The economic cost of extreme weather events

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Contents

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ICC foreword

John W.H. Denton AO

Secretary General, International Chamber of Commerce

We know all too well from the experience of businesses across the International Chamber of Commerce network that climate change is not a future problem – its impacts are being felt in the here and now.

We commissioned Oxera to quantify a central element of this experience: the economic impact of climate-related extreme weather events on both physical infrastructure and human capital.

The analysis shines a light on the acute impact of extreme weather on the real economy over the past decade – with close to 4,000 recorded events resulting in cumulative losses to the global economy of around $2 trillion.

The total magnitude of these losses of calls for a response from governments of commensurate speed and decisiveness.

In this spirit, we hope the findings of this report will serve as a call to action – both to ensure a robust climate finance package is delivered at COP29 and, moreover, that governments bring forward significantly enhanced national climate action plans in early 2025.

As Oxera's research shows, there is a real and tangible cost to delaying the action needed to stem climate change. From a business perspective, the urgency of coordinated and collective action to accelerate emissions reductions and build resilience to changing weather patterns cannot be overstated. Simply put, the time for action is now.

Executive summary

Climate change is driving extreme weather events, with a marked 83% increase in recorded climate disasters between 1980–1999 and 2000–2019. These events disproportionately impact vulnerable regions and socio-economic groups across the world, compounding existing challenges for those already disadvantaged.

The impacts of climate-related extreme weather events span a complex array of direct impacts to physical and human capital and indirect impacts to the wider economy. Direct physical impacts include the destruction of private dwellings, commercial property and infrastructure—such as roads, energy sources, and housing—along with damage to agriculture and food supplies. Human capital impacts are also stark: premature deaths, injuries, and health issues caused by extreme conditions not only represent a tragic toll but also contribute to lost productivity and place additional strain on healthcare systems. Beyond this, broader economic impacts ripple through affected areas, disrupting local supply chains, causing displacement of populations, and discouraging investment.

These events also widen existing socio-economic inequalities—with vulnerable communities often experiencing the worst outcomes—which in turn places significant pressure on government finances as public funds are redirected to relief, recovery, and resilience measures. A single climate-related extreme weather event can have cascading effects across multiple sectors, underscoring the long-lasting challenges faced by countries vulnerable to climate shocks.

Our analysis, commissioned by the International Chamber of Commerce (ICC), quantifies a subset of the economic costs of climate-related extreme weather events. Based on nearly 4,000 events across six continents from 2014 to 2023, we estimate economic losses from these events at **$2 trillion** in 2023 prices. The report's focus on acute, current events (as opposed to chronic, gradual impacts of climate change) underscores the tangible and immediate costs already reshaping communities and economies worldwide.

These estimates reflect physical asset destruction as well as human capital losses from premature deaths. Specifically, we quantify the immediate physical damage caused by extreme weather events and the monetary value of lost human lives, based on their contribution to productivity output. However, this estimate likely understates the full economic toll, as it excludes numerous categories of indirect impact, such as ongoing costs to public infrastructure, agricultural and supply chain disruptions, migration pressures, and exacerbation of social inequality. In addition, our analysis does not encompass the more holistic value of a human life, which extends beyond productivity loss to include emotional, social, and cultural contributions to communities. Moreover, data gaps, particularly in less developed regions, mean that the true economic burden could be orders of magnitude higher. Approximately **1.6 billion** people have been directly affected by these events in the decade from 2014 to 2023, highlighting the scale of human and economic costs. The estimated impact only captures a small part of the impacts so should be considered a lower bound, with the true economic impact likely orders of magnitude greater.

In 2022 and 2023 alone, economic damages reached **$451 billion**, representing a **19% increase** compared to the annual average from the preceding eight years. This rise may be partially attributed to improved reporting, especially on heat-related deaths. However, it also highlights the need for more comprehensive reporting of impacts in many vulnerable regions that are still inadequately captured.

The economic toll of a single extreme weather event on smaller, vulnerable nations can be especially severe, in some cases eclipsing a country's entire annual output. For example, we estimate that Hurricane Maria in 2017 had an economic cost equivalent to **over 300% of** Dominica's **gross value added (GVA)** for that year. This illustrates the difficulties that these nations face in preparing for unpredictable, large-scale events that can severely strain their financial resources, posing long-term challenges to recovery and resilience.

Our findings indicate that without enhanced climate action and mitigation efforts, the economic burden of climate-related extreme weather events will persist and likely grow. Vulnerable nations, already grappling with limited resources, will face mounting economic pressures that could hinder their development and recovery efforts. Additionally, the ripple effects of these events will be felt across the global economy, as disruptions in one region can trigger broader economic instability. The cumulative costs, driven by damage to infrastructure, loss of productivity, and increased demand for disaster relief, underscore the urgent need for coordinated global action to address climate change and its far-reaching impacts. Investing in resilience and adaptation strategies will be essential to mitigate these costs and safeguard global economic stability.

1 Introduction

1.1 The number and severity of climate-related extreme weather events has risen by 83% from 1980–1999 to 2000–2019, posing significant risks to individuals, businesses and economies.[1] This includes events such as heatwaves, extreme precipitation, droughts, and tropical cyclones. These extreme events threaten ecosystems, infrastructure, buildings and human lives, and are putting significant economic burden on countries. A growing body of research using 'extreme event attribution' reveals the influence of human activity in increasing the likelihood and severity of these events.[2]

1.2 In this context, economic cost analysis is crucial to understand the range and scale of these impacts to consider the case for further climate action. COP29 presents a pivotal opportunity to advance the 2016 Paris Climate Agreement by increasing global climate ambitions and securing funding for key areas of climate action including: loss and damage, adaptation, and mitigation. With the risk of insufficient global action, it is important to consider the cost of inaction. While much climate research focuses on the long-term impacts of climate change, the effects are already being felt today in the form of acute extreme weather events. The growing frequency and severity of these events underline the urgent need for action.[3]

1.3 The economic case for mitigating the costs of climate-driven extreme weather events is clear. However, the path to net zero also presents an opportunity for economic growth. Recent research from Oxera suggests that by leveraging regulation, private investment, carbon pricing, and fiscal policy, net zero can serve as a driver of economic growth.[4] While governments must prepare for measures to mitigate and respond to climate-related extreme weather events in the immediate term, they can

[1] Climate Centre (2020), 'UN: Climate-related disasters increase more than 80% over last four decades', 13 October, https://www.climatecentre.org/450/un-climate-related-disasters-increase-more-than-80-over-last-four-decades/, accessed 1 November 2024.
[2] Carbon Brief (2022), 'Mapped: How climate change affects extreme weather around the world', 4 August.
[3] UN Office for Disaster Risk Reduction (2020), 'The human cost of disasters: an overview of the last 20 years (2000-2019)', 13 October.
[4] Oxera, (2024), 'Growth Zero', https://www.oxera.com/insights/agenda/topics/growthzero/, accessed 1 November 2024.

also adopt forward-looking climate policies that drive sustainable economic growth.

1.4 For this report, Oxera have been commissioned by the International Chamber of Commerce (ICC) to set out the long list of impacts and costs associated with climate-related extreme weather events and to quantify a subset of these costs. Specifically, this report quantifies the damage to physical assets and the lost economic output associated with early deaths caused by extreme weather events worldwide from 2014 to 2023. The aim is not to determine a precise monetary figure but rather to offer a broad indication of the scale of these costs, recognising that the estimates are based on only a subset of economic impacts and are illustrative in nature. Even based on a subset of impacts, the significant economic impact already being experienced globally is demonstrated.

1.5 This report is structured as follows.

- Section 2 sets out the definition and scope of climate-related extreme weather events, before discussing their trends and distribution.
- Section 3 outlines the various categories of impact associated with these events, supported with evidence from literature.
- Section 4 aims to quantify a subset of these impacts. It first sets out the methodology and data sources used, and follows with a report on our findings.

2 Understanding the trends and distribution of climate-related extreme weather impacts

2.1 Acute vs. chronic impacts

2.1 In the literature, a distinction is made between acute and chronic physical risks associated with climate change.[5] Acute climate risks are event-driven and typically refer to short-term extreme weather events such as floods, hurricanes, wildfires, heatwaves, and droughts. These events are often sudden and can have immediate and severe impacts on communities and economies. As explained above, the frequency and intensity of these acute events are increasing as global temperatures rise, and atmospheric and hydrological patterns shift.

2.2 In contrast, chronic climate risks relate to longer-term shifts in climate patterns, such as steadily rising global temperatures, sea level rises, and changes in precipitation patterns. These risks unfold over decades and can cause persistent environmental and economic damage. Chronic risks, such as higher average temperatures and altered rainfall patterns, can disrupt ecosystems, agricultural productivity, and human health over the long term.

2.3 In this study, our focus is exclusively on acute extreme weather events triggered by climate change and their immediate impacts. For example, we consider the immediate impact of a flood reducing a substantial proportion of a country's agricultural output. We also capture longer-term consequences directly resulting from these acute events. For example, if the flood also affects future agricultural yield in the short-to-medium term due to compromised soil quality or infrastructure, such effects are included in our analysis. However, we are not examining gradual, longer-term, chronic impacts on agriculture that are unrelated to any single acute event, such as gradual reductions in crop yields due to rising temperatures or slow shifts in ecosystem viability over decades. Acute impacts are more straightforward to identify and quantify because their effects are felt more immediately and can be directly linked to a specific event. In contrast, chronic risks are more difficult to

[5] See, for example, Task Force on Climate-related Financial Disclosures (2017), 'Final report: Recommendations of the Task Force on Climate-related Financial Disclosures', June, p. 6.

robustly estimate, as they unfold over long periods, and their full effect may not yet be understood.

2.2 Definition and scope of climate-related extreme weather events

2.4 In terms of acute climate-related extreme weather events, we focus on three types of hazards.

- Hydrological—floods, landslides, and wave action.
- Meteorological—convective storms, extratropical storms, extreme temperatures, fog, and tropical cyclones.
- Climatological—droughts, glacial lake outbursts, and wildfires.

2.5 These categories align with the classification used by the United Nations Office for Disaster Risk Reduction and several academic studies. They reflect a broad understanding of the extreme weather events that are linked to atmospheric and hydrological processes, such as changes in rainfall, temperature, wind and ocean patterns, which are increasingly affected by climate change.[6]

2.6 While there is some debate over the classification of other types of extreme events, such as earthquakes, the general consensus is that they are not directly influenced by climate change in the same way as the previously mentioned hazards.[7] For instance, earthquakes are caused by tectonic shifts, not atmospheric conditions, making them less relevant for inclusion in this scope. Importantly, this study does not seek to evaluate the validity of the causal relationship between climate change and these extreme weather events; instead, we take this link as given, and focus our attention on assessing the economic impact of the events themselves.

[6] UN Office for Disaster Risk Reduction (2020), 'The human cost of disasters: an overview of the last 20 years (2000-2019)', 13 October. Also see IPCC report that classifies such events, or 'climate impact-drivers', under the categories: 'heat and cold', 'wet and dry', 'wind', 'snow and ice', 'coastal and oceanic' and 'other'. IPCC (2021), 'Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change', Cambridge University Press.

[7] NASA explains that earthquakes are caused by tectonic movements rather than weather conditions (see NASA (2019), 'Can Climate Affect Earthquakes, or Are the Connections Shaky?', 29 October, https://science.nasa.gov/earth/climate-change/can-climate-affect-earthquakes-or-are-the-connections-shaky/, accessed 1 November 2024). However, some research has explored potential indirect links, such as melting glaciers causing shifts in tectonic plates (see Friedrich, A.M. et al. (2021), 'Potential links between climate change and seismic activity: A review,' *Journal of Geophysical Research: Solid Earth*), though this remains a relatively rare and indirect connection.

2.3 Trends in climate-related extreme weather events

2.7 The frequency and intensity of various weather and climate-related extreme events have increased since industrialisation.[8] These events threaten many aspects of society and nature, including ecosystems,[9] buildings, infrastructure and human lives.[10] An overall increase in the frequency and severity of extreme weather is likely to lead to a greater economic burden, given the wide range of costs identified in this report.

2.8 On a global scale, chronic increases in warming are driving more frequent and intense 'extremes' across various types of weather, such as drought, extreme precipitation and cyclones—events which are likely to significantly impact communities and the economy. The Intergovernmental Panel on Climate Change (IPCC)'s Sixth Assessment Report presents strengthened evidence of observed changes due to human influence in the frequency and intensity of a range of event types.[11]

2.9 For example, heatwaves are occurring more frequently and intensely, while the opposite is true of cold extremes, reflecting increasing levels of global warming.[12] Across the world, extreme high temperatures in excess of 40 degrees are becoming increasingly frequent;[13] for example, during the pre-monsoon season in South Asia.[14] Increases in temperature can significantly disrupt economic activity, as well as place burdens on health and emergency services.[15] According to the World

[8] IPCC (2021), 'Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change', Cambridge University Press.

[9] United States Environmental Protection Agency (2024), 'Climate Change Impacts on Ecosystems', 22 October, https://www.epa.gov/climateimpacts/climate-change-impacts-ecosystems#:~:text=Climate%20change%20is%20affecting%20some,that%20ecosystems%20provide%20to%20society.&text=For%20example%2C%20ecosystems%20provide%20a,ability%20to%20grow%20certain%20crops, accessed 1 November 2024.

