REPORT:

INTO THE RED

Counting the cost of climate inaction

May 2025

Royal Scottish Geographical Society

Contents

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Foreword

Imagine a Scotland without any tourism or a financial services sector. That is the level of losses to our economy that are forecast to impact if we don't tackle climate change now and over the next two to three decades, and as our understanding and analysis improves, this figure is only likely to get bigger. Climate impacts are, according to the UK Climate Change Commission, already costing billions to our economy, but could reach as much as 5% to 20% of GDP within 25 years. If these figures are correct, our economy could be anything from £30 billion to £140 billion poorer by 2035 by not taking action to tackle climate change.

It was an economist, William Nordhaus who flagged the 2°C threshold as critically dangerous for climate change back in 1977, and ever since, there have been countless economic reports detailing the cost of climate action and inaction, the most high profile of which was probably the 2006 Stern Report. Economists have warned that the cost of storms, floods, droughts, and all the other predictable consequences of a worsening climate will far outstrip the costs associated with reducing our reliance on fossil fuels. In other words, the cheapest, best and most cost-effective course of action is to tackle climate change quickly, and the worst, most expensive option is to delay action or worse still, ignore it. And yet time and again we respond as if action is unaffordable. The only course of action which is truly unaffordable is to do nothing, because we will then run out of money trying to clean up afterwards, and may well have to abandon infrastructure and see other assets stranded.

Although the figures derived here have some degree of uncertainty, they mostly lie within the range of £3 Billion to £14 Billion a year in the costs of inaction every year by 2050. After 2050, this is likely to increase greatly to something around £15 to £45 billion a year. By not taking action, we are taking huge risks with our economy and our livelihoods, and every time we invest in the wrong things that add greenhouse gases, like new road building or gas fired power stations, it adds to the burden.

Every positive investment in carbon reducing activity, of course, lessens that burden. The economic lessons are very clear - the sooner we act, the cheaper and better for everybody. We need to see a minimum of 3% to 5% total net expenditure committed to climate change mitigation and adaptation measures. A minimum of 5% of public expenditure should be evidentially spent for the benefit of the climate. This equates to something around £7 billion to £11 billion a year more being spent on positive action than we're spending on carbon damaging activities. This report is the first to really bring together the many studies that exist and with a specific lens on Scotland. For those familiar with the science and economics of climate change there is little perhaps of surprise, other than the consistency across the plethora of studies. The greatest surprise is rather that with so many clear signals and alarm bells sounding for decades, we have not taken action more seriously.

Too often we define climate change as an environmental problem, but this is too general a description. It is a societal problem and its consequences reach into every sphere of our lives, from defence to health care and beyond. And it is an economic problem too – caused
in part by the short termism of political cycles and current economic models. Yet it has the potential to derail our economies. The impact of climate change left unabated could bankrupt the Scottish economy, whereas spending £3to5Billion a year on action could save the economy £30 Billion/year by 2050 and will save lives and protect communities everywhere.

Our fixation with short term cost savings is actually putting our future in jeopardy and is the worst form of false economy we could undertake. It's time to start prioritising action on climate change before we slip, further and further into the red.

Dr Mike Robinson OBE, FRSE, FRCGS, FRSA, FSEL
Chief Executive, RSGS

Summary

Climate change is already costing Scotland billions of pounds a year. Unchecked climate change could drive these costs to 5-20% of GDP, around £11bn-£45bn a year, by 2050. Spending even a few billion a year by 2030 on a just transition is a bargain compared to the economic and social damage climate change will do without further action.

On impacts like flooding, wildfires, droughts and rising temperatures there are good predictions about what the future will hold for Scotland and which areas will be most affected. This means we can act to minimise these impacts, at the same time as we rapidly reduce our own emissions. **Scotland could be saving over £30bn a year by the 2050s if we all act to tackle climate change.**

	Today	2050s	2080s
Climate costs to the economy			
Global		5-29% of GDP	20-60% of GDP (up to $60 trillion)
Scotland	'£billions'	£11-45bn (5-20% of GDP)	
Cost of flooding			
Scotland	£183m	£328-388m	£633-819m
Cost of heat-related deaths			
Scotland		£830m	at least £1.7bn
Cost of wildfires			
Highland	£300m	£1.2bn	

Floods, storms, droughts, fires and higher temperatures are already bringing misery, worry and financial hardship for many, and plant diseases and non-native species threaten nature, fisheries, farming and forestry. Almost every aspect of life is affected by our changing climate.

This report looks at the overall global, UK, Scottish and regional estimates of the current and future costs of climate change, as well as the specific cost estimates for Scotland of each climate impact. This is the first time all these numbers for Scotland have been collected together in one place. There are many estimates, some of which contradict each other, and there are gaps where no-one has yet tried to put a financial cost on the impact in question.

The current main costs to Scotland come from damage and disruption caused by flooding, damage to agricultural crops and the impact of stronger storms, as well as deaths and ill health from higher temperatures. As the world heats up the impact of higher temperatures and a more chaotic climate on people, wildlife and infrastructure will become even more significant.

Disruption to food production and distribution, here and overseas, will push prices up. Increasing temperatures mean water scarcity problems, particularly for farmers, but increases in periods of heavy rain mean more flooding and more sewage in rivers.As more and more properties are classified as at risk of flooding, insurance premiums will increase and some homes and businesses may become uninsurable.

Estimates of future costs vary widely but all of them are conservative because they are based on the idea that there will be a gradual increase in impacts as the world gets steadily warmer. Thus, they do not look at the possible very large cost of sudden changes if the planet breaches one or more of a range of climate tipping points.

Climate change is not only measured as a cost in pounds, it is also driving a rise in physical and mental health problems, reducing populations of native plants and animals, and disrupting daily life for almost everyone.

The impacts of climate change are not evenly spread among the population. If you live in a rural area, a deprived neighbourhood or are part of a minority ethnic group you are likely to be feeling those impacts more strongly already, and these gaps in vulnerability are predicted to grow sharply as climate change gets worse unless we tackle poverty and inequality at the same time as tackling climate change.

If you live in almost any poorer part of the world, you will be feeling the impacts of climate change much more strongly than people in Scotland, and the future threat is likely to be much greater while the resources to help your community cope scarcely exist.

Acting now to reduce emissions is much cheaper than waiting until things are worse. The significant and steeply rising level of economic damage already inflicted on Scotland (let alone the much larger cost likely in the future) is a big incentive to urgently reduce our emissions at home, make our country and society more resilient and play a strong part in helping the world to achieve real reductions in its emissions.

1 Introduction

Even if the world stopped all greenhouse gas emissions today the planet would continue to heat up for decades to come. We are approaching the danger threshold of 1.5ºC of temperature rise above pre-industrial levels and current strategies would see the temperature rise reach at least 3ºC by the end of the century. So we must prepare for a world which is different from today in many ways.

But it is not too late to for human society to step up action to reduce emissions and keep that final temperature rise below 2ºC – still a big change from today, still a disaster for many people and species, but a lot safer than 3ºC.

From floods and droughts to wildfires, disruption to transport and supply chains, and the spread of new diseases, climate change is already imposing major costs on society here in Scotland.

These economic impacts of climate change will only get worse as the climate changes further, but how much worse depends on how hard we work to reduce emissions and make society more resilient to the changes that are coming. Much is often made of the cost of the transition to net zero. For Scotland estimates for this transition range from £1.2 to 5bn a year by 2030.[1,2] Set against this are the billions in costs that climate change is already imposing on Scotland, and the rapid increase in these costs if we do nothing.

Types of costs imposed by a changing climate	
Economic costs	**Social costs**
Impacts on productivity	Impacts on health and well-being
Damage to assets and capital	Loss of nature and biodiversity
Disruptions to trade & global currency flow	Increasing global and local inequalities
Disruptions to raw material flow	Conflict and migration

To see the full picture we should also remember that tackling climate change can also save money and create jobs. And that we are also already having to spend money adapting to our changing climate.

Spending money to reduce climate emissions can save money and improve lives. For example, the National Audit Office estimates that for every £1 spent on protecting communities from flooding, around £9 in property damages and wider impacts can be avoided. And insulating people's homes has the quadruple benefit of reducing climate emissions, saving the householder money, creating jobs in the energy sector and making the property healthier to live in.

Scotland is already spending money on adaptation to climate change, for instance the £400m the Scottish Government has allocated to increase the resilience of the railways. The Climate Emergency Response Group estimate that £1.8bn is needed for climate resilience work between now and 2030.[3]

This report looks at what is known about the current cost of climate change impacts, and, where possible, what the future costs might be for each of these impacts.

For every £1 spent on protecting communities from flooding, around £9 in property damages and wider impacts can be avoided

Tackling climate change can also save money and create jobs

2 Whole economy estimates of the cost of climate change

2.1 Costs of inaction for Scotland and the UK

"Climate change poses profound risks to our economy. The costs to the Scottish economy, resulting from climate change, are no longer hypothetical. The Climate Change Committee have estimated the impacts of climate change already cost the Scottish economy billions of pounds per year."

Scottish National Adaptation Plan, September 2024.

For Scotland estimates of current and future costs vary widely, partly because of which impacts are included in each study.

Estimates of the cost of climate change to the Scottish economy			
Source	**Today**	**2050**	**2080**
CCC top down[4]	'billions'		
LSE[5]	£2.2bn	£6.6bn	£12bn
CCC bottom up[6]	£300m	£800m	£2bn
Scottish Government[7]		£3bn	
Stern 5-20% of GDP[8]		£11-45bn	

Although the costs are already in the billions today and these costs will increase, the good news is that we could be saving more than £30bn a year by 2050 if we and the rest of the world acts decisively on climate change.

Key facts – Scottish costs and impacts

- Climate change is already costing Scotland billions of pounds a year. Unchecked climate change could drive these costs to 5-20% of GDP, around £11bn-£45bn a year by 2050.
- Climate costs for Scotland could be rising by £400m a year; the more conservative estimates from the Scottish Government suggest the cost of climate impacts is increasing by £40m a year.
- Unchecked climate change impacts for the Glasgow city region would be £400m a year by 2050, with the burden falling disproportionately on disadvantaged and vulnerable groups.
- Highland region's GDP could be reduced by around 1.5% a year by the 2050s, and up to 3.3% a year by the 2080s.

The Scottish National Adaptation Strategy[9] uses a top-down approach from work for the Climate Change Committee to say that the impacts of climate change already cost the Scottish economy billions of pounds a year.[10] Very approximately this would see an annual average rate of increase towards Stern's 5% of GDP by 2050 of £250m a year.

A report[11] from the London School of Economics in 2022 looked at the impact on the UK economy and suggested that current climate change damages in the UK amount to 1.1% of GDP and, under current policies, this will rise to 3.3% by 2050 and 7.4% by 2100. Very approximately, for Scotland these figures might be £2.2bn today, £6.6bn in 2050 and £14.8bn in 2100 (all in 2023 £s). For comparison with other studies, in 2080 this number might be £12bn. Strong international action to tackle climate change could reduce the 2100 figure to 2.4% or £4.8bn for Scotland.

Work for the Climate Change Committee in 2021 estimated the current cost of climate change impacts to the UK economy to be £3bn a year, rising to £8bn in 2050 and over £20bn in 2080 in a high emissions scenario.[12] The biggest current impacts come from business flooding, flooding of homes, storms and damage to infrastructure like roads, railways and power systems.

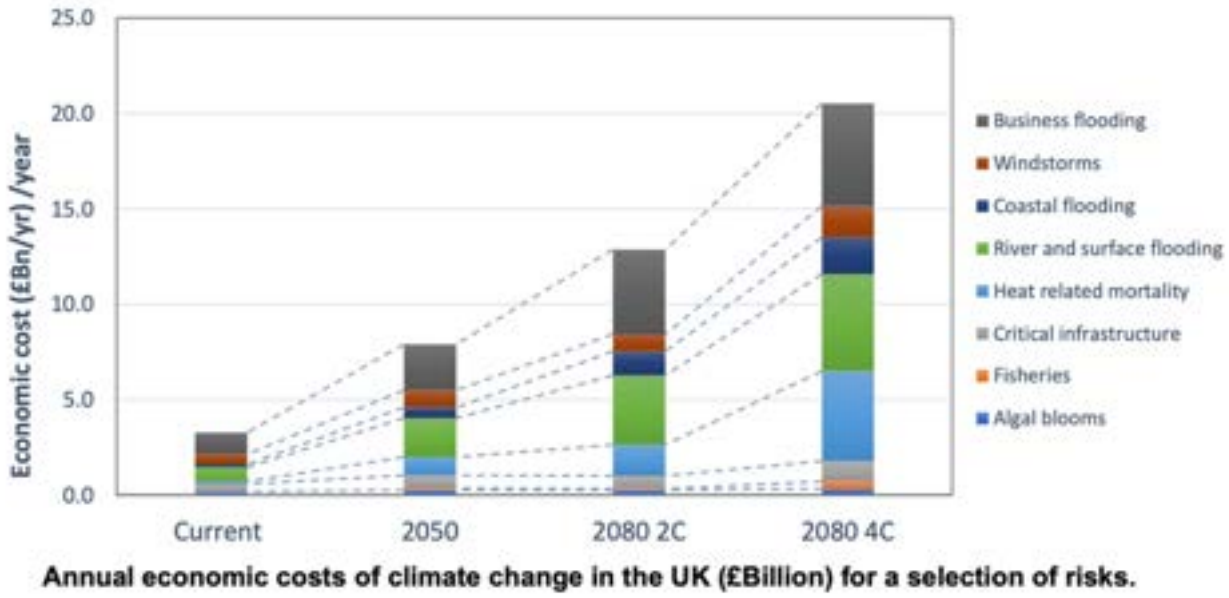


Figure 1 - estimates of increasing costs of climate change to the UK economy from work for the Climate Change Committee.[13]

A crude population-share allocation of these costs to Scotland would suggest a current climate impacts cost of around £300m. At the lower end of Stern's analysis this could rise to £11bn by 2050, a rate of increase of £400m a year. The numbers based on the CCC's estimates for the UK would see costs increasing at a rate of £17m a year between 2020 and 2050 and £40m a year between 2050 and 2080.

The Scottish Government have a lower future estimate - by 2050, the economic costs of climate change to Scotland are estimated at 1.2% to 1.6% of GDP a year, or about £3bn. [14] From the CCC-derived figure for present costs, this gives an annual average rate of increase of £40m a year from now until 2050.

Strong action will save far more money than it will cost

Estimates of the rate of increase in climate costs to the Scottish economy		
Source	**2020-2050**	**2050-2080**
CCC top down to Stern 5-20% of GDP	£250m-£1.4bn/yr	
CCC bottom up	£17m/yr	£40m/yr
Scottish Government	£40m/yr	
SG figure to Stern 5-20% of GDP	£400m-£1.5bn/yr	

An analysis by the Energy and Climate Intelligence Unit found that insulating homes, changing heating systems and delivering other net-zero measures as originally planned could have saved householders in the UK £70bn over the last decade.[15]

GDP as a measure of climate impact

Climate change can increase raw material costs, disrupt transport and increase worker sickness absence, all of which will reduce business profits and so reduce overall GDP, but it is worth remembering that GDP can also be a poor measure of climate impacts. For instance, widespread flooding across Scotland would create economic activity repairing buildings, replacing fixtures and fittings, fixing infrastructure, accommodating displaced people, making insurance payouts, increasing insurance premiums and bolstering flood defences. All of these activities would appear as a boost to Scotland's GDP.

