

In collaboration  
with Oliver Wyman



# Quantifying the Impact of Climate Change on Human Health

INSIGHT REPORT

JANUARY 2024



# Contents

Foreword	3
Executive summary	4
1 Understanding the link between climate change and human health	5
1.1 Climate change and the IPCC scenarios	6
1.2 The negative impacts of climate change on human health	9
2 Quantifying the impacts of future climate events on public health	11
2.1 Methodology for the climate-related health impact matrix	12
2.2 Deep dives on health impacts of the six weather-related events	18
3 Building climate-resilient health systems	35
3.1 Resistance and recovery, the two key pillars for sustainable health systems	36
3.2 Why policies and incentives need to change to enable climate-resilient health systems	38
Conclusion	44
Contributors	45
Endnotes	46

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# Foreword



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Climate change is having a profound impact on global health – whether it's connected to the dwindling supply of freshwater because of droughts, the increase in infectious disease in the aftermath of flooding or the toxic air pollution accompanying raging wildfires. There is no doubt that global warming and extreme weather events are exacerbating health issues worldwide and putting strain on healthcare systems already stretched to the limit in some regions.

Over the next decade, as detailed in the Forum's [Global Risks Report 2023](#), the failure to mitigate and adapt to climate change will represent our gravest risk globally, with changing climate and weather patterns already leading to alarming trends.<sup>1</sup> These include escalating new and existing pathogens, increases in air- and waterborne pollution and worsening extreme weather events such as heat waves, tropical storms and floods. Additionally, the health inequity gap has also begun to widen due to the effects of climate change on

vulnerable populations and geographies already facing hardship and limited access to high-quality, affordable healthcare.

As part of a collaboration between the World Economic Forum and Oliver Wyman, an economic analysis focussing on how climate will likely transform the health landscape over the next two decades was carried out. Our in-depth analysis – part of the Forum's Climate and Health initiative – also gauged climate's impact on the global economy and healthcare systems around the world and offered actionable strategies to mitigate and prepare for the anticipated threat.

Our goal with the report and initiative is to help the public and private sectors create more resilient and healthier communities. By raising awareness of the size and scope of the impending climate-driven health crisis, we hope to provide guidance to various regions and communities about how to use the limited time we have left to prepare.

# Executive summary

By 2050, climate change will place immense strain on global healthcare systems, causing 14.5 million deaths and \$12.5 trillion in economic losses.

While there has been much discussion about the impact of climate change on nature and the global economy, some of the most pressing consequences of the earth's rising temperatures will be on human health and the global healthcare system. This paper aims to quantify the health consequences of climate change, both in terms of the health outcomes themselves (mortality and healthy lives lost) and in terms of the economic costs to the healthcare system. Six major climate-driven event categories were analysed as important drivers of negative health impacts, including floods, droughts, heat waves, tropical storms, wildfires and rising sea levels.

The findings of the analysis showed that by 2050, climate change is likely to cause an additional **14.5 million deaths** and **\$12.5 trillion in economic losses** worldwide. Climate-induced impacts will account for a further \$1.1 trillion in extra costs to healthcare systems, creating a significant additional burden on already strained infrastructures and medical and human resources.

Of the weather events analysed, floods were found to pose the highest acute risk of climate-induced mortality, accounting for 8.5 million deaths by 2050. Droughts, indirectly linked to extreme heat, are the second-highest cause of mortality, with an anticipated 3.2 million deaths. Heat waves, which constitute a prolonged period of extreme temperatures and humidity, take the highest economic toll at an estimated \$7.1 trillion by 2050 due to the loss in productivity.

Climate change will trigger a catastrophic rise across several climate-sensitive disease outcomes, including vector-borne disease.

Warmer temperatures will increase both the breeding period and geographical range of mosquito colonies, leading to the expansion of diseases like malaria, dengue and Zika to moderate and previously less affected climate zones such as Europe and the United States. By 2050, an additional 500 million people may be at risk of exposure to vector-borne diseases.

Importantly, climate change will exacerbate global health inequities. The most vulnerable populations, including women, youth, elderly, lower-income groups and hard-to-reach communities, will be the most affected by climate-related consequences. Regions such as Africa and southern Asia face heightened vulnerability to climate change impacts exacerbated by existing resource limitations, adequate infrastructure and essential medical equipment, further complicating their ability to address and adapt to environmental challenges.

There is still time for the global economy to decisively reduce emissions and enact strategies to safeguard human health from the impacts of climate change. However, it is imperative for policy-makers to recognize and address the insufficient readiness of healthcare systems to mitigate health consequences. Unlike the case with COVID-19, which took governments and the global healthcare industry by surprise, a unique window exists to adapt and prepare healthcare infrastructures, workforces and supply chains for the escalating impact of the climate crisis. Collaborative efforts involving multiple stakeholders and industries are essential to address these challenges and to achieve a thorough and comprehensive health system transformation.



# 1 Understanding the link between climate change and human health

Climate change impacts health directly through disease and mental health issues, disproportionately affecting vulnerable communities.



# 1.1 Climate change and the IPCC scenarios

## Global warming scenarios and related causes

There are many megatrends that will characterize the 21st-century global economy. Yet none so perilous and disruptive as climate change – the mega trend that is likely to dictate the fate of all the others.

By the second decade of this century, Earth's temperature was 1.1°C above where it had been between the years 1850 and 1900, according to the United Nations Intergovernmental Panel on Climate Change (IPCC).<sup>2</sup> As a result, the world is experiencing severe tropical storms, life-threatening heat waves, droughts, wildfires, rising sea levels and flooding across the globe.

This increase in the severity of climate events is the result of the relentless rise in greenhouse gas (GHG) emissions that trap the sun's heat in the atmosphere and push Earth's temperature ever higher. These emissions have grown steadily since pre-industrial days, with a particularly rapid acceleration since the 1970s. There has not been a year since the turn of the millennium when emissions fell, with the exception of 2020 – the year the global economy was upended by the COVID-19 pandemic and most economic activity came to a standstill for months.<sup>3</sup>

Even after that disruption of more than a year, 2022 managed to break yet another emissions record, according to the International Energy Agency (IEA), and 2023 is expected to be higher still.<sup>4</sup> Carbon dioxide (CO<sub>2</sub>), methane and nitrous dioxide – the three principal greenhouse gases contributing to global warming – sustained historically high rates of growth last year, with CO<sub>2</sub> now 50% higher than its pre-industrial levels.

The recent COP28 produced bold commitments in relationship to the impact on health, including the endorsement of a Declaration of Climate and Health by more than 120 countries and pledges of over \$1 billion for health-related projects.<sup>5</sup> The newfound recognition of the scope of the global health crisis because of climate will help address this critical situation and may allow humanity to reduce the impact of climate-driven events on planetary health.

“ COP28 produced bold commitments on climate's impact on health, including a Declaration of Climate and Health endorsed by more than 120 nations.

### Using the appropriate scenario

The IPCC has now concluded that the most likely scenario for the trajectory of emissions by the year 2100 puts Earth's temperature more than 2.7°C higher than pre-industrial times.<sup>6</sup> That's 80% above the 1.5°C limit nations pledged to abide by in 2015 as part of the Paris Agreement on climate.<sup>7</sup>

The underlying causes of the increase in emissions are ever-expanding human economic activities – whether it be from burning fossil fuels, patterns of consumption and production or the world's land use and destruction of forests. To varying degrees, all regions and populations have contributed to climate change, and the entire planet will live with effects of global warming over the remainder of the century. There are multiple mitigation efforts currently underway, including the development of technologies and products that do not rely on fossil fuels, which, if sustained, can decrease GHG emissions, improve global health and bolster economic and political stability.

