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The Effects of Climate Change on Health in the UK

The Longevity Science Panel

November 2022

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Longevity Science Panel

The Longevity Science Panel (LSP) is a group of experts brought together to advise L&G on the factors that affect life expectancy in the UK. The Panel uses a multidisciplinary approach to monitor the ever-changing influences on life expectancy, drawing on its members' expertise in social/actuarial science, epidemiology, medicine, and healthcare system development.

Each year, the Panel releases an Annual Report on a topic of interest, aiming to advise key persons across industries in the UK who have a professional interest in life expectancy, such as risk managers, planners, investors and modellers. Its membership is as follows:

Dame Karen Dunnell, Chair of the Longevity Science Panel and formerly National Statistician and Chief Executive of the Office for National Statistics, with experience and understanding of data resources, socio-demographic changes and public policy, is well placed to assess the impact of population trends on future life expectancy.

Professor Richard Faragher, Professor of Biogerontology at the University of Brighton, brings knowledge of the biological basis of ageing that are likely to influence life expectancy.

Professor Steven Haberman, Professor of Actuarial Science and former Dean of Bayes Business School, is experienced in statistical modelling and mortality research, and has the expertise to consider how to convert research findings into a format for actuarial analysis.

Professor David Leon, Professor of Epidemiology at the London School of Hygiene & Tropical Medicine, has experience in analysing and understanding of determinants of trends in life expectancy and mortality within and between countries.

Professor Debora Price, Professor of Social Gerontology at The University of Manchester, is experienced in finance over the life course, especially pensions and poverty in late life, financial services for an ageing society, household money, and the financial consequences of cohabitation and separation.

Sir David Sloman, Chief Operating Officer of NHS England.

Preface and acknowledgements to the 2022 LSP report

The 2022 Longevity Science Panel report provides an overview of what is known about the current and future impacts of climate change on health, wellbeing and longevity, and the sources of uncertainty in predicting these impacts. It is intended to be useful to anyone who needs to take account of the impact of climate change on health in their day-to-day work. This includes those responsible for strategic planning in organisations in the public and private sectors in the United Kingdom. It focuses on the UK specifically, and high-income countries more generally.

The LSP would like to gratefully acknowledge the advice and input of **Dr Sari Kovats** from the Health Protection Research Unit in Environmental Change and Health, London School of Hygiene & Tropical Medicine. She has acted as an independent adviser to the Panel for this report. She is an expert in climate change and health and has contributed to various Intergovernmental Panel on Climate Change reports and the UK Third Climate Change Risk Assessment.

The LSP also acknowledges the central input to the report of:

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Executive summary

Climate change arguably constitutes the single greatest threat to human welfare, health and longevity the world is facing. The scale of the impact that human burning of fossil fuels has had on the climate has become obvious as reports of recording-breaking heat waves, extreme droughts and melting glaciers appear with increasing frequency. These extreme events are already impacting on the health and welfare of people around the world. Most recently, the summer of 2022 brought home the reality of these impacts to Europe and to the UK with record temperatures, serious droughts, and wildfires.

In this report we have attempted to distil key aspects of the major evidence sources and scientific reports on climate change and its impacts on health. While our focus is on the UK, we necessarily situate this within an international and global perspective. No assessment of the effects of climate change on health or any other aspect of human welfare in a single country can be made without taking account of the fact that climate change is a global problem.

The direct negative impacts of climate change on health in the UK include the effects of heat waves and hot weather, flooding, and infectious diseases, including vector borne diseases. Our island location and temperate climate moderate the magnitude of heatwaves, but we have a significant risk from coastal flooding. There are likely to be complex impacts on regional fresh water supply and quality, as well as on the safety and supply of food. As a rich country, we have the potential to invest in adaptation measures, including retrofitting our houses, workplaces and improving infrastructure to reduce the adverse impacts of climate change. However, this investment is currently insufficient. Extreme weather increases due to anthropogenic climate change are already affecting the physical and mental health of the UK population. The impacts of health from extreme weather will increase, and the impacts of droughts and wildfires will become more significant unless actions are taken.

One of our central conclusions is that in the future there may be a substantial burden of adverse health effects of climate change in the UK through indirect or unexpected pathways. This includes disruption of critical domestic infrastructure and to global supply chains of goods and foods, and increased extreme weather in countries outside the UK that contributes to the global economic costs of climate change. We have used the image of an iceberg, where the bulk of the (indirect) health impacts are hidden below the water. Put simply, climate change is going to make the world poorer and politically and economically more turbulent than it would be otherwise, which in turn will mean the national wealth and resources on which the health of the UK population depends will be reduced.

These indirect effects are, however, extremely difficult to quantify as they involve the systemic interactions between climate, society and health. Nevertheless, this potential set of indirect pathways should be brought more squarely into the national and global debate as a further spur to move towards Net Zero through mitigation of greenhouse gas emissions.

The impact of climate change and its health effects in the UK will not be borne equally by all sections of the UK population. The most economically deprived and those who are already frail through age or having long-term health conditions will be the most vulnerable to high temperatures and shocks induced by adverse weather events such flooding and storms. Coastal flood risks are a threat to economically deprived coastal communities. The resources available for climate adaptation are likely to reproduce the current regional inequalities in which the more socio-economically deprived areas lose out.

The magnitude of future direct and indirect climate impacts, particularly in the second half of this century, will depend on the trajectory of global greenhouse gas emissions. As part of its commitment to the Paris Agreement, current UK policy is to decarbonise it’s economy in order to reach Net Zero

emissions by 2050. This process may have health co-benefits for the UK population, particularly through a reduction in air pollution. However, as the Bank of England has suggested, the transition to a greener economy will also have costs. These may include, for example, further reductions in carbon-intensive industries and jobs, which are likely to fall on areas and people who are least able to bear them. Greater emphasis needs to be given in climate policy development to ensure that the large existing socio-economic inequalities in health are not further exacerbated.

In this report we highlight the potential impacts of climate change on mental health. People whose lives have been disrupted by flooding are at risk of anxiety/depression and PTSD (post-traumatic stress disorder). The impact of flooding on local communities can also have a major effect on health and social care services, as well as the schooling of children, with attendant adverse impacts. Further work on mental health effects appears to be warranted and should again figure more prominently in climate risk assessments.

Many sectors of the UK economy and government are aware of the importance of climate change for their business. However, the policy and regulatory environment is complex, having both national and international dimensions. In this report, we attempt to lay out in summary form some of the key stakeholders and actors. However, we have gone further, and have looked at the readiness of the UK to meet its avowed commitments under the Paris Agreement, the Climate Change Act 2008, and the Net Zero Strategy 2020.

The assessments of the UK's own Climate Change Committee established under the 2008 Climate Change Act suggests that adaptation responses to minimise the impacts of climate change are currently insufficient to adequately address risks, including to health.

For financial markets and the insurance and pensions industry the need to avoid a disorganised transition to a Net Zero economy is paramount. Recent political events in the UK illustrate the potential for unravelling of financial systems with completely unanticipated consequences. Shocks that could emanate from destabilisation and potential collapse of sectors of the economy involved in energy production could have major impacts. Effective government policies that provide clarity and consistency in how the economy can move towards Net Zero are essential. Market forces and individual efforts are not sufficient to overcome barriers to effective action, which only government policy and regulation can provide.

The scientific evidence for ongoing man-made climate change is now considered overwhelming. The major uncertainties about the future of the Earth's climate, and the implications for human health, arise not from doubts about the existence of climate change, but from the actions that countries will take to mitigate and adapt to its effects.

1 Introduction

1.1 Aims, scope, and overview

This report provides an overview of what is known about the current and future impacts of climate change on health, wellbeing and longevity, and the sources of uncertainty in predicting these impacts. It is intended to be useful to anyone whose work requires them to consider the impact of climate change on health, in particular those responsible for strategic planning in the public and private sectors in the United Kingdom. This includes national and local government, the health care sector, manufacturing, and the insurance and pensions industry, where we would expect the contents to be particularly relevant to actuaries and executives. The field of population health increasingly recognises the importance of considering the implications of climate change, and the Lancet has just published its seventh annual 'Countdown' report on the global picture[1]. While the focus here is on pathways of health impact in the United Kingdom (UK), we necessarily situate this within an international and global perspective.

Both direct and indirect impacts will be discussed. As described in our previous report, socio-economic factors have a large effect on health and longevity[i]. Therefore, we pay particular attention to the extent to which there are likely to be socio-economic and geographic inequalities in the way that climate change will impact on health and mortality. Furthermore, we pay particular attention to the potential impact of climate change on mental health. We also explore current and future regulatory and policy tools that may impact the effects of climate change on health, and introduce key concepts required to understand the landscape of the problem.

This report is not attempting to be a review of all the relevant scientific literature. We will not attempt to make quantified predictions of health impacts or to identify future research pathways, but will introduce the key concepts required to understand the challenges. These will be described as we go along, but there is also a glossary of terms in an appendix for reference.

DEFINING HEALTH

Mortality rate and life-expectancy are useful metrics for tracking population health, but there are aspects of health they do not capture. The World Health Organisation (WHO) defines health as, “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.” This broad definition serves to recentre the concept of health as something that is experienced at a first-person level and highlights the arbitrary nature of the healthy/unhealthy dichotomy. In the following sections, the impact of climate change on health will be considered in terms of both direct and indirect impacts on longevity, mortality, and health.

1.2 Responses to climate change

Climate change **mitigation** refers to actions taken to reduce or prevent the future extent of climate change. Primarily, this involves reducing the sources or enhancing the sinks of greenhouse gases. An important part of reducing emissions must be achieved through transitioning from fossil fuels to carbon-free energy sources. Major mitigation initiatives include reducing greenhouse gas emissions in sectors such as transport, manufacturing, construction, agriculture, and energy supply; as well as reducing methane emissions through waste management and sewage treatment; supporting and

[i] Inequalities have a major impact on health, mortality and longevity as described in our previous report: “Life Expectancy: Is the Socio-Economic Gap Narrowing?”[115]

promoting technologies that reduce or prevent emissions linked to human activities(anthropogenic emissions); protecting and enhancing greenhouse gas sinks and reservoirs through sustainable management and conservation of forests, oceans, and wetlands; afforestation and reforestation; rehabilitating drought affected areas; and carbon fixing[2]. Climate mitigation also includes other hypothetical measures aimed at directly modifying climate or weather patterns (geoengineering).

Alongside the development of mitigation actions and policies, **adaptation** focusses on reducing the negative impacts that climate change is having and will have in the future. This involves reducing the impacts of hazards, preparing for emergencies and planning for recovery. Adaptation strategies can be found in a wide range of sectors that have direct links to public health - water and sanitation, agriculture and food systems, forestry, fishing, flood prevention and control, disaster prevention and preparedness, and public health preparedness.

CLIMATE MITIGATION

Climate mitigations are proactive measures aiming to lessen future climate change. This can occur by reducing the emission of greenhouse gases into the atmosphere, or by increasing the rate of the removal of greenhouse gases from the atmosphere through carbon sequestration. Mitigations also include largely theoretical geoengineering approaches that seek to decouple greenhouse gas concentrations from climate change, for example by using high-altitude particles to reflect some of the sun's energy.

NET ZERO

A key goal of climate mitigation is to achieve Net Zero. This is the point at which the rates of greenhouse gas emission and removal are equal. This might be a goal for a state, organisation, or for the Earth as a whole.

CLIMATE ADAPTATION

Climate change adaptation refers to actions that intend to reduce the exposure or vulnerability of human or natural systems to the impacts of climate change and climate-related hazards through maintaining or increasing adaptive capacity and resilience[2]. Adaptations might be physical (sea walls), organisational (heatwave operational plans), or behavioural (reducing time spent outdoors). Adaptation includes both preparing for impacts and planning for recovery.

To summarise, climate change mitigation strategies are vital in reducing global greenhouse gas emissions while adaptation strategies are essential to alleviate the adverse effects of climate change events. While the primary goal of mitigation and adaptation strategies is to combat climate change and reduce its negative effects on the environment and societies, these strategies may potentially result in health benefits unrelated to climate change[2].

1.3 Report structure

We will begin this report with a description of the various ***pathways*** linking climate change to health impacts. A pathway begins with a manifestation of climate change such as increased temperature and describes how it affects health outcome and mortality rates. The impact on health may be ***direct***, as in the increased risk of heatstroke, or ***indirect***, as in the economic harms that arise from climate change and the impact this then has on mortality. Negative health impacts also include those arising from the societal and economic ***transitions*** required to ***mitigate*** or ***adapt*** to climate change.

We consider the potential effects that climate change may have on ***mental health,*** including those arising from the acute stresses of coping with extreme weather or other climate events, and from ***climate anxiety*** driven by the issue of climate change itself. We also note there may potentially be ***positive impacts*** of climate change on mental health and detail those.

The next section will deal with the unequal impact that climate change may have on different sections of society. We examine the ***inequalities*** arising ***from age***, ***gender***, ***health status***, ***occupation*** and ***where you live***.

The penultimate section examines the ***sources of uncertainty*** in how climate change will affect health in the future. This includes the uncertainties in how ***greenhouse gas emissions*** will change***,*** how the ***Earth's*** climate and ecological systems will respond, and how global human ***civilisation*** will change. We explore the potential role of ***systemic risk*** and '***Black Swan***' events – ones that are highly unpredictable and uncertain but that have major impacts. We then discuss the use of ***scenario modelling*** in the context of the many uncertainties.

Our final section covers the ***public policy and regulatory*** implications of climate change. ***Mitigation*** is necessarily a global task; however, we will focus on the UK perspective. We will then look at the UK health-related ***adaptations*** that could be pursued and what our current trajectory is.

2 Direct health impacts

SUMMARY

Direct health impacts arise from physical hazards such as higher temperatures and increased flooding, biological hazards such as increases in the risk of some infectious diseases, and hazards caused by influences on food and water.

Although there are many areas where the direct effects of climate change are expected to influence health, the magnitude of the impacts that will occur is uncertain. The risk from increased flooding is significant, but is highly dependent on how we prepare and respond to it. This is also true when considering the potential for increased transmission of vector-borne diseases, as well as impacts on water supply and safety. Food quality and safety may be affected, but supply and affordability are likely to remain larger concerns in the UK.

KEY POINTS

- In the UK, the negative health impacts of greater summer heat may remain less than the positive impacts of the reduction in winter cold.
- The health impacts from increased flooding are from impacts on mental health and from impacts occurring during the aftermath and clean-up.
- The climate impacts on air pollution are uncertain and are likely to be much smaller than any changes directly caused by human activity.
- Warmer year-round temperatures are making the UK more hospitable to vectors of disease, such as mosquitos and ticks.
- Changes in temperature and extreme weather may impact the availability and safety of food and fresh water.
- Overall, the direct health effects of climate change in the UK are highly dependent on how we respond to changing hazards.
- The direct negative effects of climate change on health in the UK are likely to be far smaller than in many countries where the effects of climate change will be more extreme and where resources to adapt are much more limited.

2.1 Impact of environmental hazards

2.1.1 Extreme heat

From the 16th to the 19th of July 2022, the UK experienced a heatwave of unprecedented intensity. A temperature of 40.3°C was recorded in Lincolnshire, a new record both for England and the UK as a whole, and an increase of 1.6°C on the previous record set in 2019. Notably, temperatures at 45 other English meteorological stations exceeded the 2019 values as well. Wales and Scotland also experienced extreme temperatures during this time, beating previous national records by 1.9 and 2.2 degrees respectively[3]. Although this heatwave event is only a single datapoint, it is part of a general warming trend for the UK, where the first two decades of the 21st century have been warmer than any other 20-year period in at least the last three centuries. It is also part of a trend for increased frequency of extreme summer heat waves even beyond the average rate of warming[4].

High temperatures can cause heat exhaustion, heatstroke, premature birth[5], and workplace accidents[6,7]; exacerbate existing morbidity[8,9]; and precipitate deaths from other causes such as respiratory failure and heart disease[10]. Heatwaves already have direct impacts on mortality and morbidity in the UK, particularly in England. There were an estimated 2,000 average excess heat-

related deaths per year in the 2000s in the UK[11]. This has been projected to have increased to over 3,000 by the 2020s, and from there to around 7,000 by the 2050s, and to over 12,000 by the 2080s[11].

While more extreme summer heat is expected to increase heat-related deaths and illness, we can also expect there to be a reduction in cold-related mortality and morbidity due to milder winters. Projections of cold-related deaths in the UK under a range of warming scenarios predict only a marginal decrease from around 43,000 in the 2020s to 36,500 in the 2080s[11]. Whether the decrease in cold-related mortality is enough to compensate for the increase in heat-related mortality in the UK is uncertain, and would depend on both the amount of future warming, and other factors such as demographic changes, adaptations made, and geographical location[12]. The impact on health of both extreme heat and extreme cold also relates to how experienced people are with dealing with the conditions, and also housing characteristics and other factors that affect high and low indoor temperatures.

There are further complexities to the potential health impact of increased temperatures in the UK. Warmer weather may increase time spent in outdoor physical activity and contact with nature[13], both of which are associated with benefits to physical and mental health[14]. However, this effect may be tempered by increased adverse weather, particularly rain[4,15]. Increased outdoor activity may have other positive health outcomes, such as a beneficial increase in population vitamin D levels[16], or negative outcomes such as a higher burden of skin cancers associated with the increased exposure to ultraviolet light[9]. Climate change may contribute to depletion of the ozone layer and further increase ultraviolet light exposure for those outdoors[17].

In summary, therefore, while the recent record summer heatwaves may be a worrying indication of the pace of climate change, the net health effect of temperature rises on health in the UK is uncertain. This is because of the large number of assumptions that have to be made when making projections for both heat-related deaths and cold-related deaths. However, as current rates of cold-related deaths in the UK in the 2020s are estimated to be around 13 times higher than heat-related ones[11], it is certainly plausible that future warming could have a net beneficial effect if proper adaption were made. This is in contrast to many countries at lower latitudes and the southern hemisphere, where annual mean temperatures have a much higher baseline, and rises have more serious impacts on health and mortality[18].

2.1.2 Flooding and precipitation

Future changes to UK weather will depend in part on the position and variability of the North Atlantic Jetstream. It is uncertain how the frequency, intensity, and quantity of rainfall in the UK will change, but in general warmer air holds more moisture and so has a greater potential for resulting in extreme precipitation events[4]. Coastal flooding will increase due to rises in sea level and glacial rebound. The impact of all kinds of flooding will be determined by the building of housing and businesses within flood plains that is associated with population increase and investment[19], as well as investment in flood defences (hard defences and nature-based solutions). Frequent flooding currently affects about two million people in the UK, and it has been estimated that this may rise to over six million by the 2080s, depending on the assumptions made[20]. Continued urbanisation and loss of green space will increase the severity of flooding when it occurs, as the ground is less able to absorb excess water[21].

Flooding, particularly when coastal, can cause deaths from drowning and injury[9]. The most severe UK flood within living memory, which hit the east coast of England in 1953, caused 307 deaths. However, only six coastal floods have been implicated in direct deaths in the UK in over 100 years[22]. Instead, the major impacts of flooding on health and wellbeing occur secondarily to the flooding event in ways that are far harder to measure. For example, car accidents, hypothermia and other morbidities can occur

during the aftermath and clean-up. The likelihood of biological and chemical contamination of water supplies also increases[23]. The greatest burden on health due to flooding is likely to be through significant and long-term impacts on mental health, including depression, anxiety and PTSD. The most severely impacted are those who are evacuated or displaced, and the impacts extend beyond those directly affected[25].

2.1.3 Air pollution

Air pollution is a complex mix of gases and particulates from a range of sources. It causes respiratory, cardiovascular and other disease in the long-term, and can aggravate other conditions in the short-term[26]. Air pollution is currently estimated to cause tens of thousands of excess deaths per year in the UK[26,27].

The UK is expected to experience more frequent and severe wildfires in future[28], the particulate smoke from which affect millions of people[29]. Recent decades have seen longer pollen seasons and increased pollen load, which exacerbates allergies and other respiratory conditions[30,31]. Surface ozone levels, which can cause respiratory symptoms and exacerbate asthma, may also be increased during more frequent periods of warm stagnant air[4].

However, human emissions, particularly from the burning of fossil fuels, are a much more significant cause of air pollution than climate change itself[32–34]. Overall, particulate pollution is projected to decrease in the UK and across Europe[35] due to moves away from fossil fuel use in energy generation and particularly transport.

2.1.4 Vector-borne disease

A warmer and wetter climate is expected to increase the suitability of parts of the UK to mosquitos and other disease vectors[36], as well as allowing transmission of a broader range of diseases[37]. This includes tick-borne encephalitis (TBE) virus, discovered in UK for the first time in 2019[38], and tick-borne Lyme disease, which increased over 500% between 2001 and 2017[39]. Eggs from alien mosquito species that can act as vectors for viral illnesses have been imported to the UK[40] and the West Nile virus was identified in Kent in 2010[41]. Once established, the prospects for eradicating zoonotic pathogens are poor; the West Nile virus was first detected in North America in 1999[42], and is now well established across the continent.

At least some of the increase seen so far in vector and vector-borne disease prevalence within the UK is due to changes in travel and behaviour, and future increases could be diminished by medical professional and public awareness, vector control measures, and monitoring efforts[9,39,43].

2.1.5 Water availability and safety

Climate change is expected to reduce the reliability of freshwater availability, and some regions in England are projected to have more significant water supply deficits in future. Water demand is also likely to increase due to population growth and economic development. Together, this may lead to disruptions to household water supply, which may have concomitant health impacts[9].

Beyond the supply, expert opinion suggests that climate change may affect water quality because of contamination from heavy rain, flooding, and runoff into waterways. The pressure on sewerage systems can increase significantly during extreme rainfall, with a resulting rise in the probability of contamination by faecal pathogens[44,45]. Coastal sewage discharge, such as can occur after heavy rain, can increase norovirus concentrations near the shore up to 10 times higher than normal[46]. Warmer water encourages the growth of pathogens, and the Food Standards Agency has developed a model to predict cholera outbreaks that incorporates climate change data[47].

