Series tables at age band 70–74, and falling to be 3% lighter than the projected rates for age band 90–94
- Considering mortality experience over 2015 to 2023 relative to the '16' Series 'all-product' tables (but without projection), we see that experience fell each year between 2015 and 2019 for both sexes, followed by a large increase in 2020, and then more volatile experience in 2021 to 2023. Experience is lighter in 2023 than in 2022 for both sexes, but still higher than pre-pandemic levels.

***Figure 3:*** **Lives-weighted 100 x actual/expected deaths by calendar year, compared with the unprojected '16' Series mortality tables for the 2015–2023 annuitant dataset**

## Pension annuities in payment with IMD fields in 2022

The Annuities Committee published **Working Paper 204** in September 2025. The paper describes analysis of data by socioeconomic status in the subset of the pension annuities in payment dataset to 2022 that included indicators based on the IMD and region, using the **CMI Postcode Mapping Tool.**

It includes two-way analysis of Age Standardised Mortality Rates (ASMRs) and Age and Deprivation Standardised Mortality Rates (ADSMRs) by different factors in the Annuities dataset, along with indicative GLM analysis.

The results of the two-way analysis show that – for both males and females – the ASMRs of the IMD dataset by IMD decile are lower than that for general population data. The difference in ASMRs between the datasets are more noticeable at more deprived deciles, and less noticeable for less deprived deciles.

The results of the GLM analysis show that IMD decile appears to be a key driver of mortality differentials based on GLM coefficients, with other factors such as region, product type, and calendar year showing smaller but still noticeable differentials in mortality.

## Term assurances to 2023

The Assurances Committee published its annual term assurance experience analysis report in July 2025 as **Working Paper 202**. The report focuses on experience in 2023, with comparisons to both restated 2022 experience and earlier 2016–2019 experience.

For the first time in an annual term assurance experience report, analysis of cause of death for mortality benefits is included. This builds on new analyses included in the previous report (Working Paper 191) by claim type (for mortality benefits), cause of claim (for accelerated critical illness, i.e., ACI, benefits), nation-specific IMD decile, and UK region, all of which have been included again in this paper.

The mortality experience in 2023 was lighter than expected across all sex and smoker groups, continuing the trend seen in 2022. This is particularly notable given the heavier experience observed during the pandemic years of 2020 and 2021. However, the story is not uniform:

- Male non-smokers showed lighter-than-expected experience at ages 55–64, but heavier experience at older ages
- Female non-smokers displayed a consistent pattern of increasing experience with age, suggesting that the current age-shape of the 'T16' mortality tables may be underestimating mortality at older ages
- Smoker subsets remain more volatile, with lower data volumes making it harder to draw firm conclusions.

We also saw a widening gap between lives-weighted and amounts-weighted mortality experience, particularly for male smokers, hinting at potential differences in experience by sum assured.

The ACI experience in 2023 was slightly heavier overall than in 2022, though still broadly in line with the 'AC16' tables. Notably:

- Male non-smokers tracked closely to expected levels
- Female non-smokers were 5% heavier than expected, with a persistent spike in claims at ages 50–54 – possibly linked to breast cancer screening
- Smoker subsets again showed more volatility, with wide confidence intervals limiting the strength of any conclusions.

Interestingly, 2023 saw a shift in ACI experience by sum assured band, with heavier-than-expected experience at higher sums assured – as opposed to the little variation by sum assured bands seen in earlier years.

## Income protection 2017–2020 experience

The Income Protection Committee published **Working Paper 193** in September 2024. The paper describes the claim inception and termination experience of individual income protection policies for the period 2017–2020.

Most of the results compare experience in 2017–2019 with that for 2020, which may have been affected by the COVID-19 pandemic. Analysis is also included for individual calendar years.

This is our first experience analysis since making significant changes to both the inceptions exposure calculation methodology, and the format of data collected from insurance companies. For the first time in a CMI income protection experience report, analysis is included by smoker status. Analysis by the typical factors for income protection is also included: sex, occupation class (OC), deferred period (DP), age, and calendar year.

The analyses compare the experience relative to that expected based on the 'IP11' claim inception and termination rates. The claim inception rates have been adjusted to allow for data issues identified in the graduation dataset – see **Working Paper 149** for more information.

***Figure 4:*** **Claim inception experience (100 x A/E, on the left-hand axes) and expected inceptions (on the right-hand axes) by age band; DP4; All OCs; and sex.**


## Income Protection 2021–2023 experience

The Income Protection Committee published **Working Paper 203** in August 2025. The paper describes the claim inception and claimant recovery experience of individual income protection policies for the period 2021–2023.

For the first time in a CMI income protection experience report, analysis is included by policy duration and commencement year. Analysis by the typical factors for income protection is also included: sex, occupation class, deferred period, age, calendar year, and smoker status.

The analyses show that, at an overall level, and compared with the 2017–2019 experience shown in Working Paper 193:

- For males, there has been an improvement in claim inception experience (i.e., fewer claim inceptions), but a worsening in claimant recovery experience (i.e., fewer claimant recoveries)
- For females, there has been an improvement in claim inception experience, and a relatively stable recovery experience.

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