## Forecasting the impact of climate change through scenario planning

Over the past two decades, the IPCC has issued several different scenarios showing how global warming might evolve. In 2014, the IPCC issued the Representative Concentration Pathways (RCPs), which were created as a time series of long-term environmental effects of emissions, concentrations of the full suite of GHG, aerosols and chemically active gases, and land use.<sup>8</sup>

The four original pathways covered a wide range of radiative forcings, which referred to external factors that influence the Earth's energy balance by altering the amount of incoming or outgoing energy. This variation contributes to changes in climate patterns. The four original RCPs include the RCP2.6, RCP4.5, RCP6 and RCP8.5. Two new ones were added later, RCP1.9 and RCP7. All represent various emissions levels and climate states for Earth by 2100. A few years later, the Shared Socioeconomic Pathways (SSPs) were released.<sup>9</sup> These were an attempt to add economic and demographic trends and technology advancements to the environmental factors already considered. The SSPs present five distinct trajectories that Earth's global warming could follow. These pathways provide a comprehensive perspective on a “business as usual” world absent of future climate policies, with projected global warming in the year 2100 ranging from a minimum of 3.1°C to a maximum of 5.1°C above pre-industrial levels.

### Scenarios used in the climate and health model

The SSPs provide scenarios describing different socioeconomic and environmental conditions, including population growth, economic development, energy use and technological advancements. These narratives help to capture the range of possible futures based on different societal choices and policy decisions.

FIGURE 1 | SSPs as defined by the IPCC in 2100

Pathways <sup>1</sup>	Description	GDP per capita, <sup>2</sup> \$, thousands	World population, billions	RCP scenario	Average temperature increase <sup>3</sup> , °C	Radiative forcing, <sup>4</sup> Watts/m <sup>2</sup>	CO <sub>2</sub> concentration, <sup>5</sup> parts per million	CO <sub>2</sub> emissions per capita, tonnes
SSP1	<b>Sustainability:</b> gradual shift to sustainable, inclusive, well-being-focused development	81	7.0	–	–	–	–	–
SSP2 – 6.0	<b>Middle of the road:</b> steady progress with persistent challenges in development, trends broadly follow their historical patterns	60	9.0	6.0	3.23	5.5	704	6.1
SSP3	<b>Regional rivalry:</b> nationalism and security concerns hinder global development efforts	21	12.6	–	–	–	–	–
SSP4	<b>Inequality:</b> growing inequalities, fragmented societies and technological disparities	38	9.3	–	–	–	–	–
SSP5	<b>Fossil-fuelled development:</b> rapid and unconstrained growth in economic output and energy use	140	7.4	–	–	–	–	–

**Notes:** 1 Shared Socioeconomic Pathways; 2 Gross domestic product in 2005 dollars, adjusted for inflation and cross-country price differences; 3 Relative to the pre-industrial era (year 1750); 4 Difference in incoming and outgoing energy in Earth’s climate system, Watts per square meter; 5 Measured in carbon dioxide parts per million.

**Source:** Riahi et al. (2017), ourworldindata.org Data Explorer; Oliver Wyman analysis

The RCPs, on the other hand, focus on quantifying the radiative forcing levels associated with different GHG concentration trajectories. They provide specific pathways for future GHG emissions and concentrations, which are used as inputs for climate models to project future climate change.

By combining the SSPs with the RCPs, researchers can explore the interactions between socioeconomic factors and GHG emissions and how they contribute to future climate outcomes. This combination allows for a more comprehensive analysis of the potential impacts of different socioeconomic pathways on climate change, helping policy-makers and researchers understand the range of alternative future scenarios and make informed decisions on that understanding.

As the basis for this study, SSP2, the “middle of the road” scenario, was chosen in combination with RCP6. The two scenarios most closely resemble current trendlines on the various factors being considered. The choice is justified based on assumptions about the emissions trajectory, policy relevance, scientific consensus, comparability and the range of impacts captured.

Based on the research, RCP6 offers the most realistic RCP choice compared to today’s outlook. The alternative RCP4.5 considers GHG emissions that are lower than current levels, while RCP7 is associated with very high GHG emissions that appear extreme given current trends.

Recent studies support the choice of the SSP2-RCP6 scenario considering temperature projections. For example, the United Nations Environment Programme’s emissions report, released in November 2023, finds the world heading for a rise in temperature of 2.5° to 2.9°C above pre-industrial levels unless countries step up action and deliver more than promised on their 2030 pledges under the Paris Agreement.<sup>10</sup>

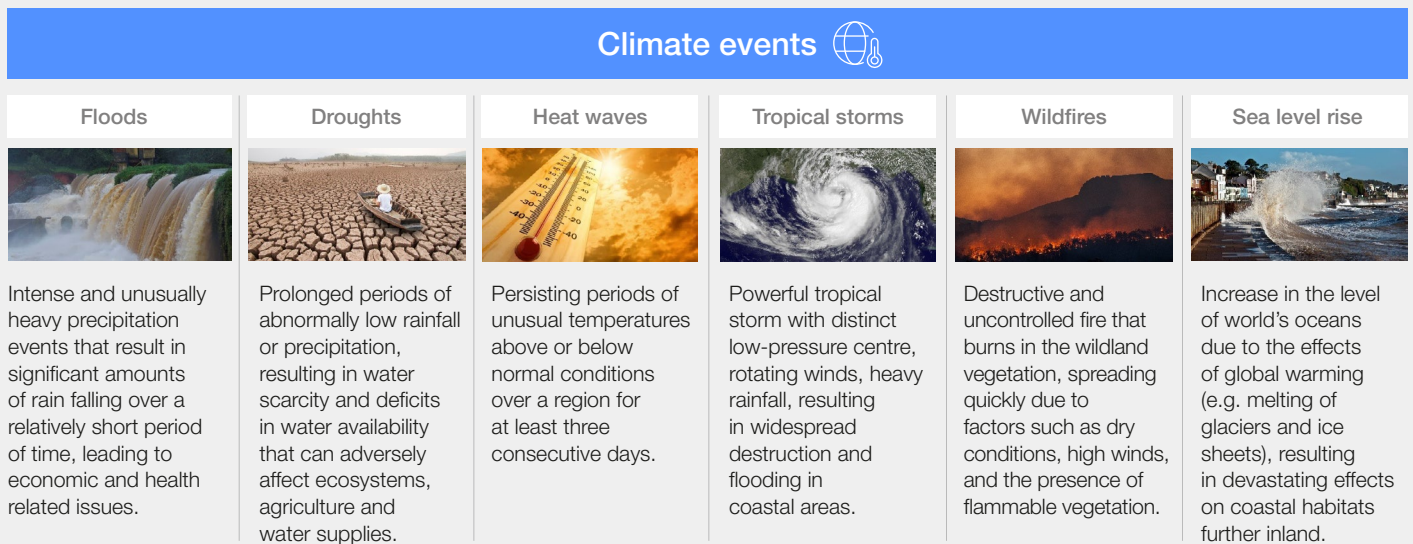
## Extreme weather events

Regardless of which scenario prevails, climate change is already to blame for temperature anomalies and air pollution spikes, as well as extreme weather-related events such as droughts, wildfires, severe tropical storms, prolonged heat waves, rising sea levels, intense rainfall and flooding.

Even with only a 1.1°C increase in the Earth’s temperature, these events are causing significant destruction to nature and infrastructure, widespread economic losses, sickness and death. For instance, by September 2023, the United States had already set a record for billion-dollar natural disasters, with almost four more months left in the year, according to the National Oceanic and Atmospheric Administration (NOAA).<sup>11</sup> This list of disasters included several tropical storms, wildfires on the Hawaiian island of Maui, flooding in Vermont and torrential rains in California.



FIGURE 2 | The effects of rising temperatures on weather



Sources: IPCC Sixth Assessment Report (AR6)

The six weather-related natural disasters, highlighted by the IPCC sixth report as having been most affected by climate change, were used as a starting point for the quantification exercise. These climate events have been widely assessed and modelled in scientific literature.