2.1.6 Food quality and safety

The warming of oceans reduces the body size of marine food species[48,49], though the major contribution to their depletion will likely remain unsustainable fishing[50,51]. Rising temperatures and carbon dioxide levels will have complex effects on the growing seasons, ranges, and nutrient yields of staple crops[52,53]. Huge increases in yields were seen during the second half of the twentieth century during the 'Green Revolution' due to mechanisation, deployment of fertilisers and pesticides, and particularly through the development of novel crop varieties[54]. In absolute terms, the direct effects of changing carbon dioxide concentrations are likely to be relatively small in comparison. However, with global food requirements still increasing, and hundreds of millions of people still undernourished[55], yield decreases of only a few percent would constitute a catastrophic impact at a world-wide level. In addition, shifting regional climates, sea levels, and an increase in extreme weather, including flooding and drought, are likely to cause increased disruptions to the stability of agricultural production. This issue is discussed further in the next section.

Changes in rainfall, temperature, and the occurrence of extreme weather events also affects the growth of various food-borne pathogens[9,56]. It has been suggested that this may result in a rise in the incidence of illnesses such as gastroenteritis[57] and increased risk of foodborne disease outbreaks with social and economic implications.

The UK, as a wealthy nation, would likely avoid the worst direct impacts on food quality and safety, but any resulting rises in food prices could increase the amount and severity of food poverty.

3 Indirect health impacts

SUMMARY

The indirect impacts of climate change on health include those arising from disruption to the processes and systems necessary for supporting healthy populations, including infrastructure, the economy and international relations.

The maintenance of health and provision of healthcare depends on functioning and reliable infrastructure. Economic growth will be affected by climate damages, as well the mounting economic cost of climate change mitigation and adaptation. The international challenges are those of supply chains, and those resulting from growing resource insecurity such as food, water, and energy.

KEY POINTS

- Population health is dependent on economic prosperity and the effective functioning of our societal systems, and climate change threatens these at many points.
- The UK is highly embedded in a global system, and so international climate effects have implications for our society, economy, and supply chains.

Population health needs to be considered at the societal level as it relies on many inputs, such as healthcare provision, education, social safety nets, availability of healthy foods, and clean water. All of these in turn are sensitive to wealth and require functioning economies. Therefore, the indirect health effects of climate change are those that follow from the disruptive social, political and economic effects of climate change in the UK, regionally, and globally.

3.1 Economic

Climate change is expected to impact economic growth in a multitude of ways. The most obvious is in the cost of damage from direct heat, flooding, or extreme weather[19]. However, there is also the cost of lost productivity, lost opportunities, stranded assets, and the transition costs of mitigation and adaptation. The cost of climate change to the UK economy by 2045 has been estimated as at least 1.0% of GDP[58]. Climate impacts cause losses and damage that reduces the availability of financial resources and hinders economic growth, financially constraining adaptation[59]. In addition, with further stress placed on government finances for climate change mitigation, adaptation, and recovery, fewer funds will be available for public spending – including for health and social care and social safety nets[9]. Between the impacts on public resources and personal finances, economic recessions in particular are associated with higher mortality rates in the population[60].

The UK economy is embedded in a much larger, global system. The anticipated global GDP impacts are expected to be more severe than for the UK alone. Swiss Re has estimated a 4.2% GDP loss at mid-century as compared to a world without climate change even if the Paris agreement target of less than 2°C increase is achieved, and at least 11% if it is not[61]. Their analysis considers how the impacts of climate change on the economies of different countries will vary. Northern hemisphere countries are expected to be less affected and better resourced to cope[61]. With a 2°C rise it is estimated that the reduction in GDP would be about 6.9% in North America, 7.7% in Europe and 15% in Asia by 2050. Climate change will lead to a poorer world overall, and if the world is poorer, the UK will be poorer than it would be otherwise.

The global nature of the consequences of climate change becomes apparent via the indirect impacts. The full scale of the mitigation and adaptation costs of climate change are, at present, not fully

realised. The changes required for a net-zero energy system alongside the costs of future energy demands are not currently factored into UK government policies. Consequently, more precise cost estimates are not available[9]. According to the Bank of England, the economic ramifications of a late mitigation are expected to be greater than that of an early mitigation[62]. This is due in part to a reduction in climate hazards, and in part due to a longer time period for a return on investment to occur.

Although the UK may experience some economic opportunities from climate change, such as the opening up of arctic trade routes and changes in agricultural capacity, these are not expected to outweigh the risks[9].

3.2 Infrastructure

The importance of physical infrastructure is easy to forget. As the efficiency, reliability, and coverage of electrical, transport, telecommunication, and other systems has improved, so has our reliance on them. As mentioned when discussing the direct impacts of flooding on health, the impacts are long-term and persist for months or years after the flood event. Living without electricity, heating, potable water, internet access, and transport connections will have immediate negative health impacts. Healthcare systems are dependent on both their own internal and specific infrastructure and external infrastructure systems. These include water supply; electricity; and roads and other transport infrastructure used by the emergency services, staff, patients, and the equipment supply networks.

There are domestic threats to food security in the UK. Reliable, high-quality water access is vital for agriculture and other activities such as power, industry, and construction[9]. According to Water UK, the investment needed to maintain existing water resilience in England and Wales is between £50 million and £500 million per annum, but this could increase to up to £800 million per annum for resilience to extreme drought. The wide ranges of these estimates reflects sensitivity to population growth and uncertainty in future climate change[63].

Within healthcare settings, episodes of extreme heat can reduce staff productivity and directly cause equipment failure, such as of refrigeration units and IT systems[9]. In general, however, the risk of flooding is of particular significance. It is projected to increase in all UK nations under all 2-4°C global temperature increase scenarios. In the UK, approximately 10% of hospitals are already in areas of significant flood risk[9]. Flooding also has the potential to interrupt access of both patients and staff to GP practices, care homes, hospices, and at-home care services. This can be through site flooding or loss of access via roads and bridges[9]. In 2015, the Royal Berkshire Hospital experienced a power cut due to flooding and consequently closed its A&E department to all but life-threatening cases[64]. This illustrates the ability of these events to undermine healthcare delivery by reducing capacity and access to routine health provision.

The major challenges faced include ensuring continuity of service provision, resilience of physical assets, and ensuring institutional policies and operating practices are responsive to changing needs. An example would be adjusting daily routines, management, and operating practices in care homes to reduce risk during a power outage secondary to an adverse weather event[65].

3.3 International interactions

The impacts of climate change on international affairs may affect health indirectly in other ways. These include food access, competition for resources, conflict, and migration.

As already discussed, climate change may directly affect domestic food yield and quality. However, as discussed in the most recent Lancet report on climate and health, food security is reliant on multiple interconnected pathways, every dimension of which is being affected by climate change[1]. The UK

imports 46% of its food, making it vulnerable to the global impacts of climate change[66]. An analysis of the causes of shocks to crop production systems globally during the period 1961-2013 found that around half were due to climate or weather events[67]. At present, approximately 20% of countries from which the UK imports fresh produce have increasing climate-associated risks[68]. Volatility in the provision of fresh produce affects their availability and cost, which has consequences for health[69]. A fresh vegetable shortage was experienced in the UK in 2017 which led to a 300% increase in prices. Higher food pricing leads to a decrease in the diversity of diets, with potentially adverse effects on health[70]. Much of the food supply chain network is managed by the private sector. Governments will need to provide incentives to encourage private sector resilience and adaptation[9].

The societal and economic impacts of climate and weather changes will cross national boundaries via impacts on markets and supply-chains, making the UK vulnerable to global hazards. Thus, societal, economic, political, ecological and climate changes occurring elsewhere have relevance for health impacts in the UK. It is expected that threats to the water, energy and food supplies that cross national boundaries will become more frequent[59].

Global competition for land and water resources is set to increase due to unsustainable agricultural expansion and changes to freshwater flows. In turn, this will serve to increase both ecosystem and human vulnerability[59]. Displacement of people around the world as a result of conflict or climate change-related events becomes much more likely with progressive warming[59]. Adverse climate and weather events will occur across borders, causing economic and societal impacts with the potential to disrupt the status quo of international relations and trade, and promote conflict. Although the exact changes are subject to a lot of uncertainty, it is likely there will be an increase in transboundary risks to the water, energy and food supplies[59].

4 Mitigations, adaptations, and the low-carbon transition

SUMMARY

Mitigation aims to limit the hazards of future climate change by reducing or reabsorbing greenhouse gas emissions. However, the benefits will mostly be limited until the second half of the Twenty-First Century because of the lag-time between a change in concentrations and a resulting change in climate. These mitigations may have other impacts on health, for example in the reduction in air pollution from fossil-fuel combustion. Adaptations aim to reduce exposure and vulnerability to climate hazards, some of which have health implications. Transition to a low-carbon economy brings its own potential risk and health impacts.

KEY POINTS

- The future climate impacts on health are largely dependent on human actions.
- Future climate-related hazards to health are dependent on global mitigation actions.
- Our exposure and vulnerability to the health impacts of climate hazards in the UK are dependent on adaptation measures.
- Adaptation and mitigation goals can sometimes come into conflict.
- Beyond physical risk, moving to a low-carbon economy involves disruption of established industries and ways of living – leading to socio-economic transition risks.
- The low-carbon transition is highly cost-effective, and the earlier the better, provided there is international co-operation.

4.1 Introduction

In addition to the direct and indirect impacts of climate change on health, there are also the effects of intentional changes made by the public and private sector to respond to climate change. Mitigation actions have the potential to reduce the severity of climate hazards by limiting the amount of warming that occurs, while adaptation actions can reduce exposure and vulnerability to climate hazards to health.

HAZARDS, EXPOSURES, AND VULNERABILITIES

Climate hazards are the destructive phenomena that threaten valued assets such as health, infrastructure, and biodiversity. This includes direct hazards such as heatwaves and floods, and downstream events like wildfires, crop failure, and vector-borne disease.

Exposure is the degree to which the assets are affected by the hazard. For example, Low-lying homes are more exposed to flooding than elevated ones.

Vulnerability is the degree to which an asset exposed to the hazard is likely to be damaged or destroyed. For example, the health of an elderly person may be more vulnerable to flooding as they are less able to evacuate.

Risk is the probability of harm from a hazard, i.e. a combination of the probability of a hazard occurring, and the exposure and vulnerability to it.

There may be conflict between mitigation and adaptation goals, for example when carbon emissions result from the use of concrete in flood defences. On the other hand, there are also opportunities to implement mitigation and adaptation goals that operate in concert, such as planting trees as a form

of natural flood defence. Health impacts may occur as by-products, for example in the form of reduced air pollution due to the electrification of transport systems. At present, most of the public attention focuses on mitigation, which requires a global effort, rather than adaptation, which tends to be implemented at a local level. This disconnect has been highlighted as a limit to action, as can it make it harder to implement adaptations in a concerted, synergistic way[71].

More generally, the transition to a low-carbon economy includes socio-economic cost and risk, with downstream implications for health. These risks are considered cost-effective in order to reduce risks arising from climate change, but only if a low-carbon transition occurs at a global level.

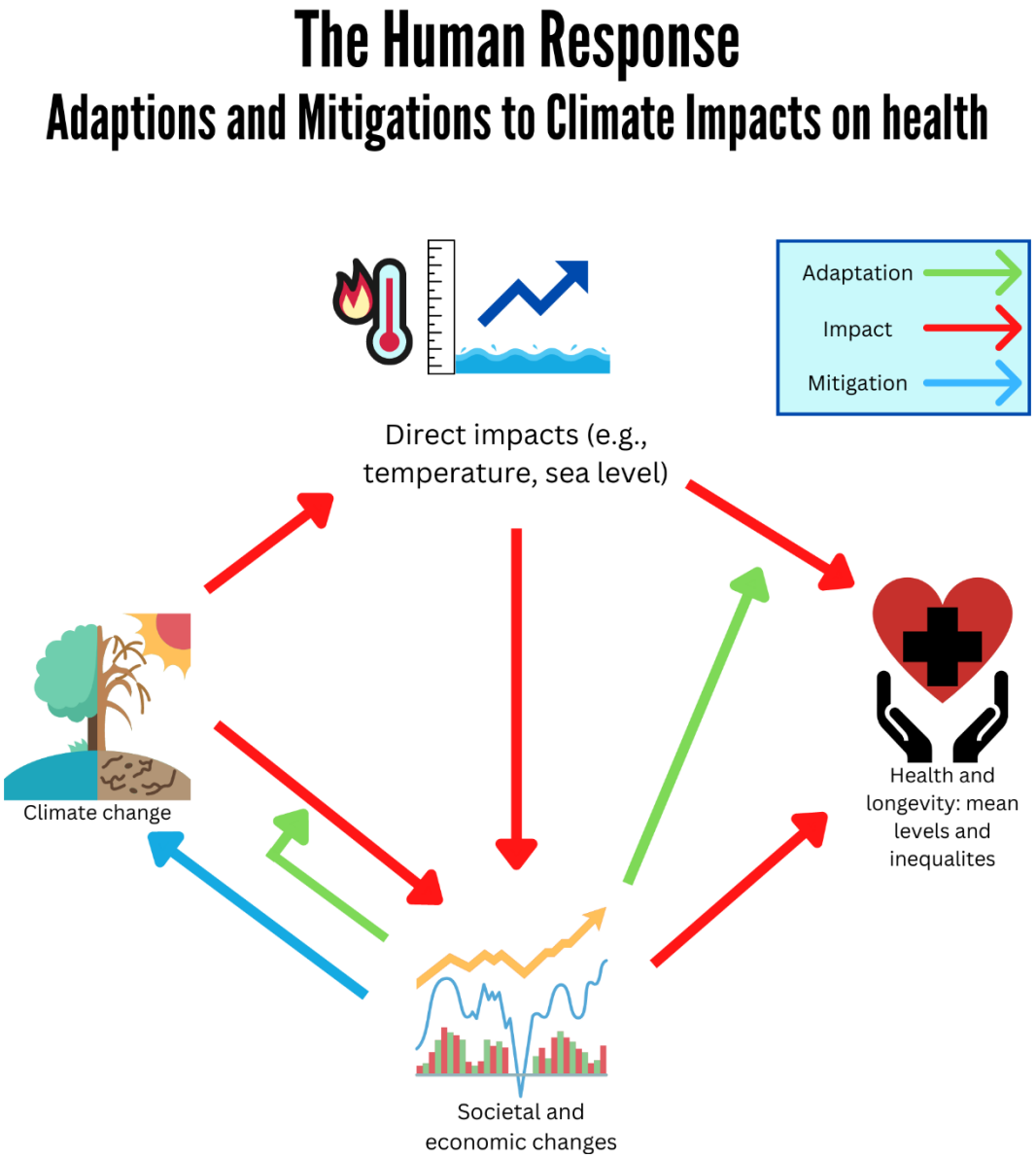

Figure 1 – The impact of climate change on health is highly dependent on the actions we take to mitigate the magnitude of the change and adapt to the consequences of it.

4.2 Housing, heat, and indoor air quality

When considering adaptation to higher temperatures, factors that moderate the hazard to health are individual vulnerability, behaviour, and indoor temperature. Actions to manage this hazard could take a variety of forms, including raising public awareness of heat risk and encouraging behavioural adaptation; improvements in housing design for new properties and retrofitting of existing properties;

and changes in urban design aiming to reduce outdoor temperatures, for example by expanding urban green areas or using appropriate building materials[9]. Architectural adaptations to indoor temperature include shading, ventilation, and cooling mechanisms[9]. Urban buildings such as housing and offices are prime targets for adaptation.

It has been estimated that 20% of homes in England are currently overheating in an average summer, so the level of residential heat adaptation should have a large effect on mortality and morbidity[9]. For existing buildings, retrofitting with passive measures such as ventilation, external shading and shutters[72,73], internal blinds or curtains[74,75], green roofs[76] and reflective external surfaces[77] are likely to be sufficient even in higher high warming scenarios. The exception is in London, where temperatures will be particularly high[9]. in addition, uncertainty remains as to how broadly such measures can be applied, and their effect is marginal at higher temperatures. Currently, about 3.0% of homes have air conditioning[78], though this proportion is likely to increase. Older people, particularly those in care and nursing homes, are particularly vulnerable to death from heat, and so would derive the most benefit from the installation of space cooling[79].

Air conditioning, although it is adaptive, has costs. Over-reliance on air-conditioning increases energy consumption and the waste heat contributes to the urban heat island effect. It may also reduce natural physiological adaptation to heat[80], and those who rely on it may then be at higher risk if power is lost. This is an example of potential maladaptation. However, if run on renewable energy then an increase in air conditioning would not increase carbon emissions.

MALADAPTATION

Maladaptations are actions that are intended to reduce vulnerability to climate hazards, but may paradoxically increase vulnerability to the same or some other hazard, or reduce future opportunities to take effective action. This may occur due to conflict between competing goals, the prioritisation of short-term goals over long-term ones, failure to plan effectively, or lack of knowledge.

Actions to reduce overheating in homes can conflict with goals to reduce carbon emissions. A primary target of the UK's Net Zero goal is the reduction of winter heating emissions from housing. Energy efficiency is often factored into the design of new builds. However, household energy efficiency programmes focussed on cold periods, ***if improperly implemented***, could exacerbate summer heat risks by reducing ventilation inside buildings[81,82]. While bedrooms in better insulated modern homes have been found to be significantly warmer[83,84], dwellings with higher levels of insulation may also overheat twice as frequently[85]. Lack of ventilation is also a risk factor for moisture and mould. At present, many homes do not comply with regulatory requirements with regard to ventilation[86]. Achieving thermal efficiency in new builds requires the use of Mechanical Ventilation and Heat Recovery (MVHR) systems. However, while potentially beneficial to indoor air quality in ideal conditions, they are often far from efficient in practice[87] and may actually result in an exacerbation of air quality-related health risks[9].

This is a clear example of the importance of taking a combined view of mitigation and adaptation approaches. The Climate Change Committee (CCC) suggests that ventilation and passive cooling should be assessed along with energy efficiency when planning the retrofitting of existing residential properties[88].

4.3 Outdoor air quality

Levels of particulate air pollution in the UK are mainly due to emissions from fossil fuel combustion. Achieving Net Zero goals is expected to result in a significant reduction in outdoor air pollution over the next two decades under most climate change scenarios[35]. Widespread electrification, conversion to "green" energy sources, and changes in agricultural practices should reduce combustion-related emissions and sources of particulates, with a resulting net health benefit[89].

4.4 Food

At present, the Climate Change Risk Assessment (CCRA) considers that policies aiming to address food safety and security are not adequately developed and that this issue remains somewhat under researched[9,70]. This makes it difficult to quantify the efficacy and adaptation in this area, or its specific health impacts.

Reducing emissions to reach Net Zero will affect food production and consumption through changes in agricultural practices and dietary preferences. Globally, it is likely that a shift away from animal products will be necessary to achieve emission reduction goals while ensuring that an increasing world population can be fed. A case could be made for increased health benefits from diets low in animal fats[9] and a cultural shift from meat to plant-based food products has some momentum in the UK[90]. The UK government is still in the process of developing policies to promote sustainable diets.

There may be harms related to adaptations in food distribution systems[70]. A trend towards diets using more locally sourced, low emissions foods may increase seasonality in the availability and consumption of fruits and vegetables, leading to micronutrients deficiency in segments of the population[91].

The overhaul of food trade agreements following Brexit may impact food standards. EU regulatory standards are extremely strict and prioritise prevention of contamination over remediation, but this may not necessarily be a priority for the UK food sector going forward. In fact, imports of low quality or contaminated food from the US has been an ongoing concern since the UK exit from the EU[92]. At the moment policies targeting food insecurity are devolved[70], something that may impede the development of national adaptation polices.

4.5 Transition risks

In addition to the role of mitigation and adaptation in increasing or decreasing direct climate risks, there are risks that emerge due to the transition towards a low-carbon economy in pursuit of Net Zero. The required adjustments to the economy will result in headwinds for growth that lead to short-term stresses, even though their net effect over the longer term will be positive. Some sources of economic growth, such as exploitation of natural gas reserves in the North Sea, will have to be sacrificed entirely. These transition risks can be seen as trade-offs for avoiding some of the climate risks. 'Greening' the economy will inevitably lead to the phasing out of some industries and jobs, but also the expansion of others. These changes are unlikely to be evenly distributed across the country.

The UK represents a global financial and insurance hub. A recent analysis by the Bank of England concluded that UK banks and insurers have made progress in risk management, but need to do much more to fully understand and manage their exposure to climate risk, including risks stemming from sectors that are likely to be heavily impacted by efforts to transition to Net Zero. Even under the 'Early Action' scenario, where global climate policy is ambitious and Net Zero is reached around 2050, economic growth is disrupted. 'Late action' results in short-term macro-economic and financial disruption, unemployment rises, and recession. 'No Action' results in permanently lower GDP growth and increased macroeconomic uncertainty, as well as permanent impacts on living and working

conditions. This relates to the concept of an ‘organised’ vs ‘disorganised’ transition to a low-carbon economy. Entire sectors, such as energy and transport, will require extensive overhauling to meet Net Zero targets. Early planning and a proactive organised transition will result in far less chaos and disruption, lock-ins, stranded assets, economic disruption, and loss of livelihoods than a reactive disorganised one[62].

The Bank of England analysis concludes that the socio-economic transition risks to achieve global Net Zero by 2050 are more than worth it to avoid the socio-economic risks arising from higher levels of warming, and that the earlier this occurs the lower the risk of economic recession in the UK[62]. However, emissions reductions are only fractionally influenced by UK actions. Ultimately, due to the global nature of the climate change challenge, a low-carbon transition in the UK will only lead to reductions in global climate change and its associated hazards if there is significant global collective action to reduce emissions.

5 Impacts on mental health

SUMMARY

Climate change can affect mental health through both physiological and psychological pathways. The physiological effects are primarily a result of extreme temperature. Mental trauma can be caused by the damage to people's homes and livelihoods through, for example, flooding. Even those not severely or directly affected by climate change may suffer anxiety and worry as a result of hearing about others who are, as well as by witnessing the tangible destructive effects of climate change on the natural environment. The future impacts on the mental health of children growing up in a climate change-dominated world are not clear, but instability, unpredictability and threat are known risk factors. Deeper questions about the responsibility we have as individuals for caring for and protecting the natural environment may prompt feelings of shame, guilt, and hopelessness in some, while inspiring resolve, compassion, and purpose in others.

KEY POINTS

- Mental health is often neglected in population health management as it does not appear as a prominent cause of death in mortality statistics.
- The potential scale of adverse mental health effects of climate change in the UK are under-researched, but potentially important.
- The most common direct impacts of climate change on mental health in the UK come from flooding.
- Mental health and wellbeing is impacted not just by direct harm, but by the threat of harm, and uncertainty about the future.