As climate change destroys livelihoods around the world and makes people's current locations unliveable more and more people will be on the move. In 2022 a record 33 million people were displaced by our changing climate.[16] By 2050 there could be more than a billion of people looking for somewhere safe to settle. Scotland could look like an attractive location, having escaped the worst impacts of climate change and apparently with plenty of space for new people. Scotland has welcomed migrants and refugees but we do not have a plan to prepare for this escalating pressure.

	Today	**2050s**	**2080s**
Uncertain access to food			
Global	2bn people	3.5bn people	
People displaced by climate change			
Global		1.2bn	

2.2 Regional costs within Scotland

Whilst we need to continue to urgently cut emissions to reduce the effects of climate change, we also need to accelerate our adaptation planning to manage the changes that are already locked in."

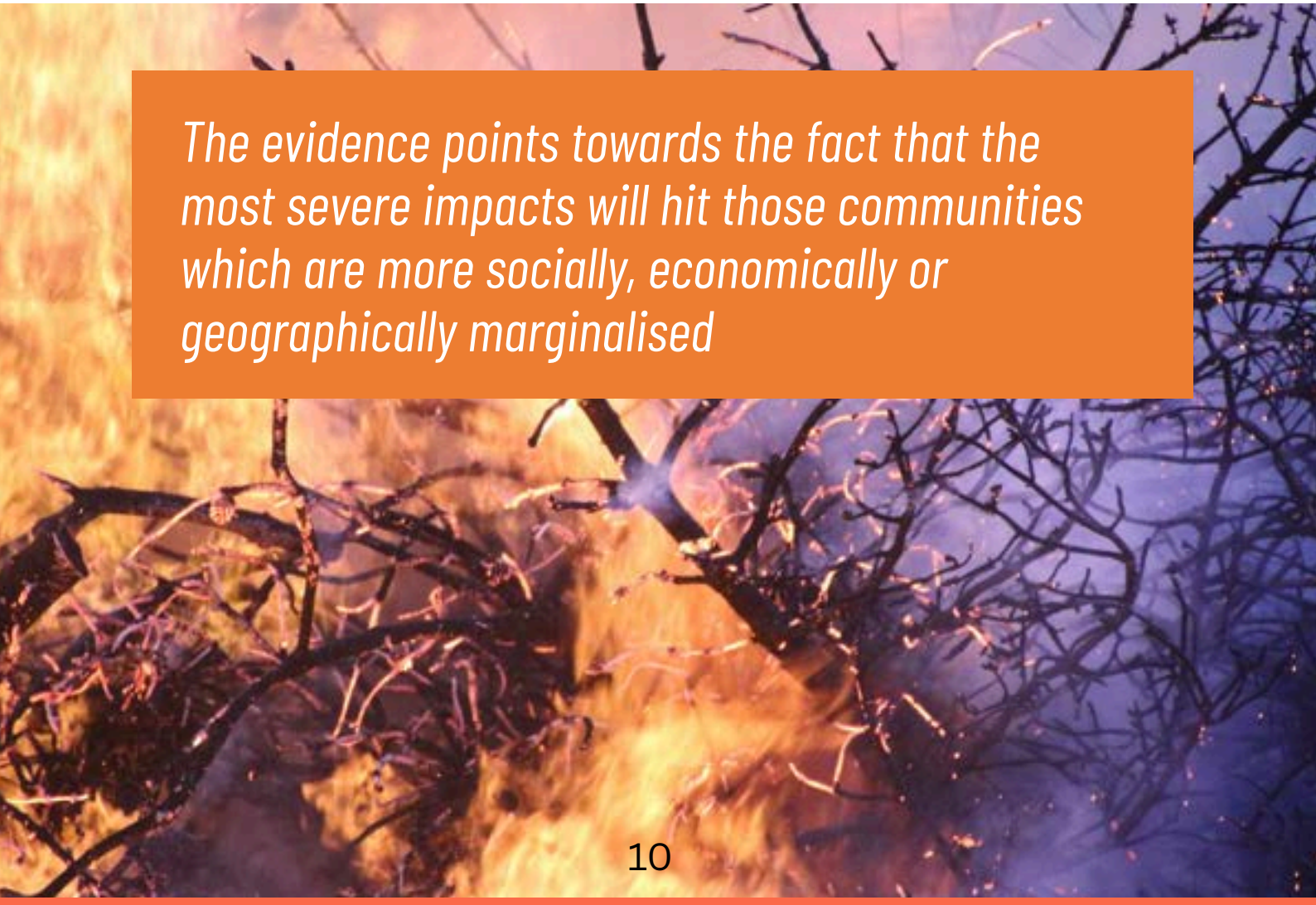
James Curran, Chair, Climate Ready Clyde

Work in 2018 for Climate Ready Clyde[17] estimated that the cost of unchecked climate change impacts for the six-local-authority Glasgow city region would be £400m a year by 2050, about 1% of Gross Value Added. They also concluded that the burden of these costs would fall disproportionately on disadvantaged and vulnerable groups. Looking at four large one-off climate-related weather events between 2012 and 2017 they found a total cost to the city region of £44.5m.

Highland Adapts have published a series of reports on the impacts of climate change on the Highlands.[18] They summarise their findings thus:

- Climate change will have potentially significant negative impacts on the Highland region equivalent to around -1.5% Gross Domestic Product (GDP) a year by the 2050s, rising to up to -3.3% a year by the 2080s.
- Impacts from flooding (coastal, river, and surface water) are estimated to increase from around £11 million per year currently to £20 million per year by the middle of the century and double that by the end of the century.
- The potential economic costs of wildfires were estimated using data from current wildfires, economic costs of wildfire suppression, and non-market impacts from the release of greenhouse gas emissions and air pollutants. Current costs are estimated to be approximately £300 million a year, driven by the high societal cost of carbon emissions. This could increase fourfold by mid-century.
- Risks to the energy sector include high negative impacts on energy generation, energy distribution, and on the delivery of net zero plans for the energy sector.
- The analysis also found some economic benefits for Highland residents from a reduced need for wintertime heating.
- Risks to salmon production from rising sea temperature and ocean acidification will increase by the 2050s. Risks to whisky production from extreme events and climate conditions will also increase significantly over this time period.
- For the forestry and timber sector, costs from high winds; drought, pests, and disease; and wildfires were estimated to rise significantly between 2030 and 2090.

There has not been much study of the specific climate change challenges faced by island communities but the South Uist-Benbecula causeway deaths of 2005 illustrate some of the special challenges faces by these communities.[19]



The evidence points towards the fact that the most severe impacts will hit those communities which are more socially, economically or geographically marginalised

2.3 Global costs of not dealing with climate change

"In making the transition to net zero, delaying decisive action to tackle carbon emissions by ten years could double the overall cost."

Office for Budget Responsibility, 2021

There are a wide range of estimates of how climate change will affect the global economy. Individual studies have looked at the impact on reducing global GDP, reducing working hours and driving price inflation.

Estimates of the reduction in global GDP caused by climate change		
Source	**2050**	**2100**
Stern Review	5-20%	5-20%
NGFS		up to 20%
Oxford Economics	20%	
Bilal et al (1ºC extra warming)	12%	
Kotz et al	11-29%	20-60%
IFoA		50%
Boston Consulting Group		34%

Key facts – global costs and impacts

- Globally, the overall costs of economic damage will be six times higher than the cost of reducing emissions to net zero.
- Climate-related economic losses have increased by a factor of more than eight between the 1970s and the 2010s.
- Over 90% of reported deaths worldwide from climate-related causes occurred in poorer countries and the associated economic losses were about 50 times higher as a proportion of GDP in the Least Developed Countries than in developed economies. In the worst case single disasters in small island states inflicted losses greater than 100% of that country's annual GDP.
- The number of people with uncertain access to food will increase from 2 billion to 3.5 billion by 2050.
- The number of people experiencing high or extreme water stress will increase from 2.6 billion to 5.4 billion by 2040. Over the past decade, the number of recorded conflict and violent incidents related to water increased by 270% worldwide.
- More frequent and more intense extreme weather events will drive mass migration; 1.2 billion people could be displaced globally by 2050, imposing massive economic costs and magnifying political instability.
- All these studies of costs assume that things will get steadily worse, but some changes could come abruptly, imposing much larger one-off or on-going costs on society.

The 2006 Stern Review[20] on the economics of climate change showed that acting today on climate change is much cheaper than waiting to act when the situation is much worse. The review found that spending 1% of GDP a year could avert the worst of the climate crisis, whereas waiting to act could mean a reduction in global GDP of 5-20% in future. In 2008, Stern recalculated the necessary annual spend to be 2% of GDP.[21]

20% of predicted global GDP in 2050 would be over $20 trillion;[22] 5% would be $5 trillion. For Scotland 20% of current GDP would be around £45bn and 5% around £11bn. [23]

More recent studies have found similar results. In 2022, Oxford Economics found a reduction of up to 20% by 2050 even with ambitious emission reduction policies.[24]

Agreeing with Stern's analysis, the UK Office for Budget Responsibility found in their 2021 Fiscal Risks report[25] that "delaying action and then introducing it abruptly carries a greater fiscal cost than early action." Their 2023 report[26] concluded that the fiscal risk from delayed action has increased since their earlier report.

Another recent study[27] looked at the impact of global temperature changes on economic activity and found that the economic damage of climate impacts may have been underestimated by a factor of six, and that an extra 1ºC increase in global temperature reduces global GDP by 12%.

The Climate Policy Initiative recently calculated the cumulative global cost of not acting to reduce emissions as $1,300 trillion by 2100, on top of another $1,000 trillion of unavoidable losses even if we stabilise the temperature rise at 1.5ºC.[28]

Included in this are:

- A reduction in global working hours of 2.2% by 2030 at a cost of $2.4 trillion.[29]
- Sea-level rises could add a further $400-520 billion a year in losses by 2100 under the most extreme warming scenarios.[30]
- Estimates of health costs.

A recent global analysis[31] for a group of central banks concluded that GDP will be reduced by 19% over the next 26 years because of already committed climate change. Their figure for the UK is a 7% reduction by 2050. They predict that the global reduction will rise to 60% by 2100 if climate emissions continue, but could stabilise at about 20% if emission fall to net zero by 2050. The study finds that the overall costs of economic damage will be six times higher than the cost of reducing emissions to net zero.

Another 2024 study[32] looked at the threat of climate change to price stability concluding that by 2035 global food prices would be rising 0.92-3.23% a year. For Europe the food inflation figure is estimated to be 0.6-1.4% a year by 2035.In the current UK 'cost of living crisis' food price inflation is currently about 3%.[33]

A new report[34] on global pension funds found that UK funds are projected to experience declines in returns of 20% to 30% by 2040, and 30% by 2050. The most at-risk pension funds in Canada, the US and the UK could see investment returns decline by more than 50% by 2050 if the impacts of climate change remain unaddressed.

A very recent report from the World Economic Forum[35] find that climate-related disasters have inflicted over $3.6 trillion in damage since 2000, with risks accelerating. They also highlight opportunities for businesses to grow in the $14 trillion green economy. They predict that ill-prepared companies will see an average drop of 7% in their earnings by 2035.

A 2025 report from the Institute and Faculty of Actuaries predicted a 50% reduction in GDP in the time period 2070-2090, also suggesting more than 4 billion deaths if temperatures exceed 3ºC by 2050.[36]

Another very recent study by the Boston Consulting Group found that productivity losses would create the biggest economic impact, with a total reduction of GDP by up to 34% if the temperature rise reaches 3ºC this century. An immediate investment of less than 2% of GDP would eliminate most of these losses.[37]

As well as overall impacts on GDP climate change considerations can have a direct impact on the value of companies. A recent study found that a new court case or an unfavourable judgement knocked an average of 0.6-1.5% off the value of a large fossil fuel firm.[38]

Climate change is also occupying the minds of the military. A 2024 report for NATO states that climate change has "a profound impact on Allied security" and shows how climate change increases tensions and makes operations harder, including by shortening the life of equipment.[39] A German report highlighted the threats to the EU as a political and economic bloc as climate change exacerbates conflicts, hunger and migration worldwide, and impacts fall more on southern EU countries than those in the north.[40] Following a Parliamentary inquiry, a report by the House of Commons Defence Committee in 2023 found that the armed forces need to do more to prepare for a climate-changed world, as well as increasing efforts to reduce their own contribution to climate change emissions.[41]

2.4 Costs of disasters

"The most vulnerable communities unfortunately bear the brunt of weather, climate and water-related hazards."

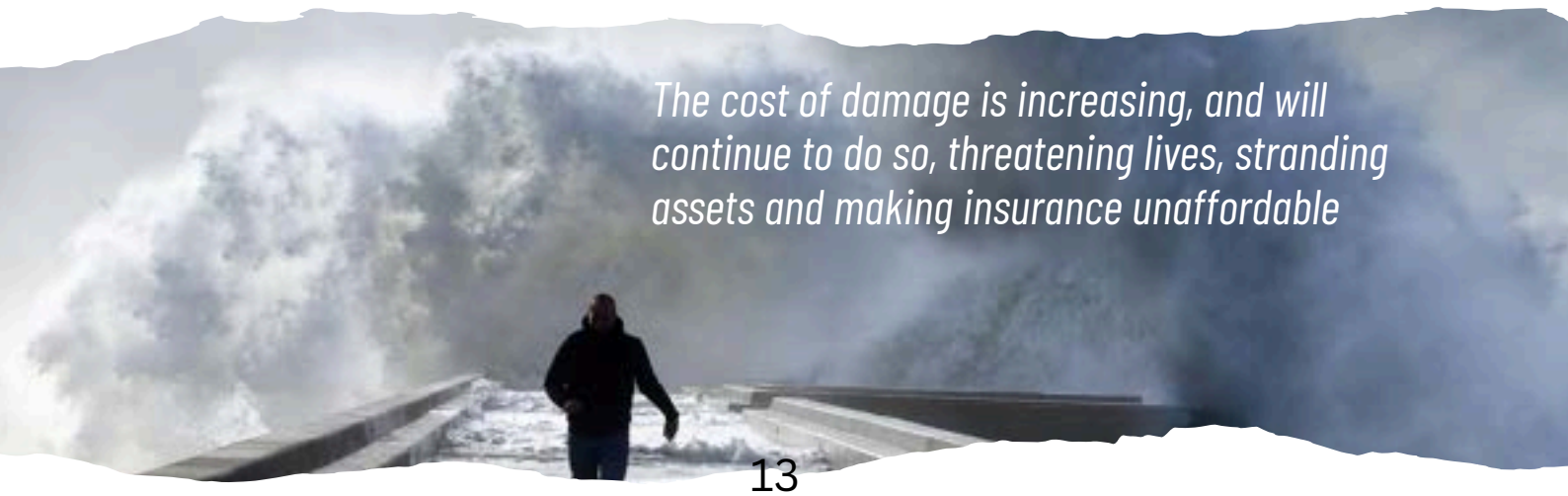
WMO Secretary-General Prof. Petteri Taalas

A component of total costs of climate change to the global economy are the costs of weather disasters – storms, floods, droughts and extreme heat.