[10] EEA (2024), 'Extreme weather: floods, droughts and heatwaves', 11 October, https://www.eea.europa.eu/en/topics/in-depth/extreme-weather-floods-droughts-and-heatwaves, accessed 1 November 2024.

[11] IPCC (2021), 'Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change', Cambridge University Press.

[12] IPCC (2021), 'Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change', Cambridge University Press.

[13] WMO (2024), 'Extreme weather', https://wmo.int/topics/extreme-weather, accessed 1 November 2024.

[14] World Weather Attribution (2024), 'Climate change made the deadly heatwaves that hit millions of highly vulnerable people across Asia more frequent and extreme', 14 May, https://www.worldweatherattribution.org/climate-change-made-the-deadly-heatwaves-that-hit-millions-of-highly-vulnerable-people-across-asia-more-frequent-and-extreme/, accessed 1 November 2024.

[15] WHO (2024), 'Heatwaves', https://www.who.int/health-topics/heatwaves#tab=tab_1, accessed 1 November 2024.

Meteorological Office (WMO), ‘extreme heatwaves in 2003 and 2010 accounted for 80% of weather-related deaths in Europe from 1970-2019’.[16]

2.10 The evolving threat of other types of events, such as severe storms, is shown through the economic cost of disasters in the US. The National Centers for Environmental Information (NCEI) estimate that, on average, there were 8.5 climate-related extreme weather events per year with estimated losses exceeding $1 billion in the US between 1980 and 2023.[17] In 2024, there have already been 24 confirmed events of this kind, and severe storms have accounted for 16 of these.[18]

2.11 Looking forward, the IPCC expects people across the world to experience extreme weather events ‘that are unprecedented, either in magnitude, frequency, timing or location’,[19] which has the potential to increase the economic costs of extreme weather events and their impacts.

2.4 The distribution of climate-related extreme weather impacts

2.12 It is important to note that, while much of the literature on climate-related extreme weather impacts is concentrated on the northern hemisphere, particularly the US and Western Europe, these impacts are not felt equally across regions. The variability in exposure, vulnerability, and capacity to respond means that countries outside of Europe and North America who have fewer resources and higher climate sensitivity, may experience disproportionate economic and social consequences from extreme weather events.

2.13 For example, according to a WMO report, Asia remains the world’s most disaster-hit region from weather, climate and water-related hazards in 2023, with extreme heat becoming increasingly severe.[20] Furthermore, the availability of early warning systems differs across regions, which affects

[16] WMO (2024), ‘Extreme weather’, https://wmo.int/topics/extreme-weather, accessed 1 November 2024.
[17] This includes losses associated with physical damage, material assets, time element losses (such as business interruption), public assets, agriculture and wildfire suppression costs, among others. These estimates are made for events that affected the US.
[18] NCEI (2024), ‘Billion-Dollar Weather and Climate Disasters’, October, https://www.ncei.noaa.gov/access/billions/, accessed 1 November 2024.
[19] IPCC (2021), ‘Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change’, Cambridge University Press.
[20] WMO (2024), ‘State of the Climate in Asia 2023’, 23 April, https://wmo.int/publication-series/state-of-climate-asia-2023, accessed 1 November 2024.

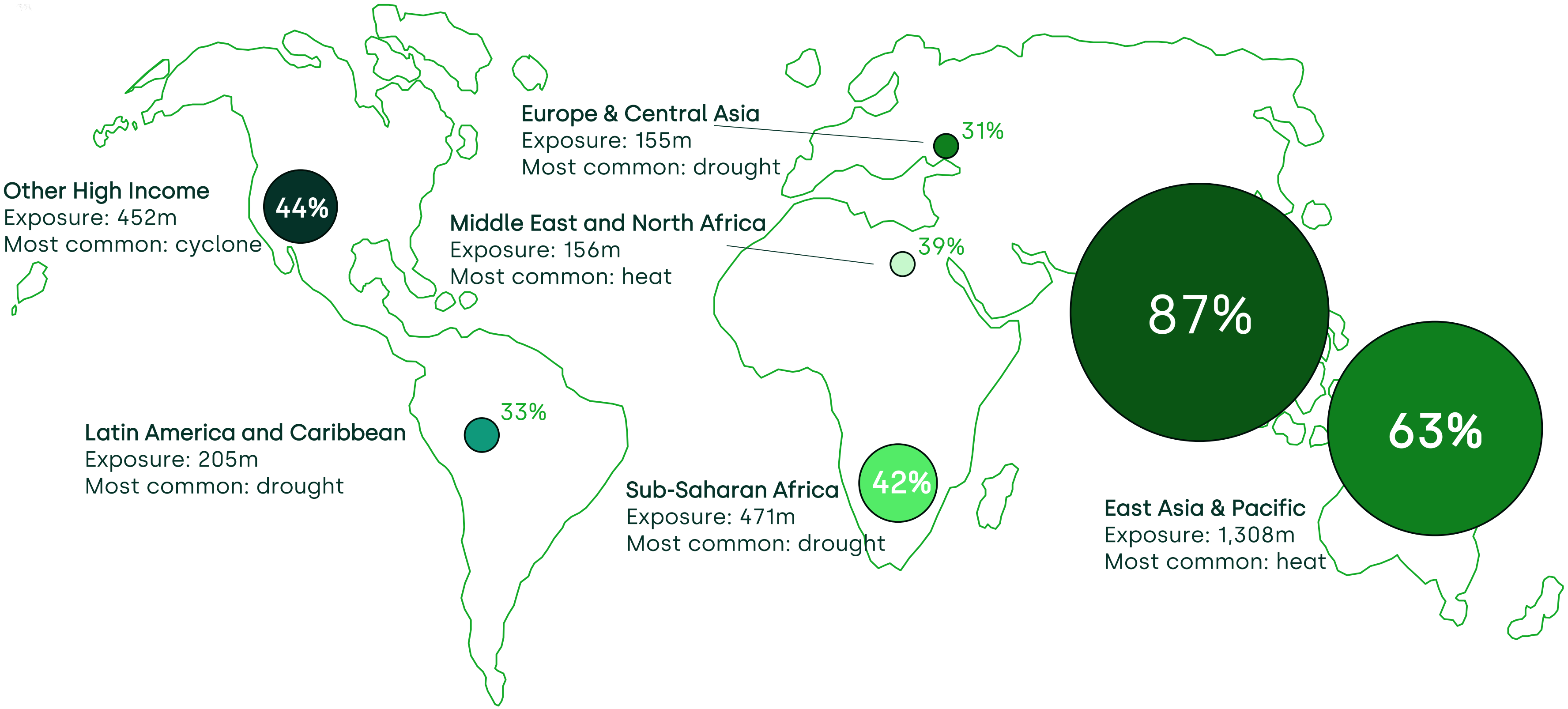
communities' abilities to prepare for events and mitigate potential damage in a timely fashion. The United Nations Educational, Scientific and Cultural Organization (UNESCO) note that a third of the world's population do not have early warning systems in place; this group is primarily comprised of those in the least developed countries and Small Island Developing States.[21] As such, the incidence and impact of extreme weather is not geographically uniform.

2.14 Figures from the World Bank Group illustrate the distribution of people exposed to, vulnerable to, or at high risk from, several types of climate shock—i.e. flood, drought, heat and cyclones.[22]

2.15 Figure 2.1 below illustrates the distribution of exposed people by region, with each circle scaled to represent the absolute number of people in each region exposed to the shocks considered. The percentages in, or next to, the circles represent the proportion of the total population in each region exposed to any type of shock. For example, in South Asia and East Asia & Pacific, there are 1.6 and 1.3 billion people exposed to shocks respectively, representing 87% and 63% of the respective populations in those regions. In these regions, the most predominant shock type is extreme heat. In comparison, in Europe and Central Asia, only 31% of the population are exposed to climate-related shocks and the most common shock type is drought.

[21] UNESCO (2024), 'Early Warning Systems', https://www.unesco.org/en/disaster-risk-reduction/ews, accessed 1 November 2024.
[22] See World Bank (2024), 'Poverty and Inequality Platform Methodology Handbook', Edition 2024-09, https://datanalytics.worldbank.org/PIP-Methodology/lineupestimates.html#regionsandcountries, accessed 1 November 2024, for the classification of countries per publication methodology.

Figure 2.1 The regional distribution of populations vulnerable to climate shocks



Note: The percentages presented in Figure 2.1 represent the proportion of the total population in each region exposed to any type of shock, using data from World Bank Group research. 'Other high income' represents mostly high-income economies, that are excluded from the geographical regions and are included as a separate group. These are described as 'industrialised economies', or 'rest of the world' and includes countries such as the US.
Source: Oxera analysis of World Bank Group, (2023), 'Counting people exposed to, vulnerable to, or at high risk from Climate shocks', Table 7.

2.16 As illustrated above, the impacts of climate-related shocks are likely to differ substantially across regions, both in scale (the number of people affected) and in nature, due to the varying types of extreme weather events experienced. This variation influences the types of economic and social impacts associated with climate-related events in each region, which are explored further in section 3 below.

2.17 As well as geographical differences, the impacts of extreme weather events is likely to exacerbate existing inequalities between socio-economic groups. These inequalities may widen both *within* and *across* countries and regions. Skoufias et al. recognise that 'climate change impacts tend to be regressive, falling more heavily on the poor than the rich'.[23] This is underpinned by a variance in human vulnerability to extreme weather, due to a combination of physical and social factors.[24] For example, poorer populations tend to live in areas less resistant to the impacts of weather.[25] The IPCC note that 'Vulnerable communities who have historically contributed the least to current climate change are disproportionately affected'.[26] The effect of climate-related extreme weather events on social inequality is discussed further in section 3.3.3 below.

[23] Skoufias, E., Rabassa, M. and Olivieri, S. (2011). 'The poverty impacts of climate change: a review of the evidence,' Policy Research Working Paper Series 5622, The World Bank, April, https://ideas.repec.org/p/wbk/wbrwps/5622.html#author-abstract, accessed 1 November 2024.
[24] Thomas, K., Hardy, R.D., Lazrus, H., Mendez, M., Orlove, B., Rivera-Collazo, I., Roberts, J.T., Rockman, M., Warner, B.P. and Winthrop, R. (2018), 'Explaining differential vulnerability to climate change: A social science review', 7 December, https://wires.onlinelibrary.wiley.com/doi/full/10.1002/wcc.565, accessed 1 November 2024 (hereafter, referred to as Thomas et al. (2018)).
[25] Thomas et al. (2018), https://wires.onlinelibrary.wiley.com/doi/full/10.1002/wcc.565, accessed 1 November 2024.
[26] IPCC (2023), 'Climate Change 2023: Synthesis Report', https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf, accessed 1 November 2024.

3 Categories of economic impact associated with extreme weather events

3.1 Introduction

3.1 This section focuses on the literature and published evidence on acute climate-related extreme weather events in order to compile a comprehensive list of the economic impacts that may arise as a result of these events.

3.2 For the reasons described in section 2.4 above, not all impacts may be relevant to each specific event or region. That said, this list illustrates the diverse negative impacts that arise from extreme weather events, ranging from direct effects such as rebuilding costs, to more indirect consequences, including increased social inequality. This section provides some examples of the costs associated with these events, but it does not aim to be exhaustive in covering every impact of every event. In each subsection, we examine the available evidence to highlight the wide-ranging impacts that can stem from a single extreme weather event, rather than quantifying or determining the magnitude of these effects (for a subset of impacts, see section 4 below).

3.3 The analysis is divided into three main areas.

- Physical impacts—these include direct damage to private dwellings, commercial properties, and critical infrastructure, and the secondary economic effects that arise from such damage, such as higher insurance costs and lost productivity due to disrupted supply chains.
- Human impacts—these cover both the health effects and social displacement caused by extreme weather, and the ways in which these effects deepen social inequalities and reduce long-term productivity.
- Broader impacts—these consider the more indirect but long-lasting financial repercussions, such as the deterrence of investment and the strain on public finances.

3.2 Physical impacts

3.2.1 Private and commercial dwellings

3.4 Extreme weather events such as hurricanes, floods, and wildfires can lead to substantial damage to private homes and commercial properties. Flooding, for instance, can inundate buildings, leading to water damage that affects structural integrity, electrical systems, and interior fixtures, often requiring complex remediation efforts. Wildfires can fully consume buildings, leaving only the foundations intact and creating further environmental hazards from the release of toxic materials. Hurricanes and severe storms not only damage roofs, windows, and external structures through high winds, but also bring in floodwaters and debris, exacerbating property damage and raising the cost of restoration.

3.5 This destruction creates direct costs for homeowners, tenants, and businesses due to subsequent repairs, rebuilding, and replacement. Analysis from Harvard University's Joint Center for Housing Studies estimates that a $10 billion increase in disaster-related damages in the US is associated with a $250 million increase in 'spending on home improvements related to disasters,' during the three years following an event.[27] Additionally, extreme weather can damage essential machinery, equipment, and inventories, impacting business continuity and recovery.

3.6 These direct costs associated with damage to private and commercial dwellings are often partially absorbed, at least in some regions, by insurers. There is therefore a secondary economic impact of damage to dwellings that manifest in the insurance sector.