5.1 Introduction

So far, we have only considered the impacts of climate change on physical health. However, the impacts on mental health and wellbeing are also significant. Poor mental health can occur alongside impacts to physical health, but also occur as a response to harms, threats, and uncertainties relating to the impact of climate change on societies and ecosystems. Poor mental health can have major social and economic impacts, and increases mortality. This is a relatively under-researched area, and while some associations are well evidenced, such as the causal relationship between flooding and post-traumatic stress disorder, others are less clearly established.

5.2 Definition of mental health

Climate change can negatively impact mental health in two main ways: by causing actual harm to people, family members, homes, livelihoods or culture, or by acting as a threat of harm and source of uncertainty. Bodily health is more than just the absence of disease. Similarly, good mental health is more than the just absence of recognised mental health disorders such as anxiety and depression. People must have a state of mind that enables them to cope with the uncertainties of life, realise their potential and engage with their communities. Integral to this idea is having the ability to make individual and collective decisions, and build relationships which shape and influence their lives[93].

The effect of climate change on overall health depends on the close relationship between physical and mental wellbeing. Poor physical health can have a detrimental effect on mental health[94] and, conversely, poor mental health can have a negative impact on physical health through behavioural changes, poor sleep, a poor diet, lack of exercise, increases in smoking, or a weakened immune system[95–97].

5.3 Impacts of climate change on mental health

5.3.1 Acute events, flooding

In the UK, acute flooding is the most common disruption to health and wellbeing caused by extreme weather. This hazard, and the population exposure to it, is expected to increase under climate change[4,98]. On an individual level, Post-Traumatic Stress Disorder (PTSD) is one of the most frequently reported and well-studied forms of post-disaster mental health outcomes[99]. The prevalence of PTSD amongst those whose homes were flooded was estimated at 36% in the English National Study of Flooding and Health[24]. Factors related to flooding that may further increase the risk of PTSD and other mental health problems such as trauma, shock, anxiety, and depression include exposure to intense, multiple, or long-lasting events (e.g., repeat flooding); the need for evacuation[100]; loss of utilities; persistent flood-related damage to homes; and importantly, problems with insurance[99,101]. Flooding can cause an increased risk of anxiety, depression and PTSD even in those who were only indirectly affected[25].

At a community level, social relationships and social cohesion are negatively impacted resulting in a loss of supportive social networks. The consequences of this can include domestic violence and child abuse [99]. In insurance terms, the impact on mental health is an important element of the intangible losses related to flooding, which are valued at 20% of the direct residential damages from flooding[19].

INTANGIBLE LOSSES

In flood risk insurance, intangible losses are losses that are difficult to measure in financial terms but still entail a loss of value. It encompasses damage to health and wellbeing, loss of life, and the inconvenience experienced during recovery, but also includes cultural, historical, and ecological losses[237].

5.3.2 Heat, drought, and air pollution

Episodes of heat, drought and air pollution can directly exacerbate mental health problems and their consequences such as suicide, interpersonal violence and a greater burden on health care services[102–105]. The effects of heatwaves on mental health have been reported hot countries like Israel, Australia and parts of the United States, but also in cooler countries like France and Canada[99].

5.3.3 Loss

The less tangible effects of climate change include the loss of personally important places, personal and occupational identity, autonomy and control, and loss of cultural and natural heritage[99]. As an island, the UK has extensive areas of low-lying coastline and flood plains which are at risk of loss. For example, the north and north-east Norfolk coastline has already experienced a loss of homes due to rapid coastal erosion caused by rising sea levels[106]. Much of the coastal village of Fairbourne in West Wales will be below normal high tide levels within the next 50 years. With the risk of flooding increasing and limited resources to manage flood defences, the villagers will be relocated or the village moved to a safer location[107]. It can be easy to think that it is only an emergency evacuation of someone's home that results in mental health difficulties, but voluntary planned displacement also harms mental health[108].

5.3.4 Climate anxiety

Concern about the impacts of climate change and future uncertainty can lead to feelings of fear, anger, powerlessness, anxiety, helplessness, sadness, despair and even guilt, shame and grief[109]. Hearing about the traumatic experiences of others or imagining future harm can cause people to question their vulnerabilities[110]. These emotional responses, which in some people could be extreme, can

hinder the ability of people to process information, behave appropriately, and make rational decisions[99].

Climate anxiety is often presented as a particular burden of the young, though it affects all age groups to a varying degree. A recent Office for National Statistics (ONS) survey of almost 4,000 adults suggests that around three quarters of adults in Great Britain, regardless of age, are 'very worried' or 'somewhat worried' about climate change[111]. Social media and online news channels give children and teenagers access to information about extreme climate events that are occurring around the world. This can cause feelings of despair and helplessness; particularly as young people have fewer resources and coping strategies available. Poor mental health and well-being in children and teenagers can influence mental health in adult life[112]. Climate activism is often a way that they can demonstrate and express their feelings[70].

5.4 Positive impacts of climate change on mental health

It is possible that climate change may have some positive impacts on mental health in the UK[9]. There may be benefits and opportunities that come with greater access to outdoor spaces for a greater part of the year[14] such as an increase in physical activity, social contact, and time spent in nature[113]. In the event of an effective and co-ordinated global response to climate change, a sense of international community and social purpose may be enhanced, along with a renewed appreciation for the natural world. However, these are likely to reflect silver linings in an otherwise dark cloud.

6 Inequalities

SUMMARY

Vulnerable populations have fewer resources and a reduced ability to cope with the effects of climate change, leading to a greater detrimental impact on health. The need for the costliest mitigations and adaptations to combat climate change are concentrated in the most deprived areas and the population of these areas are the least able to afford them.

KEY POINTS

- Within the UK, the exposure and vulnerability to climate hazards varies across the population.
- Geographical differences affect climate impacts and are related to socio-economic status.
- The risks are greatest for those groups already most vulnerable to poor health, particularly those that rely on others for care such as children, the elderly, and those with disabilities and pre-existing conditions.

6.1 Introduction

So far, the impacts of climate change on population health and wellbeing have been broken down into those effects that are more direct, those that are more indirect, and those that result from adaptations, mitigations, or a poorly managed transition to Net Zero. However, within the population, these impacts are not distributed evenly. Certain characteristics of individuals or sub-groups of the UK population may affect their exposure and vulnerability to climate impacts. In addition, anticipated negative impact of climate change on the economy may weaken the social safety net, with less resources available for vulnerable and disadvantaged people.

The UK Equality Act of 2010 identifies a series of protected characteristics in order to prevent active discrimination including age, disability, gender reassignment, marriage or civil partnership, pregnancy and maternity, race, religion or belief, sex, and sexual orientation[114]. However, the active discrimination that this act is intended to prevent does not account for the fact that there are also structural inequalities among these groups, as well as inequalities in income, employment, access to housing, and geographical location. Each of these factors modifies the exposure and vulnerability to the direct and indirect impacts of climate change, as well as the ability to adapt.

We know that the additional vulnerability that inequality confers has a substantial impact on health, mortality, and longevity. This is described in our previous report on the gap in life expectancy between those living in the most and least affluent areas in England[ii]. Using place of residence, our 2018 analysis demonstrated a 5.0 year difference in life expectancy at age 60 for men in 2015 when comparing the most and least deprived quintiles of deprivation, and a 4.2 year difference for women[115].

Those of low socio-economic level are generally more exposed and vulnerable to climate hazards to health, and the effects of climate change may increase existing socio-economic inequalities further[9]. An analysis of national income inequalities among 37 of the 38 countries within the Organisation for Economic Co-operation and Development (OECD) placed the UK sixth, with a Gini coefficient of 0.366, just behind the USA at 0.395[116]. Therefore, considering the interaction of climate change and income

[ii] Wealth is highly associated with longevity, as discussed in our previous report: "Life expectancy: Is the socio-economic gap narrowing?"[115]

inequality is an important policy challenge for the UK and must be considered when undertaking adaptations and mitigation measures.

6.2 Age inequalities

The young and the old are disproportionately affected by climate change compared to working age adults. This is due to differences in physiology, impacts on education, development, exposure, vulnerability to illness, lack of social support, declining health, and disruption to daily activities.

6.2.1 Children

Climate change and the associated increased risk of extreme weather events is likely to disproportionately affect children, particularly younger children and those with special needs[9], through ongoing trauma, lack of social support, and interruption to schooling[117]. Children are at increased risk from air pollution, heat, malnutrition, infectious disease, allergies and mental illnesses, all of which have adverse impacts on their development[118,119].

Babies and children have a less effective heat adaptation capacity than adults and are therefore more likely to suffer from a heat related illness[120]. A child's memory, stamina and cognitive performance can also be impacted by high temperatures, hindering their ability to learn, develop and retain information[121].

Extreme weather events such as flooding can damage or temporarily close educational facilities such as schools and preschools, or cause issues with access for both students and teachers. This causes disruption to education that can affect long-term learning, which, in turn, can also affect their economic activity as adults[117].

Compared to adults, children may experience more severe distress after an extreme weather event[122], as has been seen in the UK after the 2013/14 floods[123]. Children are impacted by the loss of their social support networks and by the loss of networks that enable them to thrive, such as friends, schools, health care, and social services. The mental health of children is not only affected by their own experience of climate-related disaster but also by the impact it has on their caregivers' mental health[123,124].

A study in American children who were affected by Hurricane Katrina in 2005 found that those who suffered the most damage and adverse effects from the storm also experienced less social support from others. This is probably due to the fact that the people who were in their immediate support group were also suffering from the effects of the hurricane[125]. People dependent on caregivers, such as children, may be the most affected by climate change. Their reliance on others to make decisions for their welfare may mean that these decisions will have long-term societal and economic impacts that the children have very little control over[120]. High levels of stress during childhood, like those caused by natural disasters, have been shown to affect the development of neural pathways and so damage the child's memory, decision making and executive function, with effects continuing through to adulthood[126].

Poor nutrition can have long-term effects on children, and food insecurity, often linked to poverty, may be exacerbated by climate change. Malnourishment during the early years of life is associated with motor problems, behavioural issues, lower intelligence, and fewer years of schooling[127].

Children are directly exposed to proportionately higher levels of pollution than adults due to their need to consume more food, water, and air per unit of body weight[120]. They spend a larger proportion of their time outdoors than older people, increasing their exposure to climate sensitive factors such as air pollution, insect vectors, and pesticides[120]. Rising pollen counts can exacerbate asthma, and

higher temperatures can cause dehydration. This can lead to more emergency department visits and hospital admissions for respiratory and renal disorders[120]. Future reduction in air particulates due to transitions away from fossil-fuel powered vehicles would therefore have a particularly positive affect on the respiratory health of children.

6.2.2 Elderly

Older people are more vulnerable to extreme weather events such as heat and flooding and are more likely to die[9]. Climate change is an important determinant of whether an older person can maintain well-being later in their lives[128] and socially isolated people over the age of 65 years with low socio-economic status are most at risk[128].

Older people have a reduced capacity to regulate their body temperature compared to the rest of the population, so exposure to heat can have a greater direct impact on their physical and mental health[129]. They are more likely to suffer from pre-existing medical conditions that may be exacerbated by extreme weather and are more likely to be on some medications that impair the ability to regulate temperature - increasing the risk of heat-related death[129,130]. Across three recorded heatwaves in the UK, mortality in people aged 65 and over increased, but remained stable for the rest of the population[131].

Extreme weather events may disrupt public transport, other infrastructure, or services such as social care, preventing older people from engaging in their regular outdoor activities that would otherwise provide them with social and physical benefits[99].

As with children, the elderly may depend on caregivers to make decisions for their welfare. Caregivers may struggle to access nursing homes or care facilities to help the elderly during periods of extreme weather. For those with reduced mobility or mental capacity, efforts to continue their daily routines with reduced supervision may lead to increased rates of injury or illness[129].

The elderly experience more fuel poverty and are less able to control their body temperature, increasing the risk of cold-related death[129]. A general warming trend may reduce cold-related mortality in the UK, in particular in the elderly, and this may partially or completely offset the increase in heat related deaths[132].

6.3 Gender inequalities

As described in our previous reports on life-expectancy by gender and on the recent slowdown in mortality improvement, women have been disproportionately affected by the slowdown in mortality improvements, particularly in the United Kingdom[iii]. Disproportionate impacts of climate change on the health and mortality rates in women may contribute to a persistence of this inequality[133]. Existing inequalities such as differences in workload, occupational hazards, emotional and physical distress and mortality could be exacerbated during climate-related disasters such as flooding[134].

Women are likely to be impacted more by climate effects than men[135,136]. They are more often the primary caregivers and these responsibilities can be considered an additional source of stress in times of adversity, particularly when infants and children in their care are threatened directly by displacement or food insecurity[137,138]. Women are more likely to skip meals to ensure others are fed before themselves as it is often seen as a women's responsibility to ensure families are fed[139].

[iii] The slowdown in international mortality improvements affects women more than men, as described in our previous report: "An analysis of mortality trends in developed countries, focusing on the recent slowdown in mortality improvements"[133].

Climate change impacts on infrastructure and healthcare provision may hinder women's ability to access reproductive and maternity services[139], although this may be less applicable to the UK than to other areas of the world. For pregnant women, high temperatures are associated with increased risks of adverse birth outcomes, which can also threaten their own health[99]. Increased cases of gender-based violence have been associated with the aftermath of extreme weather events, more cases of which are directed against woman than men[140]. Men are more likely to be employed in outdoor vocations such as farming than women, which carry additional environmental hazards such as sun exposure.

On the other-hand, pensioners, single people and economically inactive households are more likely to suffer from fuel poverty and are more likely to be women[129], so warmer winters may disproportionately benefit women. Whether this is enough to offset the other disadvantages that women are subject to is uncertain.

6.4 Pre-existing conditions

6.4.1 Physical and mental disabilities

Natural disasters bought about by climate change can have disproportionately negative effects on people with disabilities due to structural impairments and disruption to services[99].

For people with a disability, a lack of personal means of transport and difficulty accessing public transport can hamper evacuation during a flood. If evacuation is possible, not all shelters are suitably adapted for those with a disability[99]. A lack of support during the process of evacuation can be a source of great stress. Reports gathered from families escaping the wildfires in California detailed a high stress burden due to a lack of disability support and services after they were forced to leave wheelchairs behind[99].

Some people with a disability remain at home because mobility issues or other factors stop them from being able to reach safety. For them, delivery of food and water and access to medical facilities and home care may be impaired[99].

During major incidents, such as flooding and wildfires, public disaster information is often shared via radio broadcast rather than television. This disadvantages those with hearing difficulties, who may miss crucial warnings and public health information[99].

The additional risks for those with mental and learning disabilities will vary, but in general show an increased reliance on family and caregivers, as well as a reduced capacity to adapt successfully to extreme events.

6.4.2 Mental health

Climate change can increase the risk of mental health problems as described in the section on mental health (section 5). However, having mental health problems may make individuals more vulnerable to the effects of climate change - exacerbating inequalities relating to mental health problems.

- Some people with mental health problems may be taking medications such as anti-psychotics that can impair their ability to regulate temperature making them more vulnerable to the effects of heat[141,142].
- Those who need regular care are also vulnerable to the disruption in health services following extreme weather events.
- People with mental health problems may have a diminished emotional and psychological capacity to cope with the challenges posed by the need to adapt to climate change.

6.4.3 Hospitalised patients

The risk of overheating in hospitals and residential care buildings may be particularly severe given the vulnerability of the populations[9]. The effects may vary according to the type of health facility, the populations they cater for, and their location. In most areas of England, thermal modelling has shown the risk of future overheating to be present in most care homes[143]. Well-insulated, thermally lightweight, unshaded, modular hospital buildings are inherently at risk[9]. As many as 90% of wards are at risk of overheating during hot weather. Anecdotal evidence suggests the principal contributors are a lack of natural ventilation, solar gain, and zoning and control of heating systems[144].

Outside the context of hospitals and residential care, the preparedness and vulnerability of GP practices is difficult to assess due to the variability in their structures, features, and quality. Secure units have been highlighted as being prone to overheating due to the challenge of ventilating them, the high density of equipment creating heat, and the need to keep doors and windows secure[9]. Climate incidents can also lead to power outages. This is particularly dangerous for people who are on ventilators or other medical devices that require a power supply, or require refrigeration for their medical equipment or treatments, and is why backup generators are common[99]. Some medical conditions increase vulnerability to heat. For example, for every 1^{o}C rise in temperature, the risk of premature death for people with respiratory disorders is increased up to six-fold compared to the general population[145].

6.5 Socio-economic inequalities

Extreme weather events may have a greater impact on those with lower incomes[99,134]. When economies are stressed the health of the most disadvantaged is disproportionately affected. Living in poverty is associated with poorer physical and mental health and homelessness[99]. In the UK, people from an ethnic minority are more likely to live in poverty, though there is significant variation between groups[146].

Food poverty has a relatively high prevalence in the UK. Results from a Food Standards Agency survey suggest that around one in seven people in the UK living in household food insecurity[147]. It is commonly accepted that climate change-related disruptions to global food production and supply chains will only exacerbate the problem[68], particularly for low-income households[66]. In the UK, increase in the cost of food most adversely affects low-income households, as 15% of their expenditure is allocated to food as compared with 7.0% in the most affluent households[66]. Access to healthier fresh foods is generally more expensive than processed foods, and so the most deprived in the population may only be able to source and consume foods that are relatively unhealthy. Having a poor diet increases the risk of obesity, and can impact physical, and mental health[9].

Flooding and heatwaves are likely to have a greater impact on poorer households than richer ones[9]. They are more likely to be exposed to the damage caused by extreme weather events as poverty tends to force people to live in higher risk areas[99]. In the UK, lower income households and deprived communities are more exposed to coastal flooding, but the exposure to flooding from nearby rivers may be greater for higher income households, as living in these areas is regarded as being more attractive[9].

The build quality of lower income and private rental homes makes them more vulnerable to severe damage during adverse weather events[148]. It is harder for those in poverty to address the factors that make their homes more vulnerable, to evacuate safely as a disaster approaches, and to recover afterwards[99].

Insurance and housing adaptation interventions can disadvantage low-income households. Retrofitting and the fitting of air-conditioning is easier for high-income households, particularly if they own their own home[9].

The disruptive consequences of climate change increase the risk of economic crises and recession. These are associated with worsening public health trends and increases in mortality from a variety of causes[149]. The negative impacts of recession are primarily felt by the already most disadvantaged in the population[150].

Unfortunately, the associations between the major social determinants of health such as poverty, ethnicity, ill health, education and age can result in feedback loops and vicious cycles that amplify inequalities[151–153]. The most disadvantaged are more vulnerable to the negative health effects of climate change. Poor health adds to poverty, poverty exacerbates poor health and so inequality is magnified.

6.6 Employment

People in certain fields of work are more likely to experience the negative impacts of climate change than others. Those who are directly affected include those who work outdoors, such as farmers, people working in construction or utilities, emergency responders and healthcare workers[99] and those working in high heat environments such as factories. The threats to health may arise from direct exposure to changes in temperature or other natural disasters, or less directly from increased vector borne diseases and increased use of pesticides[99].

Farmers are at particularly high risk of climate change related stresses. Most farm work is very physical and outdoors, with an increased risk of heat related illnesses when temperatures are elevated. Increased use of fertilizers and pesticides to maintain crop yields in adverse circumstances can lead to greater exposure of farmers to the hazardous effects of these chemicals[99]. Among farmers, whose livelihood is at the mercy of the weather, drought can lead to uncertainty, shame, humiliation, and suicide[154–157]. Extreme weather events have significant impacts on farming yields, which is compounded by an increased prevalence of pathogens, increased levels of insects that may consume or destroy crops, and parasitic weeds that damage the crops and compete for space[134]. For livestock farmers, these events can be hazardous to the health and lives of their animals reducing the farm's profits for the year[134]. Farmers in coastal regions could lose their livelihoods as the rise sea levels and flooding may mean that their farmland is lost or unusable[134].

Increased temperatures in the workplace may lead to difficult working conditions for employees. This can be exacerbated by negative economic conditions such as the 2022 fuel crisis, which has increased the cost of air conditioning and heating of the work place, potentially limiting the ability to maintain comfortable working conditions.

Mitigation efforts that focus on the acquisition of land to enable biofuel production show initial negative impacts on the lives of the poor, including dispossession from farmland and forested areas in developing countries, particularly those belonging to indigenous people and female small holders[134]. Diversion of agriculture to biofuel production also has an upward pressure on food prices[158]. Increasing use of biofuels for aviation and shipping are part of the ambitions set out by the UK government in their mitigation strategy, though it is uncertain how much future biofuel production will occur in the UK itself[159]. A 'green transition' will entail significant changes to the economy and industries within the UK, which will affect the employment of some people far more than others.

6.7 Inequalities in location, environment, and housing

Inequalities in the geographical location, local neighbourhood and environment in which we live can have an impact on how we are affected by climate change[134].

6.7.1 Geographical location

The UK shows significant geographical inequality, with ex-industrial and mining towns, and coastal areas showing the least wealth and economic productivity[146]. The impacts of climate change will differ by country. The economic impact of flooding per capita is higher in Scotland, Wales and Northern Ireland compared to England[9]. Similarly, the residents of Scotland have a higher reliance on private water supplies such as streams, lochs, and groundwater springs. This means they are more vulnerable to supply disruption as they rely on regular rainfall to keep these sources replenished[9]. Exposure to heat is greater in the East and South of the UK. The exposure to flooding is greater for those located near rivers and streams, as well as those residing on the coast.

6.7.2 Neighbourhood

At a more granular level, those that live in rural communities are more exposed to the adverse events of cold weather spells and flooding, whilst those in urban areas will be more exposed to adverse effects associated with increasing temperatures and heat waves[129]. Remote communities may be more impacted by disruption affecting transport and technology services, which may lead to them being cut off from other populations and services such as emergency and routine healthcare.

Densely populated neighbourhoods with limited access to green and open spaces will see more exposure to extreme heat and greater exposure to pollution[129]. Access to public cooling facilities may be harder in marginalised areas as disinvestment in deprived urban areas can result in outdated infrastructure, a lack of extreme weather warning systems, and damaged or deteriorating storm sewers and other flood defences. This puts residents at a higher risk of suffering the physical impacts of climate change[99].