In Scotland disaster costs include not just the direct damage to property – paid by householders, business owners or insurance companies - but also the rescue costs borne by the emergency services and sometimes the military, and the clean-up and infrastructure re-instatement costs borne by local authorities and transport operators. As climate change gets worse insurance will become more expensive or even unobtainable. This will be most significant for the least well off.

The World Meteorological Organisation report that between 1970 and 2021 there were 11,778 reported disasters caused by extreme weather, climate change and water-related events, resulting in just over 2 million deaths and $4.3 trillion in economic losses.[42] Over 90% of reported deaths worldwide occurred in developing countries and the associated economic losses were about 50 times higher as a proportion of GDP in the Least Developed Countries as in developed economies. In the worst case single disasters in small island states inflicted losses greater than 100% of that countries annual GDP.

As figure 2 shows, climate-related economic losses have increased by a factor of more than eight between the 1970s and the 2010s. The true figure is likely to be far higher since it is estimated that 63% of losses are not reported.[43]



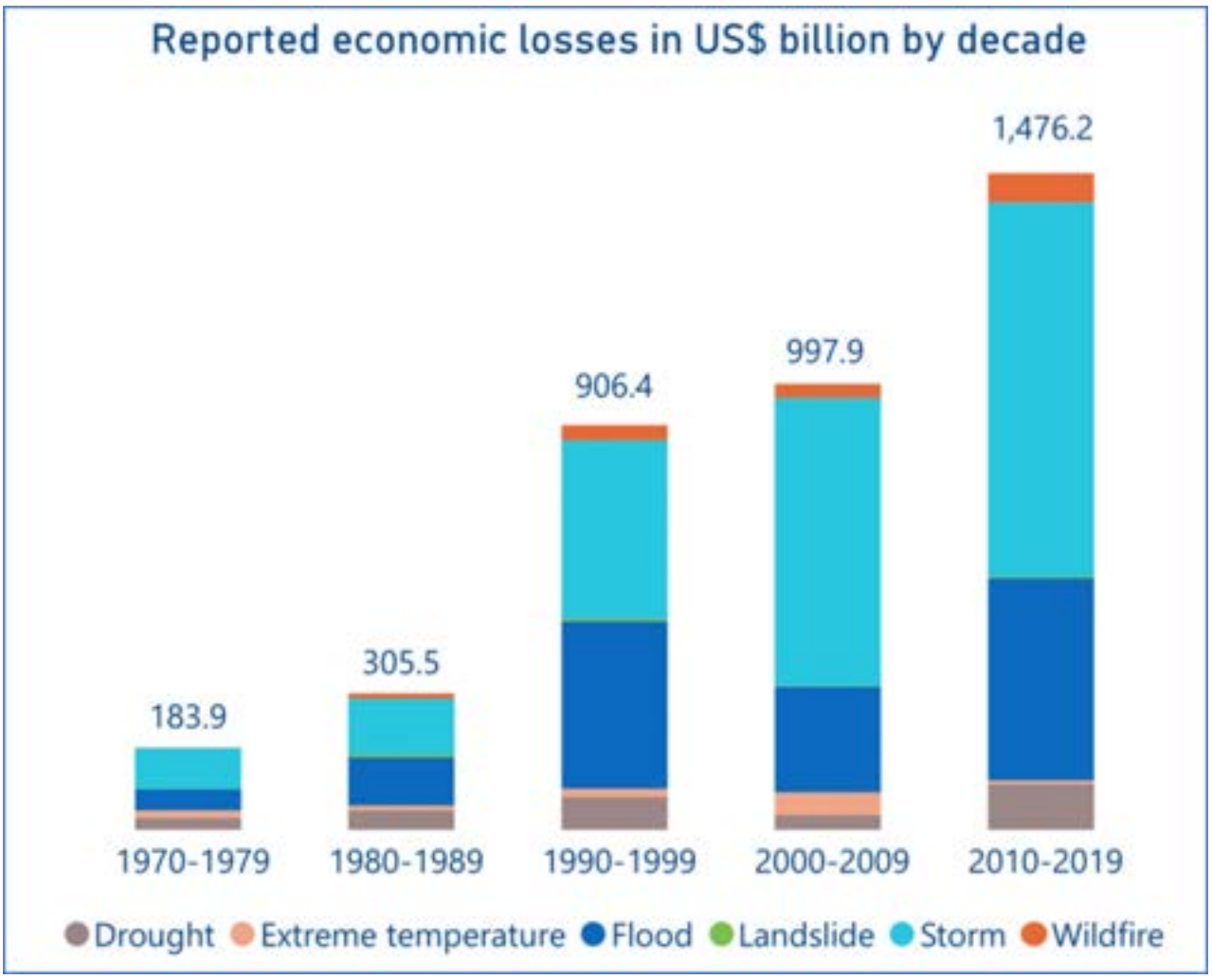


Figure 2 – inflation adjusted climate-related losses over the last 50 years. Source: Statista

A 2018 report[44] from the UN Office for Disaster Risk Reduction found that, between 1998 and 2017, climate-related and geophysical disasters killed 1.3 million people and left a further 4.4 billion injured, homeless, displaced or in need of emergency assistance. The majority of deaths were due to events like earthquakes and tsunamis, but 91% of all disasters were caused by floods, storms, droughts, heatwaves and other extreme weather events. In this period, affected countries suffered climate-related economic losses of $2.29 trillion.

In 2022 climate-related disasters (e.g. hurricanes, floods, wildfires) were responsible for $313 billion in economic losses due to damage to assets and capital, with only 42% of these losses covered by insurance.[45] Hurricane Ian in 2022 alone caused damage in the range $50-55bn. In 2022 just four major flooding events – in Pakistan, China, Australia and India – created economic losses of over $42bn, with less than $5bn, or 11%, of this covered by insurance (almost all of it in Australia).

Climate change is already driving conflict and migration, including through food insecurity and water shortages. The 2020 Ecological Threat Register[46] projected that:

- The number of people with uncertain access to food will increase from 2 billion to 3.5 billion by 2050.
- The number of people experiencing high or extreme water stress will increase from 2.6 billion to 5.4 billion by 2040. Over the past decade, the number of recorded conflict and violent incidents related to water increased by 270% worldwide.
- More frequent and more intense extreme weather events will drive mass migration; 1.2 billion people could be displaced globally by 2050, imposing massive economic costs and magnifying political instability.

2.5 Tipping points

"The world is already at risk of some tipping points. As global temperatures rise further, more tipping points become possible"

David Armstrong McKay, Stockholm Resilience Centre lead author on tipping points

There is of course a big caveat on all the studies of costs – they all assume that things will get steadily worse, but some changes could come abruptly, imposing much larger one-off or on-going costs on society. The Ukraine war demonstrates how one conflict in one part of Europe could have a dramatic impact on prices for energy and food, sparking financial crises and affecting national politics.

Work by the Stockholm Resilience Centre defines 16 climate tipping points – major changes to the Earth's systems that could be triggered by climate change.[47] They conclude that five of them are at risk of being triggered even at today's temperatures including the collapse of ocean currents, melting of the West Antarctic and Greenland ice sheets, abrupt thawing of permafrost and widespread died off of coral reefs (with severe consequences for fisheries).

The one of most concern for Scotland is the slowing down of the ocean current – the Atlantic Meridional Overturning Circulation - that keeps Scotland and north-west Europe warmer than they would otherwise be.

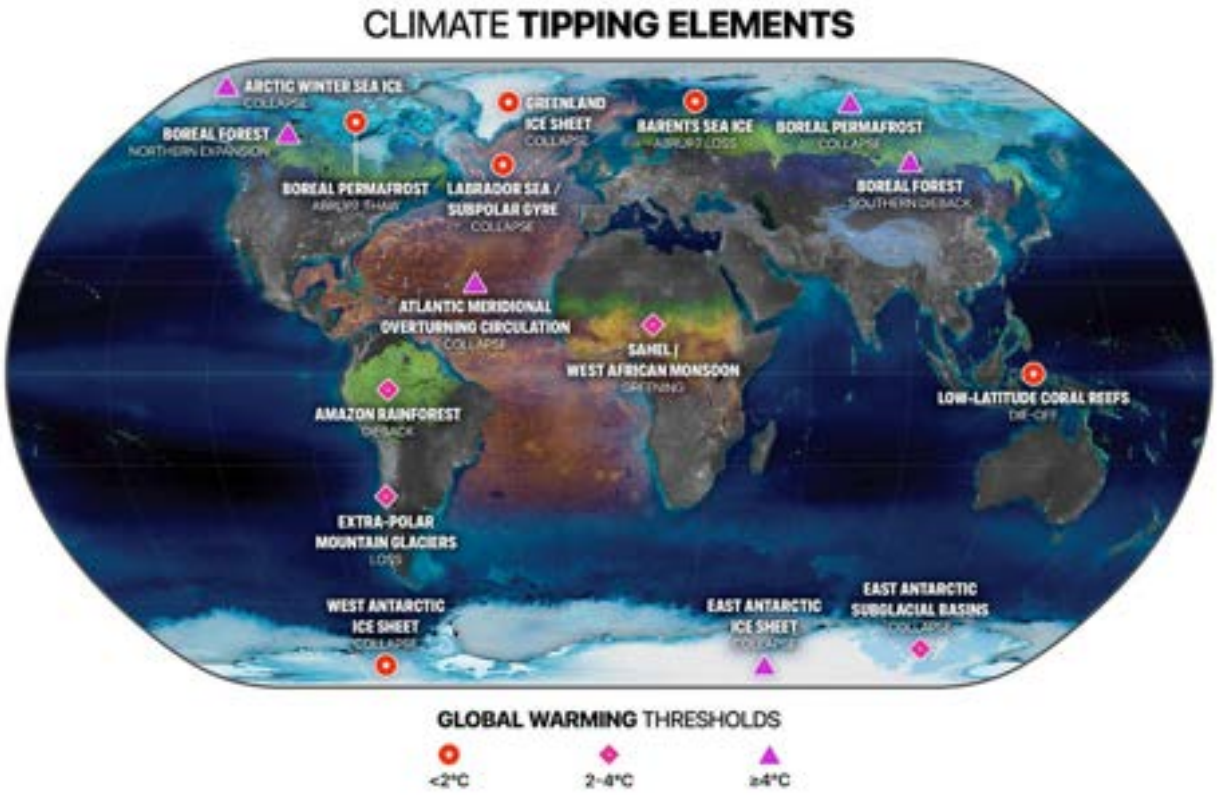


Figure 3 - the location of climate tipping elements in the cryosphere (blue), biosphere (green) and ocean/atmosphere (orange), and global warming levels at which their tipping points will likely be triggered. Source: Stockholm Resilience Centre.

There comes a point where natural feedbacks mean the system may spiral out of control and we lose the chance to minimise impacts

2.6 Equity

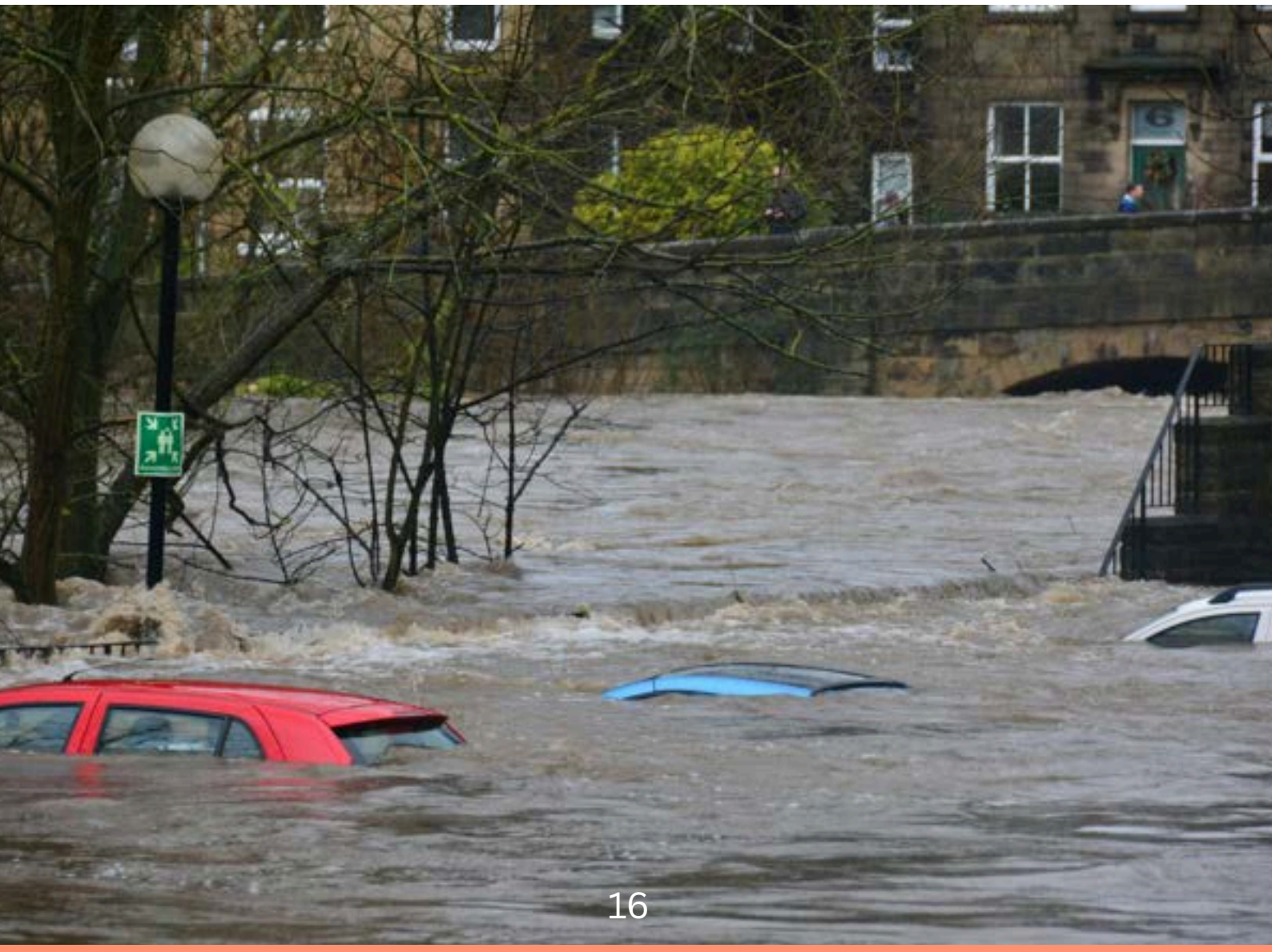
"Climate change is hitting some communities harder than others – and it's the people who have done the least to cause it who are suffering the most."

Oxfam GB

We should also remember that climate change has been slow to have an impact in Scotland and many people in poorer countries around the world are already feeling the impact of climate change more strongly than we are, are facing much bigger future threats than us and have much less in the way of resources to adapt to what is coming.