- Climate change can affect the intensity and frequency of precipitation. The rising temperatures of the world's oceans increase the amount of water that evaporates into the air and causes polar ice to melt more rapidly. This has added to rainfall totals and water table levels in some areas and led to **flooding**. High-tide flooding is now four to 10 times more frequent than it was 50 years ago in coastal areas. Currently, about 40% of the global population lives within 100 kilometres of the coast, increasing their exposure and vulnerability to rising sea levels and other coastal hazards like severe storms.<sup>12</sup>
- Some 40 million people in Africa alone are living in **severe drought conditions**. Even in more temperate climates, drought is on the rise: Almost 40% of the lower 48 states in the United States and 17% of the European population are facing drought.<sup>13,14</sup> As a result, high temperatures are threatening food and water security.
- **Prolonged heat waves** – a period of abnormally high temperatures relative to seasonal averages – have killed tens of thousands of people and led to considerable morbidity and productivity losses. In Europe, more than 62,000 people died in the record heat between late May and early September 2022, according to a recently released research study, and the months of June, July and August in 2023 were even hotter.<sup>15,16</sup>

- The number of **high-intensity tropical storms** is anticipated to increase by nearly 10% by 2050, with 90% of them expected to occur in Asia Pacific and North and Central America.<sup>17</sup>
- **Wildfires** are occurring around the globe as record heat dries out foliage and creates conditions ripe for forest fires. Besides the immense destruction of property and loss of life and livestock, wildfires worldwide are aggravating air pollution, which in turn exacerbates respiratory ailments as well as cardiovascular diseases. Research suggests that air pollution will lead to six million to nine million premature deaths per year by 2060.<sup>18</sup>
- The Earth has already experienced a 20-centimetre **rise in average sea levels** since 1880, and the rate of increase is accelerating, according to NOAA.<sup>19</sup> This has huge implications for tens of millions of people, given that eight of the world's 10 largest cities are near coasts.<sup>20</sup> This may make them more likely to become climate refugees, people who are forced to move from their homes because of global warming.

El Niño and La Niña events, occurring as part of the El Niño-Southern Oscillation (ENSO), exert profound influences on global climate patterns. El Niño, marked by elevated sea surface temperatures, is associated with warmer conditions, droughts impacting water resources and agriculture, and intensified tropical cyclones. Conversely, La Niña, characterized by cooler sea surface temperatures, brings cooler climates, increased rainfall leading to potential flooding and heightened Atlantic hurricane activity. These phenomena underscore the critical role of ENSO events in shaping regional climates and influencing various sectors, necessitating vigilant monitoring and adaptation strategies to mitigate the diverse impacts on ecosystems, agriculture and morbidity and mortality.<sup>21</sup>

“ High temperatures are threatening food and water security with 40 million people in Africa, 17% of Europe and 40% of the US lower 48 states facing drought.

## 1.2 The negative impacts of climate change on human health

### The cause-and-effect relationship between climate impacts and health outcomes

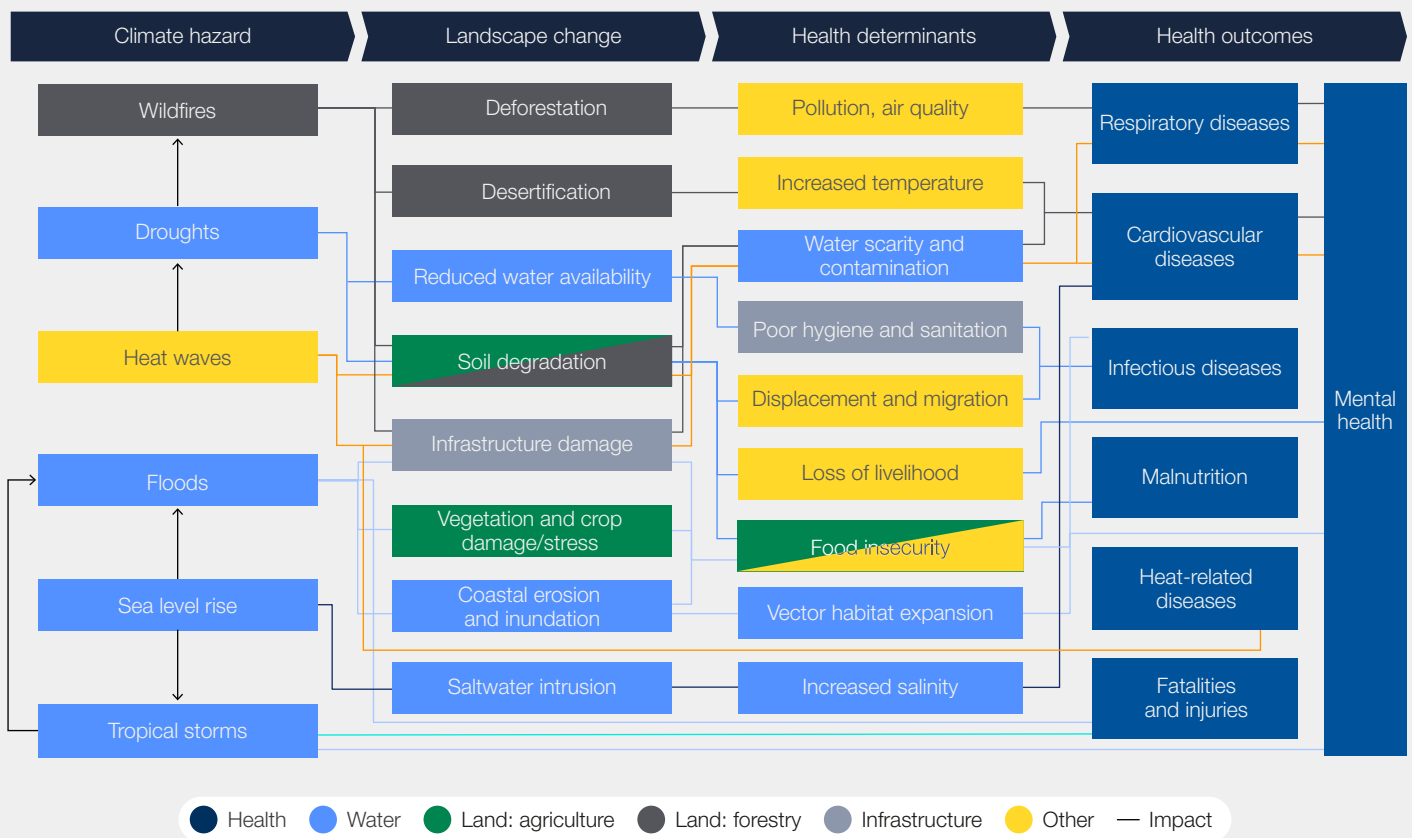
Climate change is transforming the landscape of morbidity and mortality and is already having profound impacts on human health and health systems. Understanding the cascading effects of climate events provides valuable insights into the cause-and-effect relationship between climate impacts and health outcomes.

Health outcomes involve both direct and indirect consequences of these events – some of which only appear months, and even years, after the event. Immediate impacts include deaths, physical injuries, malnutrition, respiratory and cardiovascular ailments and exposure to infectious diseases, such as cholera, dysentery and typhoid, which

result from drinking contaminated water or eating contaminated food. The stress, trauma and displacement caused by climate-related disasters can be expected to produce a surge in mental health illnesses, including anxiety, depression and post-traumatic stress disorder (PTSD). In fact, a rise in mental health conditions is an outcome that all six climate events share.

The six events often affect health determinants, including the physical environment and social and economic well-being. Today's six have a particularly devastating impact on air and water quality and food availability. Longer-term and indirect impacts of this aggravation of health determinants might include stunted development among children as a result of malnutrition, respiratory or cardiovascular diseases triggered by deteriorating air quality from a wildfire or prolonged heat wave or mental illness such as PTSD and general anxiety disorder from the disaster.

FIGURE 3 Overview of climate hazard impact on health outcomes



**Note:** Only health outcomes with most impact per hazard.

**Source:** Oliver Wyman analysis

“ Even if limiting global warming to 1.5°C proves possible, the accumulated financial loss from climate by 2030 alone is expected to reach \$2.4 trillion.

## Vulnerable populations and a widening health equity gap

Climate change exacerbates existing health disparities, disproportionately affecting vulnerable communities that lack the resources and support infrastructure to mitigate global warming’s impact or recover from climate-related disasters such as flooding or prolonged exposure to elevated temperatures leading to drought.