6.7.3 Housing

Housing quality and safety varies greatly, and is associated with socio-economic position. Those already in poorly adapted housing may also lack the disposable income to adequately prepare for the hazards associated with climate change, or to afford the repairs after these hazards have passed[129]. Top floor flats experience greater thermal stress, but ground floor flats are more likely to flood[129]. Discrimination may deny marginalised groups access to housing and so that they are left with fewer choices on where to live. This could mean they have a decreased ability to move permanently out of danger, or even relocate temporarily during extreme events[99]. These groups may be more likely to live in areas of high crime, where the resultant tendency to close doors and windows may exacerbate heat-related illnesses in the event of high temperatures[99]. Low-income households living in vulnerable areas are less able to afford insurance than their better-off neighbours to offset the financial risk of flooding or other climate related extreme weather events[134].

7 Sources of uncertainty in the effects of climate change on health

SUMMARY

The existence of climate change and the role of human activity in accelerating it is not in doubt, but its pace, magnitude, and effects on human health are uncertain. These are highly dependent on future global socioeconomic changes and climate mitigation actions. The ways in which climate changes affect health are then also dependent on social changes and what adaptations are put in place.

The presence of feedback loops, tipping points, and above all the systemic risk arising from the complexity of modern civilisation means that the overall direct and indirect impacts of climate change on health are hard to predict. To guide modelling and decision-making, sets of standardised pathways have been used to create projections. However, these pathways are defined based on plausibility, and cannot consider risks of which we are not yet aware.

KEY POINTS

- There is no longer any significant scientific uncertainty about the existence of anthropogenic climate change.
- It is certain that there will be further climate change due to existing greenhouse gas levels, and it is almost certain that there will be further increases in greenhouse gas levels in the near future.
- The key uncertainties are:
    - The future levels of greenhouse gas concentrations.
    - The effect of these on the climate system.
    - How human civilisation responds to those changes.
- There is a tension between mitigation efforts, the benefits of which occur in the future and will only be realised if global co-operation is achieved, and adaptation efforts, which have local benefits in the near-term and can be achieved with local actions alone.
- The direct effects of climate change on health have been modelled under different scenarios, and models have been built to predict the likely economic or social impacts. However, the complexity of combining these models to capture the overall direct and indirect impacts of climate change on health is daunting.
- Systemic risk arises from the interconnectedness of our global system and could be a major part of the overall risk. However, it is extremely hard to estimate due to the complexity of the global systems involved and the likely existence of 'unknown unknowns'.
- 'If/then' forecasting, where the results of different pathways of human decisions can be explored, is a useful to inform government policy.
- While attention naturally focuses on known risks of climate change, currently unknown risks may also have large future impacts on health.

So far, we have identified ways in which climate change affects health outcomes in the UK and beyond. The direct physical effects of climate change on the UK are not expected to be particularly large relative to other regions of the globe.

As we have outlined, there are also many indirect pathways through which climate change could affect health outcomes, such as damage to infrastructure or economic disruption. These may have broad systemic effects on health, for example through disruption of healthcare provision, or reduction in

societal resources available for public healthcare investment and social safety nets. Mitigation and adaptation actions also have the potential to impact health or modulate physical climate risk.

These pathways are highly uncertain and depend on chains of assumptions about the properties and behaviour of complex systems. For example, the minimum information needed to accurately predict the impact of climate change on Lyme disease cases in the UK would be: the current and future emissions of greenhouse gases; impact of greenhouse gases on the climate system down to a local level; the impact of those changes on the distribution of both the tick vectors and the animal host species; the behaviour of humans within this shared environment; the resulting rates of infection; and the ability of the healthcare system to detect and treat those cases. Negative feedbacks loops might apply in this case, for example through changes in human behaviour or research investment.

Even in a relatively simple and mostly linear scenario, as illustrated by the example of Lyme disease, each step inherits all the uncertainties of the previous one and introduces many more. Where changes are already being seen and can be attributed to the effects of climate change with reasonable certainty, highly non-linear and unpredictable effects may also apply – such as a breakthrough Lyme disease vaccination.

In this section, the sources of these uncertainties will be discussed. These can be arranged into a broadly linear pathway – from greenhouse gas emissions, to changes in the climate system, to effects on the human system. However, human action affects every stage. Mitigation actions influence the rate of greenhouse gas emissions, and adaptation actions determine the impact of the climate system on the human system. Human actions may also serve to partially decouple greenhouse gas emissions and climate change, either by sequestration of carbon or through solar geoengineering.

Uncertainty can be misused to justify for unreasonable scepticism and as an excuse for inaction. However, the majority of the uncertainties surrounding the future risks of climate change stem from the difficulty in anticipating human actions, not the physical science.

Risk can be considered as a function of hazard, vulnerability, and exposure. The physical hazards of climate change are generally not novel ones, but changes in the frequency and intensity of existing ones. These changes are, in theory, predictable, even though the timing of specific events are not, for example storms, wildfires or infectious disease epidemics. Vulnerability and exposure, on the other hand, are largely a consequence of human social, economic, political, and technological factors, and so how they will change over time is highly uncertain[70].

It is likely that there are some hazards, exposures, and vulnerabilities that are currently unknown or do not currently exist. Our lack of knowledge may bias us to underestimate the likelihood and impact of the unknown.

7.1 What is certain?

Absolute certainty is not possible or appropriate in a scientific context. However, the evidence base for the influence of human activity over time on the climate is now so overwhelming that it can be considered certain for decision-making purposes, as exemplified by the ground-breaking work of the Intergovernmental Panel on Climate Change (IPCC). A 2021 review of 3,000 climate related papers randomly sampled from 88,125 identified, found only four that were sceptical[160].

The IPCC summarises these climate influences, along with their certainties, in their summary for policymakers[161]. It has been definitively established that greenhouse gas concentrations have increased over the last 250 years, that this has been caused by human activity, and that this has already caused warming of the air, the oceans, and land. The last four decades have each been warmer

than any decade before them since 1850. As of the first two decades of the 21st Century, global surface temperatures are now around 1 degree Celsius warmer than the 1850-1900 baseline, with a greater increase seen over land than over the ocean. We also have high confidence that the rate of warming has been greater since 2006 than between 1971 and 2006[161].

In the UK, it is expected that temperatures will continue to increase across all seasons under all emissions scenarios until the middle of the 21st century at least[4].

7.2 Uncertainties in future greenhouse gas emissions

7.2.1 The key role of carbon dioxide

Although a variety of greenhouse gases are produced by human activities, some of which are far more potent than carbon dioxide per gram, the effective permanence of carbon dioxide in the atmosphere means that these emissions continue to build up over time through the burning of fossil fuels. Fossil fuels are a dense, stable, accessible, and transportable source of energy. The current global socioeconomic systems are highly dependent on their use: our machines and infrastructure are designed for a fossil-fuel economy. Despite a broad consensus on the importance and urgency of near-term mitigation action, annual carbon dioxide emissions continued to increase during the last decade[162].

7.2.2 Co-operation

Efforts to mitigate climate change by reducing fossil fuel use are taken on the basis that costly action today reduces substantive longer-term risk, and economic modelling strongly supports the cost-effectiveness of early mitigation, even when comparing scenarios that achieve Net Zero by 2050[62]. However, mitigation polices are dependent on international co-operation. They are subject to the 'commons dilemma', where short term and local economic or adaptation interests are at odds with the long-term and global mitigation interests. Co-operation between nations and states is further disadvantaged by the perceived need for some kind of 'just' transition, where the costs of climate mitigation are borne in a way that is considered fair.

THE COMMONS DILEMMA

When faced with a common, accessible resource, a user can choose not to over-exploit it out of interest for the common and future good. However, if others do not make the same decision, then the resource will still be depleted and that user will have forfeited access to the resource for nothing. Countries and individuals are faced with this dilemma when deciding whether to invest in reducing greenhouse gas emissions. In this case, the common resource can be thought of as the relatively stable and hospitable global climate that mankind has enjoyed over the last 10,000 years.

TRAGEDY OF THE COMMONS

When access to an open, common resource is not appropriately governed by agreed and enforced rules, users are incentivised to act independently in their own self-interest and exploit the resource until it is depleted. This 'tragedy' results in all the users being worse off.

7.2.3 Balancing mitigation and adaptation

Any effects of climate change that are not prevented through mitigation will require adaptation measures. The economic and social costs of mitigation represent a gamble that only pays off if everyone contributes, whereas adaptation measures directly benefit the location in which they are implemented. The dispersed and delayed benefits of mitigation and the concrete and often immediate

benefits of adaption will vary by country. Countries that are likely to experience fewer negative effects from climate change, such as those that currently have colder climates or for which the costs of mitigation are very high, may be less incentivised to co-operate in mitigation efforts.

7.2.4 Technologies

Technologies may be developed that make mitigation much cheaper and easier to achieve. For example, more effective carbon capture and storage and renewable energy generation. However, the assumption that such changes are inevitable may paradoxically reduce incentives for costly mitigation now.

7.3 Earth system uncertainties

The uncertainties associated with the effects of climate change on the various earth systems are generally due to a lack of sufficient evidence. This is particularly true when the effects are probabilistic, such as in the frequency of extreme weather events. Short-term future warming is already, to an extent, 'baked in' by historic emissions and the causal lags in the system. Even under scenarios that assume immediate severe reductions in emissions, global temperatures are still expected to rise until at least mid-century[161].

7.3.1 The effect of greenhouse gas emissions on global mean temperature

The relationship between future greenhouse gas emissions and future temperature rises is complicated. For example, the more carbon dioxide that is emitted, the greater the proportion that will remain in the atmosphere, as less of it can be absorbed by land and ocean carbon sinks. However, as temperatures rise more heat will be radiated into space. Certain kinds of particulate air pollution can partially mask the relationship between emissions and heating by reflecting sunlight. Overall, it is expected that the relationship between cumulative anthropogenic carbon dioxide emissions and global warming will be roughly linear, with the temperature rise being proportional to total emissions[161].

Some effects of this temperature rise are already observable and can be projected into the future. Others are not statistically clear or are dependent on tipping points that have not yet been reached. For physical changes to the climate like melting ice, sea level rise, coastal flooding and erosion, a confident relationship between the magnitude of warming and the scale of the physical change cannot be established. Also, the rate at which the warming translates into the physical change varies by the phenomenon being observed. for example, the effect on deep ocean currents and ice-sheet loss is relatively slow[163].

TIPPING POINTS

Tipping points are thresholds beyond which changes rapidly accelerate and may be irreversible. Small changes close to a tipping point may result in step changes in outcomes. Thus, small uncertainties in the degree of change can lead to large uncertainties in outcomes.

7.3.2 Geographic variation

There are huge geographic variations in temperature increases. For example, far higher rises are being seen and are expected in the arctic region. The Southern Hemisphere is expected to experience more extreme heat events than the Northern one[163].

The UK is projected to experience further temperature increases up until at least the mid-21st Century. However, the modelling of outcomes, even for defined emissions scenarios, is characterised by

uncertainty. Recent climate and weather modelling by the UK MET office suggests that dry summers may be more common than previously predicted, though severe wet events may also be more likely[164].

7.3.3 Tipping points and feedback loops

FEEDBACK LOOPS

Systems where the outputs also function as inputs are prone to feedback loops. Negative feedback loops tend to dampen system changes and promote stability, while positive feedback loops amplify system changes and destabilise them.

'Overshoot' warming pathways are scenarios where the world temporarily exceeds 1.5°C total warming, which then falls again later[59]. Beyond this level, human and natural systems are projected to be exposed to additional risks caused by positive feedback loops[59]. Secondary emissions - the release of additional greenhouse gases from high-carbon ecosystems – as a result of wildfires, tree mortality, peatland drying, and permafrost thawing amplify climate change. Another positive feedback loop is the melting of polar ice, which reduces the proportion of solar energy reflected. The thresholds for, and magnitude of, these positive-feedback loops is uncertain – they have not occurred before during the timeframe of human experience.

Beyond 1.5°C of warming the probability of tipping points is also increased, which may be irreversible even if the temperature is later reduced. These include physical effects such as melting glaciers, but also the destabilisation of ecosystems, particularly those least resilient to change. Faster warming and deforestation together increase the probability that the Amazon rainforest ecosystem will cross a tipping point into a dry state during this century[163].

Global change is accelerating in many domains: social, economic, environmental, and technological. We have a growing population, with greater wealth and mobility, but also a higher demand for resources per capita. The demand for energy, food, water, and mineral resources is increasing beyond the finite sustainable planetary supply. Other, non-climate, systems are approaching or exceeding boundaries beyond which their utility may degrade irreversibly. These include disruptions to natural biochemical flows due to crop fertilisation and biodiversity loss[165]. The IPCC predicts with high confidence that the combination of climate change and human activity will cause the loss or degradation of much of the world's forests, coral reefs and coastal wetlands. Increases in the frequency, intensity, and duration of extreme weather events over the next 20 years will increase the risk of ecosystem biodiversity loss[59].

7.4 Uncertainties in the global socioeconomic systems

In addition to the uncertainties around future emissions pathways and the uncertainties about how these pathways will affect the Earth system, the impacts of changes on human health will crucially depend on properties and future changes to the global human system. In the near term at least, climate risks to both natural and human systems are more dependent on changes in exposure and vulnerability than the differences in climate hazards between emissions scenarios[59].

Health and wellbeing are dependent on a number of social factors, such as healthcare provision, access to clean water, nutritious and safe food, housing, social safety nets, and law and order. Changes to these factors will occur as adaptations to climate change impacts, and other transitions and trends will occur that will modulate the impacts of climate change on health. These may be deliberate and foreseen, or may emerge from the complexity of societal evolution.

7.4.1 Adaptation

The magnitude and pace of climate change in the future depends on the global mitigation efforts being taken now and in the near term. As future adaptation is not known, studies modelling the impact of climate hazards on health, such as heatwaves, often assume either no adaptation or a continuation of current adaptation[9].

The vulnerabilities of human systems and ecosystems are interdependent. Changes in land use, resource extraction, deforestation, biodiversity, and pollution, all have negative impacts on the ability of ecosystems, societies, and individuals to adapt to climate change[59].

7.4.2 Maladaptation

Maladaptation can shift vulnerabilities and risk from one climate hazard to another, undermining the effectiveness of the measures taken. This may be through focusing on isolated risks and sectors or on short-term gains. Infrastructure and institutional change are often expensive or inflexible, potentially creating lock-ins. For example, cross-regional water transfers are predicted to be necessary to prevent water shortages in England under climate change. Water infrastructure takes a long time to plan and implement, and so there is a risk that adaptive action is left too late[9]. Another example is the building of sea walls for coastal defence, which reduces the impact on people and assets in the short term, but may lock-in to increased exposure in the long term[59]. Ecosystem based flood defences will be increasingly at risk at higher levels of warming[59]. Poorly planned tree planting may result in a low-biodiversity monoculture that is vulnerable to mass die-off due to extreme weather or disease. More generally, social changes such as socioeconomic development, migration, increasing inequality, and urbanisation, may increase future exposure and vulnerability to climate hazards[59].

7.4.3 Societal changes within the UK

The implementation of adaptation actions depend on **facility** - what options are possible, **capacity** - what resources are available for action, and **intentionality** - what needs are identified and prioritised. Broadly speaking, capacity is dependent on future economic growth, facility is dependent on technological and social changes, and intentionality is dependent on political changes. All of these changes are highly uncertain, and will affect what adaptation measures will be implemented and what level of healthcare and social safety netting will be provided[9].

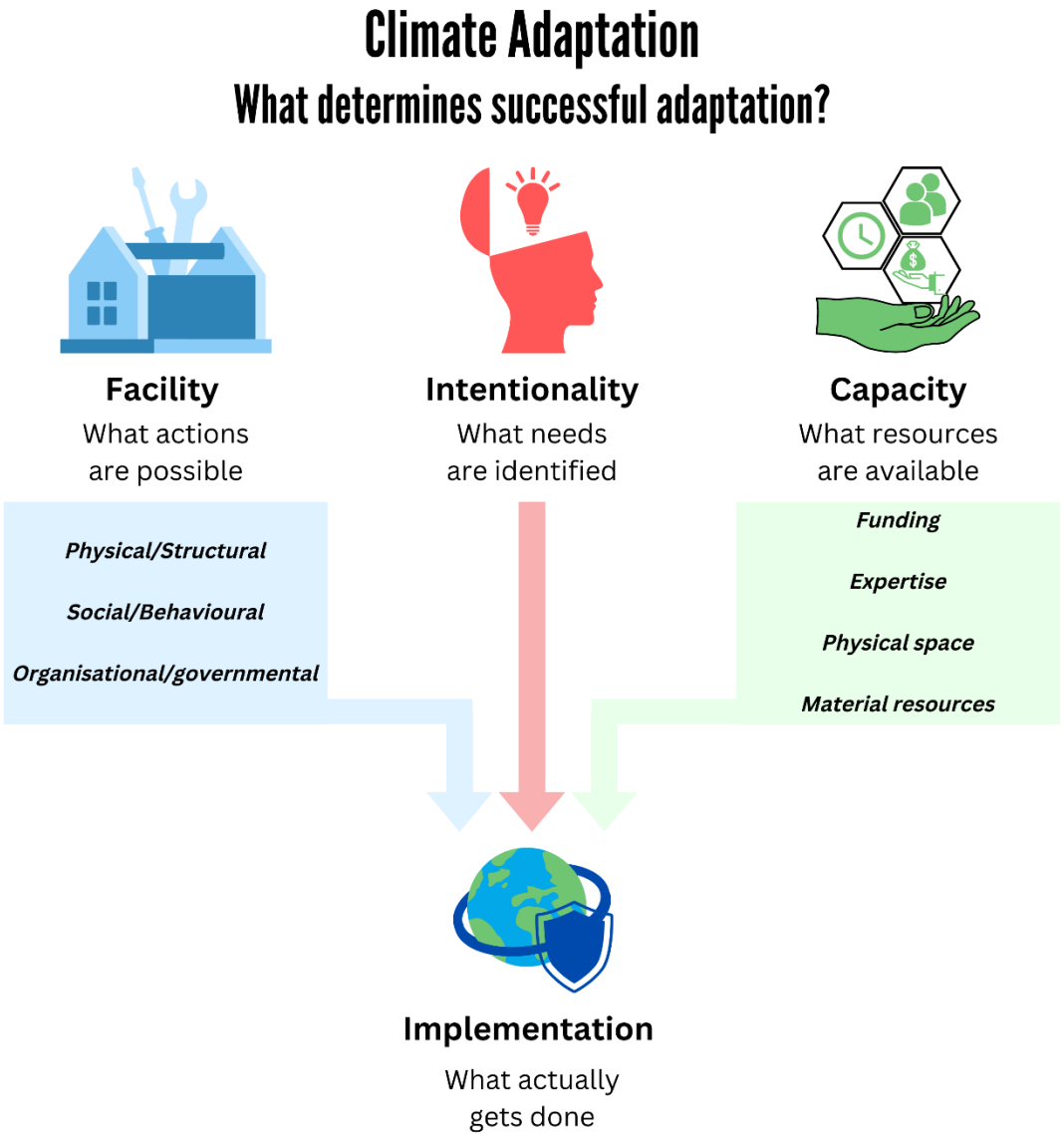

Figure 2. The steps required for successful adaptation.

7.4.3.1 Settlement structure

The forces of population growth, population age trends, and climate-motivated development will affect the future UK population distribution and settlement. The need for new building to support population growth will influence the numbers at risk of flooding, particularly if rates of single-occupancy continue to increase[9]. There is potential for urbanisation to slow with the boom in remote working catalysed by the COVID pandemic. Increased demand for non-urban housing[9] may be further enhanced as the relative disadvantages of urban environments, such as flood risk, air pollution, and the lack of green spaces become appreciated. Increased competition for homes in areas less affected by these issues is likely to favour those with greater financial means[9].

7.4.4 International influences

7.4.4.1 Introduction

There are huge uncertainties about the future direction of global geopolitics, co-operation, and stability. Some see the post-World War Two trend towards globalisation and democratisation as coming to an end, being replaced by more inward-looking nationalism along with the diminishing

power of traditional international organisations such as the United Nations. The increase in global interconnectedness has led to predictions of unprecedented changes, such as the decline of the nation-state[70]. The geopolitical future of the UK following Brexit is in the process of being determined.

7.4.4.2 Brexit and supply chains

Brexit has increased economic uncertainty while new regulatory systems and trading arrangements are being formed. The effect of regulation on food and water safety and air pollution may change as a result of balancing the priorities of economic growth versus health. The EU Directives for health protection will no longer apply in the UK and it is unclear what will be implemented in their place. Brexit may also increase chemical and biological health hazards due to weaker regulations for polluters. Access to EU data and intelligence may reduce in areas such as vector-borne disease management. UK-led climate risk-management research may also be affected by lack of access to EU research[9].

Many climate change impacts are transmitted to the UK via the flow of goods, finance, people, and information. The future nature of these flows, and so their impacts, depends partly on what trade agreements, tariffs, and border controls are put in place by the UK government[70]. Brexit has introduced changes to the UK-EU border and to how foods and goods move within the UK. Future supply chain shocks may therefore have different and unexpected impacts to those in the past[70]. Changes to trade relationships may increase the proportion of the UK's imports that come from countries with higher vulnerability to climate impacts, potentially increasing the fragility of supply chains[70]. The UK imports almost half of all the food it consumes[166]. In general, UK food security risks are highly uncertain[9].

7.4.5 Violent conflict

Although the probability of significant civil violence within the UK is considered low[167], there is the potential for unexpected climate-related social discord if resource access is not perceived as being fair, for example during water shortages and use restrictions[9].

Internationally, changing climate and extreme weather events may have already increased the frequency, severity, or length of civil conflicts[59]. The principal drivers of these conflicts are not climate related at present. However, this may change over time. Changes in resource distribution or demand might increase the risk of international conflict. For example, already over-exploited fish stocks are changing their distribution towards a concentration at higher latitudes as oceans warm, undermining the established distribution of this food source globally[59]. Competition for finite land and fresh water resources arises from economic development, agricultural expansion, population growth, regional climate changes, and desertification[59,168]. Estimates by United Nations Water suggest that global water use has increased six-fold in the last hundred years, and is currently increasing by 1% per year. Around four billion people experience severe water scarcity for at least one month per year, a number which is expected to rise in part due to climate impacts. Rivers cross national borders, making countries vulnerable to over-withdrawal, damming, and contamination from upstream neighbours[169].

Significant conflict outside the UK would impact economies and supply chains, as well as weakening international co-operation. This effect is being seen in 2022 in the form of increased energy prices in the UK due to war in Ukraine[170].