A recent report by the World Meteorological Organisation[48] found that droughts, floods and rising temperatures mean that GDP across Africa is already down 2-5% and many African countries are diverting up to 9% of their GDP to respond to climate extremes.

A recurring theme in the sections in chapter 3 is that climate impacts and costs are not spread evenly through society in Scotland either – poorer people, rural dwellers and people from minority ethnic backgrounds are usually at significantly greater risk from flooding, extreme temperature and other threats, and more likely to be under-insured or not insured for the resulting impacts.



Right now climate change is a huge multiplier of existing inequity and will exacerbate inequalities over the coming years if we don't act to prevent this.

3 Costs by impact area

In Scotland climate change is already affecting people's health and wellbeing, damaging the economy, disrupting travel, threatening nature and making farming and fishing more difficult. The main impacts we are already experiencing come from increasing flooding and water scarcity, stronger and more frequent storms, more wildfires and higher temperatures.

There are often many different estimates of costs in a particular area and sometimes there is no overall estimate of current and future costs. The following sections summarise what is known about costs for a range of impacts.

3.1 Flooding

"Flooding doesn't just happen to someone else… Whether you live by a river, near the coast, or in a built-up area, flooding can affect you. The changing climate is bringing heavier rain, higher sea levels, and more stormy weather... The question isn't if it will happen, but when - and how prepared you are."

Vincent Fitzsimons, SEPA Head of Hydrology and Flooding

Summary

Increased flooding is probably the most noticeable manifestation of climate in Scotland.

Climate change is making flooding more frequent and more severe, and areas previously unlikely to flood are now at risk. Heavier and more intense rainfall and rising sea levels make surface water, river and coastal floods more likely. Floods threaten people's homes and businesses, energy and transport infrastructure, and cultural heritage and nature sites.

Nearly 300,000 properties – homes and businesses - are already at risk and this will rise to nearly 400,000 by the 2080s, with annual costs rising from nearly £200m today to approaching £1bn in the worst case. For just homes the costs are predicted to be 4.3-6x greater than today by the 2080s.For businesses the bill for flooding damage is likely to increase by 2-2.6x by the 2080s.

At least £20bn-worth of buildings and infrastructure are within 50 metres of the coastline. By the 2080s the amount of railway track at risk from coastal flooding could increase by 75%.

Expected annual damage to residential and business properties in Scotland in future under low and high warming scenarios from all types of flooding, with no additional adaptation[49]

Present day	2050		2080	
	2ºC	4ºC	2ºC	4ºC
£183m	£328m	£388m	£633m	£819m
% increase from present	79%	112%	246%	348%

As well as damaging property and infrastructure, flooding can have long-term impacts on people's mental health and increase the risk of the spread of infectious diseases. The English Environment Agency estimate that the cost of the mental health impact on every victim of a deep flood is over £4,000.

Problems with sewage overflowing into rivers and the sea could become much worse as extreme rainfall events become four times more frequent in the 2080s than in the 1980s, and also become more extreme.

There could be a 90% increase in nationally-important nature sites at risk of flooding by the 2080s.Also by the 2080s twice as much of Scotland's best farmland could be flooding regularly.

Key facts – flooding

- 284,000 homes, businesses and services across Scotland are at risk of flooding from rivers, surface water and the sea, with this number expected to rise by 40% or 110,000 by the 2080s.
- Estimates of current annual costs of flooding in Scotland for homes and businesses range from £183m to £324m.
- The cost of flooding damage of all sorts is likely to increase 3.5 times to more than £800m by the 2080s.
- The cost flooding damage to homes in the 2080s is predicted to be 4.3-6x greater than today.
- By the 2080s every person living in a flood-prone area in Scotland would be exposed to an additional annual risk amounting to £450 (compared to £109 for similar areas in England).
- At least £20bn of assets, including 1,300km of road, 100km of rail, 600 natural heritage sites, 9,500 business and 24,500 residential properties, lie within 50 metres of Scotland's coastline.
- 19% of Scotland's coastline is estimated to be at risk of erosion within the next 30 years. Up to £1.2bn-worth of road, rail and residential property is expected to be affected by coastal erosion by 2050.
- By 2080 the length of railway track at risk from coastal flooding could increase by around 75%, and the number of at-risk railway stations by nearly 30%.
- The number of important nature sites which frequently flood could rise by 90% by the 2080s.
- By the 2080s the amount of Scotland's best farmland which floods frequently will more than double.
- 53% of Historic Environment Scotland sites are at high or very high risk from hazards such as flooding or coastal erosion.

Detail

SEPA estimate that there are around 284,000 homes, businesses and services across Scotland at risk of flooding from rivers, surface water and the sea, with this number expected to rise by 40% or 110,000 by the 2080s.[50]

SEPA issued 720 flood alerts and warnings in the winter of 2023-24, a record number in the 12-year history of the Floodline service.[51]

After the Worcestershire town of Tenbury Wells recently flooded for the seventh time in four years things have gotten so bad that there is an unprecedented discussion about completely abandoning the town centre.[52]

The draft Scottish National Adaptation Strategy[53] suggested flooding damage to property is currently averaging £200m to £250m a year – higher than the slightly older figures presented at the start of this section. In another estimate the Third Climate Change Risk Assessment flooding report (hereafter CCRA3 Flooding Report)[54] in 2020 found that Scotland is already suffering annual economic damage from flooding of £324m.

Estimates of the present cost of flooding of homes and businesses	
Watkiss	£183m
CCRA3 Flooding Report	£324m
Scottish Government	£200-250m

With sea level rise and stronger storms, coastal flooding is an increasing risk, with at least £20bn-worth of assets, including 1,300km of road, 100km of rail, 600 natural heritage sites, 9,500 business and 24,500 residential properties, lying within 50 metres of Scotland's coastline. Of this, Dynamic Coast estimates that up to £1.2bn-worth of road, rail and residential property is expected to be affected by coastal erosion by 2050 under a high-emissions scenario.[55] Also within this zone at risk from coastal flooding are 20 sewage works and 5 railway stations. 19% of Scotland's coastline is estimated to be at risk of erosion within the next 30 years.[56]

Particularly important for island communities, the Scottish Government published guidance for local authorities on producing Coastal Change Adaptation Plans in February 2023 and has committed to nearly £12m of funding for this work.[57]

By 2080, in a high emissions, low population growth scenario, the length of railway track at risk from coastal flooding could increase by around 75%, and railway stations by nearly 30%.[58]

Flooding of homes

Expected annual damage to residential properties in Scotland in future under low and high warming scenarios from all types of flooding, with no additional adaptation[59]				
Present day	**2050**		**2080**	
	2ºC	**4ºC**	**2ºC**	**4ºC**
£68.5m	£151.5m	£192.9m	£293.7m	£410.9m
% increase from present	221%	282%	429%	600%

Current expected annual damage for residential property by flooding type[60]			
Fluvial	**Surface**	**Coastal**	**Total**
£44.3m	£17.8m	£6.4m	£68.5m

The table shows that flooding damage to homes in the 2080s is predicted to be 4.3-6x greater than today. It is also calculated that by the 2080s every person living in a flood-prone area in Scotland would be exposed to an additional annual risk amounting to £450 under the high emissions scenario (compared to £109 for similar areas in England).

Key facts – flooding and equity

- People in rural areas are generally facing significantly higher risk than those in urban areas.
- Glasgow is one of the 10 UK local authorities which together account for 50% of socially vulnerable people living in areas at risk of flooding.
- In Scotland black/African/Caribbean people are 55% more likely to live in areas that regularly flooded than white people and people from other minority groups.
- 93% of homeowners have buildings insurance and 75% have contents insurance, but for the poorest 10% of households these figures fall to 85% and 59%.

As figure 4 shows there is a wide variety of exposure to cost depending on where you live in Scotland, with people in rural areas generally facing significantly higher risk than those in urban areas, although costs will increase everywhere under the high emissions scenario.

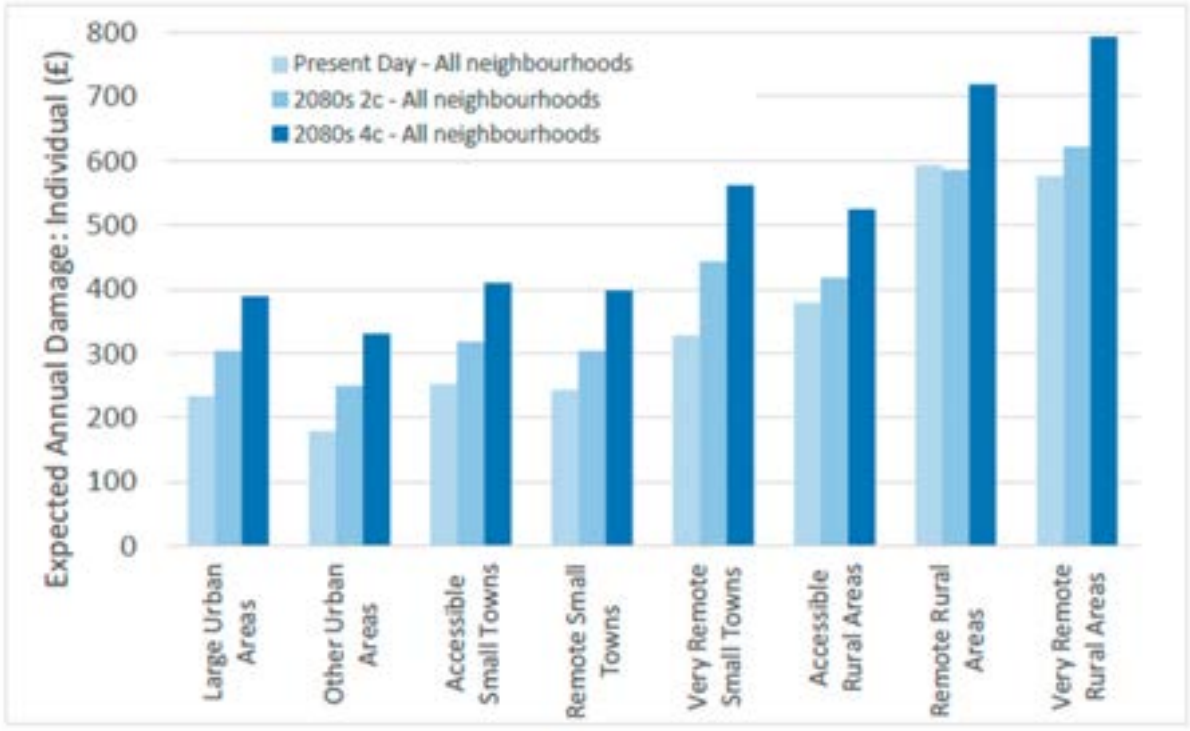


Figure 4 - expected annual damage per individual by settlement type. Source CXC Report.

Flood-prone homes are most likely to be in poorer areas. Glasgow is one of the 10 UK local authorities which together account for 50% of socially vulnerable people living in areas at flood risk.[61] Those with fewer resources cannot afford to protect their homes or recover from fully from flooding, and ethnic minorities can be affected most. A 2020 study found that in Scotland black/African/Caribbean people were 55% more likely to live in areas that regularly flooded than white people and people from other minority groups.[62]

In a year with 12 named storms, UK insurers paid out a record £585m in 2024 for weather-related damage to homes and possessions.[63] Some residents are only able to obtain insurance for at-risk property because an agreement between the UK Government and the insurance industry created the FloodRe scheme which makes sure that cover is always available – low-risk properties are effectively subsidising high-risk properties through higher premiums. However, the scheme comes to an end in 2039.

A similar "insurer of last resort" in California is having to raise $1bn from private insurance companies to meet claims for damage from the wildfires.[64]

The Association of British Insurers estimate that 93% of homeowners have buildings insurance and 75% have contents insurance, but for the poorest 10% of households these figures fall to 85% and 59%.

A recent report found that homes in the US are likely to lose nearly $1.5tn of their value over the next decade as insurance cost rise and home owners make different choices about where to live, with 55 million Americans expected to move to areas with less climate risk by 2055.[65]

Flooding and mental health

Climate change can affect mental health, from general climate anxiety to post traumatic stress after a severe weather event. Flood victims are particularly prone to anxiety from being displaced and separated from their community, and worried about getting insurance, their house price and the next flood. Not surprisingly, evacuation and displacement can lead to anxiety, depression and post-traumatic stress disorder.

The Environment Agency has developed a methodology[66] for putting a price on the mental health effects of flooding of people's homes, based on the depth of the flood above the house's floor level. This includes the cost of treatment and loss of employment and assumes the mental health impact will last an average of two years after the flood.

Cost of mental health impacts of floods (2018 £)	
Flood depth about floor level	**Mental health cost per adult**
0-30cm	£1,878
30-100cm	£3,028
more than 100cm	£4,136

Flooding of businesses and other non-residential buildings

Flooding of their premises is a very obvious problem for a business but they may also face increased costs and delays because of interruption to trading, disruption to their supply chains, climate-driven increases in raw material cost and disruption to infrastructure e.g. road, rail, power.

Key facts - flooding – businesses and public services

- SEPA's 2018 National Flood Risk Assessment found that there are around 10,000 business and industry buildings facing a high likelihood of flooding, and the bill for flooding damage will increase by 200-260% by the 2080s.
- The current annual damage cost of £114m represents 17% of total UK damages, showing that the problems is worse in Scotland.
- By the 2080s, the number of emergency services facilities which will be at risk of flooding increases by 35%; for GPs surgeries the increase is 55% to a total of 135 and for hospitals the increase is 42%.
- For Scotland's 5,000+ schools, 387 are already at risk of flooding, by the 2080s this increases by 57% to 606.
- Scotland already has a problem with sewers overflowing and polluting rivers, burns and coastal waters following heavy rainfall. Extreme rainfall events could be four times as frequent by 2080, and even more extreme, compared to the 1980s, putting even more pressure on sewage systems.
- Scottish Water's 2024 Climate Change Adaptation Plan estimates that an additional £2-5bn will need to be invested by 2050 to sustain current service levels and manage climate change related impacts.
- From April 2023 to the end of March 2024 Network Rail reported that delays caused by bad weather, including flooding, increased by 124% compared to ten years earlier.

SEPA's 2018 National Flood Risk Assessment found that there are around 10,000 business and industry buildings facing a high likelihood of flooding, and the risk will increase as the climate changes.

Expected annual damage to business properties in Scotland in future under low and high warming scenarios from all types of flooding, with no additional adaptation[67]				
Present day	**2050**		**2080**	
	2ºC	**4ºC**	**2ºC**	**4ºC**
£114m	£176m	£195m	£339m	£408m
% increase from present	54%	71%	197%	257%

The current annual (direct) damage cost of £114m represents 17% of total UK damages, showing that the problems is worse in Scotland.[68]

For the health and social care sector, under a high emissions, high population growth scenario, by the 2080s, the number of emergency services facilities which will be at risk of flooding increases by 35%; for GPs surgeries the increase is 55% to a total of 135 and for hospitals the increase is 42%.[69]

For Scotland's 5,000+ schools, 387 are already at risk of flooding, by the 2080s, a high emissions, high population scenario drives an increase of 57% to 606.