3.7 Indeed, as events become increasingly intense and frequent, the expected losses associated with rebuilding will rise and be reflected in insurance costs. In addition, greater unpredictability in weather brings additional challenges for insurers, by rendering existing climate models and risk strategies less reliable.[28] This is likely to further increase costs for the provision of cover, as new investment and research is required.

3.8 In certain areas, these impacts are felt more acutely than others. For example, the World Economic Forum issued a report in 2023, detailing the effect of wildfires on the Californian market. Globally, Jones et al. found that the average fire

[27] Hermann, A. (2018), 'How Much Will Homeowners Spend to Rebuild & Repair After Hurricane Florence?' Joint Center for Housing Studies of Havard University, 24 September, https://www.jchs.harvard.edu/blog/how-much-will-homeowners-spend-to-rebuild-repair-after-hurricane-florence, accessed 1 November 2024.
[28] CERES (2012), 'Stormy Future for Insurers: The Growing Costs and Risks of Extreme Weather Events', 5 September, https://www.ceres.org/resources/reports/stormy-future-insurers-growing-costs-and-risks-extreme-weather-events, accessed 1 November 2024.

weather season length (FSWL) has lengthened by 27%. These increases were particularly apparent in the Amazon, Mediterranean and the western forest of North America. In California, wildfire events continue to cause crises for the insurance industry:[29] key players in the market react by ceasing to offer residential and commercial real estate coverage in parts of the state, and consequently there is a risk of the emergence of an 'insurance desert'.[30]

3.9 This has significant adverse knock-on effects for those seeking to obtain mortgages or invest in new housing developments.[31] Even in more developed economies, around three-quarters of climate-related catastrophe losses are currently uninsured in the European Union (EU).[32] Given that insurance is described as an 'enabler' for people and companies by the International Labour Organisation,[33] this 'insurance protection gap' is likely to inflict indirect opportunity costs, as individuals and companies have fewer resources available to invest in other economic activities or developments, limiting potential economic growth as well as deepening socio-economic inequalities.

3.2.2 Infrastructure

3.10 Extreme weather events pose substantial risks to infrastructure, including roads, transport networks, energy grids, supply chains, telecommunications, and water systems. Damage to these systems can lead to widespread disruption, slowing recovery efforts and, in severe cases, isolating communities or obstructing the delivery of essential services.

Direct infrastructure impacts

3.11 Extreme weather events such as floods, droughts, heatwaves, and storms place immense pressure on the built environment,

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[29] The Guardian (2024), "'Left with nothing": inside California's wildfire home insurance crisis', 10 August, https://www.theguardian.com/us-news/article/2024/aug/10/home-insurance-park-wildfire-california-butte-county, accessed 1 November 2024.
[30] World Economic Forum (2023), 'How wildfire risk and extreme heat is changing the insurance industry', 7 July, https://www.weforum.org/agenda/2023/07/wildfire-risk-extreme-heat-changing-insurance-industry/, accessed 1 November 2024,
[31] World Economic Forum (2023), 'How wildfire risk and extreme heat is changing the insurance industry', 7 July, https://www.weforum.org/agenda/2023/07/wildfire-risk-extreme-heat-changing-insurance-industry/, accessed 1 November 2024.
[32] ECB (2023), 'The climate insurance protection gap', 24 April, https://www.ecb.europa.eu/ecb/climate/climate/html/index.pt.html, accessed 1 November 2024.
[33] ILO (2016), 'Insurance and economic development: Growth, stabilization and distribution', September, https://www.ilo.org/sites/default/files/wcmsp5/groups/public/@ed_emp/documents/publication/wcms_614874.pdf, accessed 1 November 2024.

often rendering infrastructure inoperable or impassable. For instance, a study on flood risk in the US found that roughly 25% of all critical infrastructure,[34] which equates to approximately 36,000 facilities, is currently at risk of becoming inoperable due to flooding. Similarly, 23% of road segments (nearly 2 million miles), and 17% of social infrastructure are also exposed to operational risks from flooding.[35] The situation is expected to worsen over the next 30 years, with an additional 63,000 miles of roads, 6,100 social infrastructure facilities, and 2,000 pieces of critical infrastructure likely to be impacted by flood risks, making them inoperable or inaccessible.[36] This data from the US, where infrastructure is generally built to high standards and located in less flood-prone areas compared to many other regions, suggests that the global impact of flood risks on infrastructure could be even more severe.

3.12 In the transport sector, climate-related extreme weather events pose significant risks to aviation, road, and rail systems. First, the sector depends heavily on critical resources like fuel, and the disruption to supply chains caused by climate-related events (discussed further below), creates significant risks. Second, transport-specific impacts such as flight delays, airport closures, and increased wear on infrastructure lead to direct economic costs. Aviation is particularly vulnerable, with flight schedules disrupted by extreme heat, storms, and other climate-related conditions.[37]

3.13 Utilities infrastructure is also vulnerable to extreme weather events. Energy systems are highly sensitive to climate variability, as both energy demand and supply are closely linked to atmospheric conditions. Extreme weather events pose significant risks to energy infrastructure and can lead to supply disruptions, resulting in partial or total blackouts. For example, nearly ten million people were left without electricity during the Great Texas Freeze of 2021 due to widespread system failure.[38] Furthermore, storms, heat waves, and floods frequently damage

[34] This includes utilities, airports, ports, and emergency services such as police, fire, and hospitals.
[35] Social infrastructure includes schools and government buildings.
[36] First street foundation (2021), 'First Street Foundation Releases Nationwide Resilience Report Finding 25% of All Critical Infrastructure and 23% of Roads Have Flood Risk Which Would Render Them Inoperable', 10 October.
[37] ICAO (2020), 'Effects of Climate Change on Aviation Business and Economics', https://www.icao.int/environmental-protection/Documents/Factsheet%20Business%20and%20Economics%20Final.pdf, accessed 1 November 2024.
[38] NCEI (2023), 'The Great Texas Freeze: February 11–20, 2021', 24 February, https://www.ncei.noaa.gov/news/great-texas-freeze-february-2021, accessed 1 November 2024.

power systems, while mechanical damage to equipment due to thermal stress is a growing concern in regions that experience extreme heat.

3.14 Renewable energy sources, such as wind and solar, are especially vulnerable. These systems are characterised by sharp fluctuations in net-load, making them more prone to operational challenges under extreme weather conditions.[39] For example, ice accumulation on wind turbines and transmission lines can significantly reduce power generation and lead to outages. In Finland, up to 45% of wind power downtimes have been attributed to icing events.[40] Wind turbines are also susceptible to damage from tropical cyclones and thunderstorms. Studies suggest that increasing extreme wind speeds could lead to a 12% rise in the capital costs of wind energy installations by the end of this century, as infrastructure will need to be strengthened to withstand these conditions.[41] Meanwhile, extreme heat and droughts impact solar and thermal power plants, reducing their efficiency and cooling capacity, which can further strain the energy grid.[42] In addition, as renewable energy sources constitute a growing share of the global energy mix, the risks associated with extreme weather events will become increasingly significant in the future.

3.15 The risks extend beyond renewable energy to more conventional power systems. Hydropower, which accounted for 16.6% of global power production in 2016, is subject to significant variability depending on annual precipitation.[43] During dry years, countries reliant on hydropower face considerable energy security risks. Similarly, thermal power plants, which rely heavily on water for cooling, are vulnerable to disruptions in water supply. For instance, in 2009, one-third of French nuclear power plants were temporarily shut down during a heat wave due to a lack of available cooling water.[44]

[39] Abdin, A.F., Fang, Y.P. and Zio, E. (2019), 'A modeling and optimization framework for power systems design with operational flexibility and resilience against extreme heat waves and drought events', *Renewable and Sustainable Energy Reviews*, **112**, pp. 706–719.
[40] Jasiūnas, J., Lund, P.D. and Mikkola J. (2021), 'Energy system resilience – A review', *Renewable and Sustainable Energy Reviews*, **150** (hereafter, referred to as Jasiūnas et al. (2021)).
[41] Zhang, D., Xu, Z., Li, C., Yang, R., Shahidehpour, M., Wu, Q. and Yan, M. (2019), 'Economic and sustainability promises of wind energy considering the impacts of climate change and vulnerabilities to extreme conditions', *The Electricity Journal*, **32**:6, pp. 7–12.
[42] Jasiūnas et al. (2021).
[43] Jasiūnas et al. (2021).
[44] Jasiūnas et al. (2021).

3.16 In summary, there are various direct impacts of extreme weather events on infrastructure, which we have illustrated through the lens of roads, such as transport and energy. However, the consequences of such events are not limited to these areas alone; they also affect other services, including telecommunications and water supply, as discussed below.

Secondary impacts

3.17 Infrastructure disruptions from extreme weather events can also have significant secondary effects that ripple across the economy and impact daily life. One such secondary effect is on supply chains.

3.18 Globalisation has brought significant benefits, including increased levels of trade, and lower prices for consumers.[45] However, the emergence of complex supply chains brings challenges and risk, in the form of greater exposure to worldwide shocks through global trading relationships.[46] Whilst not an extreme weather event, Covid-19 highlighted the fragility of global supply chains.[47] Both supply and demand suffered adverse shocks in a wide range of industries, causing supply shortages for items from toilet paper to aluminium cans.[48]

3.19 Extreme weather events can significantly disrupt supply chains by hindering businesses' ability to obtain essential inputs required for production. For instance, natural disasters such as hurricanes or floods may lead to the closure of factories or suppliers, causing delays in the delivery of raw materials. This may mean that businesses struggle to maintain their production schedules, leading to inventory shortages and production halts. Additionally, transportation networks can be affected, making it challenging for companies to source materials from alternative suppliers or to distribute finished goods.

[45] World Economic Forum (2019), 'An economist explains the pros and cons of globalization', 11 April, https://www.weforum.org/agenda/2019/04/an-economist-explains-the-pros-and-cons-of-globalization-b2f0f4ae76/, accessed 1 November 2024.
[46] Bank of England (2024), 'A portrait of the UK's global supply chain exposure', 30 September, https://www.bankofengland.co.uk/quarterly-bulletin/2024/2024/a-portrait-of-the-uks-global-supply-chain-exposure, accessed 1 November 2024.
[47] World Economic Forum (2021), 'An expert explains: How COVID-19 exposed the fragility of global supply chains', 30 July, https://www.weforum.org/agenda/2021/07/covid-19-pandemic-global-supply-chains/, accessed 1 November 2024.
[48] World Economic Forum (2021), 'An expert explains: How COVID-19 exposed the fragility of global supply chains', 30 July, https://www.weforum.org/agenda/2021/07/covid-19-pandemic-global-supply-chains/, accessed 1 November 2024.

3.20 In recent years, shipping supply on the Rhine has been disrupted by both excessively high[49] and low water levels,[50] while flooding caused problems for the supply of pigs, peanuts and coal in central China.[51] Typhoons in Malaysia disrupted the semiconductor industry in 2021, causing product assembly to be halted for some global suppliers.[52]

3.21 These supply chain disruptions can exacerbate the initial effects of extreme weather, leading to broader economic implications, such as increased costs, reduced productivity, and diminished profitability for businesses. In addition, damage to transport infrastructure can lead to longer journey times, further impacting productivity and disrupting daily routines. Similarly, outages or slowdowns in energy and telecommunications can reduce output, hinder business operations, and affect broadband speeds, which further impedes productivity.

3.22 Beyond effects to productivity, damage to critical infrastructure also has knock-on social and health implications. Disruptions in transport networks can limit people's ability to visit friends and family, affecting mental and emotional wellbeing. Damage to energy infrastructure can leave homes without heating during adverse weather, and interruptions to water supplies may mean reliance on unsanitised sources, creating additional health risks.

3.23 Furthermore, healthcare systems themselves are also at risk of being severely disrupted by extreme weather events. This risk is particularly acute for low- and middle-income countries.[53] Healthcare facilities may have critical infrastructure destroyed,

[49] World Cargo News (2024), 'High water level impacts cargo transport on Rhine', 4 June, https://www.worldcargonews.com/news/2024/06/high-water-level-impacts-cargo-transport-on-rhine/?gdpr=accept, accessed 1 November 2024.
[50] Reuters (2022), 'Shipping disruption continues as Rhine water levels fall again in Germany', 12 August, https://www.reuters.com/markets/commodities/shipping-disruption-continues-rhine-water-levels-fall-again-germany-2022-08-12/, accessed 1 November 2024.
[51] Yale Environment 360 (2022), 'How Climate Change Is Disrupting the Global Supply Chain', 10 March, https://e360.yale.edu/features/how-climate-change-is-disrupting-the-global-supply-chain, accessed 1 November 2024.
[52] Techwire Asia (2021), 'Malaysian floods disrupts semiconductor supply chain; devastates workers', 3 November, https://techwireasia.com/2021/12/malaysian-floods-devastate-workers-disrupts-semiconductor-supply-chain/, accessed 1 November 2024.
[53] Salam, A., Wireko, A.A., Jiffry, R., Ng, J.C., Patel, H., Zahid, M.J., Mehta, A., Huang, H., Abdul-Rahman, T. and Isik, A. (2023), 'The impact of natural disasters on healthcare and surgical services in low- and middle-income countries', July, https://pmc.ncbi.nlm.nih.gov/articles/PMC10406090/#:~:text=As%20the%20frequency%20and%20severity,countries%20with%20limited%20surgical%20capacity, accessed 1 November 2024 (hereafter, referred to as Salam et al. (2023)).

or be affected by power outages and water shortages.[54] At the same time, demand is likely to surge,[55] due to injuries and acute illness. Initial symptoms suffered by patients may develop into more chronic health issues. Therefore, damage to critical infrastructure that reduces access to healthcare following extreme weather events can have profound and long-lasting impacts in terms of health and well-being. The economic costs of these effects are discussed in more detail in section 3.3.1 below, with a particular focus on the labour force.