While climate-related disasters are detrimental to healthcare resources for all populations, there are additional threats to vulnerable communities, which already face limited access to quality medical care. Low-income and hard-to-reach communities tend to live farther from health services and facilities and face additional challenges to accessing health services, such as a lack of transport. These populations often have to pay out-of-pocket costs for access to medical supplies and treatment.

This differential in access to high-quality care perpetuates the disparities in health outcomes, widening the gap between the levels of mortality and morbidity experienced by disadvantaged populations and more privileged groups. Environmental disasters only serve to exacerbate these inequities. For instance, communities reliant on traditional livelihoods in agrarian or coastal areas often bear the brunt of climate-related disruptions – experiencing loss of income, displacement and reduced access to essential social services.

In Sub-Saharan Africa, southern Asia and Central America, around 80 million people will be at risk of hunger by 2050.<sup>22</sup> Not only do these populations already face higher risk of food insecurity, but they are also less likely to receive adequate relief to address the devastation to livelihoods, property, and food and water supplies.

## The importance of effective and reliable access to healthcare

Climate change also has profound impacts on the robustness and reliability of healthcare services affecting a country’s economy and social network. In the acute aftermath of a significant climate event, there is the threat of physical damage to healthcare

and other vital infrastructure that disrupt access to medical care and services such as the delivery of diagnostics, treatments and other healthcare-related supplies.

Additionally, healthcare systems face increased pressure when faced with surges in demand. This is especially true in low- and middle-income countries where healthcare systems may be less equipped and underfunded. Moreover, environmental disasters can also cause healthcare professional absenteeism, which leads to understaffing in times of increased patient needs. Understanding these connections is crucial for designing effective public health policies and building healthcare systems resilient enough to withstand and mitigate the effects of climate change.

## Impact on the economy and communities

Climate change can be expected to reduce GDP growth and restrict livelihoods for many. Approximately 3.3 billion to 3.6 billion people live in areas highly vulnerable to climate change, according to the United Nations, with many from low and middle-income countries.<sup>23</sup> Eight countries most affected by climate change compiled by the United Nations’ World Food Programme includes six African countries.<sup>24</sup> While developed regions account for two-thirds of global emissions, Africa – which only produces about 2-3% of global emissions – is already suffering a disproportionate amount of the pain from climate change, according to the World Meteorological Organization (WMO).<sup>25</sup>

Even if limiting global warming to 1.5°C by the end of the century proves possible, the accumulated financial loss by 2030 from extreme temperatures alone is expected to reach \$2.4 trillion.<sup>26</sup> By 2030, more than 2% of total working hours worldwide are projected to be lost every year because it is either too hot to work or employees are forced to operate at a slower pace because of the heat. In southern Asia and Sub-Saharan Africa, the resulting productivity loss may reach 5%, according to the International Labour Organization.<sup>27</sup>

## Displacement

By 2050, there could be as many as 1.2 billion climate refugees.<sup>28</sup> More than half of the world’s population will live in regions with severely limited water supplies by 2040. This includes extensive regions in China and India.



## 2 Quantifying the impacts of future climate events on public health

Climate change intensifies global health risks, causing higher morbidity and mortality.



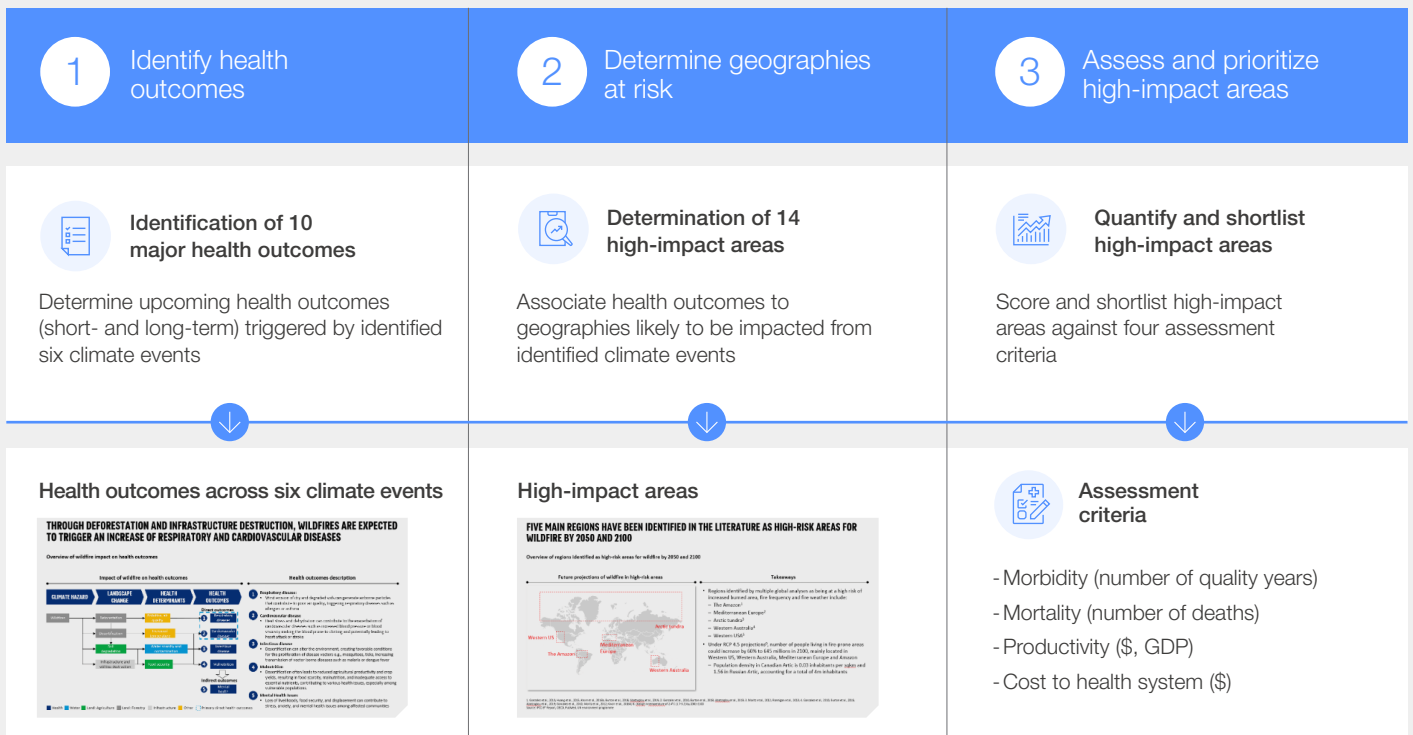


## 2.1 Methodology for the climate-related health impact matrix

The current analysis followed a stepwise approach to ensure a comprehensive understanding of the different health outcomes affected by climate change and the associated geographical risks.

This methodology facilitated the identification of high-impact target areas for which solutions could be developed.

FIGURE 4 Stepwise approach used to determine, quantify and prioritize the long list of high-impact areas



Source: Oliver Wyman analysis

**1. Identification of key weather-related events and modelling of health outcomes:** The first step was to determine the weather events most affected by rising temperatures and climate change and identify short- and long-term health outcomes triggered by them. As seen in Figure 2, six weather events were chosen for analysis based on the proven escalation in severity and frequency linked to rising temperatures. These six events also affect a region's environment and economy, leading to the destruction of agriculture, deforestation, desertification, coastal erosion, water scarcity and soil degradation.