Flooding and energy infrastructure

Flooding and strong winds present increasing threats to energy infrastructure including electricity transmission lines and substations.

Water scarcity will reduce output from hydro-electricity schemes and strong winds can require wind turbines to stop generating, or even damage them. Overall these two technologies will experience a range of positive and negative impacts as the climate changes but it is thought that the overall outcome will most likely be positive in terms of overall levels of electricity generated.

Flooding and water supply and treatment

Scotland already has a problem with sewers overflowing and polluting rivers, burns and coastal waters following heavy rainfall.[70] Extreme rainfall events could be four times as frequent by 2080, and even more extreme, compared to the 1980s, putting yet more pressure on sewage systems.

Scottish Water's 2024 Climate Change Adaptation Plan estimates that an additional £2-5bn will need to be invested by 2050 to sustain current service levels and manage climate change related impacts.[71]

Flooding and transport

The main risks to the transport network are from extreme events, especially flooding, heatwaves and storms. These can lead to costs for repairs to infrastructure, costs to passengers and travellers, and disruption to supply chains for businesses.

In the year from April 2023 to the end of March 2024 Network Rail reported that delays caused by bad weather, including flooding, increased by 124% compared to ten years earlier.[72]

The Scottish Government has committed to spending £400m over the next five years to improve the resilience of the railways and between 2016 and 2026 the Scottish Government is supporting local authorities action on flood resilience with nearly £500m.

By their nature airports comprise large flat areas so they are generally well designed to get through periods of heavy rain without flooding, although there may be consequences for neighbouring areas. However, sometimes they can be overwhelmed - Edinburgh airport's runway was flooded by the River Almond in December 2022 and at Gatwick airport on Christmas Eve in 2013 flooding took out power, IT and communications equipment, and flooding of the nearby M23 and closure of the Gatwick train station also affected passengers and staff.[73]

Flooding and nature

According to the CCRA3 Flooding Report Scotland already has 225,000ha of nationally-important designated sites (RAMSAR, SPA, SAC designations) which experience frequent flooding (although in some case this is of course a good thing). Under the high emissions scenario this is predicted to rise to around 425,000ha by the 2080s, a 90% increase. Even in the low emissions scenario this is expected to exceed 370,000ha by the 2080s, an increase of 65%.

SEPA estimates there are around 284,000 homes, businesses and services across Scotland at risk of flooding

Flooding and farming

Flooding across Scotland poses risks to agriculture through loss of crops and stock, infrastructure damage and negative impacts on soils. For example, arable farmers across the UK are estimated to have lost a billion pounds because of exceptional rainfall over the last year.[74] Fields have been too waterlogged to plant some crops and others have rotted in the ground. High quality wheat harvests could be down by 40%, so bread prices will rise.[75]

The CCRA3 Flooding Report finds that by the 2080s, under the high-emissions scenario, the amount of Scotland's best farmland which floods frequently will more than double.

Similar conditions in countries like France and Germany, extreme heat in southern Europe and drought in Morocco mean imports to make up for reduced production at home will be scarcer and more expensive.

Flooding and cultural heritage

Historic Environment Scotland have determined that 53% of the sites they look after are at high or very high risk from hazards such as flooding or coastal erosion. Another assessment looked at coastal archaeological sites and listed 145 sites as high priority, all in Orkney or the Western Isles.[76]

Conclusion

Flooding is an increasingly serious problem in Scotland. Homes, business, farmland, transport and energy infrastructure, and cultural and nature sites are all threatened. The good news is that we have good data about the properties and land at risk – now and in the future. And we know how to use natural flood management techniques and hard engineering to protect what can be protected. A combination of giving up on indefensible areas and sensible protection schemes elsewhere could result in savings of hundreds of millions a year by the 2080s.

3.2 Human health and changing temperatures

"If we don't act, climate change will soon overwhelm the world's health systems… Climate change is endangering lives and livelihoods as global food systems struggle to feed a growing world and water sources are compromised. And climate change is triggering a surge in infectious diseases like dengue and cholera which endanger millions…Measures to reduce emissions can produce major health benefits, including lessening air pollution, which kills seven million people every year."

Dr Tedros Adhanom Ghebreyesus, Director-General of the World Health Organization; Dr Sultan Ahmed Al Jaber, President-designate of COP 28 United Nations Climate Change Conference; and Dr Vanessa Kerry, WHO Special Envoy for Climate Change and Health, November 2023

Summary

People are already dying in Scotland because of elevated temperatures brought on by climate change and the number could be six times higher in 30 years' time, with a combined annual cost from death and illness in the billions by the 2070s, with an additional £500 million a year being spent to deal with people who are made ill by high temperatures.

The most socially disadvantaged groups are generally at most risk, with the young, the old and the ill particularly vulnerable.

Higher and more extreme temperatures can encourage diseases, increase allergies and boost the impact of air pollution, and are also a problem for road and rail infrastructure, for nature and for farming.

150,000 people living or working in premises connected to a private water supply face an increasingly unpredictable future.

Worrying about climate change takes a serious toll on people's mental health, especially among young people, leading to feelings of uncertainty and being overwhelmed and emotions including anger, despair and grief.

Key facts - health and high temperatures

- More than 60 people a year are already being killed off by climate change in Scotland and this number is likely to double by the 2030s and be more than six times higher by the 2050s.
- Costs of heat-related deaths in Scotland could go from £125m today to £1.7bn in the 2070s. Costs for people made ill by high temperature could be £500m in the 2080s.
- Glasgow will increase from no heatwave days per decade in the period 1981-2020 to 5-10 heatwave days per decade in the 2050s, and 10-50 heatwave days per decade in the 2070s.
- The most socially vulnerable neighbourhoods in large urban areas are three times more likely to be exposed to high temperatures than other neighbourhoods.
- In the future people in the Asian ethnic group are more than 20% more likely, and black groups more than 45% more likely, to live in neighbourhoods where temperature extremes are above those experienced by white people.
- Rail buckling events are expected to be four to five times more frequent by the 2050s. By the 2080s, the annual cost of buckling and heat-related delays under a high climate change scenario could increase eightfold.
- Warmer conditions may increase cases of Lyme disease and boost food and water-borne bacterial infections like salmonella, listeria and campylobacter.
- Longer and more intense pollen seasons, along with longer seasons for fungal spores, are likely to worsen seasonal allergies in sensitive individuals.
- In the UK, more than 2 in 5 young people reported that thoughts and feelings about climate change have a negative impact on their mental health.

Detail

According to the World Health Organisation 3.6 billion people already live in areas highly susceptible to climate change. The WHO conservatively projects 250,000 additional yearly deaths by the 2030s because of climate change impacts on diseases like malaria, and coastal flooding.[77] Globally, the direct damage costs to health is estimated to be between $2–4 billion a year by 2030.

The latest report by the Lancet's Countdown on Health and the Climate Change project found that heat-related deaths, food insecurity and the climate-driven spread of infectious diseases were all at record levels in 2023.[78]

Costs to society of health-related climate impacts in Scotland[79]

£m	2020s	2030s	2050s	2070s	2080s
Heat-related deaths	£125m	£310m	£830m	£1,700m	
% increase from today		148%	564%	1260%	
Heat-related illness					£500m

Climate change can affect health in many different ways, as illustrated in this WHO diagram.

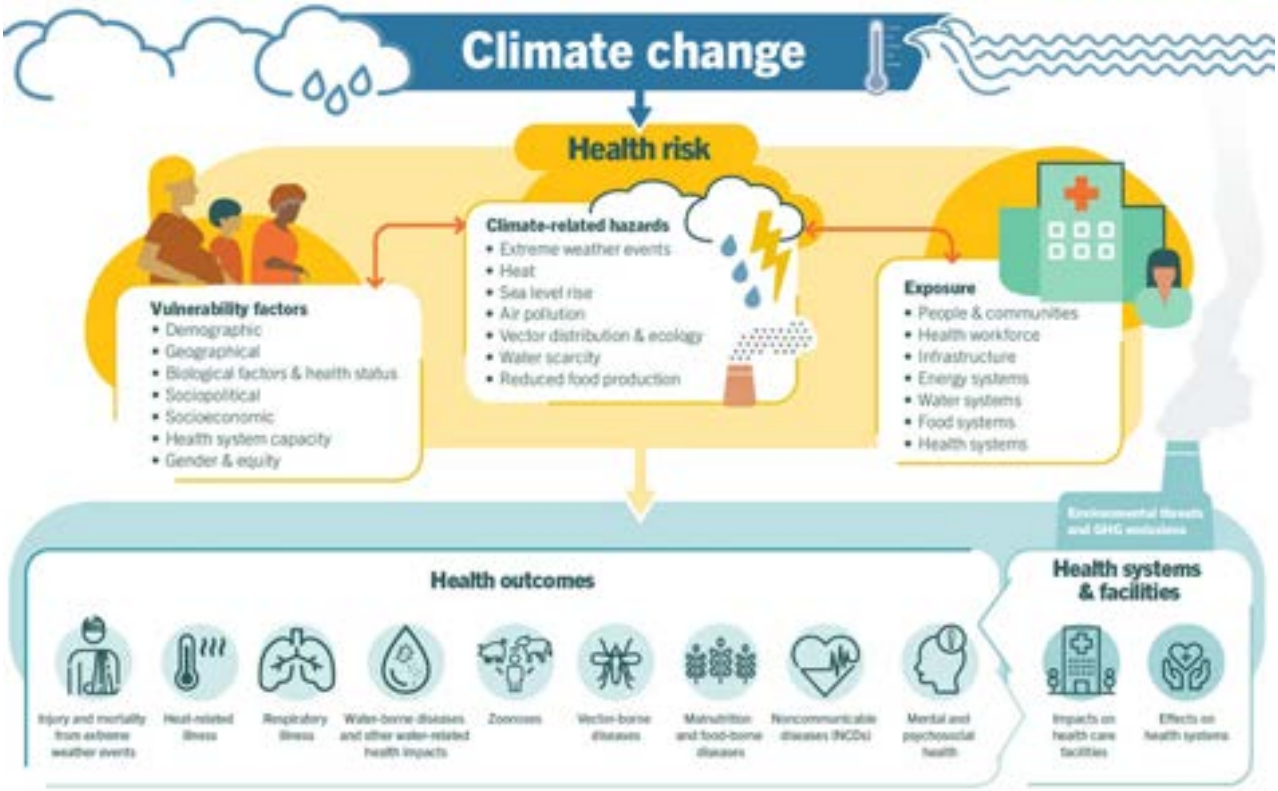


Figure 5 – how climate change affects human health. Source: WHO

Climate change is also eroding the societal structures which support good health including livelihoods, equality, food systems and access to health care and social support structures. These impacts are almost always worst for those already marginalised within society.

In Scotland climate-related ill heath creates costs on the health service, on the individual and on businesses through lost work time.

From the Scottish National Adaptation Plan[80]:

In Scotland, Ipsos Mori found that the majority (82%) of adult people in Scotland polled were either very or fairly concerned about climate change.[81] In polling at a similar time the Mental Health Foundation found that in the UK, more than 2 in 5 young people (41% of those aged 18 to 24) reported that thoughts and feelings about climate change have a negative impact on their mental health.[82] For younger children, BBC Newsround found in 2019 that 62% of 8-16 year olds in Scotland were worried about climate change.[83] The impact on young people, both in terms of worrying about the future of our planet and the degradation of nature, is stark.

In 2024, the Scottish Government, through ClimateXChange, commissioned an evidence review on "Climate change and mental wellbeing in Scotland" which found that climate change is already having an impact on people's mental health and wellbeing both through the direct effects of climate related events, for example injury or trauma from a flooding event, or indirectly as a result of disruption to livelihood, displacement, access to services or worry about future impacts. These impacts are likely to increase in future. The Scottish Government's Chief Medical Officer recognizes that "more flooding will compound existing inequalities and the greatest health burden associated with flooding is likely to be the long-term mental health impacts."[84]

The forthcoming CXC study mentioned above highlights that 'ecodistress' or 'eco-anxiety' is experienced differently by different groups, with young people and other vulnerable groups identified in the report (such as ethnic minorities, people from deprived and marginalised communities and people with pre-existing health conditions) particularly affected. Climate anxiety is often associated with feelings of uncertainty, unpredictability, lack of control and being overwhelmed, and emotions such as anger, frustration, despair, guilt, shame and grief are part of this experience.

Higher Temperatures

High temperatures, particularly combined with high humidity, can be lethal. The European heatwave of 2003 is estimated to have killed over 70,000 people, the 2023 heatwave about 62,000 people,[85] and the recent high temperatures in the Middle East killed over 1,300 people on the Hajj pilgrimage.[86] A recent UNICEF report found that eight times as many children will be exposed to extreme heat around the world in the 2050s compared to today.[87]

Watkiss Associates[88] find that there is a high risk to health and wellbeing from high temperatures in the 2050s and 2080s in the UK. Work for the UK Government suggests the current heat-related death toll in Scotland is 62, likely to rise to 155 in the 2030s, 415 in the 2050s and 840 in the 2070s.[89]

The annual cost to the economy of these deaths is estimated as £125m in the 2020s, £310m in 2030s, £830m in the 2050s and £1.7bn in the 2070s. These costs might be offset by reduced excess deaths from winter cold, perhaps a saving of £1bn by the 2080s, however, deaths from cold are also expected to rise, despite rising average temperatures, because of the aging population.

Another study[90] estimated that heat-related deaths will increase to around 70-285 a year by 2050 and 140-390 a year by the 2080s assuming no population growth. Looking at future heatwaves in Glasgow they found an increase from 0 heatwave days per decade in the period 1981-2020 to 5-10 heatwave days per decade in the 2050s, and 10-50 heatwave days per decade in the 2070s.