3.24 Lastly, the interconnected nature of infrastructure systems means that disruptions in one area, such as extreme weather events impacting a critical facility, can lead to cascading effects throughout the wider network. For instance, a flood damaging a power substation could result in widespread electricity outages, affecting hospitals, transport systems, and water supply operations, each of which would subsequently have knock-on effects. This interconnectedness can amplify the overall impact, creating a ripple effect that exacerbates the disruptions experienced across multiple sectors.[56]

3.2.3 Agriculture

3.25 Acute climate events such as floods, droughts, and extreme heat also significantly impact agricultural production.

3.26 Research highlights that Northern Europe is increasingly experiencing more heavy precipitation, leading to potential flooding, while Southern Europe increasingly faces severe drought and temperature extremes.[57] Central Europe is expected to experience both heat extremes and increased heavy precipitation. These patterns follow established trends, with the economic impacts of drought and heat already being the largest contributors to agricultural losses in Europe. Crops like maize (yields particularly impacted by heat), tubers

[54] Salam et al. (2023), https://pmc.ncbi.nlm.nih.gov/articles/PMC10406090/#:~:text=As%20the%20frequency%20and%20severity,countries%20with%20limited%20surgical%20capacity, accessed 1 November 2024.
[55] Davis, J.R., Wilson, S., Brock-Martin, A., Glover, S. and Svendsen, E.R. (2010), 'The Impact of Disasters on Populations With Health and Health Care Disparities', *Disaster Medicine and Public Health Preparedness*, **4**:1, pp. 30–38, https://pmc.ncbi.nlm.nih.gov/articles/PMC2875675/#:~:text=This%20effect%20creates%20a%20%E2%80%9Csecondary,chronic%20diseases%20following%20a%20disaster, accessed 1 November 2024 .
[56] Markolf, S.A., Hoehne, C., Fraser, A., Chester, M.V. and Underwood, B.S. (2019), 'Transportation resilience to climate change and extreme weather events – Beyond risk and robustness', *Transport Policy*, **74**, pp. 174–186.
[57] European Parliament (2023), 'The impact of extreme climate events on agricultural production in the EU', April, p. 14.

(flooding), and soybeans (heat stress and droughts) are particularly vulnerable to such extremes. Grasslands are also highly susceptible to heat stress and drought, which has knock-on effects for livestock by affecting reproduction, dairy capacities and mortality.[58]

3.27 Globally, droughts and extreme heat have also been found to significantly reduce agricultural production. For instance, there were losses of 9–10% due to a reduction in national cereal production between 1964 and 2007.[59] The reduction is primarily due to both smaller harvested areas and lower yields, especially during droughts. Research also shows that cereal production damage from more recent droughts (1985–2007) averaged 13.7%, while droughts during the preceding period (1964–1984) caused average estimated losses of 6.7%. Average damages are therefore estimated to have increased by around 7% across periods, with developed countries experiencing more damage than developing ones. This discrepancy could be attributed to differences in agricultural systems and infrastructure resilience to climate extremes.

3.28 In addition, there is an established link between droughts, farmland degradation and subsequent abandonment. According to the United Nations Environment Programme (UNEP), approximately 500 million hectares of farmland have been abandoned due to drought and desertification.[60] This land degradation severely impacts crop productivity through mechanisms such as nutrient immobilisation and salt accumulation, making soils infertile.[61]

3.29 In conclusion, agriculture is particularly vulnerable to the increasing frequency and severity of climate-related extreme weather events. The resulting losses from crop and livestock failures pose significant challenges to food security and

[58] European Parliament (2023), 'The impact of extreme climate events on agricultural production in the EU', April.
[59] Lesk, C., Rowhani, P. and Ramankutty, N. (2016), 'Influence of extreme weather disasters on global crop production', *Nature*, **529**, pp. 84–87.
[60] UNEP (2017), 'High and dry: Degraded lands are driving people from their homes', 15 June, https://www.unep.org/news-and-stories/story/high-and-dry-degraded-lands-are-driving-people-their-homes, accessed 1 November 2024.
[61] Arora, N.K. (2019), 'Impact of climate change on agriculture production and its sustainable solutions', *Environmental Sustainability*, **2**, pp. 95–96.

livelihoods. As climate change continues to exacerbate these risks, agricultural losses are projected to rise in the future.[62]

3.3 Human impacts

3.3.1 Health impacts on the labour force

3.30 Climate-related extreme weather events affect individuals and communities beyond the impact on physical assets. They also have human impacts, such as the impact on the health of the population through illness and injury. For instance, heatwaves can cause heat-related illnesses and exacerbate pre-existing health conditions, while flooding can contaminate drinking water supplies, thereby increasing the risk of waterborne diseases. Additionally, the stress and trauma associated with displacement and loss can have lasting mental health effects on individuals and communities.

3.31 In economic terms, one way to quantify these health impacts would be through lost productivity. For example, according to the International Labour Organization (ILO), 'excessive heat during work creates occupational health risks; it restricts a worker's physical functions and capabilities, work capacity and productivity. Temperatures above 24–26°C are associated with reduced labour productivity. At 33–34°C, a worker operating at moderate work intensity loses 50 per cent of his or her work capacity'.[63] This means that at these elevated temperatures, workers are only able to produce half as much in an hour as they would have under optimal conditions, and at even higher temperatures, work can become nearly impossible without adaptation measures, such as air conditioning.

3.32 Compounding the issue, extreme temperatures also increase the likelihood of occupational injuries. For instance, a study conducted in Spain found that '2.7 per cent of all occupational injuries could be attributed to non-optimal ambient temperatures, among which extreme temperature highs played a significant role'.[64] This equated to an annual loss of 42

[62] European Parliament (2023), 'The impact of extreme climate events on agricultural production in the EU', April, p. 10.
[63] International Labour Organization (2019), 'Working on a warmer planet: the impact of heat stress on labour productivity and decent work', p. 13.
[64] Martínez-Solanas, È., López-Ruiz, M., Wellenius, G.A., Gasparrini, A., Sunyer, J., Benavides, F.G. and Basagaña, X. (2018), 'Evaluation of the Impact of Ambient Temperatures on Occupational Injuries in Spain', *Environmental Health Perspectives*, **126**:6. June.

workdays per 1,000 workers and represented 0.03% of Spain's gross domestic product (GDP) in 2015.

3.33 In the most extreme cases, climate-related extreme weather events can result in premature deaths. These deaths are tragic, and represent a loss not only to the loved ones of those affected, but also to wider society. Similar to the above, one way to consider the impact of these deaths in economic terms is to estimate the loss of output resulting from a person dying prematurely. This lost output is representative of the economic value a person could have contributed during their working life if their life had not ended early. These direct impacts associated with early deaths are discussed and quantified in section 4 below.

3.3.2 Migration and displacement of people

3.34 Climate change has emerged as a significant driver of human displacement and migration. The term 'climate refugees' was first introduced in 1985 by UN Environment Programme (UNEP) expert Essam El-Hinnawi. It refers to individuals who are 'forced to leave their traditional habitat, temporarily or permanently, because of marked environmental disruption'.[65] The Internal Displacement Monitoring Centre (IDMC) cite the steep rise in extreme weather events as a driver of internal displacement within low- and middle-income countries.[66]

3.35 According to the United Nations High Commissioner for Refugees (UNHCR), between 2008 and 2016, an average of 21.5 million people were forcibly displaced each year due to weather-related events such as floods, storms, wildfires, and extreme temperatures.[67] Analysis from the IDMC highlights the significant impact of weather on human habitation, as extreme weather events accounted for more than 89% of all disaster displacement between 2008 and 2020.[68] Forecasts indicate that this number will increase in the coming decades with climate

[65] European Parliament (2023), 'The concept of "climate refugee": Towards a possible definition', October.
[66] IDMC (2021), '2021 Global Report on Internal Displacement (GRID)', 20 May, https://api.internal-displacement.org/sites/default/files/publications/documents/grid2021_idmc.pdf#page=42, accessed 1 November 2024.
[67] UNHCR (2016), 'Frequently asked questions on climate change and disaster displacement', 6 November, https://www.unhcr.org/uk/news/stories/frequently-asked-questions-climate-change-and-disaster-displacement, accessed 1 November 2024.
[68] IDMC (2021), '2021 Global Report on Internal Displacement (GRID)', 20 May, https://api.internal-displacement.org/sites/default/files/publications/documents/grid2021_idmc.pdf#page=42, accessed 1 November 2024.

change and natural disasters projected to displace up to 1.2 billion people globally by 2050.[69]

3.36 The UNHCR highlights several of the transmission mechanisms by which extreme weather can lead to human displacement. Firstly, extreme weather may cause immediate threats to safety,[70] forcing individuals to flee a certain area. In addition, the provision of basic needs and rights may be lacking following an extreme weather event. As discussed in section 3.2.2 above, damage to critical infrastructure may inhibit the local community's ability to access clean water and healthcare. Displacement due to such events can also affect individuals differently depending on factors like age, gender, and refugee status, with vulnerable groups often facing greater challenges in accessing shelter, resources, and support.[71]

3.37 Thalheimer et al. studied how extreme weather and conflict affect internal displacement in Somalia. They found that a temperature rise of 1°C to 2°C could lead to approximately 2,400 more internally displaced persons (IDPs)—a tenfold increase in their predictions. They also noted that a 5cm drop in rainfall could double the number of predicted IDPs, highlighting the significant impact of extreme weather on displacement. [72]

3.38 As the frequency and intensity of some weather-related hazards increase, vulnerable communities are increasingly prone to crises and poverty, creating conditions for forced displacement to occur.[73]

3.3.3 Social inequality

3.39 Lastly, various studies have shown that extreme weather events disproportionately affect lower-income households, which can

[69] Institute for Economics & Peace (2020), 'Over one billion people at threat of being displaced by 2050 due to environmental change, conflict and civil unrest', 9 September.
[70] UNHCR (2023), 'Displacement in the context of extreme weather events', 29 April, https://unfccc.int/sites/default/files/resource/exweatherevents_displacment_unhcr_yonetani.pdf, accessed 1 November 2024.
[71] UNHCR (2023), 'Displacement in the context of extreme weather events', 29 April, https://unfccc.int/sites/default/files/resource/exweatherevents_displacment_unhcr_yonetani.pdf, accessed 1 November 2024.
[72] Thalheimer, L., Schwarz, M.P. and Pretis, F. (2023), 'Large weather and conflict effects on internal displacement in Somalia with little evidence of feedback onto conflict', *Global Environmental Change*, **79**, https://www.sciencedirect.com/science/article/pii/S0959378023000079, accessed 1 November 2024.
[73] UNHCR (2024), 'Climate change and displacement', https://www.unhcr.org/uk/what-we-do/how-we-work/climate-change-and-displacement, accessed 1 November 2024.

lead to increased social inequality, even in a given country, over time.

3.40 There are thought to be three interconnected factors contributing to the disproportionate loss of assets and income among disadvantaged groups.[74] First, these groups often face greater exposure to climate hazards due to living in more vulnerable areas, such as flood-prone zones with inadequate infrastructure. Second, they have greater susceptibility to damage from these hazards, as their housing is often of poorer quality, making it more likely to sustain severe damage during events like floods or storms. Finally, disadvantaged households have less ability to cope with, and recover from, damages, due to limited financial resources and access to insurance, which can delay or prevent rebuilding efforts.

3.41 There is also research which shows that natural disasters are linked to declines in credit scores, increases in debt collection and mortgage delinquency. These impacts disproportionately affect those with lower incomes and minorities, and are likely to lead to long-term financial hardship, exacerbating pre-existing inequalities.[75]

3.42 These dynamics create a vicious cycle where disadvantaged communities suffer more during extreme weather events, which exacerbates pre-existing inequalities.

3.4 Broader impacts

3.4.1 Investment

3.43 Climate-related extreme weather events have broader impacts that extend beyond immediate physical and human concerns. One of the longer-term economic impacts of climate-related extreme weather events is on investment.

3.44 Following an extreme weather event, if private and public resources in a certain area are channelled towards reconstruction and replacement, this spending has an associated opportunity cost.[76] These funds may otherwise have

[74] Nazrul, I.S. and Winkel, J. (2017), 'Climate change and social inequality', Department of Economic & Social Affairs, October.
[75] Ratcliffe, C.E., Congdon, W., Teles, D., Stanczyk, A. and Martín, C. (2020), 'From Bad to Worse: Natural Disasters and Financial Health', *Journal of Housing Research*, **29**(sup1), pp. 25–53.
[76] Batten, S., Rhiannon, S. and Tanaka, M. (2020), 'Climate Change: Macroeconomic Impact and Implications for Monetary Policy', in T. Walker, D. Gramlich, M. Bitar and P. Fardnia (eds), *Ecological,*

been invested in, for example, research and development, which is linked to both innovation and productivity growth.[77] Thus, damage reparation in the wake of extreme weather events can harm long-run productivity.