Even if the contribution from climate factors is minor, violent conflict has the potential to have large direct effects on human health and wellbeing, as well as indirect effects through disruptions to economic, healthcare, and social functioning. Even when climate hazards do not increase the

probability of violent conflict, weather and climate extremes will increase vulnerability to any that occurs[59].

7.4.6 Migration

Human displacement will be increased by more extreme precipitation and flooding, droughts, cyclones, and sea level rise[59]. These weather-related disasters can lead to migration, which has economic, social, and political consequences.

For the year 2020, the Internal Displacement Monitoring Centre (IDMC) reported a figure of over 30 million new disaster related displacements world-wide, with weather related disasters accounting for most of them; flooding and storms jointly accounted for 28.6 million[171]. Conservative estimates suggest that by the year 2050, around 216 million people will have to migrate within their own countries due to climate change[172]. The true number of people who will undergo internal migration will remain uncertain, as any governmental policies introduced to combat climate change both nationally and internationally will have a large influence. Migration also has knock-on economic effects. For the year 2020, the global cost of one year of displacement was reported as $20.5 billion, including costs for housing, education, health and security needs, and loss of income[171].

Whilst we can be certain that climate change will lead to migration, the timing, location, and scale is unpredictable. It can be increased by other factors such as violent conflict, which may themselves be exacerbated by climate effects. The size and impact of migration into the UK and within the UK will depend largely on future international and government immigration and refugee policies[9]. These are generally highly contentious political issues.

7.4.7 Impact of novel technologies

2050 is twenty-eight years away. In 1994, twenty-eight years ago, only 0.36% of the world's population used the internet. By 2020 this had risen to 60%, and 95% in the UK[173]. The first complete human genome wasn't sequenced until 2003 and cost around three billion US dollars, while today a human genome can be sequenced for around one millionth of the cost[174]. Technological advancements can be rapid, occurring in unexpected places, and cannot be predicted from investment alone. Just as the technology of internal combustion set anthropogenic climate change in motion, other technologies, present or future, will determine how it continues. These impacts could be positive or negative with respect to climate change or its effects on human health. Net Zero targets require some kind of carbon capture technology at a scale and affordability that does not currently exist[175]. Decentralised infrastructure technologies such as smart grid systems may allow the rapid deployment of renewable energy sources. Improved early warning systems could significantly reduce the mortality associated with extreme weather events. New vaccine technologies might render emerging viruses a historical problem. Genetic modification may produce crop strains that are resistant to drought and flooding.

Infrastructure, transport, communication, and healthcare provision in the UK are increasingly dependent on reliable electrical supply. Future changes to power systems may increase or decrease resilience to system shocks. Renewable sources such as solar and wind are intermittent, but a diversity of sources and the increased scope for decentralisation, along with improvements in energy storage and demand-side management, may increase the overall resilience of energy supply, particularly in rural areas[59].

Emerging renewable technology and its falling cost may encourage states and regions to attempt energy independence and become less reliant on petrostates. This should increase resilience to overseas shocks, such as the war in Ukraine, but may disrupt the geopolitical status quo and

undermine incentives for international diplomacy if states are less dependent on each other for energy resources.

Theoretical mitigation strategies involving solar radiation modification approaches involve seeding the upper atmosphere with reflective particles. This would reflect a proportion of solar radiation and produce a cooling effect, such as has been seen following volcanic eruptions[176]. The risks to humans and our ecosystems from such an approach are not well understood. In addition, the underlying greenhouse gases still remain in the atmosphere and would still have impacts on ocean acidification and crop yields. There is also a risk of overcompensation, particularly at regional scales[59]. Unlike mitigation through emission reduction, such approaches could be undertaken by a single state or corporate actor unilaterally, raising the potential for conflict.

7.5 Scenarios

The sources of uncertainty in the climate and global socioeconomic systems mean that having a single model of the future impacts of climate change on health is extremely challenging and probably impossible at the present time. Worse, our decisions relating to mitigation and adaptation depend on the results of our modelling, as well as being an input to it. However, to say anything comprehensible about the future, some kind of modelling is necessary. Dealing with this problem involves a focus on 'if/then' forecasting, where internally-consistent, standardised scenarios are developed as illustrations of plausible paths, and their implications are then explored. Over time, these scenarios have shifted from being focused entirely on the climate system to including consideration of the whole of civilisation[177]. Sets of standard scenarios such as the Representative Concentration Pathways (RCPs), used by the IPCC, create a standardised scenario matrix framework. These pathways are described in more detail in Appendix 2: Scenarios.

7.6 Systemic risk

7.6.1 Reports on systemic risk

In previous sections we have occasionally touched on how interactions can cause transmission of risk between pathways. The International Panel on Climate Change (IPCC) reports that the impacts and risks of climate change are becoming more complex and harder to manage. Climate hazards can occur simultaneously, interacting with each other and with non-climate hazards. This results in the compounding and cascading of risks between sectors of society and across geographic regions[59].

The most recent Climate Change Risk Assessment (CCRA) report claims that the global state of geopolitics and the socio-economic background conditions are now more favourable than in the past to the transmission and amplification of risks to public health, food security, international law and governance, and to violent conflict. The increasing evidence for this view was considered sufficient to introduce a new class of risk in their report: "Risk amplification from the interactions and cascades of named risks across systems and geographies"[70].

The head of the IMF has described climate change as contributing to a global transition to a state of "greater uncertainty, higher economic volatility, geopolitical confrontations, and more frequent and devastating natural disasters – a world in which any country can be thrown off course more easily and more often"[178].

SYSTEMIC RISK

A conventional risk is one that is recognisable and stable in a known set of circumstances and so can be managed in isolation, for example through regulation or insurance. Systemic risk, on the other hand, emerges from the properties of a complex interconnected system. Here, risk in one pathway can propagate into others and create non-linear risk cascades with consequences for the whole system[70].

A simple example of systemic risk is a line of dominos, where the risk to the whole structure is not simply the sum of the risks to each individual domino, but instead must consider their interdependence. Interactions within a complex system may also lead to emerging risks, ones that only exist in the particular context due to interactions within the system[70]. In our domino example, an emerging risk may be that the clattering of ten dominos falling at once is enough to wake a baby, while the sound of a single domino would not. Some conditions may act as risk amplifiers or risk attenuators[70]. A draft from the window increases the chances that some dominos will fall, while placing them on a flatter surface decreases it. The system can become more resilient to cascades by increasing the spacing between the dominos, though this will require a larger surface, decreasing efficiency.

The Earth system, the global socioeconomic system, and the combined system of both are extremely complex and dynamic, with an effectively infinite number of interconnections, positive and negative feedback loops, and tipping points. This is why the timing of highly disruptive geopolitical shocks and their consequences are essentially unpredictable, limiting the ability to attribute them to specific causes[70]. Recent examples include the global financial crash of 2008, the emergence of Covid-19 in 2019, and the outbreak of war in Ukraine in 2022. Although climate is not the main factor in many global risks individually, its contribution at many interacting points in the system raises its impact on the total risk to more than the sum of its parts[70].

7.6.2 Modelling systemic risk

The National Risk Register[167] considers a wide range of plausible risks to the UK, including environmental ones. However, these don't include climate tipping points and abrupt changes[9], or interactions between risks. A modelling study produced in support of the most recent Climate Change Risk Assessment (CCRA) report investigated cascading risks resulting from climate hazards within the UK. However, it does not include international climate risks, non-climate risks, or complex and unpredictable social events such as industrial action, widespread public disorder, terrorist attacks, or cyber attacks[179].

Climate hazards also include both chronic annualised damages and extreme or one-off events[9]. There are interactions in transmission pathways between a panoply of low likelihood risks. However, there is much less information on the probability or impact of these risks, which suggests that their likelihood could be underestimated[70]. It is likely that the risk of cascading hazards is similarly neglected due to complexity and lack of data. It is a general property of linear models that they deal best with small perturbations from the stable or current state rather than dealing with non-linear effects, tipping points, and system state changes.

Even if we could include every parameter we wanted, and account for these non-linearities, there will always be hazards, exposures, vulnerabilities, and causal connections that are currently unknown. Needless to say, the nature of our systemic risk is highly uncertain. Not only can we not predict specific system shocks, but it is also extremely difficult to assess the size of our exposure to systemic risk.

A CASE STUDY OF SYSTEMIC RISK

The Chooz nuclear power plant lies on the Border of Belgium and France and provides 4.7% of France's nuclear electricity. In August 2020 the plant was forced to shut down over a period of days after an extended drought reduced the flow of the river Meuse, meaning that there was not enough water available to cool the reactors[238]. In addition, when water levels are low, already a stressor to aquatic life, the extra heat in the outflow from the reactors represents a risk multiplier[239]. The connections and vulnerabilities of our human systems and the natural ecosystems is shown here operating in both directions.

7.6.3 Examples of climate shock systemic risk in the UK

Modern societies such as the UK rely on the reliable functioning of closely networked interacting systems. The driving efficiency gains of this networking can also make the systems vulnerable to cascading interruptions that create a systemic risk, independent of the individual risks. Cascading failure is recognised and often studied in the context of shocks to specific systems, such as the power grid, the internet, transportation, finance, and ecologies. However, the risk of failure cascade due to the coupling between systems, often in completely different domains, is largely unknown and so not often considered[70].

RISK CASCADE

This occurs when there is non-linear transmission of risks across multiple domains. A simple example would be a fan of dominos, where the first topples two, which topples another four, which topples another eight. If the cascade is large enough the entire system can be affected.

For the UK, the major risk for catastrophic climate events is flooding. Here, sudden failure of defences, warnings, or the ability to evacuate would multiply the hazard[9]. Cascading risks could then occur, such as transport, power and IT disruptions; loss of water supply infrastructure; water contamination from sewage, pesticides or historical landfill; health service disruption; civil unrest, and economic damage[9,179]. Infrastructure failure can also be sudden, total, and have major impacts. This includes chemical and radioactive breaches, as well as dam and reservoir failure. Sudden slope failures like the Aberfan disaster of 1966, and individual wildfires are recognised as dangerous occurrences, however the timing of these types of events remains highly unpredictable [9].

Cascading climate risk to health may be further amplified by other non-climate system shocks. For example, an ongoing pandemic may cause competing pressures on emergency and health services, as occurred during the 2020/2021 winter UK floods[9]. Climate hazards are also likely to co-occur – for example heatwaves, air stagnation, drought, and wildfire – leading to synergistic negative health effects while also degrading effective public health response[9].

In case studies of supply shocks transmitted to the UK either through direct supply disruption or indirect market disruption, the amplifying impact of unpredictable citizen behaviour can be seen in the occurrence of panic-buying. Examples include vegetable and salad shortages after European extreme weather in 2017-18[70], and during the early stages of the Covid-19 pandemic, where supermarkets were stripped of essentials such as pasta, rice, and toilet paper[180].

7.6.4 Suppression of risk cascades

Although the level of systemic risk to climate change is unknown, examining past shocks and the dynamics of complex systems in general can allow human action to reduce it. International co-

operation in multilateral institutions and processes would increase resilience and suppress risk cascades[70]. The risk of violent conflict is reduced through international co-ordination and support of political stability. Co-ordination is also important for responding to disruptions to food chains and extreme weather events, and in maintaining law and governance. Sharing of information reduces risk, for example in the event of crop failure and within the UK finance sector[70]. The process of deliberately improving systemic resilience can be considered a climate change adaptation in its own right. Thus the current lack of systemic resilience represents an adaptation gap to international risk cascades[70].

7.7 Black swans

So far, this section has focused on known unknowns, areas where we know there is uncertainty, and may be able to quantify it to some extent, or at least explore plausible scenarios. However, it is possible that 'unknown unknowns', climate risks that we are currently unaware of, will end up having large or even dominant effects on human health.

BLACK SWAN EVENTS

Black swan events are rare or extreme events that are unpredictable as a consequence of our ignorance about the existence of relevant information – or *'unknown unknowns'*. It is so named after the hypothesis used by the philosopher John Stuart Mill to illustrate the point that it isn't possible to draw a conclusion based on the observation of a limited sample. He pointed out that the statement that, 'all swans are white.' cannot be proven until all swans have been observed and found to be white. He was writing many years before the discovery of the continent of Australia and its native black swans.

Black Swan Theory suggests that unprecedented events that are outside the realm of expectations are often the largest causes of system shock, change, and collapse. The theory posits that even when they do occur, black swan events are often post-rationalised as having been predictable after all, blinding us to their impact[181]. Pandemics and financial crashes do not qualify, as the uncertainty is related to the timing and impact rather than their existence. However, the discovery of fossil fuels could be included, which led to modern civilisation as we know it, complete with anthropogenic climate change. The discovery of nuclear weaponry is another example, the shadow of which has loomed over all international relationships since 1945. Finally, only three decades from its inception, the internet is now as integral to the lives of billions of people as running water and electricity. Future black swans may have an impact on climate change and its relationship to human health that we cannot yet imagine, for better or worse.

8 Policy and regulation

SUMMARY

The landscape of climate policy and regulation involves both mitigation and adaptation actions at all scales from local to global. The goals of mitigation are simple, though its implementation may not be. Adaptations to climate change form a much more complex picture. It is uncertain what adaptations are needed now to reduce future impacts, how best to co-ordinate action, and who is responsible for it. Policy will evolve over time, and policy commitments will not always translate to action in a straightforward way. However, there are some changes that can be expected within the UK. These include:

- Increasing regulation of emissions. For example, requiring companies that produce high levels of emissions to upgrade their facilities to reduce, capture or eliminate them, or purchase offsetting.
- Updates to building regulations, including types of building material and transportation of materials.
- Interventions to improve food security.
- Continued electrification of land transport.
- Increasing share of renewables in generating electricity.
- Infrastructure changes focused on increasing resilience.

KEY POINTS

- Setting out a transition policy framework and pathway reduces the probability of a disorganised transition and its associated losses.
- Effective mitigation and adaptation to climate change require a high degree of planning and co-ordination at every level, from states to individuals.
- There is a need to improve the resilience of human society to shocks.
- Government policy and regulation is essential, as individual and commercial interests do not always align with the interests of society as a whole, in the present and in the future.
- Co-operation on climate mitigation between states is disincentivised by self-interest, and is increasingly challenging in the retreat from a globalised world that we are witnessing.
- The Paris Agreement and 2008 UK Climate Change Act commits the UK to large greenhouse gas emissions reductions over the next three decades.
- The current UK mitigation policy focuses on supply-side emissions reductions, with minimal planned burden on the consumer. According to the Committee on Climate Change (CCC), credible plans exist for less than half of the required reduction.
- Climate adaptation targets are hard to define, appear generally not co-ordinated across government departments and sectors, and are currently a devolved issue within the UK. Responsibility for adaptation is unclear.
- According to the Committee on Climate Change (CCC), UK adaptation policy is currently insufficient to produce the necessary resilience to address climate risks, and this adaptation gap has widened in the last five years.

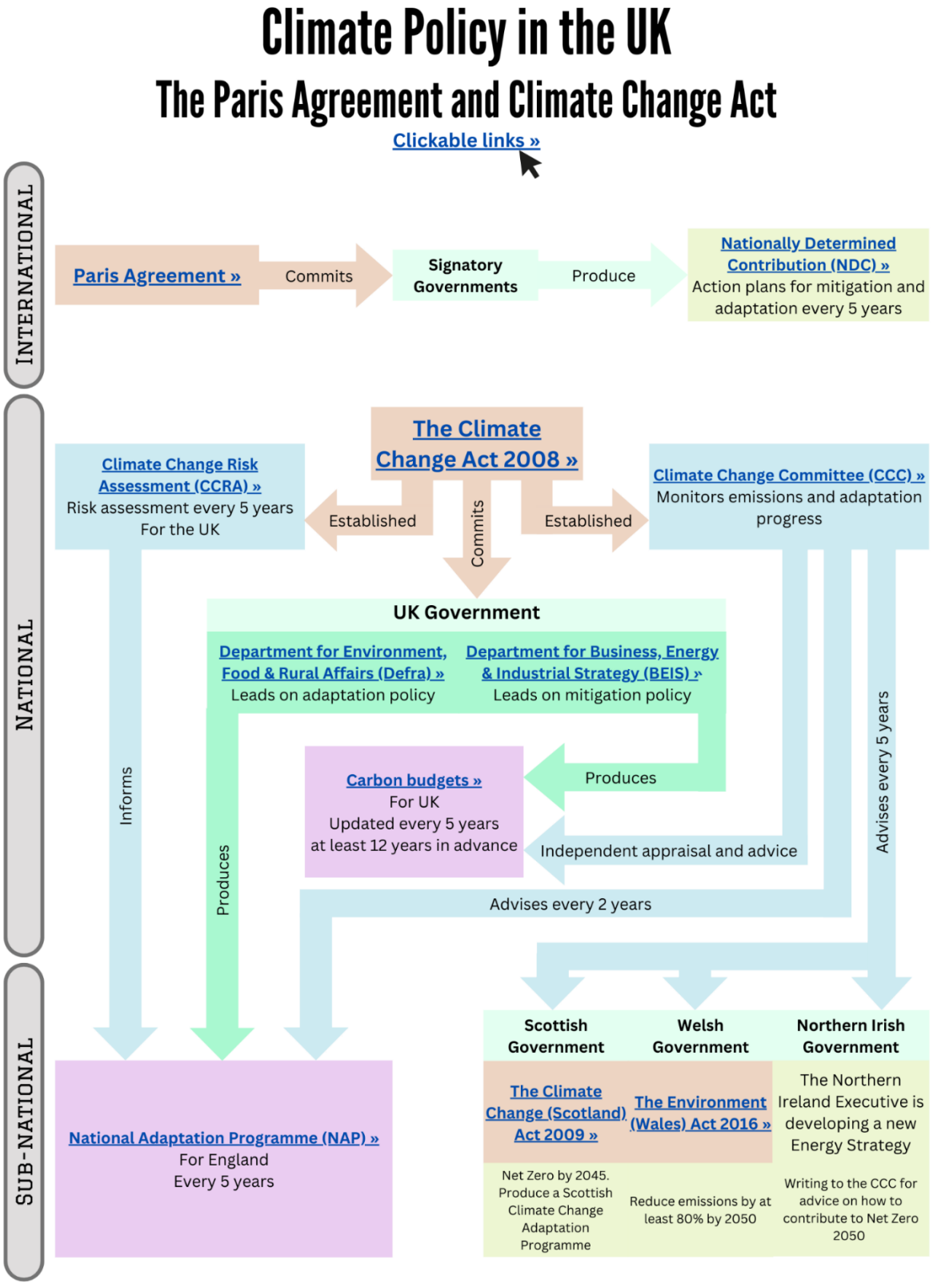

Figure 3 - The UK is a signatory of the international Paris Agreement and passed its own Climate Change Act in 2008. This committed the UK government to producing regular UK carbon budgets and national adaptation programmes for England. Devolved governments also passed climate acts and policies, including adaptation programmes[182].

The previous section examined why it is not possible to say with certainty what the direct and indirect climate change impacts on health will be. This is largely because the impact climate hazards can be increased or decreased by the social, economic, and geopolitical context in which they occur. The Third UK Climate Change Risk Assessment report[183] describes the future as increasingly "TUNA" – Turbulent, Uncertain, Novel, and Ambiguous[70]. The intractable uncertainty suggests that planning should not focus on predicting the occurrence of specific risks, but instead on classes of risk such as supply chain interruption or infrastructure damage. Frequent system shocks should be expected, making building system resilience a high priority[70].

A table with short descriptions of key policies, regulations, bodies, and documents, along with hyperlinks for more information, can be found in Appendix 5: Key policy policies, regulations, bodies, and documents.

8.1.1 The function of climate policy and regulation

As discussed in the section on inequalities, the impacts of climate change on health will vary across the world as well as between different sections of the UK population. This is true of the direct and indirect health impacts of climate change itself, but also in the health impacts of mitigation and adaptation efforts. Appropriate consideration and response to these inequalities is a matter for national policy where rights can be protected in law.

National and international policy and regulation can reduce the circle of uncertainty for organisations and individuals, improving their ability to make decisions with confidence and plan for the future. Setting out a Net Zero transition policy framework and pathway reduces the probability of a disorganised transition and its associated losses. National policies and international agreements also allow states to act with more confidence. Sharing of information between states and government agencies allows improved monitoring of risk, such as the occurrence of vector species and disease outbreaks[9].

Government policy and regulation represents an opportunity to intervene in a more co-ordinated, and equitable fashion than can be achieved through individual action or market forces. Some actions cannot, in principle, be left to markets, regardless of incentives, so policy and regulation is imperative.

A case Study – The Great Smog of London and the Clean Air Act

In December 1952, London experienced an episode of severe smog that lasted five days. This was the result of the interaction between particularly cold and still weather conditions and airborne pollutants, primarily from burning coal. For hundreds of years London had been known for its poor air quality, but this had gradually worsened as the city had expanded and industrialised. This particular episode, termed the Great Smog of London, directly caused up to ten thousand deaths[240].

Air pollution and the production of city smog is a highly visible example of a '***negative externality'*** - a cost to a third party that is caused by the production or consumption of goods. Individuals who have no control over the decisions that go into the activities generating pollution have to suffer the costs of it. Market forces cannot provide a solution to this kind of problem, so regulation is necessary.

It was only after 1956, when the UK parliament introduced the Clean Air Act, that restrictions on the emissions of smoke from buildings lead to an improvement in air quality[241].

Policy co-ordination between different parties can help to resolve competing interests and balance mitigation and adaptation efforts. Where market forces or individual actions are insufficient or not incentivised, progress on adaptation and mitigation can be made while still allowing competition to continue to drive innovation. Incentives can also be modulated through taxation and subsidy policy.

National government has an important role in performing, funding, and supporting basic research and development, and encouraging deployment of new technologies during the proof-of-principle phase before private investors are comfortable with the risks.

Co-ordination at a national and international level is necessary to promote resilience to system shocks. For example, the IPCC identifies feasible systemic interventions to increase the reliability of energy systems including:

- Making energy markets more responsive to climate impacts.
- Updating design standards for assets that take into account present and future climate changes.
- Adopting smart-grid approaches to buffer both supply and demand-side variations.
- Creating physically robust transmission systems.
- Improving capacity to handle supply deficits[59].

Planning for longer time scales is essential to prevent 'locking-in' to short-term strategies, particularly when considering infrastructure and the built environment where the time-horizon for the impact of decisions can be measured in decades and centuries.