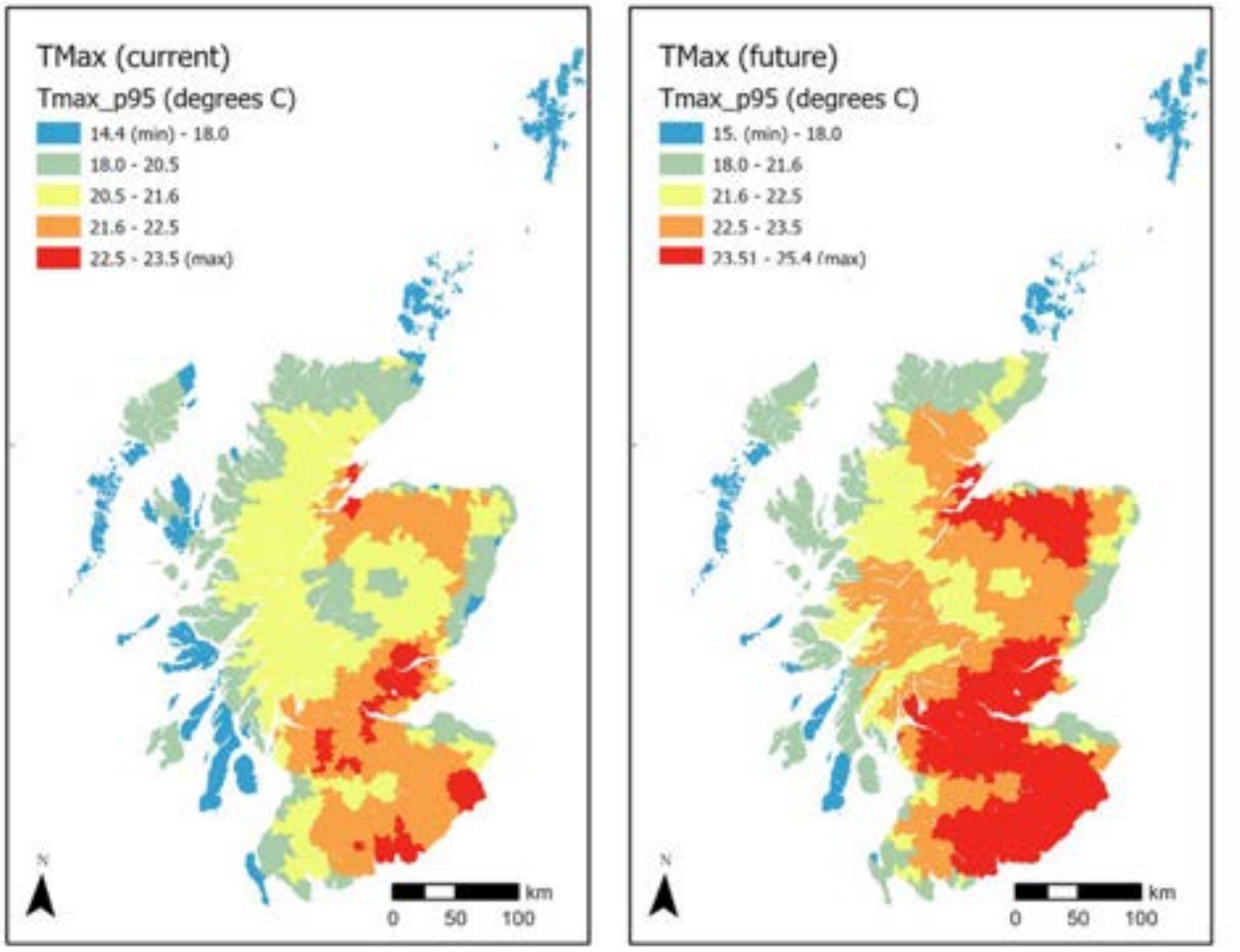


Figure 6 - hottest daily temperatures experienced in Scotland now and in the future. Source CXC Report[91]

As well as deaths, extreme heat sends people to hospital. This is very hard to cost but Watkiss Associates estimate a cost of around £11bn for the UK by the 2080s. Allowing for lower temperatures in Scotland this might come to about £500m for Scotland.

The health service is not fully prepared for what is to come. It is estimated the up to 90% of UK hospital wards are at risk of overheating in hot weather and a study of five Scottish health care facilities found that staff reported overheating issues at four of them.[92]

Most of the UK's buildings are not designed to cope with prolonged high temperatures, with some commentators raising the idea of people having to sleep outside their too-hot homes on the hottest nights. A 2022 study for the ClimateXChange[93] (hereafter the CXC report) found that the most socially vulnerable neighbourhoods in large urban areas are three times more likely to be exposed to high temperatures than other neighbourhoods (and more likely to experience poor air quality).

Their analysis also found that in the future people in the Asian ethnic group are more than 20% more likely, and black groups more than 45% more likely, to live in neighbourhoods where temperature extremes are above those experienced by white people.

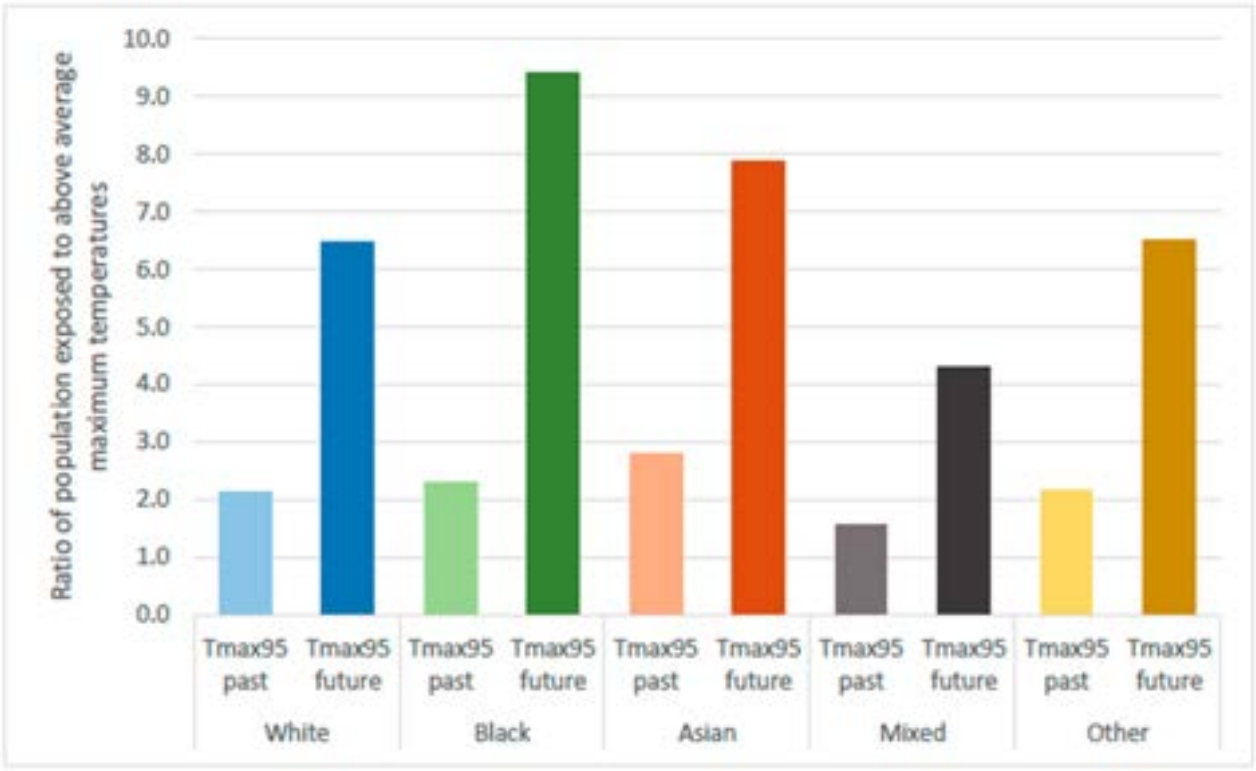


Figure 7 - exposure to above average maximum temperatures now and in the future by ethnic group. Source: CXC Report.

Another impact of high temperatures is that in dry periods the ground can dry out, increasing the likelihood of subsidence and causing heavy rain to flow quickly in to areas where it may cause flooding rather than being partially absorbed into the soil.

Temperature and transport

For the railways there are increased risks of rails buckling, debris on the line and line-side fires, and increasing needs for cooling for carriages. Watkiss Associates estimate additional costs of up to £100m a year by 2050 for the UK rail network.

In 2003, 137 rail buckling incidents across the UK rail network cost £2.5 million in delays and repairs. Buckling events are expected to be four to five times more frequent by the 2050s. By the 2080s, the annual cost of buckling and heat-related delays under a high climate change scenario could increase eightfold.[94]

A study of the 2003 heatwave found that additional road maintenance across the UK cost £40.6m.[95]

Temperature and water supply

Around 150,000 people live or work in premises connected to a private water supply and those relying on surface water are already becoming less reliable in the summer as average temperatures increase.

Temperature and air pollution

Air pollution kills about 1,700 people a year in Scotland and climate change can make it worse by altering weather patterns, strengthening heatwaves, making wildfires more common and increasing the release of chemicals from vegetation and soils that go on to form air pollution. In the summer, more frequent and intense heat waves are likely to lead to more episodes of ozone and particulate pollution.[96] In 2023 all of Scotland's 11 monitoring sites for ground-level ozone exceeded air quality standards, four of them more than 100 times.[97] Some climate solutions – like fewer and cleaner cars and phasing out gas boilers – will help reduce the problem.

Temperature and disease

Diseases transmitted by insects and ticks are sensitive to temperature because the carriers expand their range as temperatures rise. Risks of mosquito-transmitted diseases are likely to increase in the UK, but there is a low risk of malaria becoming established.Cases of Lyme disease may increase if people spend longer in the countryside and more ticks survive the warmer winters. Rising temperatures may also increase the risk of food- and water-borne bacterial infections like salmonella, listeria and campylobacter.[98]

Longer and more intense pollen seasons, along with longer seasons for fungal spores, are likely to worsen seasonal allergies in sensitive individuals.[99]

Conclusion

Scotland has not yet experienced the kind of heat waves which have killed 10,000s of people in Europe. This gives us time to help GPs and health facilities gear up to give appropriate targeted advice to vulnerable citizens and help those affected. Doing this right could save many lives and hundreds of millions of pounds a year by the 2070s.

Similarly, building future climate realities into the planning and refurbishment of railways and roads can considerably reduce future disruption.

Climate change is a serious worry for many people, especially young people. Strong and committed action to reduce emissions and plan for our changing climate would help to allay some of this anxiety.

3.3 Droughts and fires

"Here in Scotland, wildfires are getting bigger and lasting longer. Since 2010, there have been eight wildfires recorded which have lasted more than five days. All eight of these incidents have been since 2018."

Area Commander Michael Humphreys, the Scottish Fire and Rescue Service's wildfire lead and Chair of the Scottish Wildfire Forum, November 2024

Summary

Drought and wildfires are both increasing in frequency and severity. Even in water-rich Scotland, water scarcity is becoming a problem for householders and businesses in some areas and a lack of snow is a growing problem for the skiing industry.

Key facts - droughts and fire

- There is likely to be a doubling of the number of days with a high risk of fire in the UK if the global temperature rise reaches 2ºC, with the length of the wildfire season also likely to increase.
- Current costs of wildfires in Highland Region are around £300m a year. This could increase fourfold by 2050.
- Serious droughts which currently only occur once every 20 year will happen every three years by 2040.
- More frequent and severe droughts will disrupt agriculture, leading to food shortages, price increases and food insecurity.

Detail

As climate change brings hotter, drier summers the risk of wildfires increases, with the Met Office projecting a doubling of the number of days with a high risk of fire in the UK if the global temperature rise reaches 2ºC, with the length of the wildfire season also likely to increase.[100]

An economic analysis study by Highland Adapts[101] found that the total cost of wildfires is around £300m a year and this could reach £1.2bn by 2050. These estimates include the £500,000 cost of putting out fires but also the costs incurred due to air pollution and carbon emissions.

In Scotland water scarcity has already seen bottled water delivered to homes usually reliant on private water supplies, farmers not allowed to take water for irrigation and whisky distilleries having to temporarily halt production. A recent study found that Scotland's natural water resource is becoming increasingly variable[102] with droughts predicted to become more frequent, severe and longer lasting in the next few decades.[103] The likelihood of an extreme drought event will increase from one event every 20 years to one event every three years by 2040, with typical events 2-3 months longer than now. This is a problem for water supplies for people and farming but also for nature, particularly for raised bogs.

Episodes of drought can cause subsidence which can damage buildings and transport infrastructure. Following the heatwave of 2018 the Association for British Insurers reported that over 10,000 UK households made claims related to subsidence, totalling £64 million, nearly four times the amount for the year before.[104]

A shortage of snow is already threatening Scotland's skiing industry, with the Lecht Ski Centre having to raise extra money just to keep going after a 2023-24 winter with little snow.[105]

A drought in 2003 led to severe damages to 14-20% of Sitka spruce trees at some sites in north eastern Scotland. Drought stress also makes trees more susceptible to fungal diseases.[106]

Conclusion

Increasing periods of dry weather are leading to more droughts and wildfires, with consequences for water supply to homes, businesses and farms, problems for forestry and wildlife, and damage to buildings. Future trends in both drought and wildfire are relatively clear and vulnerable geographical areas have been identified, so planning for the future climate is possible.

Scotland has a Water Scarcity Plan[107], SEPA regularly reports on water scarcity and serious water scarcity problems trigger the Scottish Government's emergency response system, as in June 2023. The Scottish Fire and Rescue Service have been investing in equipment to tackle wildfires and continues to work with partners to educate the public on the dangers of inadvertently starting a fire in the countryside.

An economic analysis study by Highland Adapts found that the total cost of wildfires is around £300m a year and this could reach £1.2Bn by 2050

3.4 Storms

"Climate change isn't a distant threat. It worsened extreme weather events that left more than 570,000 people dead. If we keep burning oil, gas and coal, the suffering will continue."

Dr Friederike Otto, co-founder and lead of World Weather Attribution at the Centre for Environmental Policy, Imperial College London

Summary

Although the scale of future change is hard to predict, the increasing frequency and strength of storms is leading to property damage, disruption to transport and energy networks, and soil erosion, as well as contributing to flooding. The economic costs of major storms can be in the hundreds of millions of pounds and the cost of landslips can be in the millions. In the case of the 2020 Stonehaven derailment climate change contributed to three deaths, with fines and compensation in the millions of pounds.

Key facts - storms

- The multiple storms of early 2016 are estimated to have cost the Scottish economy £700m.
- 40% of Scotland's motorways and arterial roads are vulnerable to landslides.
- Transport Scotland has spent more than £11m clearing landslide debris from the A83 Rest and Be Thankful over the last decade.
- Soil erosion by water in Scotland has been estimated to already cost £31-50m a year.
- Periods of strong turbulence at aircraft cruising altitudes over the North Atlantic have increased by 55% over the last four decades. In a few decades, passengers may experience individual episodes of turbulence two or three times longer than today's average of ten minutes.

Detail

Landslides have repeatedly closed roads in Scotland. For instance, Transport Scotland has spent more than £11m clearing landslide debris from the A83 Rest and Be Thankful over the last decade.[108] Communities and businesses have also borne costs due to the resulting delays. Transport Scotland is proposing to build a tunnel through the area at a cost of £405-470m.