3.45 Furthermore, when deciding where and whether to invest, firms typically take account of various factors such as market size, political stability, and the availability of infrastructure. Risks related to natural disasters and extreme weather events are thought to be increasingly considered in the decision-making process as natural disasters can damage production facilities, disrupt supply chains, and burden the economy by destroying critical infrastructure and assets.[78] As a result, companies may choose not to invest in regions prone to earthquakes, hurricanes, or floods, leading to a disadvantage in certain regions in terms of attracting long-term investment.

3.46 These impacts also extend to investment from abroad. Foreign direct investment (FDI) refers to investments made by a company or individual in one country into business interests located in another country. FDI plays a crucial role in the economic development of host countries by facilitating capital flows, technology transfer, and job creation.

3.47 Empirical evidence supports the idea that natural disasters can significantly affect FDI inflows. For instance, Escaleras and Register (2011) found that FDI tends to decline in the aftermath of natural disasters, particularly in manufacturing sectors that rely heavily on infrastructure. Their study, which examined 94 countries over a 20-year period, showed a statistically significant negative relationship between the frequency of natural disasters and FDI inflows.[79] That said, Doytch (2020) further highlights that while manufacturing FDI is often negatively affected in the short term, some disasters may lead to long-term positive effects, consistent with the theory of 'creative destruction' as economies rebuild and modernise after

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Societal, and Technological Risks and the Financial Sector, Palgrave MacMillian. Version of book chapter referenced via https://www.frbsf.org/wp-content/uploads/sites/4/Batten-Sowerbutts-Tanaka-Climate-change-Macroeconomic-impact-and-implications-for-monetary-policy.pdf, accessed 1 November 2024.

[77] BEIS (2021), 'From ideas to growth', BEIS Research Paper Number: 2021/041, https://assets.publishing.service.gov.uk/media/615d9a36e90e07198108144f/niesr-report.pdf, accessed 1 November 2024.

[78] Neise, T., Sohns, F., Breul, M. and Diez, J.R. (2021), 'The effect of natural disasters on FDI attraction: a sector-based analysis over time and space', *Natural Hazards*, **110**, pp. 999–1023.

[79] Escaleras, M. and Register, C.A. (2011). 'Natural Disasters and Foreign Direct Investment', *Land Economics*, **87**:2, pp. 346–363.

disasters. However, the services sector does not show this same pattern, with climate and hydrological disasters having long-lasting negative effects on FDI in services.[80]

3.48 In summary, extreme weather events and natural disasters can deter FDI by increasing operational risks and undermining the locational advantages that firms seek when making investment decisions. The empirical evidence indicates that countries prone to such events may struggle to attract and retain FDI, especially in sectors reliant on infrastructure.

3.4.2 Government finances

3.49 As the risk of physical hazards due to extreme weather events increase, there are also economic consequences for governments and institutions. Climate-related extreme weather events have the potential to significantly impact governments' fiscal positions through increased public spending (e.g. disaster relief) and reduced tax income (e.g. due to lower productivity).

3.50 There is often increased public spending following extreme weather events due to the need for disaster relief and recovery efforts. This is particularly the case for developing countries, which are more likely to have less-developed private insurance markets,[81] meaning a greater burden may fall on the government.

3.51 The Organisation for Economic Co-operation and Development (OECD) assesses that the largest disaster-related liability for governments is damage to public assets.[82] These buildings and infrastructure are likely to be key to the effective functioning of the economy, and therefore the exposure of these assets to extreme weather events represents a risk for central governments. The explicit level of exposure is dependent on pre-arranged commitments in place through policy: if a private operator suffers uninsured losses and becomes unable to provide services deemed essential, public-private partnership

[80] Doytch, N. (2020), 'Upgrading destruction?', *International Journal of Climate Change Strategies and Management*, **12**:2, pp. 182–200.
[81] OECD (2019), 'Fiscal Resilience to Natural Disasters', 20 May, https://www.oecd.org/en/publications/fiscal-resilience-to-natural-disasters_27a4198a-en.html, accessed 1 November 2024.
[82] OECD (2019), 'Fiscal Resilience to Natural Disasters', 20 May, https://www.oecd.org/en/publications/fiscal-resilience-to-natural-disasters_27a4198a-en.html, accessed 1 November 2024.

contracts may induce pressure for governments to step in and absorb rising costs.[83]

3.52 In addition, government spending on new infrastructure may have otherwise boosted productivity through increasing the capital stock of that economy. Given that many public sector investments have high initial costs but minimal marginal costs, diverting public sector funding towards damage repair could lead to other public projects being forgone, with private sector agents unable to meet the high barriers to entry of investment.[84] Therefore, the diversion of funds for repair and reconstruction cost can have longer-term opportunity costs through 'lost' productivity growth.

3.53 Furthermore, an economic downturn associated with a disaster means a government will likely need to increase the level of social transfers it makes in the short term. This may be in the form of health and medical support, or the provision of temporary housing solutions.[85] The European Commission acknowledges that support required for vulnerable parties within the economy may extend beyond those of household and firms to financial institutions.[86] In addition, governments themselves may suffer credit-risk, and see their international financial accessibility impacted.[87]

3.54 As well as public spending rising, the other side of the fiscal balance sheet may also be affected. As explained in sections 3.2.2 and 3.3.1 above, when extreme weather disrupts local economies, productivity declines, leading to lower output and reduced business profits. The Inter-American Development Bank (IDB) recognises the potential for business revenues to decline due to lost hours of work and international trade disruption,

[83] OECD (2019), 'Fiscal Resilience to Natural Disasters', 20 May, https://www.oecd.org/en/publications/fiscal-resilience-to-natural-disasters_27a4198a-en.html, accessed 1 November 2024.
[84] Economic Policy Institute (2017), 'The potential macroeconomic benefits from increasing infrastructure investment', 18 July, https://www.epi.org/publication/the-potential-macroeconomic-benefits-from-increasing-infrastructure-investment/, accessed 1 November 2024.
[85] OECD (2019), 'Fiscal Resilience to Natural Disasters', 20 May, https://www.oecd.org/en/publications/fiscal-resilience-to-natural-disasters_27a4198a-en.html, accessed 1 November 2024.
[86] European Commission (2022), 'The Fiscal Impact of Extreme Weather and Climate Events: Evidence for EU Countries', Discussion Paper 168, July, https://economy-finance.ec.europa.eu/system/files/2022-07/dp168_en.pdf, accessed 1 November 2024.
[87] European Commission (2022), 'The Fiscal Impact of Extreme Weather and Climate Events: Evidence for EU Countries', Discussion Paper 168, July, https://economy-finance.ec.europa.eu/system/files/2022-07/dp168_en.pdf, accessed 1 November 2024.

among other drivers,[88] which could lead to reduced accounting profit for firms. As personal income and corporate profits fall, the tax base reduces and therefore tax revenue is likely to suffer.[89] For low income countries, the IDB estimates an average decline in annual government revenues of 1.1% for countries that experience at least one extreme weather event during the year.[90] This is associated with an increase in the budget deficit of 0.9%. As highlighted, the cumulative effect of lower tax income and increased public spending can create a precarious fiscal situation for governments, limiting their ability to respond effectively to ongoing and future climate-related challenges.

3.5 Conclusion

3.55 Taken together, the economic impacts of climate-related extreme weather events span immediate financial losses, disruptions to essential infrastructure, and longer-term human and social consequences. These impacts are often interconnected, with initial damages to physical assets and infrastructure creating ripple effects that can disrupt productivity, shift populations, and strain public resources. This underscores the significant burden these events place on economies, while also highlighting the potential for exacerbated inequality, especially in regions most exposed to climate shocks.

[88] IADB (2021), 'What are the fiscal risks from extreme weather events and how can we deal with them?', September, https://blogs.iadb.org/gestion-fiscal/en/what-are-the-fiscal-risks-from-extreme-weather-events-and-how-can-we-deal-with-them/, accessed 1 November 2024.
[89] European Commission (2022), 'The Fiscal Impact of Extreme Weather and Climate Events: Evidence for EU Countries', Discussion Paper 168, July, https://economy-finance.ec.europa.eu/system/files/2022-07/dp168_en.pdf, accessed 1 November 2024.
[90] IADB (2021), 'What are the fiscal risks from extreme weather events and how can we deal with them?', September, https://blogs.iadb.org/gestion-fiscal/en/what-are-the-fiscal-risks-from-extreme-weather-events-and-how-can-we-deal-with-them/, accessed 1 November 2024.

4 Quantifying the economic damage to physical assets and human capital associated with extreme weather events

4.1 Introduction

4.1 In section 3 we presented qualitative evidence on a wide range of economic impacts associated with extreme weather events linked to climate change, drawing from the literature and existing evidence. In this section, we focus on quantifying a subset of these impacts: the destruction of physical assets and the lost productivity from loss of human capital (measured by early deaths that could have otherwise been avoided). In order to quantify these effects, we use data on extreme weather events compiled by the University of Louvain in Belgium and the World Health Organization (the 'EM-DAT dataset'), alongside publicly available data for every country globally.

4.2 It is important to acknowledge that quantifying the costs associated with extreme weather events is inherently challenging due to several limitations. The available data, including the EM-DAT dataset, may not comprehensively capture all events or their full impacts, and the quality of reporting varies across countries and over time. Additionally, the estimates rely on several assumptions to fill gaps in the data, which are set out below. As such, our estimates should be treated as illustrative, providing an indication of the scale of the subset of impacts quantified rather than a precise estimate. These estimates are intended to help understand the magnitude of a subset of the categories of economic impact of extreme weather events, rather than to provide a definitive monetary value. They should be seen as a lower bound, as they do not capture the full scope of potential costs outlined in section 3 above.

4.2 Methodology and data sources

4.3 As mentioned above, we quantify some of the costs related to both physical assets and human capital lost due to climate-related extreme weather events. For physical assets, we capture the economic cost of rebuilding, insurance claims, and the total damage figures linked to a range of such events. For human capital, we estimate the economic cost of early deaths resulting from these events, reflecting the loss of potential economic contribution that would have occurred in the absence of the disaster. Further details on the data sources used for these estimates, as well as a more in-depth explanation of what we are quantifying, are provided in the subsections below.

4.2.1 Data sources

4.4 In order to estimate these impacts we use data from a number of sources.

EM-DAT database

4.5 This database is compiled by the Centre for Research on the Epidemiology of Disasters (CRED) at the University of Louvain in Belgium, originally set up as a joint initiative with the World Health Organization.

4.6 EM-DAT has been collecting disaster data since 1988, although CRED notes that the dataset is most complete from 2000 onwards. For our purposes, this is sufficient, as our analysis focuses on the last ten years, from 2014 to 2023. The database draws on a variety of sources, including UN bodies, governmental and non-governmental agencies, insurance companies, research institutes, and the press.

4.7 To be included in the dataset, events must meet a minimum threshold of either ten deaths, 100 people affected, a declaration of state of emergency, or a call for international assistance.[91] However, because the data is compiled from multiple sources, coverage is more complete in some areas than others. Larger events that are widely reported are generally well captured, but smaller, underreported events may be missing. Similarly, in regions such as Sub-Saharan Africa, where insurance coverage is less widespread, cost estimates may be more limited due to a lack of available data from insurers. Despite these limitations, EM-DAT is a robust and reliable source, and it is the best available dataset for our purposes. While it may provide a conservative estimate of costs—as not all events or cost categories may be fully captured—it enables us to quantify

[91] There are instances where the EM-DAT dataset records the same event across multiple countries, such as Hurricane Irma impacting the US, Cuba, Antigua, and other Caribbean islands. Analysis for this report has been conducted at an event-country level (rather than event level) to ensure impact can be attributable to countries.

the economic impact of 3,973 events across six continents since 2014.[92]

Publicly available data

4.8 To conduct our analysis, we rely on a range of additional data points, collected from publicly available sources. For each country, this includes: population,[93] gender[94] and age demographics,[95] labour force participation,[96] retirement age,[97] GVA,[98] and life expectancy.[99] The data covers the period from 2014 to 2023. Where data for certain years is unavailable—for instance, in the more recent years (2023) where data has not yet been published or where country-specific data is missing (such as retirement age in specific countries)—assumptions have been made to address these gaps.[100]

4.3 Destruction of physical assets

4.9 The destruction of physical assets includes costs that relate to rebuilding, insurance claims, and other damages to assets that may not be insured. We use the 'total damage' figure from the EM-DAT dataset, which is defined as the 'value of all economic losses directly or indirectly due to the disaster, in thousands of

[92] Although there are seven continents, there have been no recorded climate-related events in Antarctica in the EM-DAT dataset.
[93] World Bank Group, 'Population, total', https://data.worldbank.org/indicator/SP.POP.TOTL, accessed 1 November 2024.
[94] World Bank Group, 'Population, male (% of total population)', https://data.worldbank.org/indicator/SP.POP.TOTL.MA.ZS, and 'Population, female (% of total population)', https://data.worldbank.org/indicator/SP.POP.TOTL.FE.ZS, accessed 1 November 2024, respectively.
[95] United Nations Population Division (2024), 'Demographic indicators', https://population.un.org/wpp/Download/Standard/MostUsed/, accessed 1 November 2024.
[96] World Bank Group, 'Labour force, total', https://data.worldbank.org/indicator/SL.TLF.TOTL.IN, accessed 1 November 2024.
[97] OECD (2023), 'Pensions at a Glance 2023', 13 December, https://www.oecd.org/en/publications/2023/12/pensions-at-a-glance-2023_4757bf20.html; International Social Security Association, 'Pensionable ages', https://www.issa.int/databases/country-profiles/pensionable-ages, accessed 1 November 2024, respectively.
[98] World Bank Group, 'Gross value added at basic prices (GVA) (current US$)', https://data.worldbank.org/indicator/NY.GDP.FCST.CD, accessed 1 November 2024.
[99] United Nations Population Division (2024), 'Demographic indicators', https://population.un.org/wpp/Download/Standard/MostUsed/, accessed 1 November 2024.
[100] For unavailable years, we have used an average annual growth rate over a proceeding five-year period, and applied it to the previous year's value to forecast data. For 2023, we used 2018 to 2022, and to forecast 2024 we used 2018 to 2023. This was applied to missing data on population, labour force, gender population splits, and median age. We applied a similar principle to forecast GVA, however decided to exclude annual growth rates for 2020 and 2021 due to the impact of Covid-19 on economic data. Where missing data specific to a country cannot be imputed (e.g. retirement age), judgements have been made to complete the data. This was achieved by comparing countries with a similar GDP per capita, and also observing data from neighbouring countries if appropriate. This occurred on a very small number of countries, thus representing a very small fraction of climate-related deaths. We also used life expectancy data as a robustness check on our retirement age estimates. We limited the estimated retirement age so that it could not exceed the life expectancy of a specific country.