Data linking the impact of weather events on health outcomes and health determinants were collected from a variety of sources, including the World Health Organization (WHO) framework for climate change, the IPCC, other UN-sponsored agencies

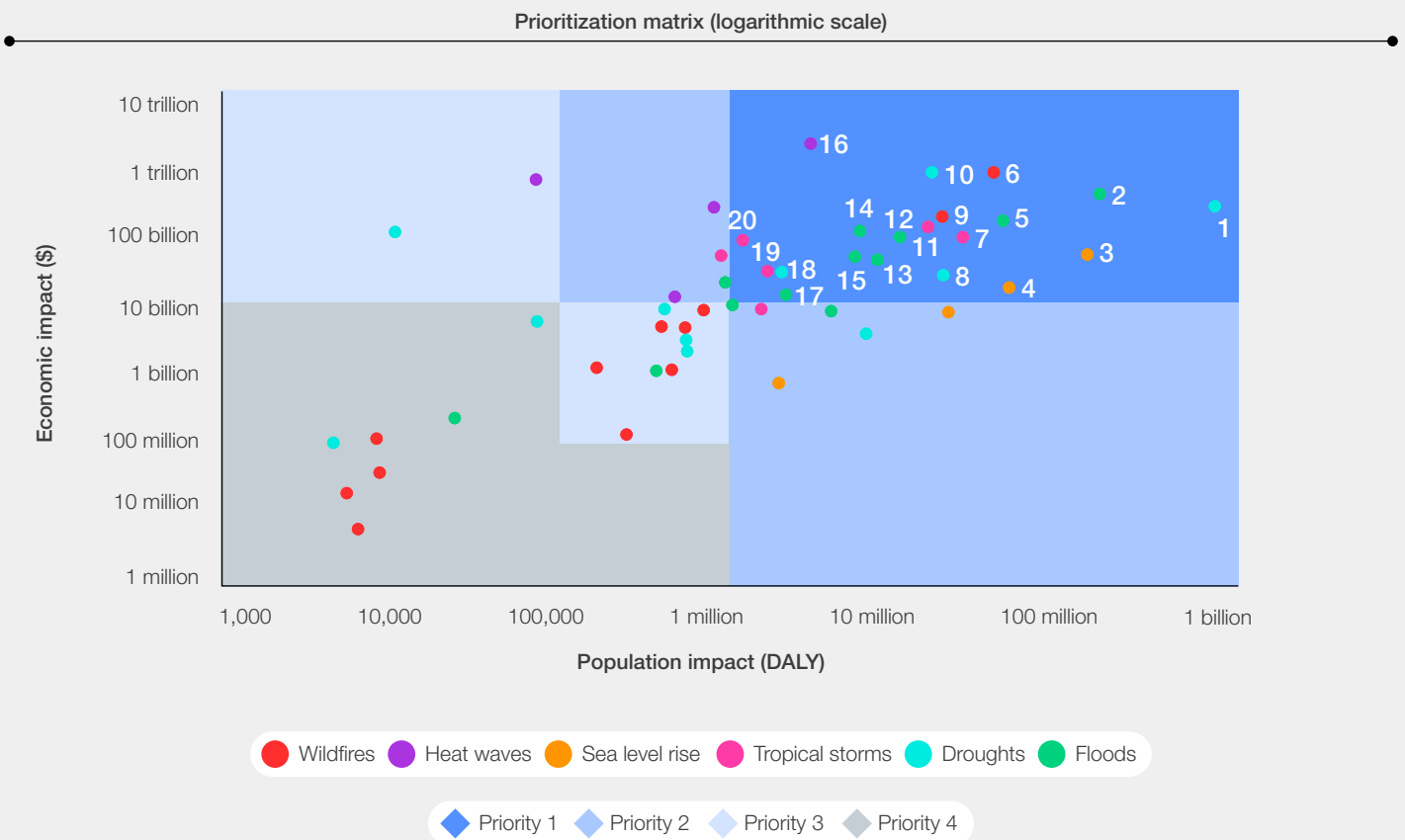
and the WMO as well as more than 50 medical and scientific research sources.<sup>29,30,31</sup>

**2. Determination of vulnerable geographies:** The next step was to identify geographical hot spots likely to experience the effects of the six climate events and associated health outcomes. Based on climate data and resources, quantitative analyses of the climate change impact on health events across the geographies at risk were conducted. Health projections were informed by public and peer-reviewed climate model portal sources, such as Climate Change Knowledge Portal or Climate Analytics' Climate Impact Explorer to ensure consistent baselines and projections of the likely increase in the occurrence of a given weather event in the SSP2-6 scenario. These were verified by leading economic experts at the WHO and Swiss Tropical and Public Health Institute.

Combining geographies at risk and likely health outcomes highlighted “high-impact areas”. Some examples of high-impact areas include South-East Asia where prolonged heat waves are likely to cause a significant increase in heat-related diseases or Western United States where wildfire smoke and subsequent air pollution are likely to exacerbate asthma and other respiratory ailments in neighbouring countries and regions.<sup>32</sup>

**3. Assessment and prioritization of 2050’s high-impact areas:** In order to identify possible adaptation and preparedness interventions, the final step consisted of scoring the high-impact geographic areas against four assessment criteria that considered both health and economic impacts.

FIGURE 5 Projection of health outcomes triggered by climate events by 2050 (cumulative)



Event	Geography	Health impact
1 Droughts	Western Southern Africa	Stunting
2 Floods	Middle Africa	Malaria
3 Sea rise	Asia	Hypertension
4 Sea rise	Africa	Hypertension
5 Floods	South-East Asia	PTSD
6 Wildfires	Western US	GAD
7 Storms	Asia	PTSD
8 Droughts	Mediterranean	GAD*
9 Wildfires	Mediterranean Europe	GAD
10 Droughts	Mediterranean	Stunting

Event	Geography	Health impact
11 Storms	Asia	Casualties
12 Floods	South-East Asia	Malaria
13 Floods	Northern South America	PTSD
14 Floods	Asia	Dengue
15 Floods	South-East Asia	Casualties
16 Heat waves	South-East Asia & India	Heat-related
17 Floods	Africa	Dengue
18 Droughts	Mediterranean	Cholera
19 Storms	North & Central America	PTSD
20 Storms	North & Central America	Casualties

\*Generalized anxiety disorder

Source: Oliver Wyman analysis





“ By 2050, six weather-related events will define the destructive impacts of climate change on planetary health.

The health impact was modelled using the disability-adjusted life years (DALY) methodology. DALYs are metrics used by the WHO and other organizations to measure years of life lost to premature mortality associated to a specific cause as well as years of healthy life lost to disability or reduced health.<sup>33</sup> DALYs are calculated based on two criteria: morbidity and mortality. In this research, morbidity is defined as the average number of years a patient will live with a disease, condition or disability that was a consequence of the weather event.

Morbidity, in number of years, was calculated using the average life expectancy of people living in a specific geography, the average age of the patient population and the reduced life expectancy caused by the weather-related medical condition. Morbidity, in terms of number of cases, was calculated based on the increased incidence of weather events and extrapolating the impact on current morbidity, as documented in the literature for the reference year (varies across studies).

Mortality, was determined based on the number of deaths triggered by a climate event. These can be the direct result of the event, such as flood-related drownings, or an indirect consequence, such as the exacerbation of respiratory diseases triggered by wildfires or cardiovascular diseases during heat waves.

For the geographic areas considered at risk, mortality was calculated based on the increased

incidence of weather events and extrapolating the impact on mortality, as documented in the literature for the reference year (varies across studies).

The economic impact was considered as the sum of the productivity loss, caused by the increase in detrimental health outcomes and the cost of treatment. Productivity loss evaluates the economic impact of the disease on the population and relates to absenteeism, reduced performance or premature mortality triggered by the disease. Absenteeism was calculated using the numbers of working days lost due to an event-related condition and also ultimately expressed in terms of the loss of GDP per capita in the relevant geography.

The cost to health systems was extracted from medical and scientific literature for each condition and translated as parameters for the modelling, with inflation applied where necessary. For instance, if the cost of healthcare treatments was based on 2015 actual data, it was corrected for inflation to generate realistic health system cost projections (for 2023-2050, we included a yearly factor of 2.5% inflation).