8.1.2 Sources of policy limitation

Policy-making is more complex than the academic research on this subject generally acknowledges. The creation of new programs, plans and initiatives is a multidimensional process taking account of the interconnected pathways between various government departments and services that may be culturally disconnected and with differing goals. Policy and decision-makers must be able to balance the interests of different groups, meet legal obligations, deliver action sensitively in a timely way, and all within budget. And, in a democratic system, policies need to be explicable to voters and to appear to demonstrate results within the time-frame of a single election cycle[184]. Several attempts have been made to develop comprehensive frameworks to encourage holistic and dynamic assessments of climate change policies, but these have remained conceptual and have not been applied in real-world settings[2,185].

Public health organisations have an essential role in climate planning and action[186]. The health impacts of climate change will not occur in isolation and have combined and cumulative effects. A sound evidence base for policymaking is required, produced by climate and other scientists working with social scientists and policy analysts[184].

It is necessary to commit to policy decisions and stick to them in the long term. Future generations do not get to vote on current policies, so it may be politically tempting for politicians to disregard future problems in favour of rectifying short-term ones. One option for making climate friendly policies more robust is to create legally-binding frameworks around them. Litigation around climate change actions or inactions has increased in recent years and has been used to both delay and advance effective action[187].

8.2 Mitigation policies and regulations

8.2.1 Barriers to mitigation co-operation

Worldwide action in the coming decades is essential for achieving the goals of decarbonising the global economy and building resilience to climate change. The actions taken need to be perceived as fair across countries, nations, and generations, and yet it is far from clear how this can be achieved. There are competing and mutually incompatible ethical principles that could be applied, such as 'polluter pays' or 'beneficiary pays'[188]. In addition, co-operation in climate mitigation is disincentivised by the commons dilemma, competition for resources, and future discounting. These difficulties mean that the problem of collective climate action has been described as 'the perfect moral storm'[189].

Mitigation actions taken by the UK only make sense in the context of a global community in which all major players are also committed to decarbonisation. Therefore, future UK Net Zero policies are dependent on international pledges being met going forward.

8.2.2 The Paris Agreement and UK commitments

The process of reducing greenhouse gas emissions requires co-ordinated international policy, which is supplemented by local policy-making and action to design and implement effective mitigation and adaptation strategies. The Paris Agreement from the United Nations Framework Convention on Climate Change (UNFCCC) 21st Conference of Parties (COP21)[190] has the aim of keeping the global temperature rise below 2°C, or preferably 1.5°C, compared to pre-industrial levels.

The Paris agreement is a legally binding international treaty and currently includes commitments from 194 parties to reduce their emissions and work together to adapt to the impacts of climate change. The operational details for the practical implementation of the Paris Agreement were agreed on at the UN Climate Change Conference (COP24) in Katowice, Poland, in December 2018, in what is colloquially called 'the Paris Rulebook', and finalised at COP26 in Glasgow, Scotland, in November 2021[191]. The Agreement provides a pathway for developed nations to assist developing nations in their climate mitigation and adaptation efforts while creating a framework for the transparent monitoring and reporting of countries' climate goals. Implementation of the Agreement is also essential for the achievement of the Sustainable Development Goals.

The agreement works on a cycle of increasingly ambitious climate actions. It calls on countries to strengthen their commitments over time. Every five years, each country is expected to submit an updated national climate action plan - known as a Nationally Determined Contribution (NDC). In their NDCs, countries communicate actions they will take to reduce their greenhouse gas emissions and to adapt to the impacts of rising temperatures[191]. The Paris Agreement invites countries to formulate and submit long-term strategies as well. Unlike the NDCs, they are not mandatory[191].

Currently, global pledges and targets have been judged by the United Nations Environment Programme as insufficient to meet the Paris Agreement goal of limiting warming to 1.5°C. If current NDCs are fully implemented, warming of 3.2°C can still be expected by the end of this century[192].

Although UK domestic targets have been rated by Climate Action Tracker as "1.5°C compatible" (the only developed country to achieve this rating), this falls to "Almost Sufficient" when non-domestic emissions are considered. Of all the signatories, only a single state, The Gambia, is rated as "1.5°C compatible" in its climate targets[193].

Pledges are not actions, but they facilitate planning and makes it easier to hold states to account. Given the currently rising greenhouse gas emissions[194] we have years and not decades before the threshold for remaining within a 1.5°C is crossed[195]. UK domestic emissions are currently 47% below

1990 levels. The sixth UK carbon budget and NDC commit to achieving a 68% reduction by 2030, completely decarbonised UK power systems by 2035, and Net Zero domestic emissions by 2050[159].

8.2.3 UK Climate Change Act 2008

Beyond the Paris Agreement, The UK Climate Change Act 2008 is a legally binding framework that includes both mitigations and adaptations[196]. The key outcomes of the act are:

- A requirement for the government to set legally binding 'carbon budgets' for reducing UK greenhouse gas emissions in line with targets, which are set at least 12 years in advance in order to give policymakers, businesses, and citizens time to prepare. The sixth carbon budge, published in 2021, includes shipping and aviation for the first time[197,198].
- The establishment of the Climate Change Committee (CCC), which advises on the carbon budgets and provides appraisal of the UK adaptation programme implementation every two years, and advice to the devolved nations every five years.
- The publication of an independent Climate Change Risk Assessment (CCRA), updated every five years.
- A requirement for the government to produce a National Adaptation Programme (NAP), updated every five years, which sets out adaptation policies for England and reserved UK matters (e.g., security and foreign affairs)
- The Adaptation Reporting Power (ARP), which gives the UK and Welsh government the power to require relevant bodies to report on their preparedness.

8.2.4 UK mitigation policy

The UK's target of Net Zero by 2050 was informed by recommendations made by the Climate Change Committee in 2019, which in turn were based on the conclusions of the 2018 IPCC special report on global warming of 1.5^{o}C[199,200]. The target is largely supported by UK public opinion, with a recent Ipsos MORI survey finding 78% support a Net Zero target of 2050 or earlier[201]. However, as with many areas of government policy, it is uncertain to what extent this translates to a willingness-to-pay. Support for specific Net Zero policies has been found to fall when respondents are made aware of the implications for themselves personally[202].

The most recent Net Zero strategy report, presented to parliament in 2021, is titled "Build Back Greener"[159]. This phrasing reflects a general principle of approach: that transition to Net Zero is compatible with, and in fact dependent on, continued economic growth and development. The approach relies on green technologies eventually becoming cheaper, easier, and more competitive in the open marketplace, with funding required to encourage both development and uptake in the short-term. Thus emissions reduction can be focused on the supply-side rather than demand side. This report was produced by the Department for Business Energy and Industrial Strategy (BEIS), which leads on mitigation policy.

In Build Back Greener, four key policy principles are presented:

1. The transition can occur with the grain of consumer choice, with minimal actions required from citizens that are not in their personal economic interests. This will imply minimal inconvenience or cost of living increase. For example, biofuel development will allow 'guilt-free' airplane travel.
2. The cost of the transition will be borne by the largest polluters through carbon pricing.
3. Government transition support will be targeted at the most vulnerable, for example for energy costs.
4. Support for businesses will continue the reduction in costs for low-carbon technology.

Transport and energy represent the areas where most emissions reductions have occurred so far, and also where much of current policy is targeted, continuing trends towards electrification of land travel and phasing in of renewable capacity for grid electricity.

A breakdown of the greenhouse gas emissions by sector in the UK is given in Figure 4. Mitigation efforts have so far focused primarily on electricity supply, but must increasingly impact other sectors in order to meet government targets[88].

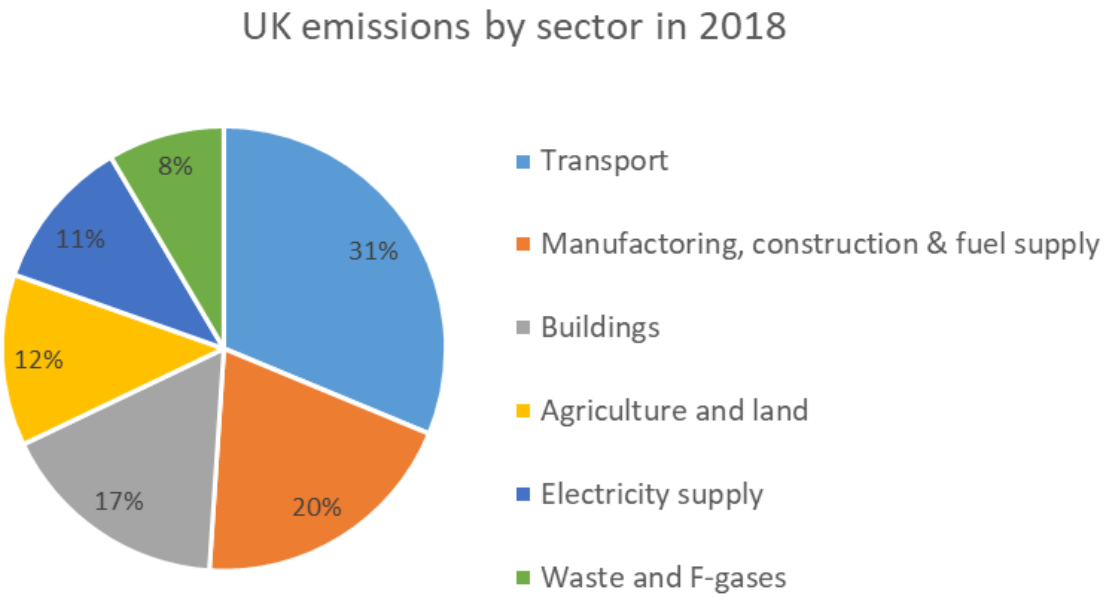

Figure 4 – UK emissions by sector in 2018. Source: BEIS (2020) Provisional UK greenhouse gas emissions national statistics 2019; CCC analysis.

8.2.4.1 Energy

The key energy policy is complete decarbonisation of the power system by 2035, though this is noted as being subject to security of supply. This transition is based on expansion of renewable capacity, new nuclear generation, storage capacity, hydrogen power, and carbon capture and storage (CCS) to compensate for unavoidable emissions. Specifically, this involves:

- Ending coal fired power generation entirely.
- Halving current emissions from oil and gas by 2030 (though offshore extraction licencing is expected to continue subject to 'climate compatibility checkpoints').
- Increasing offshore wind capacity to 40GW by 2030, including 1GW of floating offshore wind, as well as increasing onshore wind, solar, and other renewables.
- Securing a final investment decision on a new large nuclear plant by the end of this parliament and deploying a 'Future Nuclear Enabling Fund' to explore the options around nuclear energy generation including small modular reactors.
- Increasing hydrogen production to 5GW by 2030.
- Developing 'new flexibility measures', including energy storage.

To encourage these transitions, grants will be made available for hydrogen production and carbon capture business models.

At a consumer level, the policy ambition is that by 2035 all new heating appliances in homes and workplaces will be low-carbon. Heat pumps, which are expected to become much more cost-effective

in the meantime, are targeted for 600,000 installations per year by 2028. To encourage this transition, grants will be used to encourage low-carbon heating uptake, particularly for heat-pumps, which includes social housing decarbonisation grant schemes and funding for public sector decarbonisation. In addition, there is an aim to rebalance policy costs from electric to gas this decade in order to make electricity cheaper.

8.2.4.2 Transport

Transport policy targets electrification rather than changes to vehicle ownership or usage, though some investment is promised to encourage walking and cycling. Towards the beginning of the Covid-19 pandemic, there was an increase in the number of trips and distance travelled by walking and cycling. However, between 2020 and 2021, walking trips and distance walked have reduced by 1.0% and 4.0% respectively, and cycling trips and distance cycled has reduced by 27% and 37% respectively[203]. The main policy is the ending of sales of new petrol and diesel cars by 2030, and that by 2035 all cars must be capable of zero emissions. There is a plan to introduce a Zero Emissions Vehicle (ZEV) mandate as a signal to investors. Rail electrification will continue, with an ambition to remove diesel-only trains by 2040. In addition, zero emissions road freight trials are to be expanded. Funding for vehicle grants and Electro Voltaic (EV) infrastructure is to be made available, including the Automotive Transformation Fund (ATF) to encourage electrification of vehicles and supply chains. Funding will also be available for sustainable Aviation Fuel (SAF) plants, with an ambition of 10% sustainable aviation fuel by 2030.

8.2.4.3 Industry and workers

Industrial policy is less clear, and mainly involves investment funds to encourage transition efforts. This includes investment in new industries and innovation projects as part of a 'green industrial revolution' – combining government and private capital, and helping investors to access this capital for green projects. This is also part of Green Finance Strategy[204], which includes the ambition to make the City of London a global centre for Green Finance. The Industrial Energy Transformation Fund (IETF) has been set up to help high energy use business reduce emissions.

Less specifically, there are also vague commitments to 'support' farmers in the adoption of low carbon farming practices, including carbon fixation and land use efficiencies; continue 'phase down' of F-gases; 'new ways' of making concrete, cement, and steel; and a general 'move towards' a circular economy.

F-GASES

Fluorinated gases are hydrofluorocarbons (HFCs), which contain hydrogen, fluorine, and carbon. They are used in a range of applications such as air conditioning, refrigeration, heat pumps, and in industrial foams, aerosols, and solvents. Although they do not cause ozone depletion like the chlorofluorocarbons (CFCs) that they often replace, F-Gases are powerful and long-lived greenhouse gases.

Where emission reductions are not possible, for example in aviation, a UK Emissions Trading Registry (ETS) will introduce the 'polluter pays' principle. This replaces the EU ETS now that the UK has left the European Union. The introduction of a Sustainability Disclosures Regime, which would include mandatory climate-related financial disclosures, will increase the transparency of the environmental impact linking businesses, the financial system, and investors. The Task Force on Climate-related Financial Disclosures (TCFD) was launched by the Financial Stability Board (FSB) at COP21 in 2015 and has developed recommendations for voluntary financial risk disclosures[205]. These have been endorsed

by the UK government, and a roadmap towards mandatory climate disclosures was published in 2020, with the intention of making TCFD-aligned disclosures mandatory by 2025. This roadmap applies to seven categories of organisation:

- Listed commercial companies.
- UK-registered companies.
- Banks and building societies.
- Insurance companies.
- Asset managers.
- Life insurers and FCA-regulated pension schemes.
- Occupational pension schemes[206].

8.2.4.4 Carbon fixing

Despite a lack of current deployment, carbon fixation is essential to the Net Zero target. While targets of tree planting and restoring peatlands are presented as generally beneficial, there is only so much land available. Therefore any feasible carbon fixation solution will be mostly technological. The key policy in the UK Government 'Net Zero Strategy: Build Back Greener' is delivery by 2030 of four Carbon Capture Usage and Storage (CCUS) clusters, with a total capacity of 20-30 $MtCO_2$/year (approximately 5.0% of current emissions). There is an ambition to deploy at least 5$MtCO_2$/year of engineered Greenhouse Gas Removals (GGRs) by 2030. The strategy is initial investment in GGR, with an aim to move towards market-based framework.

8.2.4.5 Further reading

More detail of current government proposals for transition to Net Zero can be found in the Ten Point Plan for a Green Industrial Revolution[207], The Energy White Paper[208], North Sea Transition Deal[209], Industrial Decarbonisation Strategy[210], Transport Decarbonisation Plan[211], Hydrogen Strategy[212], and the Heat and Buildings Strategy[213].

8.2.4.6 Progress and feasibility

The Committee on Climate Change (CCC) reports regularly on UK mitigation progress. The strongest progress is reported for surface transport and electricity supply, where there is clear progress in the electrification of private cars and strong deployment of offshore wind. However, necessary progress is not being made in a wide range of areas. Credible plans exist for only 39% of the required reduction, mostly from further progress on vehicle emissions and energy supply, and so the Net Zero strategy is not currently credible. Agriculture and land use emissions show a lack of progress, failing to meet existing targets. Energy efficiency improvements in building are well below necessary levels. A lack of data for manufacturing and construction makes progress hard to ascertain. In addition, the current strategy relies heavily on unproven future engineered CO_2 removals[214].

8.3 UK health-related adaptation policies and regulations

8.3.1 Introduction

The health impacts of climate change are inherently local, as some populations are substantially more vulnerable than others due to differences in geography, exposure, and sensitivity to health effects. Public planning and policymaking for climate change has so far been focused on mitigation rather than adaptation. As the main goal of climate-adaptive policies is to protect human wellbeing at the local level, public health should be a natural leader of these adaptation efforts[186].

Approximately 70% of District, County, Unitary & Metropolitan Councils in the UK have declared a climate emergency. However, the focus tends to be on mitigation in pursuit of Net Zero rather than adaptation. While adaptive measures can have effects that are reasonably rapid, some may take time

to implement, such as retrofitting of existing housing stock to prepare them for future climates[9]. In addition, many of the adaptive factors that will determine the impact of climate change on the health of the UK population are determined by government departments not directly related to health, or as a result of the choices of individuals[9].

While the goals of mitigation efforts can be easily defined and tracked ("Net Zero by 2050"), adaptation priorities are harder to identify. This is partly due to the uncertainty as to what future climate hazards will occur, as well as uncertainty as to what adaptations are necessary for a given climate risk. Future adaptation needs are dependent on short-term mitigation outcomes. From 2040 onwards, the results of current mitigation efforts become the dominant factor in climate risk[58].

8.3.2 Current progress on adaptation

The Department for Environment, Food & Rural Affairs (DEFRA) is responsible for producing the National Adaptation Programme (NAP) policy documents. The Climate Change Committee (CCC) reports that UK adaptation policy is currently insufficient to produce the necessary resilience to address climate risks, and that this adaptation gap has widened in the last five years. Adaptation planning for warming of 2°C is lacking, and scenarios of 4°C have not been prepared[214]. The third Climate Change Risk Assessment (CCRA3) reports 61 climate risks or opportunities, of which 34 are ranked as needing more action than is currently planned[183].

The UK government has acknowledged that its actions so far have not been sufficient and set the following priorities for NAP3 in 2023:

- More action in these risk areas.
- Short-term actions to improve resilience, as they would be cost-effective.
- Incorporate climate considerations in decisions with long-term effects like housing and infrastructure.
- Consider low-probability high-impact events from high warming scenarios and cascading risks.

Specific adaptation measures that are known to be cost-effective include early warning systems, heatwave plans and alerts, monitoring for pests and disease, climate-resilient infrastructure, climate-appropriate agriculture, and peatland restoration. Lack of information and awareness of climate risk is recognised as a barrier to adaptation[58].

8.3.3 Devolution

Other than UK-wide areas such as security and foreign affairs, adaptation responsibility is devolved to the four nations, each of which have their own programs. The relevant legislation is given in Appendix 3: Devolution.

Policy development is not equal across the four nations that make up the UK, with England having the most in place. Northern Ireland seems to be further behind the other nations. The reasons for this could be lower levels of funding for research and therefore data for these areas, and the fact that climate impacts, particularly of heat and water stress, are expected to impact England the most. For example, England and Wales have policies in place for heatwaves while Scotland and Northern Ireland do not, though Scotland has one in development[9].

8.3.4 Ownership of risk and response

The overall UK landscape of current policies is a complex one, with variation across the devolved nations. The variation relates to:

- Certainty as to whether a policy is being acted on.

- Whether the policy addresses the health impact of a particular risk.
- How comprehensive it is.
- The stage of development.

Adaptation policies specifically targeted to health are also only a subset of all adaptation policies that will affect health[9]. For each risk/health impact, there is variation in the number of policies currently in place to ensure recommended adaptations are acted on.

There is a lack of clarity as to ownership of climate risk and adaptation response. An internal government exercise is being conducted to establish risk ownership and policy gaps[58]. Individuals as well as the government must take responsibility for carrying out necessary adaptations. But here too, there is potential for confusion as advice may differ between individual advisors and organisations. For example, for emergency planning and response to flooding in England there are 6 organisations that provide advice:

- Local Resilience Forums (LRFs).
- Environment Agency/NRW.
- National Flood Forum.
- Local councils.
- Utility companies.
- Highways England[9].

8.3.5 NHS plan

The National Health Service (NHS) currently produces approximately 4.0% of England's total carbon emissions[215]. In 2020, the NHS launched its campaign 'For a Greener NHS' to respond to the health emergency that climate change brings. The NHS Net Zero commitment has two targets:

- For the emissions that the NHS controls directly (the NHS Carbon Footprint), Net Zero by 2040, with an ambition to reach an 80% reduction by 2028 to 2032.
- For the emissions that the NHS can influence (the NHS Carbon Footprint Plus), Net Zero by 2045, with an ambition to reach an 80% reduction by 2036 to 2039.

The Greener NHS plan lists multiple interventions to decarbonize the NHS:

1. Reduce emissions from the hospital estates and facilities by:
    a. Introducing a new Net Zero Carbon Hospital Standard which will involve the use of innovative, low-carbon materials, as well as a novel design that will allow flexibility and shifts in how care will be delivered in the future.
    b. Reducing the emissions from the primary care estate by supporting improved insulation, lighting, and heating in care buildings in England.
2. Reduce carbon emissions related to travel and transport by:
    a. Transition to zero-emission vehicles.
    b. Reducing unnecessary journeys and enabling healthier forms of commuting such as walking and cycling.
3. Decarbonizing the supply chain, for example by reducing single-use plastics, device reuse and refurbishment, and encouraging suppliers to meet NHS commitments.
4. Optimise prescribing, substituting high-carbon products for low-carbon alternatives, and improvements in production and waste processes. Medicines, especially anaesthetic gases and inhalers, currently account for 25% of emissions within the NHS[215].

The NHS, the UK Health Security Agency (UKHSA), and the Care Quality Commission (CQC) collaborate to monitor the climate impacts on healthcare delivery. The UKHSA is responsible for the weather early warning systems and vector surveillance programmes and is contributing to the development of the third National Adaptation Programme (NAP). The NHS integrated risk assessments make use of UKHSA early-warning systems to reduce risk to NHS facilities. In addition, the UKHSA has announced that it will soon be launching a new Centre for Climate and Health Security[216].

The CQC performs a range of risk assessments, including collecting data on service interruptions from extreme weather events[217].

The most recent 2021 Health and Care Adaptation report aims to help healthcare teams understand, plan and response to climate risks, and includes details of current actions and policies[217], as shown in Appendix 4: Health and Care Adaptation Report policies and recommendations.

8.3.6 Flood

Policies on flood risk management in England have been published by DEFRA and the Environment Agency (EA). Risk management authorities (RMAs) and Lead Local Flood Authorities (LLFAs) are also mentioned as bodies that lead on the work at a more local level. The LLFAs were developed as a result of the Flood and Water Management Act (FWMA) of 2010 (England and Wales). For coastal erosion, there are Shoreline Management Plans (SMPs) that give a broad assessment of the long-term risks associated with coastal processes, but are non-statutory[9].