US dollars ('000 US$), relative to the start year'.[101] The dataset provides total damage estimates for 1,294 extreme weather events from 2014 to 2023.

4.10 It is important to note that this figure is likely to be an underestimate, as economic losses are generally less well reported in the dataset compared to human impact variables (which we use to estimate the destruction of human capital in section 4.4 below).[102] In addition, there is likely to be a lag in the reporting of these estimates, as the true cost of an extreme weather event may not be fully known until months or even years after the event. As a result, the total damage figures presented should be considered conservative estimates. This is reflected in the EM-DAT dataset for 2024, where we observe less reporting of total damage figures. For this reason, 2024 has been excluded from the analysis.

4.4 Destruction of human capital: early deaths

4.11 As explained in section 3.3.1 above, in the absence of climate-related extreme weather events, many of those who died prematurely would have continued to live and actively participate in the labour force, contributing to their country's economic output. Our estimate measures the aggregate lost earnings over the remaining working lives of individuals whose deaths were caused by such events. Lost output is expressed as GVA per person, which reflects both employment costs and a profit margin.

4.12 There are alternative methods for estimating the economic impact of premature deaths, including welfare-based approaches, such as the Value of a Statistical Life (VSL). This captures the amount individuals are willing to pay to reduce mortality risk. In contrast, the approach adopted here quantifies losses based on productivity impacts, providing a narrower economic measure. While VSL offers a broader societal perspective, which extends beyond productivity loss to include emotional, social, and cultural contributions to communities, a productivity-based measure provides a more direct and conservative estimate of economic losses from premature

[101] EM-DAT Documentation, 'Economic Impact Variables', https://doc.emdat.be/docs/data-structure-and-content/impact-variables/economic/, accessed 1 November 2024.
[102] EM-DAT Documentation, 'Specific Biases', https://doc.emdat.be/docs/known-issues-and-limitations/specific-biases/, accessed 1 November 2024.

deaths, representing a lower bound that focuses specifically on lost economic output.

4.13 To calculate this, we first take the number of deaths reported in the EM-DAT dataset and estimate how many of the deceased would have been people active in the labour force. We then estimate the output (in terms of GVA) that these individuals would have contributed during their remaining working years, based on the difference between their age at the time of death and the retirement age in their country.[103]

4.14 This approach involves several assumptions: we focus only on the working population (reflecting labour participation rates), assume that extreme weather events affect people equally, account for gender differences where relevant (e.g. differences in retirement age between men and women) and take a static measure of GVA per person, using the GVA from the year of the event, without accounting for potential future GVA growth.

4.5 Findings

4.5.1 Overall findings

4.15 Over the ten-year period from 2014 to 2023, we find that the economic cost associated with nearly 4,000 climate-related extreme weather events amounted to $2 trillion in 2023 prices.[104] This includes both the economic cost associated with the destruction to physical assets, and the destruction of human capital in the form of early deaths. In the most recent two years considered—2022 and 2023—the cost was $451 billion in 2023 prices.

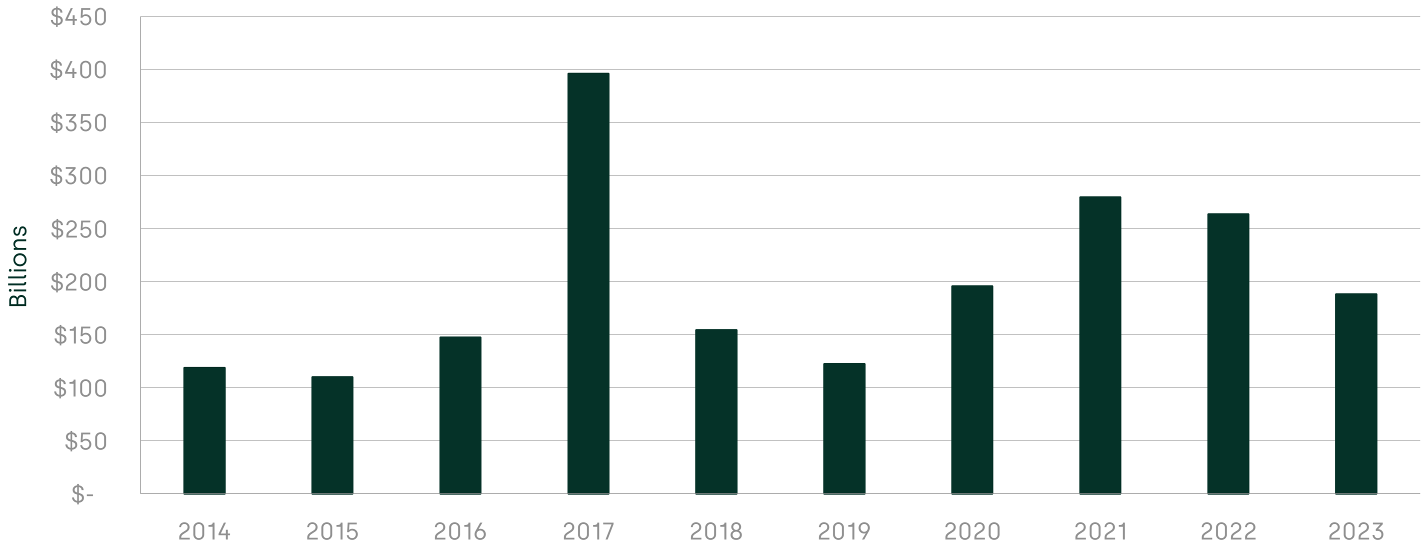
[103] We estimate the number of years an individual would have remained in the labour force by taking the difference between the retirement age and the median age in each country. Where retirement age data was unavailable, we estimated it using the retirement ages of similar countries, both geographically and in terms of GDP per capita. Where appropriate data is still unavailable, we have recorded the male and female life expectancy in this country and assumed an individual will be working up to this age. While we could have considered a distribution of ages affected, using the median age is a reasonable simplification for estimating lost working years due to premature death. Although a distribution of ages might provide more granularity, the median age captures the central point of the age distribution. Provided the median age is representative of the working population, the difference between using the median and a more complex distribution is unlikely to significantly affect the results, particularly given other assumptions in the model (such as retirement age and labour participation rates). Since extreme weather events typically affect a broad cross-section of the population, and assuming the age distribution of fatalities is not heavily skewed away from the median, any potential variation is unlikely to result in a substantial difference in the final output. One potential exception could be extreme heat events, which may disproportionately impact older populations. However, we do not expect this to have a material effect on the model's outputs.

[104] This total, and figures throughout the rest of the report, are expressed in 2023 USD.

4.16 As explained throughout this report, these estimates are likely to be a significant underestimate of the true economic cost of climate-related extreme weather events, as it quantifies only a subset of the various impacts listed in section 3 above. Additionally, underreporting biases in certain regions within the EM-DAT dataset, as discussed earlier, contribute to this underestimation. Nevertheless, these figures can serve as a useful lower bound, illustrating the economic impact that is already being felt today due to climate-related extreme weather events.

4.17 As shown in Figure 4.1 below, with the exception of 2017, where there was a particularly active Atlantic hurricane season, average annual losses have been broadly increasing. The average annual economic impact from climate-related extreme weather events increased from $190 billion (the eight-year average for 2014–2021) to $226 billion across 2022 and 2023, representing a 19% increase.

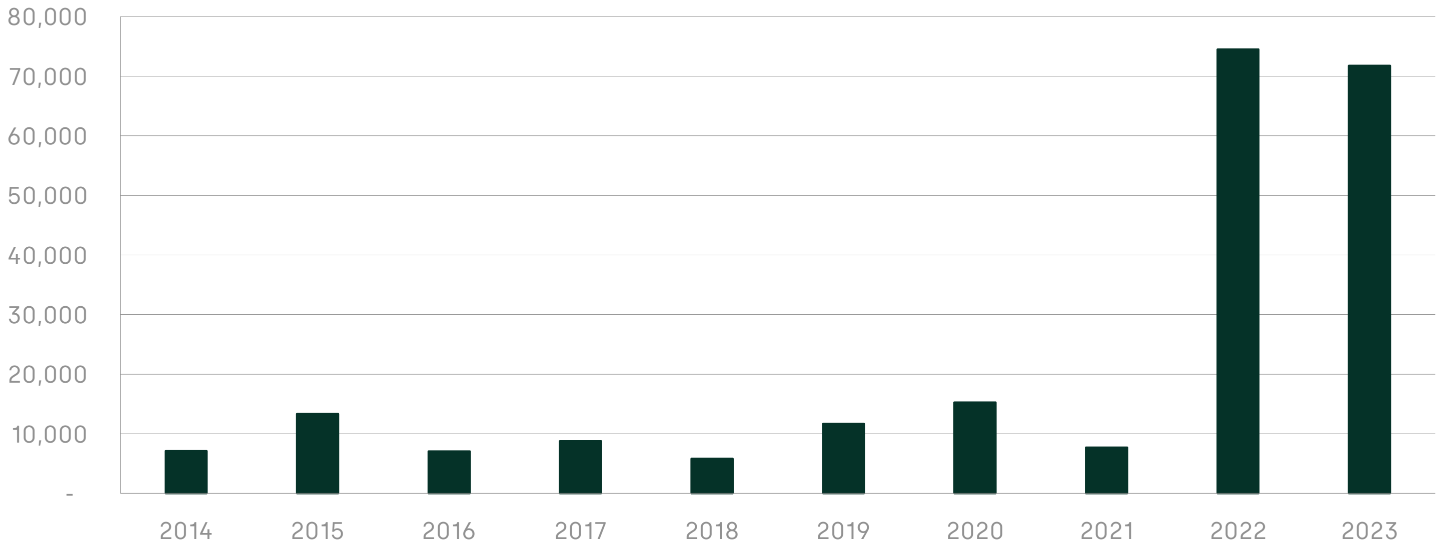
Figure 4.1 Economic impact of climate-related extreme weather events, 2014 to 2023



Note: all results expressed in terms of 2023 USD. The spike in 2017 is due to an active Atlantic hurricane season, causing significant destruction in the region. The year 2017 saw the first (Hurricane Harvey, US), third (Hurricane Maria, Puerto Rico), and fifth (Hurricane Irma, US) largest events by economic impact across all years. These three events alone accounted for 70% of the estimated economic impact recorded in 2017.
Source: Oxera analysis of EM-DAT dataset and publicly available data sources listed in section 4.2.1 above.

4.18 Over the ten-year period, approximately 95% of the economic cost estimated stems from the destruction of physical assets, while the remaining 5% is attributable to economic losses linked to early deaths caused by extreme weather events (human impact). Whilst the losses associated with physical assets has increased over the last decade (with the exception of 2017, see note to Figure 4.1 above), the economic impact from early deaths has seen a sharp rise in 2022 and 2023, see Figure 4.2 below. There are just over 350,000 climate-related deaths recorded in the EM-DAT between 2014–2023, with 60% occurring in these last two years (this is discussed at para. 4.20 below).