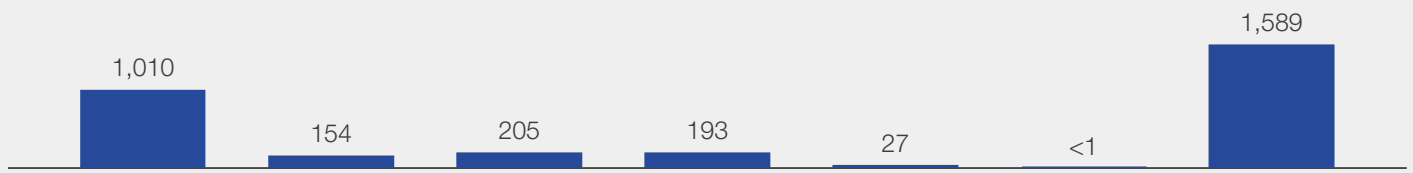
#### The global quantification of loss

By 2050, six weather-related events will define the destructive impacts of climate change on planetary health. The current analysis conducted indicates that 14.5 million deaths worldwide could be prevented by 2050.

FIGURE 6 | Projection of health outcomes triggered by climate events by 2050 (cumulative)

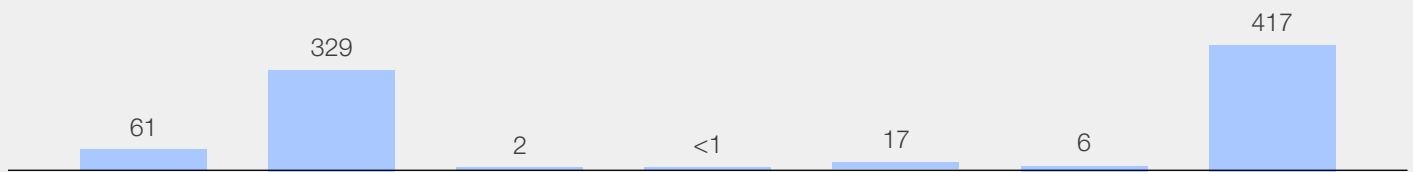
**Morbidity health impact**

millions, years lived with disability (YLD)



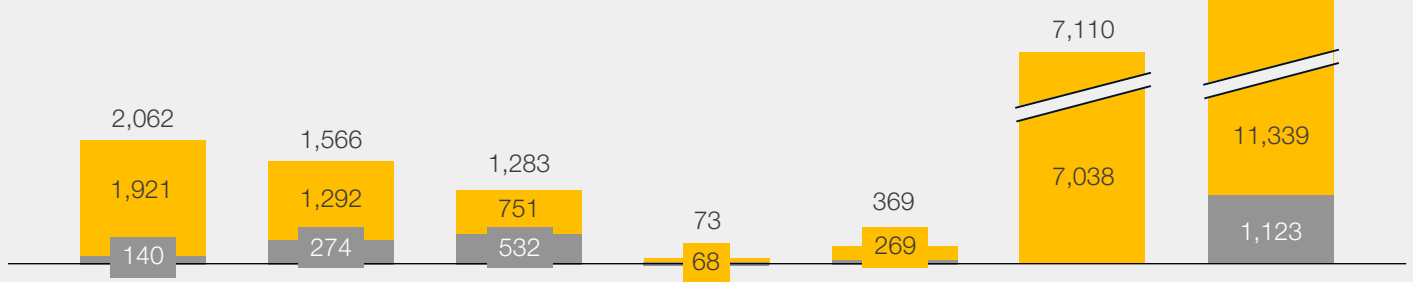
**Mortality health impact**

millions, years of life lost to due to premature mortality (YLL)



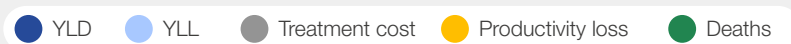
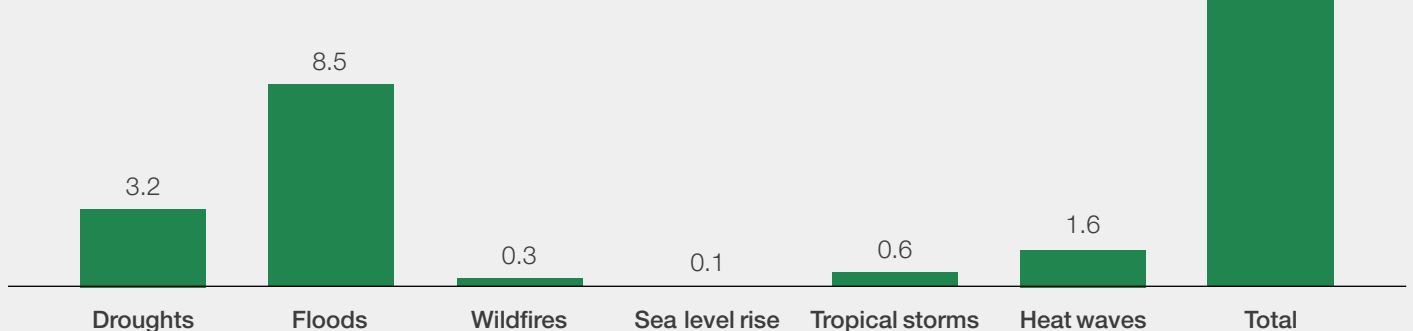
**Economic impact**

\$, billions



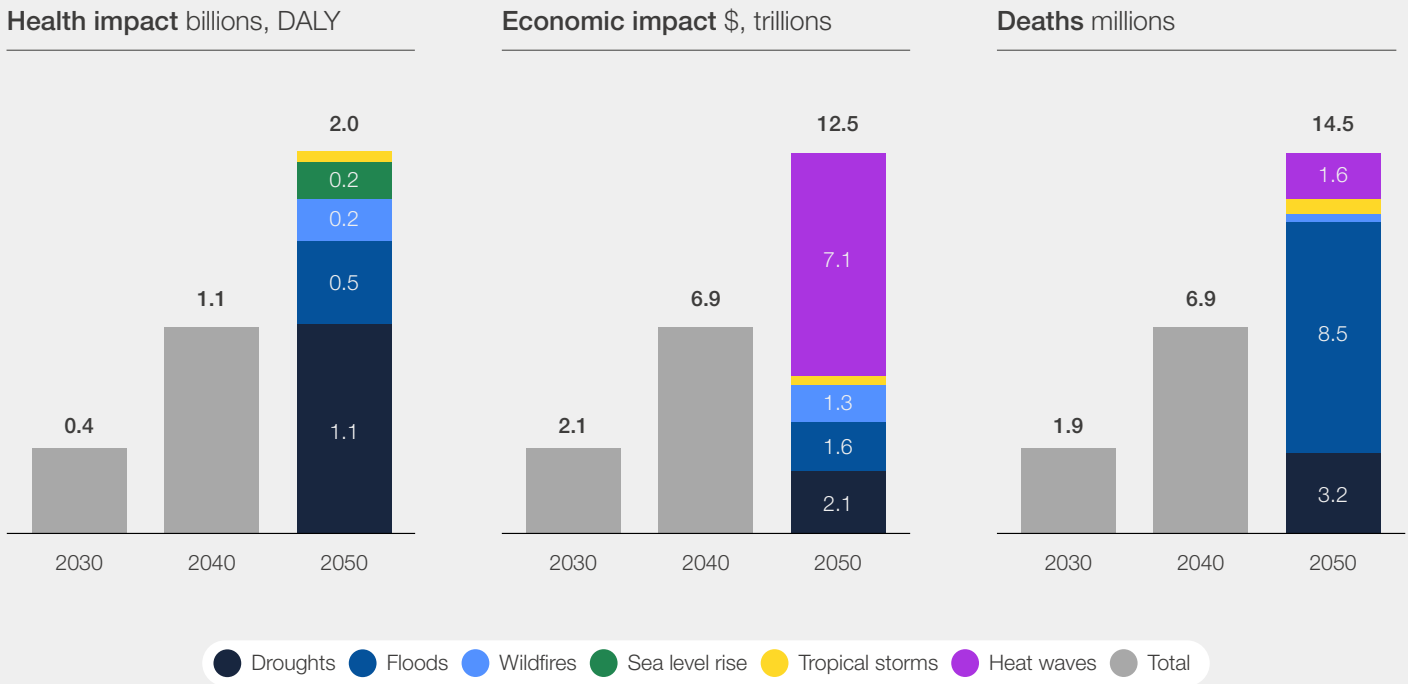
**Deaths**

millions



Source: Oliver Wyman analysis

FIGURE 7 | Projection of health outcomes triggered by climate events, cumulative



Source: Oliver Wyman analysis

“ Only 21% of the health impact will be attributable to mortality, while 79% is due to long-term disabilities and health conditions that developed subsequent to the climate event.