An analysis of five landslip events in Scotland found direct costs, including the emergency response, to be between £400k and £1.7m for each event. The knock on cost of the infrastructure being unavailable ranged from £180k to £1.4m.[109]

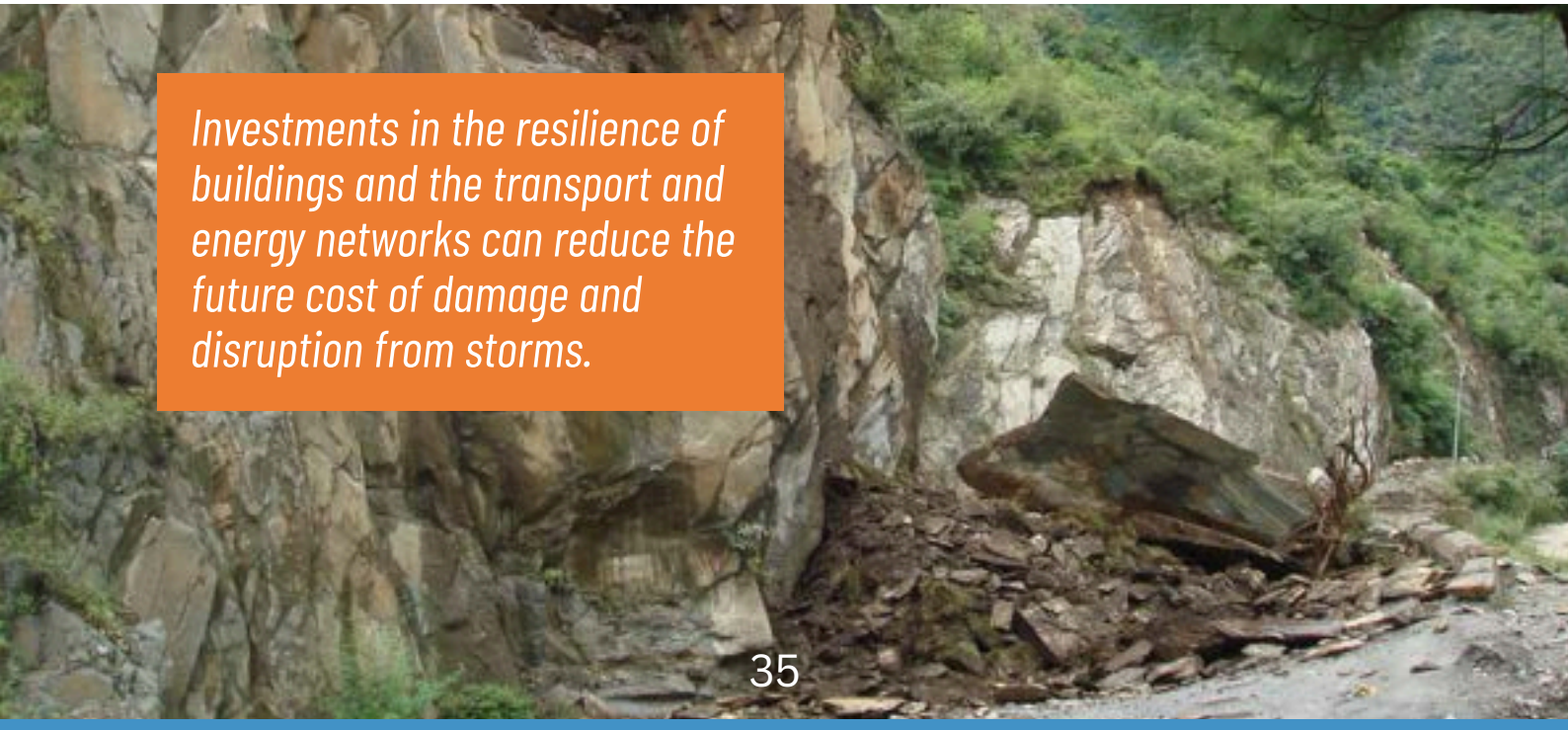
A 2017 analysis found that 40% of Scotland's motorways and arterial roads are vulnerable to landslides.[110]

There were multiple contributory factors to the 2020 Stonehaven derailment which killed three people and injured the other six people aboard the train, but the Rail Accident Investigation Branch report[111] concluded that climate change was one factor, saying *"despite an increasing awareness of the threat, Network Rail had not sufficiently recognised that its existing measures did not fully address the risk from extreme rainfall events, such as summer convective storms."*

Following the accident and in the light of the likelihood that climate change will exacerbate this risk still further, Network Rail commissioned two task forces to advise on the ways that it could improve its understanding of earthworks management and potential improvements to its mitigation measures. Network Rail was fined £6.7m and it is thought that nearly £1m has been paid to victims and relatives.

Railway earthworks are vulnerable to heavy or long duration rain and to longer, drier summers. Between 2003 and 2014 there were an average of 67 earthwork failures every year across the GB transport networks. More and longer periods of heavy rain and periods of warmer drier weather mean that this problem will be significantly worse in the future. This is particularly a problem for rural areas, where transport routes often follow steep-sided valleys which are prone to landslips.[112]

The multiple storms of early 2016 are estimated to have cost the Scottish economy £700 million.[113]



Investments in the resilience of buildings and the transport and energy networks can reduce the future cost of damage and disruption from storms.

Storm Arwen[114]

In November 2021 Storm Arwen created nearly 10,000 faults across the GB electricity network, cutting off supply to more than a million customers including many in Scotland. Around 40,000 GB customers were disconnected for more than three days and 4,000 for more than a week.

For the worst affected, the electricity grid companies paid out around £40m in compensation.

For aviation, storms and turbulence mean more delays and diversions, and increase the risk of injuries and even death during severe turbulence. Periods of strong turbulence at aircraft cruising altitudes over the North Atlantic have increased by 55% over the last four decades.[115] Paul Williams of the University of Reading suggests that, in a few decades, passengers may experience individual episodes of turbulence two or three times longer than today's average of ten minutes.[116]

A 2010 study for England and Wales estimated a 20% increase in soil erosion by the end of the century.[117] Soil erosion by water in Scotland has been estimated to cost £31-50m a year.[118] The heavier rainfall and more frequent episodes of very heavy rain predicted for the future will drive these costs up.

Conclusion

Storms create damage from their strong winds and heavy rainfall, costing the economy tens or hundreds of millions of pounds. Investments in the resilience of buildings, and the transport and energy networks can reduce the future cost of damage and disruption from storms.

3.5 Plant and animal diseases, and non-native species

"Climate and nature have been wholly linked for three billion years, in a colossal carbon cycle that now includes humankind. We … know a nature-rich future is our best response to the climate emergency."

Francesca Osowska, Chief Executive, NatureScot

Summary

Warmer temperatures can help plant and animal viruses, pathogens and diseases to spread. Some of these, including Potato Cyst Nematode could be devastating for agriculture or forestry in Scotland. The future for fisheries and aquaculture is uncertain. The changing climate also encourages non-native species to become established in Scotland, competing with native wildlife and causing problems for farmers and foresters, at a cost of £300m a year.

Key facts - plant diseases and non-native species

- Warmer temperatures can help viruses, pathogens and diseases to spread. Potato Cyst Nematode could put an end to the Scottish seed potato industry by 2050 if action is not taken.
- Forestry is at risk from the spread of pests and diseases like Phytophthora ramorum, dothistroma needle blight and the great spruce bark beetle, as well as increasing damage from expanding deer populations.
- Invasive Non-Native Species already cost the Scottish economy around £300m a year and 30 new invasive non-native species with a high risk of becoming a problem are likely to become established in Scotland in the next decade.
- Commercial fisheries face uncertain times as traditional species like cod and mackerel move out of Scottish waters and others like hake and pollack grow in numbers.
- Wild salmon and sea trout are already suffering heat stress in spawning rivers.

Detail

Potato Cyst Nematode is already a serious issue for Scotland's potato growers and could put an end to the Scottish seed potato industry by 2050 if action is not taken.[119]

Predictions are that by the 2080s, in a high emissions scenario, all of Scotland apart from the Highlands will be warm enough for the rapid spread of the bluetongue virus in sheep, cattle, deer and other ruminants.[120]

New Zealand flatworms are already a widespread problem in Scotland which climate change will make worse, with potentially significant impacts on agricultural production.

Forestry is at risk from the spread of pests and diseases. Phytophthora ramorum is a fungal pathogen that can kill a wide range of trees and is already a significant problem in the south west of Scotland. Dothistroma needle blight poses a risk to commercial forestry particularly in east and north Scotland. The great spruce bark beetle has become established in southern Scotland. It is also expected that climate change will result in an increase in deer populations, leading to further problems for forestry and native tree growth.[121]

Invasive Non-Native Species are the second most serious threat to global biodiversity and already cost the Scottish economy around £300m a year.[122] Many people are already familiar with the problems caused by Giant Hogweed, Japanese Knotweed and Signal Crayfish buta 2023 Scottish Government study identified 30 additional invasive non-native species with a high risk of becoming a problem in Scotland in the next decade.[123]

Work for Scottish Wildlife Trust looked at the economic consequences of action or inaction on biodiversity.[124] Not surprisingly, it concluded that acting now was cheaper and more effective than waiting to act later.

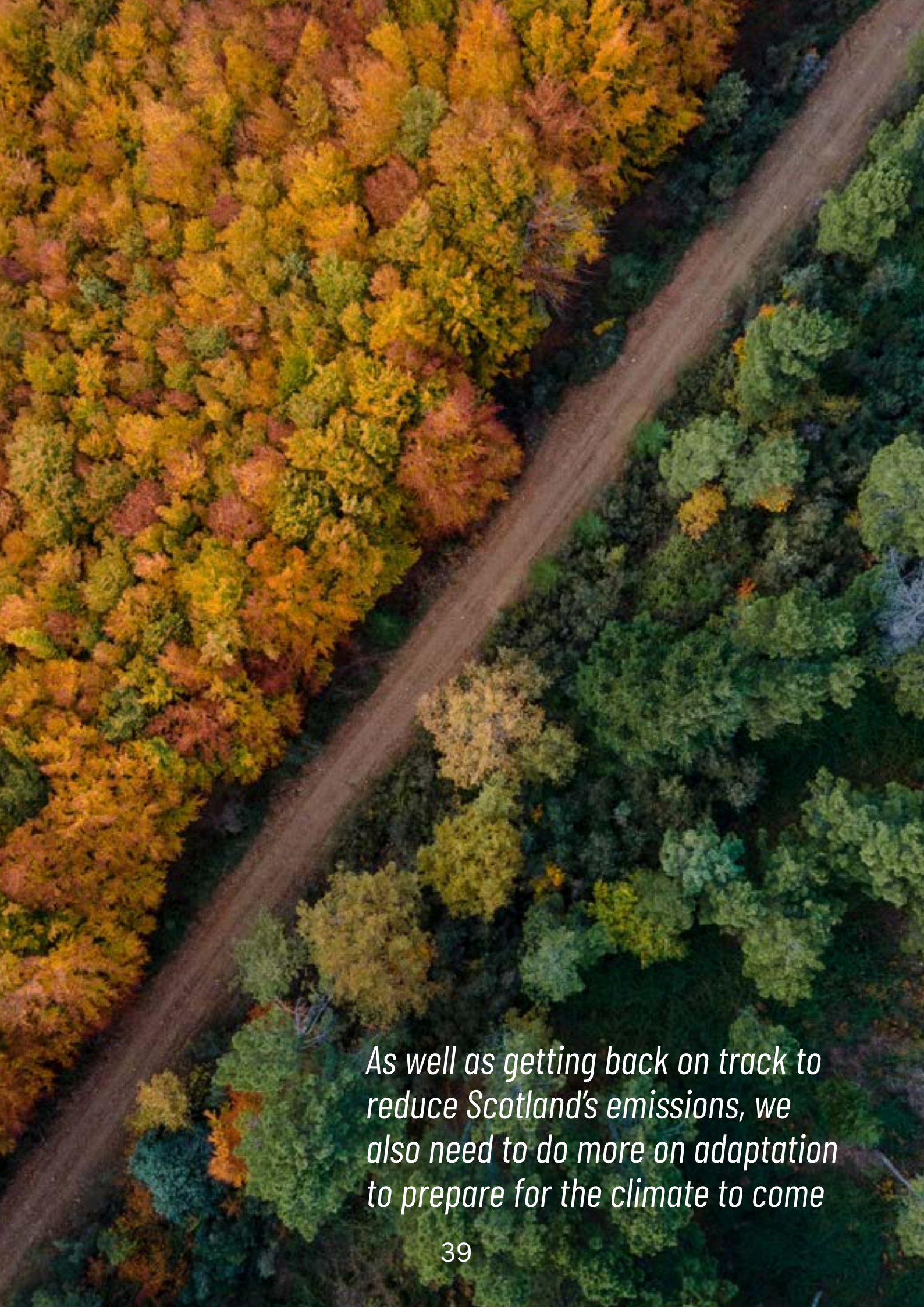
In 2021 fisheries contributed £321m and aquaculture £472m of Gross Value Added to the Scottish economy. A recent report for ClimateXChange[125] concluded that Scottish marine ecosystems and fisheries "face a dynamic and uncertain future due to a changing climate" with climate change and ocean acidification having ecosystem-level impacts on the range and distributions of commercially-fished species in Scottish waters. Key species like cod and mackerel are expected to move out of Scottish waters over the next 30 years as temperatures rise. Other species, like hake, pollack and even anchovy, are already moving north into Scottish waters.

Wild salmon and sea trout are sensitive to river water temperatures when they journey to their spawning grounds and the majority of Scottish rivers are already seeing temperatures which induce stress in wild salmon.[126] A 2017 study for Marine Scotland found that freshwater wild fisheries contributed £80m to the economy and supported more than 4,000 jobs.[127] An update on this work is underway.

Higher temperatures are expected to increase the growth rate of many farmed fish and shellfish but problems with disease and parasites are also likely to increase, especially in fish which are suffering thermal stress. Algal blooms and jellyfish swarms, encouraged by warmer water temperatures, are also likely to become more of a problem for the aquaculture industry.[128]

Conclusion

Invasive non-native species are already a big threat to nature and climate change is bringing more new species every year. Agriculture and forestry are already suffering because of non-native species and for potato growers catastrophe looms. Which fish species Scotland's fishing fleet target will have to change as the balance of species in Scottish waters shifts. There are clear predictions of many of the changes to come, which mean industry and society can prevent some negative changes and work around others.



As well as getting back on track to reduce Scotland's emissions, we also need to do more on adaptation to prepare for the climate to come

4 Conclusions

Climate change is already costing Scotland billions every year. Without action, this bill will be in the tens of billions by the end of the century. Fortunately, we can act. We need to invest in climate solutions now to head off the much larger costs that will come if we do not act. Across spending plans climate change needs an invest-to-save approach.

Here in Scotland we are at a classic moment of potential inaction. The current Climate Change Plan is now aimed at a target that we have scrapped and the government's own indicators show that less than half of the actions in that plan are on track to deliver. There will not be a new Climate Change Plan agreed until the spring of 2026. Instead of waiting for this new plan, the Scottish Government needs to deliver on the promises it made in the current Climate Change Plan and additional commitments it has made since.

An obvious first step would be stop funding things that make climate change worse, for instance, subsidies for the fossil fuel industry and major road building.

RSGS has run a dozen sectoral specific climate emergency summits to discuss how different sectors of society can help respond to climate change, plus a summary 'Big Solutions' report, all of which were submitted to UK and Scottish Government (see www.rsgs.org/climate-emergency-summits). In addition the Stop Climate Chaos Scotland coalition has produced a manifesto of over 100 ideas that could be put into action today or included in the new Climate Change Plan.[129]

As well as getting back on track to reduce Scotland's emissions, we also need to do more on adaptation to prepare for the climate to come, from flood and wildfire planning to gearing up the health service for heatwaves.

In these days of growing misinformation we need trusted sources of clear information on climate change actions and impacts, linked to formal and informal educational initiatives like the Climate Solutions programme for individuals and organisations.[130]

As well as action on our emissions at home Scotland needs again to be a good global citizen on climate change, setting a good example, helping other countries reduce their emissions and cope with the change that is coming, and supporting calls from poorer nations and people for stronger action.