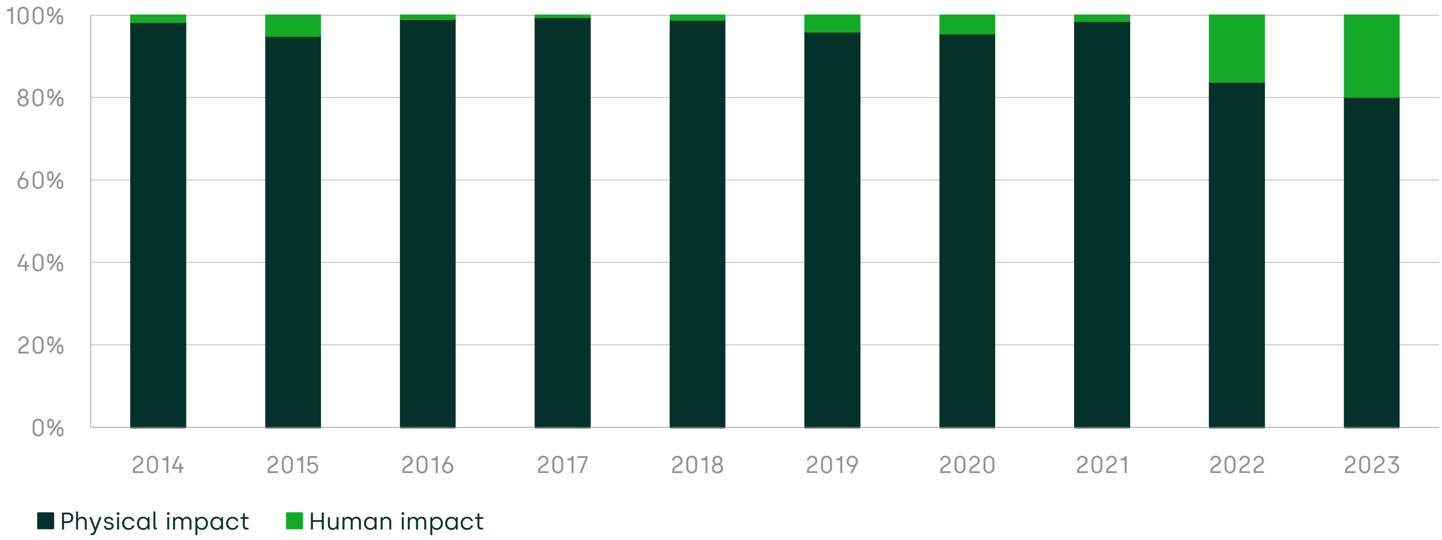
Figure 4.2 Number of annual climate-related reported deaths



Note: climate-related deaths defined as all deaths occurring in Meteorological, Hydrological and Climatological events in the EM-DAT dataset.
Source: Oxera analysis of EM-DAT dataset.

4.19 Consequently, human impact costs make up a larger proportion of the economic cost estimated in 2022 and 2023. As illustrated in Figure 4.3 below, of the $451 billion estimated economic impact in 2022 and 2023, almost $80 billion (18%) has resulted from the 145,000 climate-related deaths occurring over these two years.

Figure 4.3 Proportion of economic cost attributable to loss of physical vs. human assets



Source: Oxera analysis of EM-DAT dataset and publicly available data sources listed in section 4.2.1 above.

4.20 The rise in the number of climate-related deaths in 2022 and 2023 is largely a result of the increased reporting and quantification of excess mortality in Europe. The years 2022 and 2023 have not just been the warmest years on record, but also some of the wettest, leading to large-scale impact across the continent. These extremes have led to heatwaves, wildfires, droughts, and flooding. The increasing severity of extreme weather events has also led to increased efforts to quantify and measure human impact, whether that be excess mortality or number of individuals affected. Across Europe alone, the number of heat-attributable deaths stood at almost 110,000 across 2022 and 2023, whereas there were only 13,000 across the preceding eight years from 2014 to 2021. In response, the UN Secretary, General Antonio Guterres, was noted as saying:[105]

'Sirens are blaring across all major indicators... Some records aren't just chart topping, they're chart-busting. And changes are speeding-up'

4.21 Whilst this increased reporting of heat-attributable deaths has helped uncover a clear human impact, it also highlights the

[105] United Nations (2024), 'Leaders "Must Step Up and Act — Now" to Address Climate Change, Says Secretary-General, in Message on Launch of Global Report', 19 March, https://press.un.org/en/2024/sgsm22168.doc.htm, accessed 1 November 2024.

near-absence of reported impacts in other regions of the world, such as Sub-Saharan Africa. In the EM-DAT dataset, just one heatwave was reported in Sub-Saharan Africa between 2014–2023, compared to 93 in Europe. As set out in section 2.4 above, the World Bank Group considers the number of people vulnerable to climate shocks to be considerably larger than in Africa than in Europe, and with the underreporting of data from the region, the true economic costs will be significantly underestimated. Due to the income differences between Europe and Sub-Saharan Africa, a similar increase in reporting would not lead to an equivalent increase in absolute terms, but it is likely that the true costs of climate-related extreme weather events will far exceed the $2 trillion quantified in this analysis.

4.5.2 Impacts of events by country

4.22 As shown in Table 4.1 below, when looking at the economic costs in absolute terms, the distribution of impact is concentrated in countries with large populations, large economies and well-established institutions that report on climate-related events. It is therefore unsurprising to see the US, China and India at the top of the list.

Table 4.1 Ranking of countries by economic cost from climate-related extreme weather events, 2014–2023

Rank	Country	Sum of economic impact 2014–2023 (Billion, USD 2023)
1	United States	$934.7
2	China	$267.9
3	India	$112.2
4	Japan	$90.8
5	Puerto Rico*	$87.3
6	Germany	$65.4
7	Italy	$35.0
8	Australia	$33.7
9	France	$29.4
10	Brazil	$24.8

Note: As noted elsewhere in this report, the absence of a country from this ranking does not necessarily imply that its impacts are less severe than those listed. Instead, it may reflect variations in reporting practices, with some countries providing more comprehensive data on the economic impacts of climate-related extreme weather events than others. *We acknowledge that Puerto Rico is a territory of the US rather than

an independent country. However, the EM-DAT dataset categorises Puerto Rico separately, which is why we have listed it independently from the US in our analysis.
Source: Oxera analysis of EM-DAT dataset and publicly available data sources listed in section 4.2.1 above.

4.23 Despite accounting for the largest economic losses, many of these countries show much lower losses on a per capita basis. As shown in Table 4.2 below, in general, it is smaller, and lower-income countries which experience the highest level of per capita losses, demonstrating the inequality of impact between developed and less-developed nations.

4.24 It is also worth noting that the results presented in the table do not account for the potential scale of under-reporting in these regions. Therefore, the actual economic impacts could be significantly larger than those reflected in the current figures.

Table 4.2 Ranking of countries by economic impact per capita, 2014–2023

Rank	Country	Estimated Economic Impact, 2014–2023 (Billion, 2023 USD)	Population (Thousand)	Economic Impact per Capita (2023 USD)
1	Saint Martin (French part)	$5.1	32	$158,886
2	British Virgin Islands	$3.7	32	$118,245
3	Sint Maarten (Dutch part)	$3.1	41	$75,497
4	Dominica	$2.4	73	$33,278
5	Puerto Rico	$87.3	3,206	$27,248
6	Guam	$4.3	173	$24,862
7	Turks and Caicos Islands	$0.6	46	$13,493
8	Bahamas	$5.4	413	$12,976
9	Antigua and Barbuda	$0.3	94	$3,296
10	United States	$934.7	334,915	$2,791

Note: 2023 population figures used for per capita calculation.
Source: Oxera analysis of EM-DAT dataset and publicly available data sources listed in section 4.2.1 above.

4.5.3 Impact of events by disaster

4.25 Table 4.2 above ranks the top ten countries by per capita economic impact over the ten-year period from 2014–2023. In many cases, a country's position in the top ten is largely due to a single, high-impact disaster within the period. When focusing on a shorter time horizon, or a specific extreme weather event, the economic burden of a single event relative to the country's output becomes clear.

4.26 The EM-DAT dataset shows that the largest events by estimated economic impact are concentrated in the Americas, and are largely driven by the Atlantic hurricane season. As seen in Table 4.3 below, seven of the top ten largest events in absolute terms are in the Americas, with hurricane Harvey in 2017 causing over $118 billion of economic impact. While this may, in part, be because this is the region with the most established reporting, it may also relate to the relatively high economic value and replacement costs of assets within the region. Consequently, similar extreme weather events are likely to incur higher absolute costs in the US compared to lower-cost regions.

Table 4.3 Ranking of economic impact by singular disaster, including country, year, and type of disaster, 2014–2023

Rank	Country	Year	Subtype	Event Name	Economic Impact (Billion 2023 USD)
1	United States	2017	Storm	Hurricane Harvey	$118.3
2	United States	2022	Storm	Hurricane Ian	$104.5
3	Puerto Rico	2017	Storm	Hurricane Maria	$84.6
4	United States	2021	Storm	Tropical Storm Ida	$73.3
5	United States	2017	Storm	Hurricane Irma	$71.1
6	Germany	2021	Flood		$45.2
7	United States	2021	Storm		$34.2
8	China	2016	Flood		$28.0
9	China	2023	Storm	Tropical Cyclone Doksuri	$25.0
10	United States	2022	Drought		$23.2

Note: When an event name is missing from the table, it indicated that the EM-DAT dataset did not attribute a name to that event. While hurricanes and cyclones are commonly names, events like storms and droughts typically are not.
Source: Oxera analysis of EM-DAT dataset and publicly available data sources listed in section 4.2.1 above.

4.27 The estimates above provide an indication of the scale of impact, but presenting losses as a proportion of total output can give a clearer indication of where the relative impacts are felt the most. For example, while large in absolute terms, hurricane Harvey, from 2017, represented a total impact of just 1% of the US's annual GVA in 2017. Table 4.4 below illustrates the countries most impacted by climate-related events, as a proportion of total output.

4.28 It is important to note that the loss as a percentage of total GVA exceeds 100% for Dominica and Sint Maarten. This situation arises because these countries experienced a single significant event within the ten-year time frame.[106] While such extreme occurrences are not expected to happen every year, this demonstrates how one major event can have a significant impact on the total economic output of a small nation, raising concerns about sustainability and the long-term implications of repeated disasters.

Table 4.4 Ranking of countries by economic cost from single climate-related extreme weather events as a proportion of annual GVA

Rank	Country	Year	Economic Impact (Billion, 2023 USD)	Annual GVA (Billion, 2023 USD)	Loss as a % of total GVA
1	Dominica	2017	$1.8	$0.5	333%
2	Sint Maarten (Dutch part)	2017	$3.1	$1.6	197%
3	Dominica	2015	$0.6	$0.6	106%
4	Vanuatu	2015	$0.6	$0.8	69%
5	Puerto Rico	2017	$84.6	$127.9	66%
6	Turks and Caicos Islands	2017	$0.6	$1.1	58%
7	Grenada	2024	$0.4	$1.1	38%
8	Bahamas	2019	$4.4	$13.8	32%
9	Tonga	2020	$0.1	$0.5	27%
10	Antigua and Barbuda	2017	$0.3	$1.7	18%

[106] Dominica 2017 – Hurricane Maria; Sint Maarten 2017 – Hurricane Irma; Dominica 2015 – Hurricane Erika.

Source: Oxera analysis of EM-DAT dataset and publicly available data sources listed in section 4.2.1 above.

4.29 Our findings underscore the significant economic toll of climate-related extreme weather events already being incurred globally. This $2 trillion estimate, representing only lower bound, highlights that the true cost is likely to be much higher when considering underreported impacts and indirect effects across sectors. The results also reveal how a single severe event can have a disproportionate impact on smaller economies—in some cases, multiple times the annual output—illustrating both the immediate economic strain and the long-term fiscal and social challenges these nations face in rebuilding and recovering.

4.5.4 Affected people

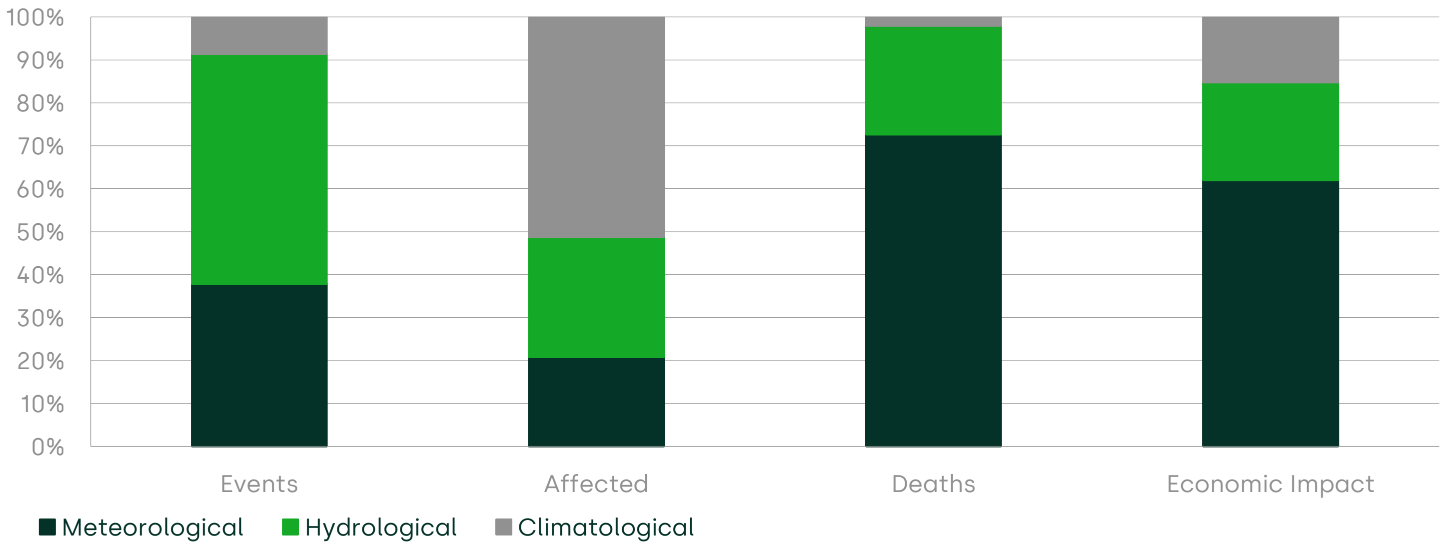
4.30 While the totals in the analysis above account for the monetary impact associated with productivity loss due to early deaths, they do not capture the less extreme, but significant, productivity losses for those indirectly affected by extreme weather events.