The escalating frequency of floods is anticipated to take the highest toll, with an estimated 8.5 million deaths. Without mitigation and adaptation measures, the Asia Pacific region is likely to suffer the highest mortality totals because of the flooding anticipated in heavily populated coastal areas and the prospect of higher-than-normal rainfall, WMO data suggests.

The second-highest mortality rate will be from droughts, with an estimated 3.2 million associated deaths worldwide. The acute and long-term effects on the morbidity and mortality of children under the age of five are the biggest driver of drought’s impact.

Heat waves are expected to claim approximately 1.6 million lives by 2050, with those aged 65 and older being the most susceptible to the prolonged extreme temperatures. While heat waves may have a lower count of DALYs versus droughts and floods, they are projected to have the highest economic impact of the events studied. The resulting productivity loss from these periods of extreme heat affect a broader population and pose a significant challenge to economic stability. Heat-related illnesses and reduced work capacity during extreme heat events can lead to substantial economic disruption.

The projected impact of tropical storms is expected to result in an additional one-half million deaths by 2050, while the devastating spread of wildfires is predicted to claim another 300,000 lives. Finally, rising sea levels will result in 100,000 more lives lost.

**Why morbidity will have the highest negative impact**

The impact of climate events on health outcomes is primarily driven by morbidity rather than mortality. It is projected that only 21% of the overall health impact will be attributable to mortality, while a concerning 79% is due to long-term disabilities and health conditions that developed subsequent to the climate event. This trend raises concerns about the lasting effects of climate events on the well-being of individuals. It also highlights an alarming trend of climate events leading to generations of unhealthy individuals.

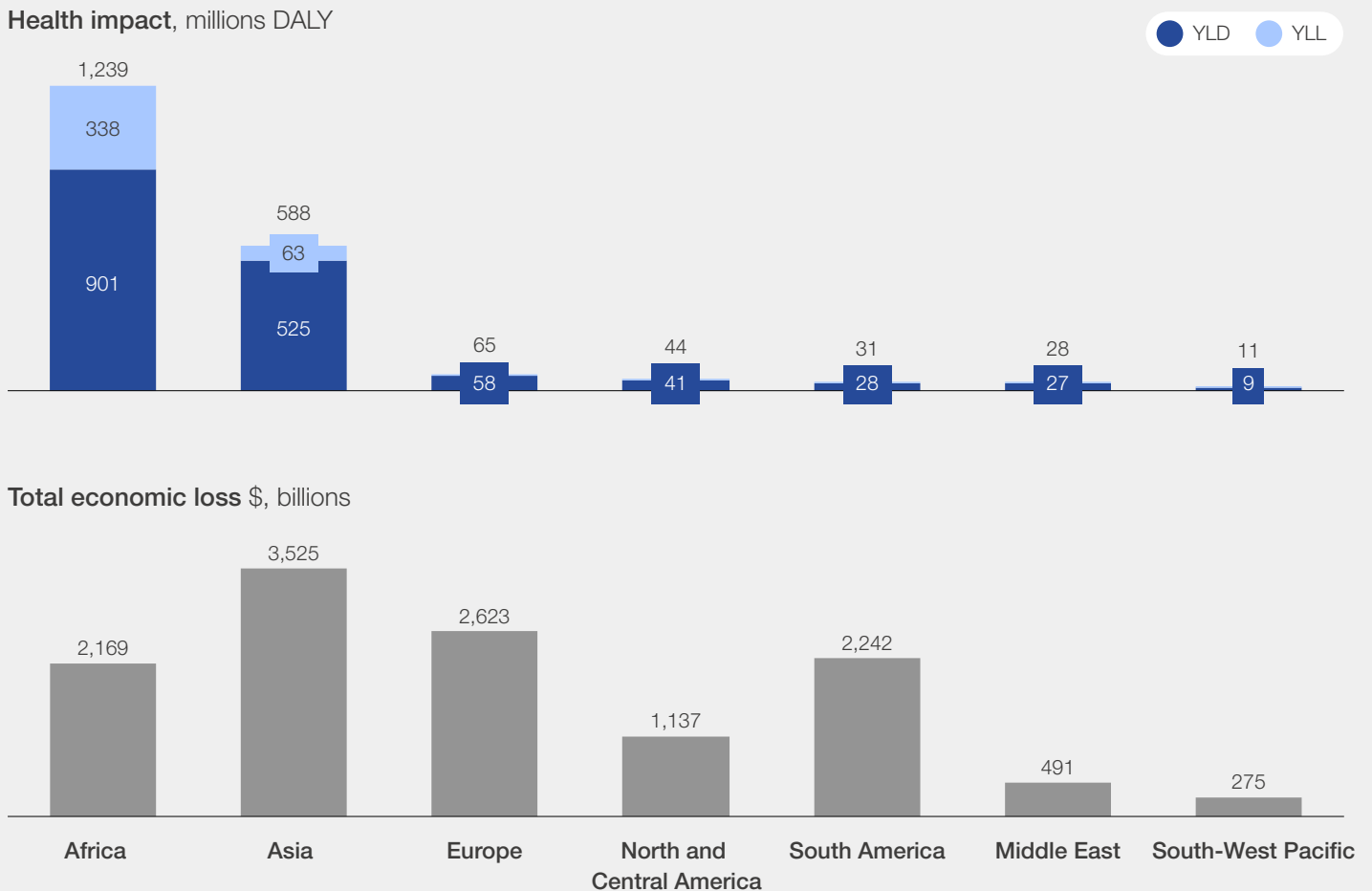
The prevalence of stunted development among children and generalized anxiety disorder illustrates why morbidity may have such a negative impact over the rest of the century. The incidence of both is significantly higher than almost any other disease or condition, except for malaria, which follows close behind.



Morbidity will also be a factor in why developing nations see more impact from climate change. While the devastating impacts of climate change events are globally distributed, developing countries will be disproportionately affected due to their dense populations living in low-lying coastal zones

and large swaths of geography in these areas that have hot and dry climates. Yet the losses also reflect the fact that low-income and other vulnerable populations are less able to evacuate areas affected by a disaster and have fewer resources to help them mitigate the impact of these weather events.

FIGURE 8 Projection of health outcomes triggered by climate events by 2050 (cumulative)



Source: Oliver Wyman analysis

Regions in Africa and the Middle East are expected to shoulder the brunt of this disparity, sustaining a staggering cumulative impact of 1.27 billion DALYs lost and a combined economic cost of \$2.7 trillion from lost productivity and healthcare costs. Following closely behind, Asia is projected to face the second-highest impact, with 588 million DALYs lost and economic impact losses amounting to \$3.5 trillion.

While the impacts in other regions are comparatively lower, they are still significant. Europe faces cumulative health impacts of 64.5 million DALYs lost and an economic impact of \$2.6 trillion. In North and Central America, the economic impact totals \$1.1 trillion, while DALYs are estimated at 44.0 million.

South America and the South-West Pacific Ocean are projected to experience lower impacts, with 30.8 million DALYs lost and \$2.2 trillion in economic losses for South America and 11.1 million DALYs lost and \$275 billion in economic losses for the South-West Pacific Ocean.

The total cumulative healthcare system costs to provide treatment for diseases caused by climate change are projected to be over \$1.1 trillion by 2050. Nearly half of this cost burden is expected in North and Central America, reflecting relatively higher hospitalization and treatment costs in these regions. Asia is another major contributor towards healthcare costs due to climate change predominantly driven by the large number of people affected by climate-related disasters.