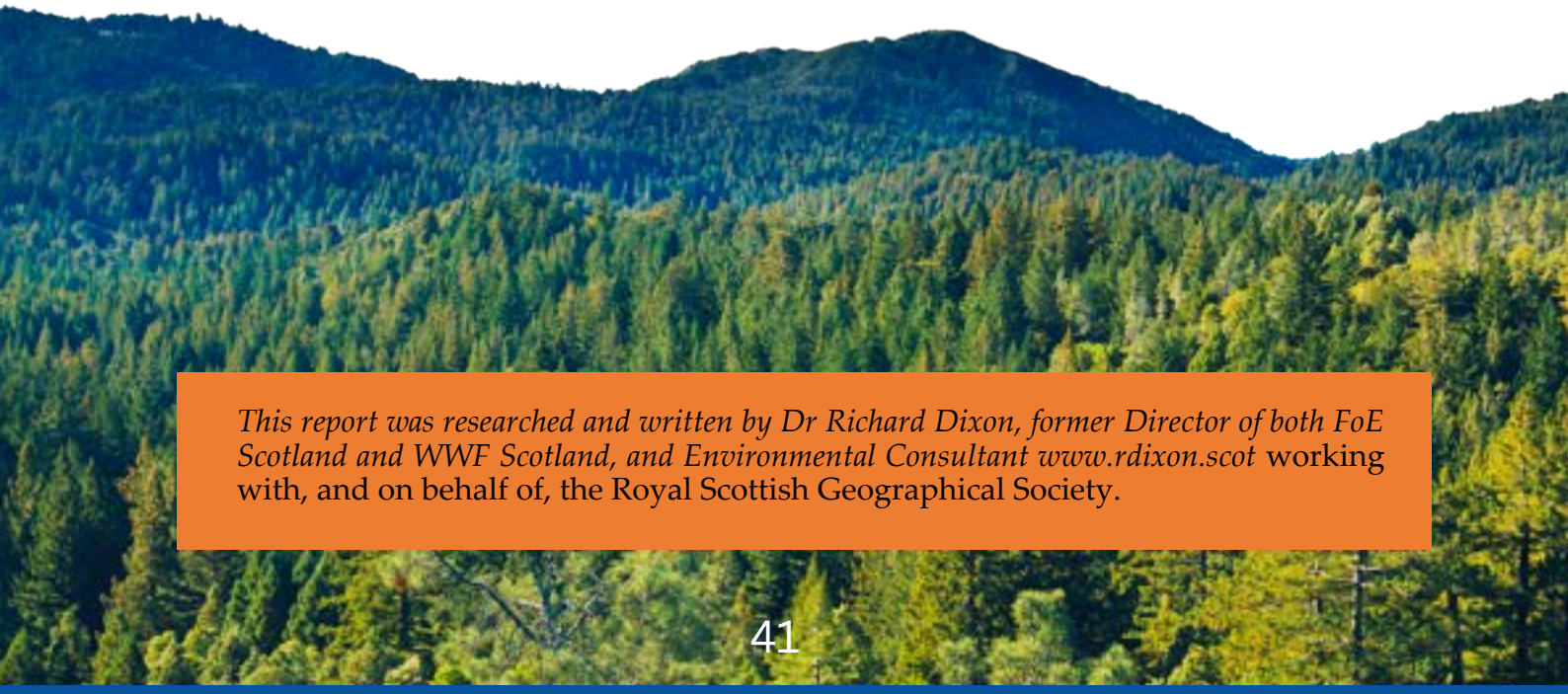
Acting here and acting together with others globally we can save lives, protect nature and reduce the future cost to the Scottish economy of climate change by tens of billions of pounds.

All references can be found separately.

5 Recommendations

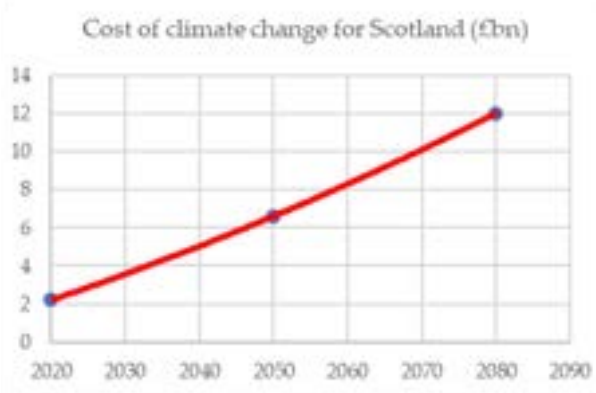
The Scottish Government, in collaboration with the UK Government where needed, should:

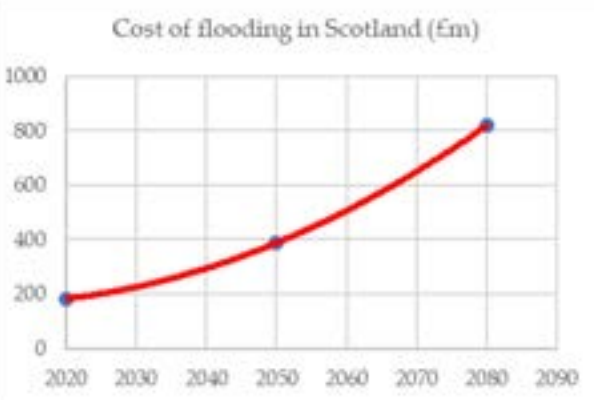
- Ensure a minimum proportion of existing and future public expenditure is net carbon positive – expand public sector duty to assess carbon impacts in all public budgets.
- Create a Climate Wealth Fund – invest a share of e.g. windfall tax, carbon taxes, climate related fines, energy revenues etc. in a future focused pot to fund short- and long-term climate action.
- Establish an independent Climate Oversight Body – to scrutinise policies and drive climate action, like the Future Generations Commissioner for Wales.
- Mandate Climate Expertise on Boards – require boards in industry and public bodies to learn about climate change and assign a responsible board member for climate action.
- Invest in Climate Education & Skills Training – embed climate learning across all education sectors and make organisational climate literacy a requirement for public contracts.
- Publish and Deliver the Climate Change Plan – with an integrated and fully funded implementation plan for all sectors.
- Fund ongoing studies on climate impacts – including on measures to reduce or eliminate these impacts.

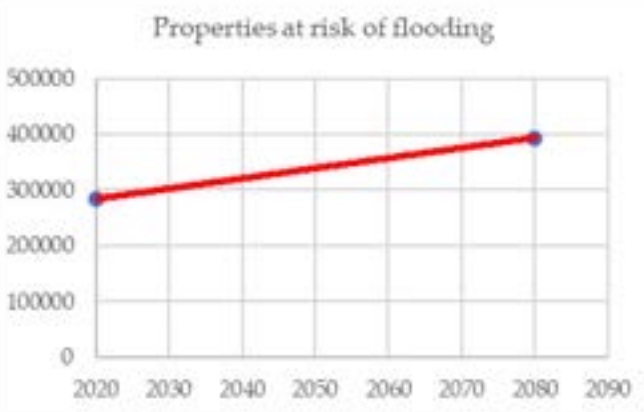


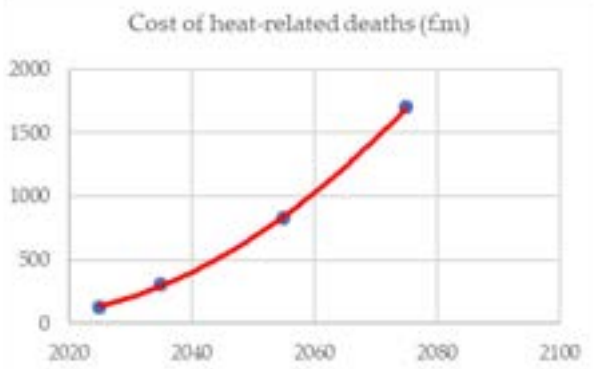
This report was researched and written by Dr Richard Dixon, former Director of both FoE Scotland and WWF Scotland, and Environmental Consultant www.rdixon.scot working with, and on behalf of, the Royal Scottish Geographical Society.

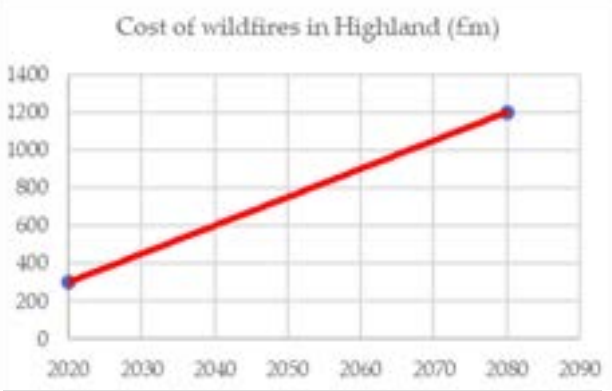
HEADING FOR TROUBLE?

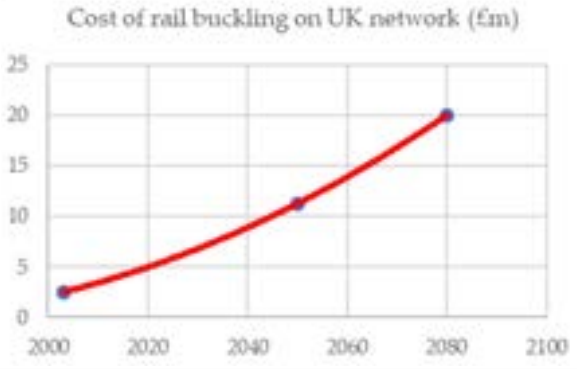


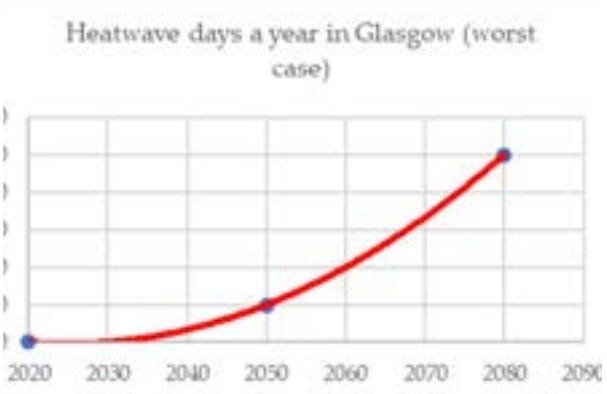


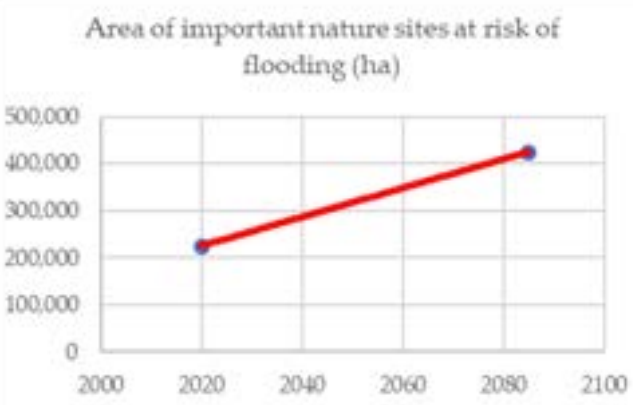




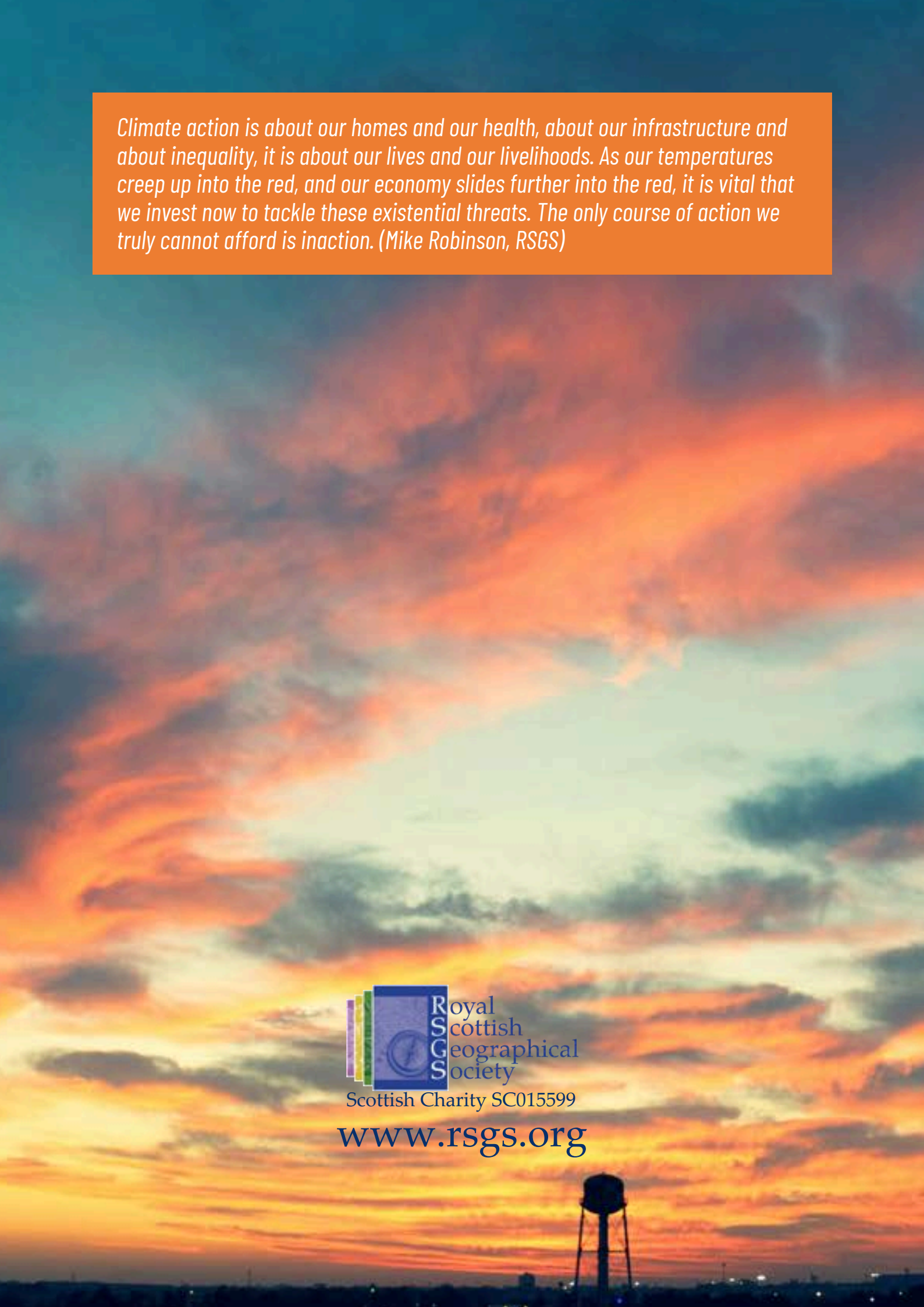








Climate action is about our homes and our health, about our infrastructure and about inequality, it is about our lives and our livelihoods. As our temperatures creep up into the red, and our economy slides further into the red, it is vital that we invest now to tackle these existential threats. The only course of action we truly cannot afford is inaction. (Mike Robinson, RSGS)



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