4.31 Individuals who are injured and require recovery time, displaced from their homes, or obliged to take time off work for repairs or caregiving, represent a notable group whose productivity is disrupted. The EM-DAT dataset provides figures on the total number of people affected by these events. There is also the possibility of lost productivity for those still working but dealing with the trauma and aftermath of the event.

4.32 In principle, it would be possible to quantify the associated productivity losses for this group, though this would require additional data on the duration and extent of these impacts (e.g. time taken off work) which is currently unavailable. With this wider lens—encompassing not only output loss through premature deaths but also disruption for affected individuals—the economic impact reported would be higher.

4.33 Inclusion of the number of people affected can give a further indication of scale and distribution of impact. Depending on which type of impact is measured, there is significant variation by disaster type. Figure 4.4 shows how the event frequency, number of people affected, number of reported deaths, and economic impact is split across the three climate-related sub groups. Despite making up just over a third of all events, and 20% of all people affected, meteorological events (including hurricanes and storms) are responsible for over 70% of all reported deaths and 60% of economic impact. In comparison, hydrological events (including floods and landslides) have a higher frequency (over 50% of events), but contribute to over 20% of reported deaths and economic impact.[107]

Figure 4.4 Proportion of number of events, number of people affected, number of reported deaths, and economic impact by event subgroup

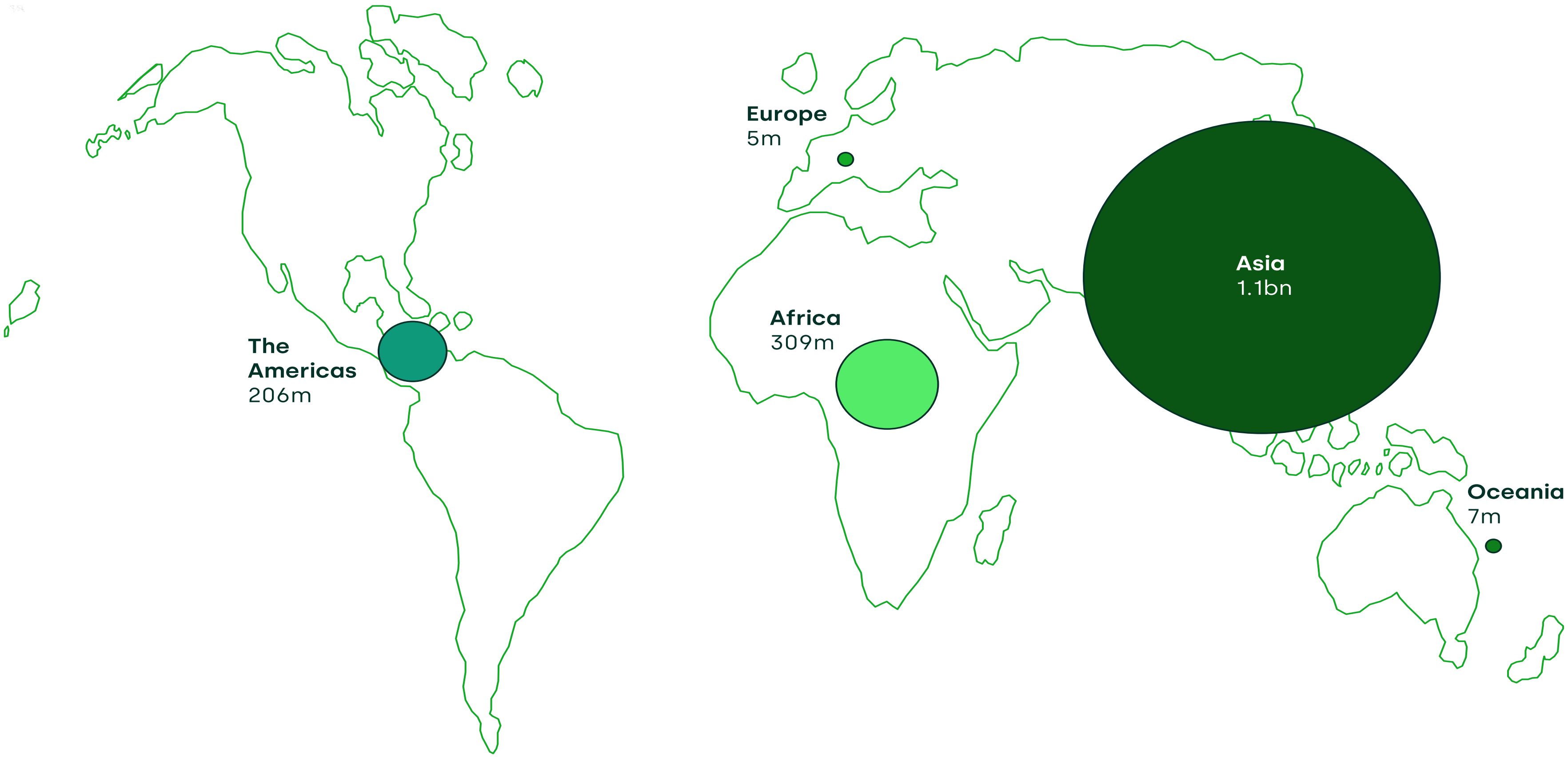


Source: Oxera analysis of EM-DAT dataset and publicly available data sources listed in section 4.2.1 above.

4.34 Figure 4.5 illustrates the distribution of people affected by region, with circle sizes scaled to reflect the absolute numbers in each area. The high impact on Asia is evident; however, as the continent includes some of the world's largest and most densely populated countries, this figure aligns closely with population shares. Major events have significantly contributed to these numbers, such as the 2015 drought in India (affecting over 330 million people), the 2016 floods in China (impacting 60 million people), and the 2022 flooding in Pakistan that left nearly a third of the country underwater (affecting 33 million people).

[107] This is largely driven by drought in Asia and Africa. These events have many millions affected, but comparatively few deaths recorded.

Figure 4.5 Distribution of number of people affected by region



Note: regions aligned with those reported in the EM-DAT dataset.
Source: Oxera analysis of EM-DAT dataset and publicly available data sources listed in section 4.2.1 above.

4.35 We also note the distribution of reported deaths across the different regions, shown in Figure 4.6 below. Despite having roughly 10% of the world's population, 35% of all climate-attributable reported deaths have occurred in Europe. In practice, the likely reason for this disproportionate impact is, as mentioned throughout this report, driven by differences in reporting. The efforts to quantify heat-attributable deaths over the European heatwaves of 2022 and 2023 start to give a sense of what the true scale of climate-related deaths could be if reporting was improved across the globe.

4.6 Conclusion

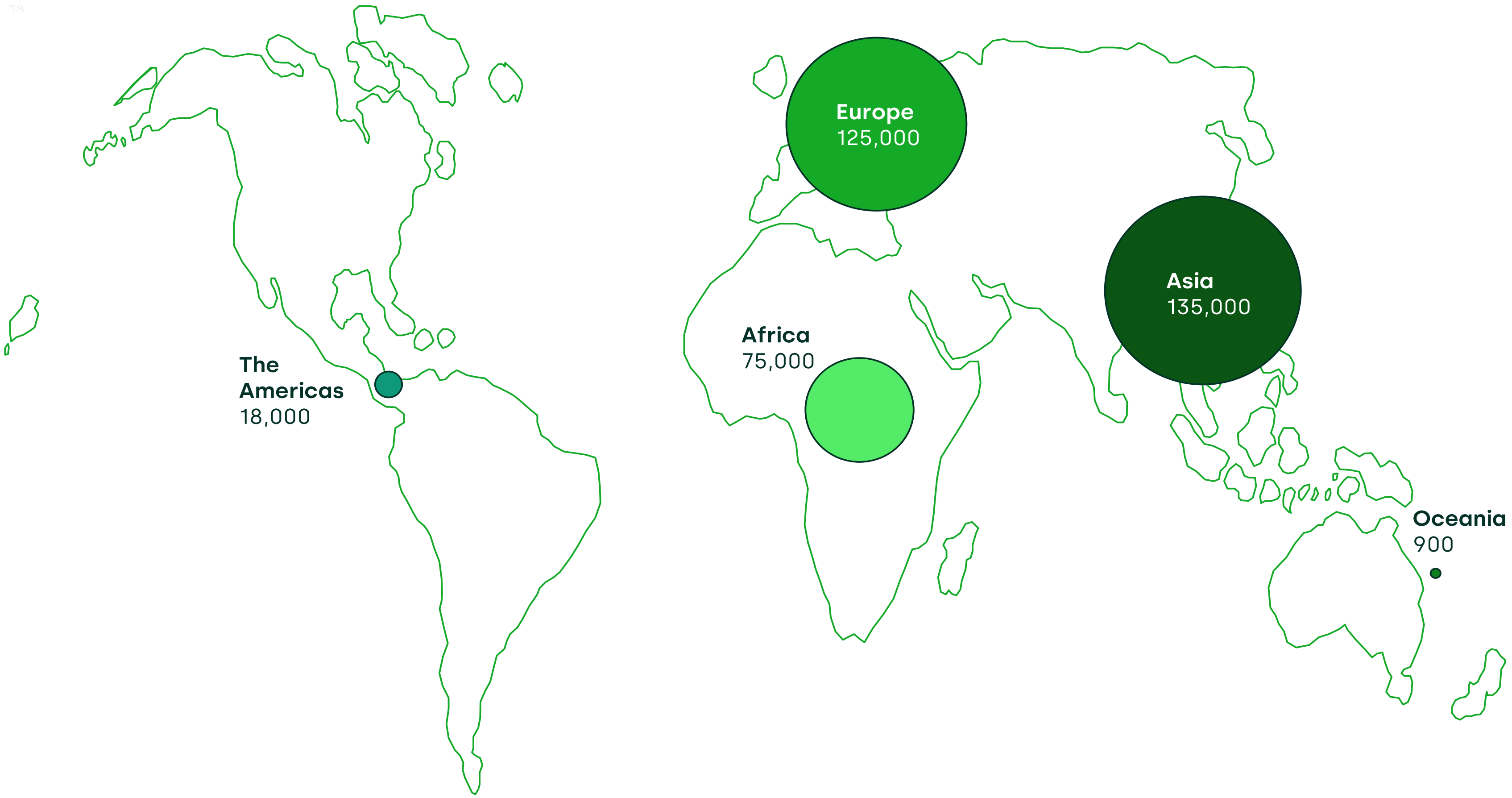
4.36 We estimate that nearly 4,000 climate-related extreme weather events from 2014 to 2023 created economic costs of $2 trillion. This figure reflects both the direct costs of physical asset destruction and human capital losses from premature deaths. However, it likely represents only a lower bound, as a result of underreporting and that it excludes numerous indirect and longer-term impacts such as effects on migration, social inequality, government finances, and shifts in investment priorities—all of which are critical in understanding the broader socio-economic toll of climate events.

4.37 Importantly, the distribution of impact varies significantly across regions, driven not only by underreporting and reporting biases but also by geography, demographic factors, such as population density, as well as economic differences, such as disaster preparedness and income levels.

4.38 An increasing focus on reporting climate events is raising awareness of the economic implications and helping to capture the true scale of the impact, especially in vulnerable areas where exposure to such events is high. Although large, defined events like hurricanes are currently among the most extensively recorded, climate change will likely introduce a higher frequency of less-visible events, such as heatwaves and droughts, that will cumulatively strain local and global economies.

4.39 Going forward, further research into the indirect, long-term effects and the broader social implications of climate-driven economic losses is needed to refine these estimates. Additionally, ongoing improvements in data collection, particularly in underreported regions, will help to provide a fuller picture of the scale and distribution of the impacts. Without substantial mitigation efforts, the economic burden is likely to continue to escalate, disproportionately affecting vulnerable regions and potentially driving deeper inequalities. Consequently, our estimates underscore an urgent need for adaptation strategies and investment in resilience to address both the immediate and the emerging effects of climate-related extreme weather events.

Figure 4.6 Distribution of number of reported deaths by region



Note: regions aligned with those reported in the EM-DAT dataset. As noted throughout the report, many climate-related extreme weather events are likely to be unreported in the EM-DAT database, and hence they are not captured this figure.
Source: Oxera analysis of EM-DAT dataset and publicly available data sources listed in section 4.2.1 above.

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