8.3.7 Building and heat

The current housing policies across England, Wales, and Northern Ireland do not address the impact on health from overheating in buildings, and even in Scotland the guidance is limited. Future policies for new buildings are beginning to address the problems that higher temperatures will bring, but incentives to retrofit existing buildings are lacking[9].

New buildings do not usually include resilience to future hazards such as improved insulation and energy efficiency and risk health by increasing the chances of overheating and damp. Insufficient adaptation of new buildings arises from inadequate building standards and informally through occupant behaviour. A Future Homes Standard should be introduced in England by 2025 that considers low-carbon heating and energy efficiency, and in 2021 the Ministry of Housing, Communities & Local Government (MHCLG) proposed introducing new regulatory requirements for the prevention of overheating[9].

England's heatwave plan appears to lack some effectiveness in that information often fails to reach frontline healthcare staff. Nurses frequently report that their organisations are not prepared for heatwaves[218]. In care homes:

- There is a lack of cooling strategies.
- Lack of awareness of responsibility in managing building systems to counter overheating.
- Inflexibility in adapting to overheating.
- No statutory legal maximum internal temperature[143].

This suggests a deficit in logistical preparatory regulation for the management on these increasingly frequent overheating events.

In the education and prison systems, adaptation planning for climate change scenarios up to 4°C by 2100 is being considered for both sectors in England and Wales[9].

8.3.8 Food

The UK currently lacks specific policies addressing climate impacts on food safety and security. Existing actions are being taken mostly by the private sector. However the private sector may not be able to take all necessary actions alone. Supply chain and system resilience will often run counter to efficiency and competition motivations, with a risk of private companies internalising gains and externalising costs. There is therefore a role for the government in removing barriers and encouraging private sector adaptation and resilience, while maintaining competition[9].

8.3.9 Water

16.7 million people in the UK live in areas with a water deficiency, mostly in London and the South East. In recognition of a growing threat to supply, the Environment Agency recently published the National Framework for Water resources, which identifies strategic water needs for English regions up to 2050. The report suggests that one of the ways to increase resilience to drought is 'water transfer': moving water from a place where it is available to a place where it is needed. Longer transfers seem to confer greater drought protection since neighbouring areas are likely to have similar levels of water-stress. However, there are significant challenges around infrastructure, energy requirements, environment impact, public health and acceptability[219]. DEFRA is exploring measures to reduce demand-side usage[220]. Northern Ireland Water published a Water Resources and Supply Resilience (WR & SR) Plan in 2020[221] and Scotland published a National Water Scarcity Plan in the same year[222].

8.3.10 Worker wellbeing

Workplaces have a duty of care for worker health, safety, and wellbeing. The Health and Safety Executive (HSE) is Britain's national regulator for workplace health and safety. They are dedicated to protecting people and places and helping everyone lead safer and healthier lives. The HSE role goes beyond worker protection to include public assurance and they work to ensure people feel safe where they live, where they work and, in their environment.

The HSE has published guidance on heat stress in the workplace[223]. The guidance is aimed for workplaces specifically at risk due to the hot environment created by the process, or restricted spaces, for example different types of manufacturing plants, bakeries and kitchens. However, the guidance does not take account of any changes to working conditions that are required due to climate change. The Chartered Institute of Personnel and Development (CIPD) published a press release in July 2022 in response to the expected heatwaves urging employers to embrace flexible working arrangements to help staff stay comfortable and productive[224]. While there is no specific legal minimum or maximum temperature for workplaces in the UK, employers should make sure the workplace temperatures stay "reasonable".

8.4 Impact of Brexit

There are a number of consequences for UK climate policy that may arise from Brexit:

- The UK will not have to implement key EU Directives for health protection, which has broad and specific impacts on policy development (and therefore health).
- Reduced access to EU research funding.
- Reduced access to data.
- Reduced intelligence and evidence sharing mechanisms.
- Uncertainty over what the future immigration policies will be.
- Uncertainty around the policies for air and water quality and food safety.
- Uncertainty around food security with possibly more reliance on domestic trade.

- Reduced access to the European Centre for Disease Prevention and Control (ECDC) which could hinder policies and regulations around vector borne diseases[9].

8.5 The Insurance and Finance industry

The economic consequences of international climate risks can be transmitted to the UK via the finance industry. London operates a global insurance market that offers products that cover both direct climate change effects like agriculture insurance, as well as indirect impacts like business interruption. Therefore, policy regarding the disclosure of insurance risks due to climate change is essential.

Investment risks are clear where assets are damaged through extreme weather, or due to the interruption of supply chains. UK Pension funds rely on the performance of many asset classes over long timescales and so are at high risk of further stress[70].

The Sustainable Insurance Forum (SIF) includes the Bank of England Prudential Regulation Authority (PRA) among its 25 jurisdictions and works to implement recommendations put in place by the Taskforce for Climate-related Financial Disclosures (TCFD)[225]. These recommendations relate to:

- **Governance** – organisations should disclose climate related risks and opportunities.
- **Strategy** – organisations should disclose the actual and potential impacts of climate related risks and opportunities on the organisation's businesses, strategy, and financial planning.
- **Risk management** – organisations should disclose how they identify, assess and manage climate related risks.
- **Metrics and targets** – organisations should disclose the metrics and targets used to assess and manage relevant climate related risks and opportunities[225].

In 2019 the UK government announced that as part of the Green Finance Strategy, TCFD disclosures would be made mandatory across the economy. A new UK joint regulator and government TCFD taskforce was created to deliver on this commitment, with TCFD-aligned disclosures to become fully mandatory across the UK economy by 2025[226].

In 2021 the UK government published a roadmap to implement new Sustainability Disclosure Requirements (SDR) that apply to companies, asset managers and asset owners, including pension schemes and investment products. These require reporting on climate effects as well as financial risks and opportunities that these pose to the business[226]. Over time, the SDRs will include broader issues, including the impact that the businesses and investments will have on the environment, and considerations around adopting the corporate sustainability reporting standard in development by the IFRS. These polices build on the existing PRA supervisory expectations for how insurers and banks should enhance their approaches to managing the financial risks associated with climate change[225].

The PRA highlights three channels of financial risk that will be bought about by climate change: ***physical risks***, ***transitional risks***, and ***liability risks***. The PRA expects the response to financial risks to be proportionate to the scale and complexity of the business, with the businesses' approach to the management of financial risk expected to mature over time.

Businesses should provide evidence on how their firm monitors and manages risk, including risk exposure limits and thresholds that the firm can bear, including, but not limited to, the long-term financial decisions, and the results of stress and scenario testing for both short- and long-term time horizons. Banks and insurers must disclose information on material risks and principal risks and consider further disclosures that enhance their transparency on how they manage the financial risks of climate change. It is also expected that firms consider engaging with the TCFD initiatives to further develop their approach to climate related financial disclosures[227].

Since the 2019 announcement, the Financial Conduct Authority (FCA) finalised its TCFD-aligned disclosure rules for UK premium listed companies, consulted on proposals to extend TCFD requirements to standard-listed issuers and to require asset managers, life insurers and pension providers to publish TCFD aligned disclosures. The Department for Business, Energy, and Industrial strategy (BEIS) has consulted on mandatory climate-related financial disclosure requirements for large private companies, limited liability partnerships and some public companies. The Department for Work and Pensions (DWP) bought legislation before parliament to require a variety of pension schemes to make certain TCFD disclosures mandatory and effectively manage climate related risks and opportunities[226].

8.6 Where the UK stands in climate policy and regulation

The UK has one of the most ambitious climate mitigation targets in the world, and our aim of achieving Net Zero by 2050 is likely compatible with limiting average global warming to 1.5°C. However, the progress so far has been made largely through picking the low-hanging fruit of decarbonisation policy, such as phasing out coal-fired power stations. Future progress depends on more systemic changes and technologies that have yet to be developed, as well as continued public support for measures that threaten jobs, economic growth, and established ways of living. Mitigation efforts within any one country are also useless if not part of a global successful decarbonisation process. There is a risk that expensive and disruptive mitigation policies will be abandoned if attempts at global co-operation, such as the Paris Agreement, do not yield results. In that case the future climate hazards to health will be much greater.

Although adaptations, including those that affect health, are considered as part of the UK Climate Change Act of 2008 and the climate acts of the devolved nations, this area is plagued with uncertainties. What degree of climate change will be seen? How will this affect the UK directly? What adaptation response is required and who is responsible for them? How will international impacts propagate through an increasingly complex global system, and how will that system evolve over time?

There is a growing recognition that adaptation policy needs to respond to classes of risk rather than specific risks, that increasing system resilience to unpredictable shocks can prevent risk cascades. However, resilience can come at the cost of efficiency, competitiveness, and profit. For both mitigation and adaptation policy, therefore, there is a struggle to address the areas in which our desire for personal choice, free markets, and economic growth conflict with our desire to protect ourselves and future generations from the impacts of climate change on our health. The answers to these trade-offs are inherently ideological and political, and incoming governments will create, change, or reverse policies over time.

9 Report summary

KEY POINTS

- Climate change is a global problem. Not only does the future of climate change depend on total global greenhouse gas emissions, but climate effects abroad affect the UK society and economy.
- The major uncertainties about the future of the Earth's climate arise not from doubts about the existence of climate change, the role of human actions in causing it, or the effects it will have around the globe, but from the actions that countries will take to mitigate and adapt to its effects.
- The direct impacts of climate change on health are the most obvious, but in the UK are likely to be only the tip of the iceberg compared to the indirect impacts.
- Disruptions to the UK economy, in part caused by climate-induced global economic stresses, are a key but under-appreciated indirect pathway through which climate change may adversely impact on population health in the UK.
- Climate change will be experienced unevenly across different sections of the UK population, and may result in a deepening of the already substantial health inequalities in physical and mental health that exist in this country.
- To be effective, mitigation efforts absolutely require global co-operation, and international instruments such as the Paris Agreement aim to bind countries into mutually beneficial behaviour. However, factors such as the commons dilemma and short-termism threaten progress.
- Market forces and individual efforts are not sufficient to overcome barriers to effective action, which only government policy and regulation can provide.
- The UK has ambitious mitigation targets, but it is not clear that we are on track to meet them.
- According to the Climate Change Committee our current adaptation responses are insufficient to address climate risks, including to health. It is unclear what adaptation measures are required and who is responsible for them, and we risk widening the gap between what is needed and what is being achieved.
- For mitigation in particular, and also adaptation, the earlier actions are taken, the more cost-effective they become. However, uncertainty, competition, and short-term thinking may prevent us from acting appropriately.

10 Report Conclusions

There is an overwhelming scientific consensus that climate change is happening and that it is substantially attributable to the activities of humanity - most notably, from the burning of fossil fuels and the elimination of natural CO_2 sinks such as rainforests. It is a global phenomenon, and the impacts are not experienced in isolation by any part of the world. There are visible direct health consequences of the rising temperature such as the death and disability arising from heat stroke, but their scale is only the 'tip of the iceberg' in comparison to the indirect health consequences arising from the social and economic disruption that it will cause.

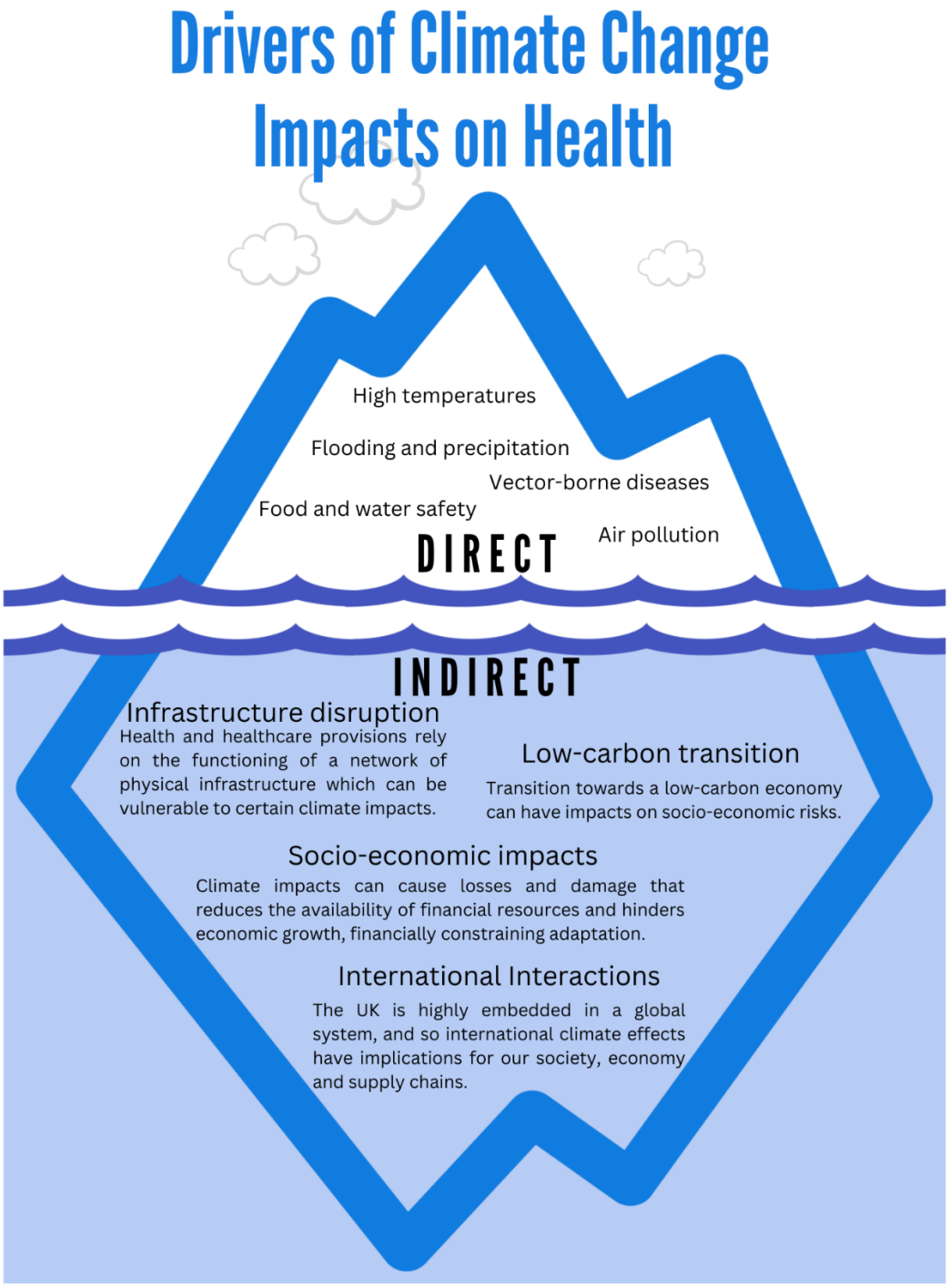

Figure 5 – 'Tip of the Iceberg' – There are many pathways through which climate change impacts health. In the UK, the direct physical impacts of changes in temperature and weather represent only a minor part of the whole.

Climate change is expected to diminish the effective global supply and safety of food and water. Whilst domestic food production will be less impacted in the UK than other countries, particularly those on the equator and in the Southern hemisphere, nearly half the UK food supply is imported and we should expect food to become scarcer, more expensive and potentially less safe as a consequence of disruption to the food distribution networks that ensure the timely and safe transport and preservation of food. Whilst the UK may be partially protected from the inevitable increase in malnutrition and food-borne illnesses globally because of its relatively strong economy and well-developed infrastructure, the indirect effects will be felt. Impoverishment of our export markets will weaken us economically, and the potential consequences of a contracting food and water supply internationally may give rise to conflict and migration over and above that caused by flooding and severe weather events. This would further disrupting the global economy and the supply chains for food and other goods.

The impact on the economy is key, as health and mortality is strongly correlated with wealth. The timing of mitigation actions is critical – the earlier the better. This creates a fresh self-interest dilemma, as the current population needs to make sacrifices for the benefit of future generations. Climate change is expected to shave more than 10% of global GDP by the mid-21st Century and the earlier action is taken, the less that economic loss will be.

Healthcare will be affected by climate change in different ways. The weakening of the economy is bound to weaken our healthcare systems, but this will be exacerbated by increased costs arising from the need to modify buildings to adapt to warmer temperatures and the degradation of infrastructure by more frequent and severe flooding.

Government policy needs to be co-ordinated at an international level to ensure successful mitigation of climate change, and needs to be carefully crafted at the national level to ensure that the negative impacts are borne fairly across the population and do not add to health and other inequalities. Not all of the impacts are necessarily negative. There may be significant benefits that arise that are unrelated to the adaptation to climate change, such as the electrification of transport combined with expanded sources of renewable energy and facilitating the use of bicycles and access to footpaths. These measures would result in cleaner air and an increase in exercise across the population, regardless of climate change effects.

There are short-term costs connected to taking steps to mitigate climate change and adapt to its consequences. Although these are expected to be much less than the long-term cost, the future benefit will not be felt by at least some proportion of the population that needs to make these sacrifices, and their impact is unlikely to be felt evenly across society. Climate change may exacerbate health inequalities. The costliest mitigations and adaptations to combat climate change are concentrated in the most deprived areas and the population of these areas are the least able to afford them. Another source of irony is found in the fact that, in general, those that have contributed least to the problem of climate change will also be the most affected by it.

Whilst we have certainty about the nature of climate change and humanity's role in it, there is uncertainty around the collective response across the world, what technological mitigations and adaptations we may be able to develop, and what risks arise from the complexity of the interconnected pathways and systems that allow the harms of climate change to play out. Globally co-ordinated action is required, as market forces and individual action are not sufficient to adequately address the problem. The existence of self-interest at a national level is a serious barrier to effective action, and we need to seek mechanisms that will unlock the universal benefits of a globally co-ordinated response.

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12 Appendix 1: Glossary

Adaptation - Action to reduce the exposure or vulnerability of human or natural systems to the impacts of climate change and climate-related risks, by maintaining or increasing adaptive capacity and resilience[2].

Afforestation – The creation of new forests through planting and seeding in a place where there was not previously any forest.

Anthropogenic – As a result of human activity. As in 'anthropogenic climate change' or 'anthropogenic emissions'.

Black swan events – Rare or extreme events that are unpredictable as a consequence of our ignorance about the existence of relevant information – or *'unknown unknowns'*. It is so named after the hypothesis used by the philosopher John Stuart Mill to illustrate the point that it isn't possible to draw a conclusion based on the observation of a limited sample. He pointed out that the statement that 'All swans are white' cannot be proven until all swans have been observed and found to be white. He was writing many years before the discovery of the continent of Australia and its native black swans.

Commons dilemma – The dilemma faced by individuals sharing a finite resource that can be depleted if over-used. The best outcome for all users occurs when all of them choose to moderate their use of the resource. However, when some of these users choose excessive consumption, the more altruistic users who do, lose out.

Commons tragedy – The unnecessary loss of a finite shared and depletable resource as a result of its consumption by users acting in self-interest.

Climate anxiety – The mental health effects of climate change in people not severely or directly affected, occurring as a result of empathy for those who are, or because of disruption to their lives, homes or livelihoods.

Earth system – The collection of systems in our planet that interact to produce the environment in which we live, including those in the land, seas and atmosphere.

Exposure - the degree to which the assets come into contact with a hazard. For example, Low-lying homes are more exposed to flooding than elevated ones.

F-gasses - Fluorinated gases are hydrofluorocarbons (HFCs), which contain hydrogen, fluorine, and carbon. They are used in a range of applications such as air conditioning, refrigeration, heat pumps, and in industrial foams, aerosols, and solvents. Although they do not cause ozone depletion like the chlorofluorocarbons (CFCs) that they often replace, F-Gases are powerful and long-lived greenhouse gases.

Hazards - destructive phenomena that threaten valued assets such as health, infrastructure, and biodiversity. This includes direct hazards such as heatwaves and floods, and downstream events like wildfires, crop failure, and vector-borne disease.

Intangible damages – In flood risk insurance, intangible losses are losses that are difficult to measure in financial terms but still entail a loss of value. It encompasses damage to health and wellbeing, loss of life, and the inconvenience experienced during recovery, but also includes cultural, historical and ecological losses.

Locking-in – the inertia in a pathway that can arise from the long timescales needed to change complex processes or infrastructure.

Maladaptation – actions that result in an increased vulnerability to climate hazards, or else prevent or reduce future opportunities for effective action. This may occur due to conflict between competing goals, the prioritisation of short-term goals over long-term ones, failure to plan effectively, or lack of knowledge.

Mitigation - Proactive measures aiming to lessen future climate change. This can occur by reducing the emission of greenhouse gases into the atmosphere or by increasing the rate of the removal of greenhouse gases from the atmosphere through carbon sequestration.

Negative externalities – Costs that are borne by a third-party that arise from the production or consumption of goods.

'Overshoot' warming pathways - Pathways that temporarily exceed 1.5°C total warming and then fall again later[59].

Pathways – The mechanisms by which a change in climate leads to a particular outcome such as a change in health or mortality.

Representative Concentration Pathways (RCPs) - Four pathway scenarios designed to standardise our understanding of climate risk using models. They specify greenhouse gas concentrations that will result in total radiative forcing (the difference between incoming and outgoing radiation from the atmosphere) of 2.6, 4.5, 6.0, and 8.5 watts per square meter by 2100. Each pathway is therefore also associated with a target change in temperature by 2081-2100 of 1.6, 2.4, 2.8, or 4.3°C[228].

Reforestation – The restoring of forest in a previously forested but subsequently deforested area by planting and seeding.

Retrofitting – improvements to buildings to make them more energy efficient.

Risk cascade - This occurs when there is non-linear transmission of risks across multiple domains. A simple example would be a fan of dominos, where the first topples two, which topples another four, which topples another eight. If the cascade is large enough the entire system can be affected.

Sink – anything that absorbs more than it generates, in particular greenhouse gases and carbon. As in 'greenhouse gas sink' or 'carbon sink'. Examples are rainforests and oceans.

Systemic risk – A risk that is amplified through cascading actions and events through a series of different systems such as physical, economic and social systems.

Tipping point – Thresholds beyond which changes rapidly accelerate and may become irreversible.

Urban heat island effect – is where a conurbation is significantly warmer than the surrounding areas due to the greater intensity of human activity and environmental engineering.

Vulnerability - the degree to which an asset exposed to the hazard is likely to be damaged or destroyed. For example, the health of an elderly person may be more vulnerable to flooding as they are less able to evacuate.

13 Appendix 2: Scenarios

Representative Concentration Pathways (RCPs) are four pathways that specify greenhouse gas concentrations that will result in total radiative forcing (the difference between incoming and outgoing radiation from the atmosphere) of 2.6, 4.5, 6.0, and 8.5 watts per square meter by 2100. Each pathway is therefore also associated with a target change in temperature by 2081-2100 of 1.6, 2.4, 2.8, or 4.3°C[228].

RCP pathways can be combined with Shared Socio-economic Pathways (SSPs), which are five scenarios developed as narratives of alternative global socio-economic trajectories[229]:

- SSP1: Sustainability – Taking the Green Road (low challenges to mitigation and adaptation).
- SSP2: Middle of the Road (medium challenges to mitigation and adaptation).
- SSP3: Regional Rivalry – A Rocky Road (high challenges to mitigation and adaptation).
- SSP4: Inequality – A Road Divided (low challenges to mitigation, high challenges to adaptation).
- SSP5: Fossil-fuelled Development – Taking the Highway (high challenges to mitigation, low challenges to adaptation).

Finally, and most recently, Shared climate Policy Assumptions (SPAs) link RCPs and SSPs and create sets of scenarios for specified climate adaptation and/or mitigation policy approaches[177,230].

Together, the RCPs, SSPs, and SPAs form a three-dimensional scenario matrix. Alternative plausible futures can then be explored, and the results are directly comparable between different modelling studies. Just as important, the impacts of the different scenarios can be presented in a way that is conducive to decision and policy-making: “If we follow path X, we are likely to see outcome Y.”

14 Appendix 3: Devolution

Other than UK-wide areas such as security and foreign affairs, adaptation responsibility is devolved to the four nations, each of which have their own adaptation programs.

For Scotland, this is set out in the Climate Change (Scotland) Act 2009[231]. Climate Ready Scotland: Second Scottish Climate Change Adaptation Programme (SCCAP2), was published in September 2019, and includes 170 policies for adaptation up until 2024[232].

The Environment (Wales) Act 2016 includes requirements for emissions reduction targets[233], while Prosperity for All: A Climate Conscious Wales is the second five-year adaptation plan, published in 2019[234]. In addition, the Wellbeing of Future Generations Act 2015 includes consideration of climate impacts in Wales[235].

Although Northern Ireland does not currently have its own climate change legislation, two bills are currently passing through the Northern Ireland Assembly[58]. Northern Ireland's second climate change Adaptation Programme (NICCAP2) was also published in 2019, with the third edition due in 2024[236].

15 Appendix 4: Health and Care Adaptation Report policies and recommendations

The policies include:

- Building NHS staff knowledge of climate risk.
- A single updated Adverse Weather and Health guidance.
- Routine collection of data related to climate event impacts on care delivery.
- Collaboration with other agencies to explore opportunities for research and funding.
- Adaptation of facilities and supply services to increase climate resilience, including cross-sector collaboration with other government bodies.
- Identification and national reporting by the CQC of sites that trigger risk assessments from overheating.
- Integration of long-term adaptation planning in the Green Plans of Integrated Care Services (ICS) by 2025.
- Planning for future flooding through collaboration between National Estates and Facilities team and NHS trusts.
- Assessment of potential synergy and conflict between mitigation and adaptation goals.
- Development by the National Estates and Facilities team of Net Zero Hospital Building Standards that reduce overheating risk.
- Funding for accelerated adoption of adaptation activities by trusts such as cooling, greenspace, and surface drainage.
- Identification by ICSs of sites with evidence of overheating risk to ensure investment or retrofitting.
- Delivery by NHS and UKHSA of e-learning modules for workers.

16 Appendix 5: Key policy policies, regulations, bodies, and documents

Table 1 – key terms used in the section on Policy and regulation, a short description of the term, and a hyperlink for more information.

Term	Description	Hyperlink
Third UK Climate Change Report	The Climate Change Committee contributes to the 5-year assessments under the Climate Change Act 2008, by identifying the hazards that climate change poses to the society and economy of the UK.	https://www.gov.uk/government/news/government-publishes-uks-third-climate-change-risk-assessment
Clean Air Act	Local authorities have powers under the Clean Air Act 1951 to set up smoke control zones and to control emissions of smoke, grit, dust and fumes from industrial premises.	https://www.legislation.gov.uk/ukpga/Eliz2/4-5/52/enacted
The Intergovernmental Panel on Climate Change (IPCC)	The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change. It generates reports on special topics and methods, but its main activity is generating assessments of the state of scientific, technical and socioeconomic knowledge on climate change.	https://www.ipcc.ch/
Paris Agreement	The United Nations is the body responsible for facilitating the Paris agreement, which is a legally binding international treaty adopted in 2015 by 196 countries at the Conference of Parties 21 (COP 21) in Paris. It includes commitments to reduce emissions with the aim of keeping temperature rises below 2° pre-industrial levels.	https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
Conference of Parties	This is the administrative body of the United Nations Framework Convention on Climate Change (UNFCCC). It holds annual meetings 'United Nations Climate Change Conferences' (UNCCC) referred to as 'COP' and the sequence number of the conference - e.g. the COP 26 in Glasgow in 2021. where the signatory countries (currently 198). Notable COP meetings were COP 3 in Kyoto in 1997 where the 'Kyoto protocol' was signed which was in force until superceeded by the Paris agreement arising from COP 21 held in 2015.	https://www.unccd.int/convention/governance/cop

Nationally Determined Contribution (NDC)	The Nationally Determined Contributions set out what steps each country will take to contribute to the global fight against climate change.	https://unfccc.int/ndc-information/nationally-determined-contributions-ndcs
Climate Action Tracker	The Climate Action Tracker is an independent Scientific analysis of the actions governments take to combat climate change with reference to the goal of limiting global warming well below 2°C. It is conducted by a collaboration of interested bodies.	https://climateactiontracker.org/
United Nations	The United Nations hosts the International Panel on Climate Change (IPCC), the United Nations Framework Convention on Climate Change, the United Nations Climate Change Conferences, and is the body responsible for facilitating the Paris agreement.	https://www.un.org/en/
The United Nations Framework Convention on Climate Change (UNFCCC)	The UNFCCC was created in 1992 as the main forum for international action on climate change. It commits participants to the support of scientific research and regular meetings. Its administration body is the Conference of Parties (COP).	https://unfccc.int/
The Climate Change Act 2008	The Climate Change Act 2008 is a piece of UK legislation laid down in 2008 that sets out the 2050 target for the reduction in emissions and creates the UK administrative framework for tackling climate change.	https://www.legislation.gov.uk/ukpga/2008/27/contents
Climate Change Committee (CCC)	The Climate Change Committee (CCC) is an independent, statutory body established under the Climate Change Act 2008. They advises on the carbon budgets and provides appraisal of the UK adaptation programme implementation every two years, and advice to the devolved nations every five years.	https://www.theccc.org.uk/
Carbon budgets	The Carbon Budgets are allowances for carbon emissions set out by the UK Secretary of State to cover five-year periods beginning with 2008.	https://www.gov.uk/guidance/carbon-budgets
Climate Change Risk Assessment (CCRA)	The UK Government is required, under the 2008 Climate Change Act, to publish a Climate Change Risk Assessment (CCRA) every five years which is published on the Government website. The assessment sets out the risks and opportunities facing the UK from climate change.	https://www.ukclimaterisk.org/

National Adaptation Programme (NAP)	The National Adaptation Programme (NAP) sets the actions that government and others will take to adapt to the challenges of climate change in the UK. It sets out key actions for the next 5 years. The report also details how we will manage the third cycle of adaptation reporting. This report forms part of the five-yearly cycle of requirements laid down in the Climate Change Act 2008.	https://www.gov.uk/government/publications/climate-change-second-national-adaptation-programme-2018-to-2023
Adaptation Reporting Power (ARP)	The Adaptation Reporting Power (ARP) set out in the Climate Change Act 2008 provides for the Secretary of State to direct reporting organisations (those with functions of a public nature or statutory undertakers) to report on how they are addressing current and future climate impacts.	https://consult.defra.gov.uk/environmental-quality/adaptation-reporting/#:~:text=Overview,current%20and%20future%20climate%20impacts.
Department for Business Energy and Industrial Strategy (BEIS)	The Department for Business, Energy and Industrial Strategy (BEIS) is a UK Government Department responsible for climate change, clean energy and growth, science research and innovation, industrial strategy, and deregulation.	https://www.gov.uk/government/organisations/department-for-business-energy-and-industrial-strategy
Future Nuclear Enabling Fund (FNEF)	The Future Nuclear Enabling Fund (FNEF) is a £120 million fund set up by the BEIS in response to the 'Net Zero Strategy: Build Back Greener' in 2021. It aims to support the deployment of up to 24GW of nuclear capacity by 2050.	https://www.gov.uk/government/publications/future-nuclear-enabling-fund-fnef
Office for Zero Emissions Vehicle (ZEV)	The Office for Zero Emission Vehicles (OZEV) is a team working across the UK Government to support the transition to zero emission vehicles (ZEVs). It is part of the Department for Transport and the BEIS.	https://www.gov.uk/government/organisations/office-for-zero-emission-vehicles
Automotive Transformation Fund (ATF)	The Automotive Transformation Fund (ATF) is a funding programme created by the Advanced Propulsion Centre, a non-profit organisation. It will distribute up to £1billion to support the development of a supply chain for the electric vehicle industry in the UK.	https://www.apcuk.co.uk/automotive-transformation-fund/
Advanced Propulsion Centre	The Advanced Propulsion Centre is a non-profit organisation in the UK working with the UK Government to develop the electric vehicle industry in the UK.	https://www.apcuk.co.uk/

Sustainable Aviation Fuel (SAF)	The sustainable aviation fuel (SAF) mandate, set by the UK Government, aims to have least 10% (around 1.5 billion litres) of aviation fuel to be made from sustainable sources by 2030.	https://www.gov.uk/government/consultations/mandating-the-use-of-sustainable-aviation-fuels-in-the-uk
Industrial Energy Transformation Fund (IETF)	The Industrial Energy Transformation Fund (IETF) is a UK Government fund that supports the development and deployment of technologies that enable businesses with high energy use to transition to a low carbon future.	https://www.gov.uk/government/collections/industrial-energy-transformation-fund
Emissions Trading Registry (ETS)	The UK Emissions Trading Registry operates in a similar way to an online bank account. The Registry is a secure web-based application that serves as both the UK Emissions Trading Scheme Registry (UK ETS Registry) and the UK Kyoto Protocol Registry.	https://view-emissions-trading-registry.service.gov.uk/
Task Force on Climate-related Financial Disclosures (TCFD)	The Task Force on Climate-related Financial Disclosures (TCFD) was set up by the Financial Stability Board to improve and increase reporting of climate-related financial information.	https://www.fsb-tcfd.org/
Carbon Capture Usage and Storage (CCUS)	Carbon Capture Usage and Storage (CCUS) refers to the panoply of methods of removing carbon from the atmosphere and storing it as part of mitigation. The UK Government announced has focused on this as part of its Clean Growth Strategy. The approach is designed to enable the UK to become a global technology leader for CCUS and ensure that government has the option of deploying CCUS at scale during the 2030s, subject to costs coming down sufficiently.	https://www.gov.uk/guidance/uk-carbon-capture-and-storage-government-funding-and-support
Greenhouse Gas Removals (GGRs)	Greenhouse Gas Removals (GGRs) are projects designed to remove carbon from the atmosphere as part of CCUS.	https://www.gov.uk/government/consultations/greenhouse-gas-removals-call-for-evidence
Green Industrial Revolution	The Green Industrial Revolution is 10-point plan outlined by the UK Government to help drive the development of technologies important for mitigation including CCUS, renewable energy sources and carbon free transport.	https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution
The Energy White Paper	"Energy white paper: Powering our net zero future" is a White Paper issued by the BEIS in December 2020 setting the Ten Point Plan for achieving Net Zero by 2050.	https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future

North Sea Transition Deal	The North Sea Transition Deal sets out an ambitious plan for how the UK's offshore oil and gas sector and the UK Government will work together to deliver the skills, innovation and new infrastructure required to meet greenhouse gas emissions reduction targets.	https://www.gov.uk/government/publications/north-sea-transition-deal
Industrial Decarbonisation Strategy	The Industrial Decarbonisation Strategy published by the BEIS in March 2021 is a plan to help all parts of UK industry transition to a low carbon economy without exporting the carbon emissions to industry abroad.	https://www.gov.uk/government/publications/industrial-decarbonisation-strategy
Transport Decarbonisation Plan	The Transport Decarbonisation Plan was issued by the UK Department of Transport setting out a series of targets related to the transition to Net Zero in the transport industry.	https://www.gov.uk/government/publications/transport-decarbonisation-plan
Hydrogen Strategy	The Hydrogen Strategy was issued by the BEIS in August 2021 and sets out a plan for developing low-carbon hydrogen fuel and the associated infrastructure required to support it as a substitute for hydrocarbons in the UK.	https://www.gov.uk/government/publications/uk-hydrogen-strategy
Heat and Buildings Strategy	The Heat and Buildings Strategy, issued by the BEIS in sets out the government's plan to significantly cut carbon emissions from the UK's 30 million homes and workplaces in a simple, low-cost and green way whilst ensuring this remains affordable and fair for households across the country. Like the transition to electric vehicles, this will be a gradual transition which will start by incentivizing consumers and driving down costs.	https://www.gov.uk/government/publications/heat-and-buildings-strategy
Department for Environment, Food, & Rural Affairs (DEFRA)	Department for Environment, Food, & Rural Affairs (DEFRA) is a UK Government department. It is responsible for improving and protecting the environment in the UK.	https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs
Local Resilience Forums (LRFs)	Local resilience forums (LRFs) are multi-agency partnerships made up of representatives from local public services, including the emergency services, local authorities, the NHS, the Environment Agency and others. The LRFs aim to plan and prepare for localised incidents and catastrophic emergencies. They work to identify potential risks and produce emergency plans to either prevent or	https://www.gov.uk/guidance/local-resilience-forums-contact-details

	mitigate the impact of any incident on their local communities.	
Environment Agency	The EA is an executive non-departmental public body, sponsored by the Department for Environment, Food & Rural Affairs. It was established in 1996 to protect and improve the environment.	https://www.gov.uk/government/organisations/environment-agency
National Flood Forum	The National Flood Forum is a charity formed in 2002, and exists to support individuals and communities at risk of flooding.	https://nationalfloodforum.org.uk/
Highways England	Highways England operates, maintains and improves England's motorways and major A roads.	https://nationalhighways.co.uk/
UK Health Security Agency (UKHSA)	UKHSA is an executive agency, sponsored by the Department of Health and Social Care. It is responsible for protecting the public from the impact of infectious diseases, chemical, biological, radiological and nuclear incidents and other health threats.	https://www.gov.uk/government/organisations/uk-health-security-agency
Care Quality Commission (CQC)	CQC is the independent regulator of health and adult social care in England. It monitors, inspects and regulates services.	https://www.cqc.org.uk/
2021 Health and Care Adaptation report	Published by the UK Health Security Agency in 2021, the report's ambition is to help local, regional and national teams understand, plan and respond to climate change, while delivering on net zero commitments.	https://www.england.nhs.uk/wp-content/uploads/2021/12/NHS-third-health-and-care-adaptation-report-2021.pdf
Risk management authorities (RMAs)	Defra has overall national responsibility for policy on flood and coastal erosion risk management (FCERM) in England. The department provides funding for flood risk management through grants to the Environment Agency, local authorities and internal drainage boards. These risk management authorities and others have their own responsibilities and powers that they can use in order to carry out these responsibilities.	https://www.gov.uk/government/collections/flood-and-coastal-erosion-risk-management-authorities

Lead Local Flood Authorities (LLFAs)	LLFAs are county councils and unitary authorities. They lead in managing local flood risks (i.e. risks of flooding from surface water, ground water and ordinary (smaller) watercourses). This includes ensuring co-operation between the Risk Management Authorities in their area.	https://www.local.gov.uk/topics/severe-weather/flooding/local-flood-risk-management/managing-flood-risk-roles-and#:~:text=Lead%20Local%20Flood%20Authorities%20(LLFAs),-LLFAs%20are%20county&text=prepare%20and%20maintain%20a%20strategy,and%20scrutiny%2C%20and%20delivery%20planning.
Flood and Water Management Act (FWMA)	A 2010 UK Act of Parliament relating to the management of the risk concerning flooding and coastal erosion.	https://www.legislation.gov.uk/ukpga/2010/29/pdfs/ukpga_20100029_en.pdf
Shoreline Management Plans (SMPs)	These documents contains links to all the shoreline management plans in England and Wales. Shoreline management plans are developed by Coastal Groups with members mainly from local councils and the Environment Agency. They identify the most sustainable approach to managing the flood and coastal erosion risks to the coastline.	https://www.gov.uk/government/publications/shoreline-management-plans-smps
Future Homes Standard	The government hosted a public consultation from 1 October 2019 to 7 February 2020 on proposed changes to the Building Regulations. This is the government response to that consultation. This was the first stage of a 2-part consultation which proposed an ambitious uplift in the energy efficiency of new homes through changes to Part L (Conservation of fuel and power) of the Building Regulations. The second stage has now been published as the Future Buildings Standard.	https://www.gov.uk/government/consultations/the-future-homes-standard-changes-to-part-l-and-part-f-of-the-building-regulations-for-new-dwellings
Ministry of Housing, Communities & Local Government (MHCLG)	Now called the Department for Levelling Up, Housing and Communities. The goals of this government department include investing in local areas to drive growth and create jobs, delivering the homes our country needs, supporting our community and faith groups, and overseeing local government, planning and building safety.	https://www.gov.uk/government/organisations/ministry-of-housing-communities-and-local-government

National Framework for Water resources	Published by the Environment Agency (EA) in 2020, these documents set the strategic direction for long-term regional water resources planning in England.	https://www.gov.uk/government/publications/meeting-our-future-water-needs-a-national-framework-for-water-resources
Water Resources and Supply Resilience (WR & SR) Plan	Published by Northern Ireland Water (NI Water) in 2020, the plan sets out how NI Water intends to maintain the balance between supply and demand for water for all its customers over the long-term and the operational and management options and activities available to respond to short-term critical events such as drought and freeze-thaw. A key strategic aim of this plan is to improve the resilience of Northern Ireland's water supply system.	https://www.niwater.com/sitefiles/resources/pdf/2020/wrm/waterresourcesupplyresilienceplan-mainreport.pdf
National Water Scarcity Plan	This is Scotland's first national water scarcity plan, published in 2020, setting out how water resources will be managed prior to and during periods of prolonged dry weather.	https://www.sepa.org.uk/media/219302/scotlands-national-water-scarcity-plan.pdf
Health and Safety Executive (HSE)	The Health and Safety Executive (HSE) is Britain's national regulator for workplace health and safety.	https://www.hse.gov.uk/
Chartered Institute of Personnel and Development (CIPD)	The CIPD is the professional body for HR and people development. The registered charity champions better work and working lives and has operating for more than 100 years.	https://www.futurelearn.com/partners/cipd
EU Directives for health protection	Article 153 of the Treaty on the Functioning of the European Union gives the EU the authority to adopt directives in the field of safety and health at work. The Framework Directive, with its wide scope of application, and further directives focusing on specific aspects of safety and health at work are the fundamentals of European safety and health legislation.	https://osha.europa.eu/en/safety-and-health-legislation/european-directives
European Centre for Disease Prevention and Control (ECDC)	The European Centre for Disease Prevention and Control (ECDC) was established in 2005. It is an EU agency aimed at strengthening Europe's defences against infectious diseases.	https://www.ecdc.europa.eu/en
Sustainable Insurance Forum (SIF)	SIF is the platform for insurance supervisors and regulators who want to address sustainability issues impacting consumers, firms and markets in their jurisdictions, and who have an interest in collaborating with their peers to share knowledge and identify best practices.	https://www.sustainableinsuranceforum.org/

Prudential Regulation Authority (PRA)	Established as part of a new wave of regulation in financial services after the financial crisis of 2007, the PRA supervises around 1,500 financial institutions including banks and insurance companies.	https://www.bankofengland.co.uk/knowledgebank/what-is-the-prudential-regulation-authority-pra
Green Finance Strategy	A strategy document produced by the Department for Business, Energy & Industrial Strategy (BEIS) in 2019. It built on the work of the Green Finance Taskforce. The purpose was to accelerate the growth of green finance.	https://www.gov.uk/government/publications/green-finance-strategy
Sustainability Disclosure Requirements (SDRs)	Companies, including listed issuers, and asset managers and asset owners will be required to report on their sustainability risks, opportunities and impacts. The regime will build on measures already taken or underway to implement disclosure rules aligned with the recommendations of the Taskforce on Climate-related Financial Disclosures (TCFD) across the economy, expanding the scope to cover wider sustainability topics beyond climate change. SDR will also include disclosure requirements relating to the forthcoming UK Green Taxonomy (defined as a 'common framework setting the bar for investments that can be defined as environmentally sustainable').	https://www.fca.org.uk/publication/discussion/dp21-4.pdf
Financial Conduct Authority (FCA)	The Financial Conduct Authority (FCA) regulates the financial services industry in the UK. Its role includes protecting consumers, keeping the industry stable, and promoting healthy competition between financial service providers.	https://www.gov.uk/government/organisations/financial-conduct-authority
Department for Work and Pensions (DWP)	The Department for Work and Pensions (DWP) is responsible for welfare, pensions and child maintenance policy. As the UK's biggest public service department it administers the State Pension and a range of working age, disability and ill health benefits to around 20 million claimants and customers.	https://www.gov.uk/government/organisations/department-for-work-pensions
The Climate Change (Scotland) Act 2009	An Act of the Scottish Parliament to set a target for the year 2050, an interim target for the year 2020, and to provide for annual targets for the reduction of greenhouse gas emissions, and to make further provision about adaptation.	https://www.gov.scot/policies/climate-change/

The Environment (Wales) Act 2016	The Act places a duty on Welsh Ministers to set targets for reducing greenhouse emissions and also to set carbon budgets. key aims are to build resilience in the environment to extreme weather events, to better evaluate progress and provide certainty to help drive investment for a low-carbon Wales.	https://gov.wales/sites/default/files/publications/2019-05/environment-wales-act-2016-overview.pdf