## 2.2 Deep dives on health impacts of the six weather-related events

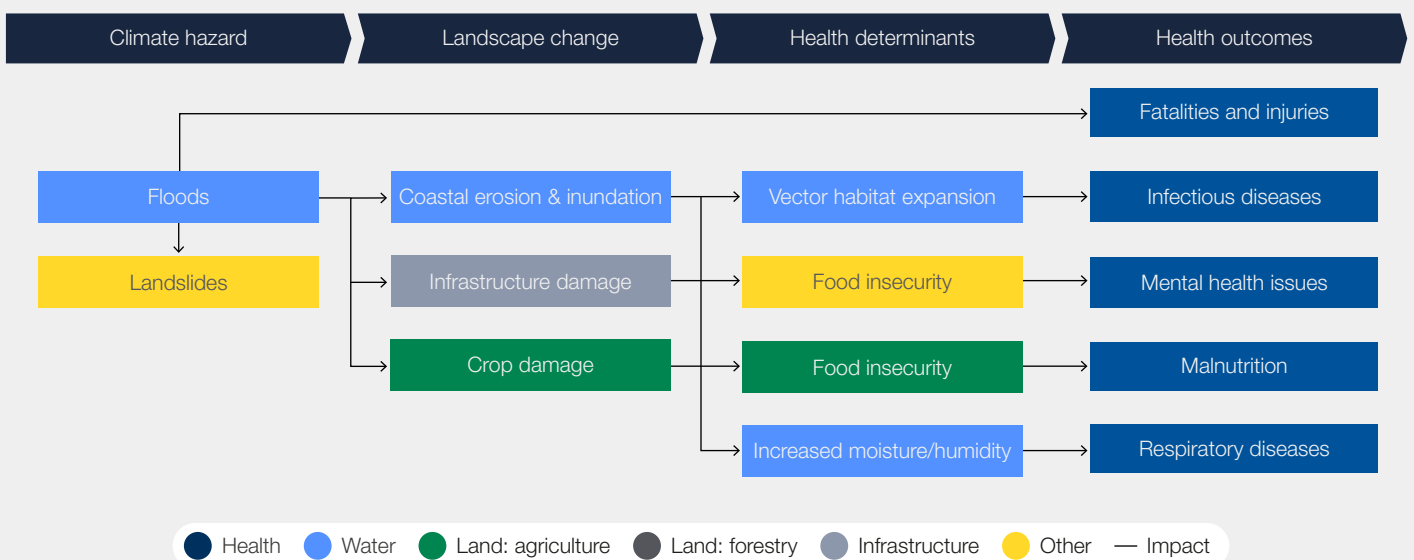
### Climate event 1: floods and extreme rainfall

#### Health outcomes

Floods and extreme rainfall events pose significant risks to human health. Floods can lead to tragic fatalities, primarily caused by drowning or

hypothermia. Additionally, individuals may sustain injuries from debris and encounter electrical hazards in flooded areas. The physical dangers associated with floods are evident, but the mental health impact should not be overlooked. Acute flooding events, as well as the subsequent loss of homes and livelihoods, can contribute to PTSD, anxiety and depression among affected individuals.

FIGURE 9 Overview of floods impact on health outcomes



Source: Oliver Wyman analysis

Floods can also have devastating effects on vulnerable groups, including the elderly, children, people experiencing homelessness and individuals with disabilities. These populations may face challenges evacuating or finding safe shelter during flood events, putting their lives and well-being at risk. Floods make it difficult to seek out medical care, with roads impassable and vehicles, including emergency vehicles, often inoperable.

In addition, it is widely recognized that high rainfall increases the density of microbial agents in surface water, elevating the risk of waterborne diseases. Stagnant water resulting from floods creates favourable conditions for the expansion of vector habitats, increasing the transmission rates of vector-borne diseases. This dual threat of waterborne

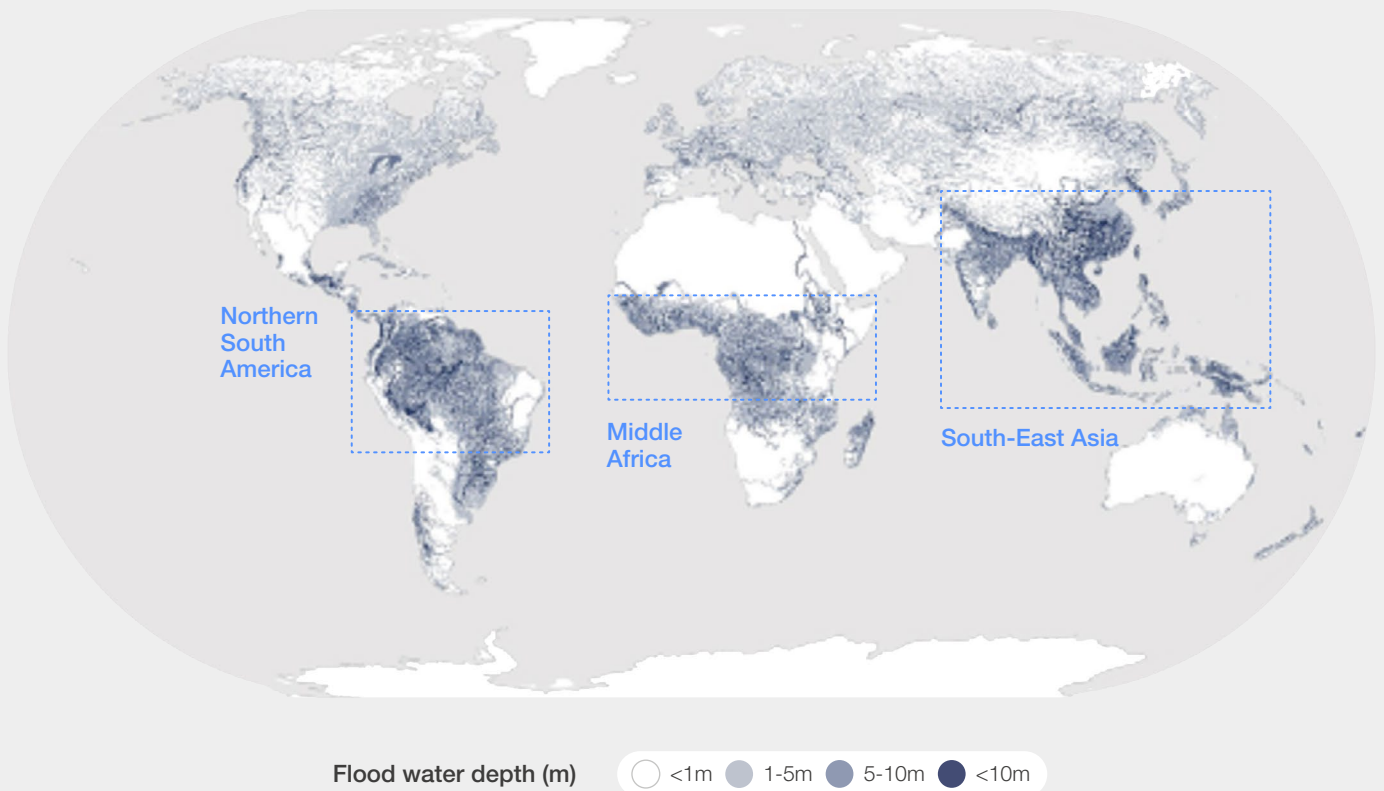
and vector-borne diseases further compounds the health risks associated with floods.

### Projecting the future incidence

South-East Asia is the region with the highest concentration of flood-exposed people globally, making it particularly vulnerable to the impacts of floods. Northern South America is another key region at risk, with floods accounting for a significant portion of climate-related disasters and deaths in the area. In fact, from 1970 to 2019, floods accounted for 59% of climate-related disasters and 77% of climate-related deaths in South America.<sup>34</sup> Additionally, the midsection of Africa is projected to experience a distinct rise in flood risk.

FIGURE 10 South-East Asia, northern South America and Middle Africa represent key regions projected to face the highest impact due to floods and rainfall

### Overview of projected global flood exposure (2051-2070)



Sources: IPCC Sixth Assessment Report (AR6), World Bank; WMO; Oliver Wyman analysis

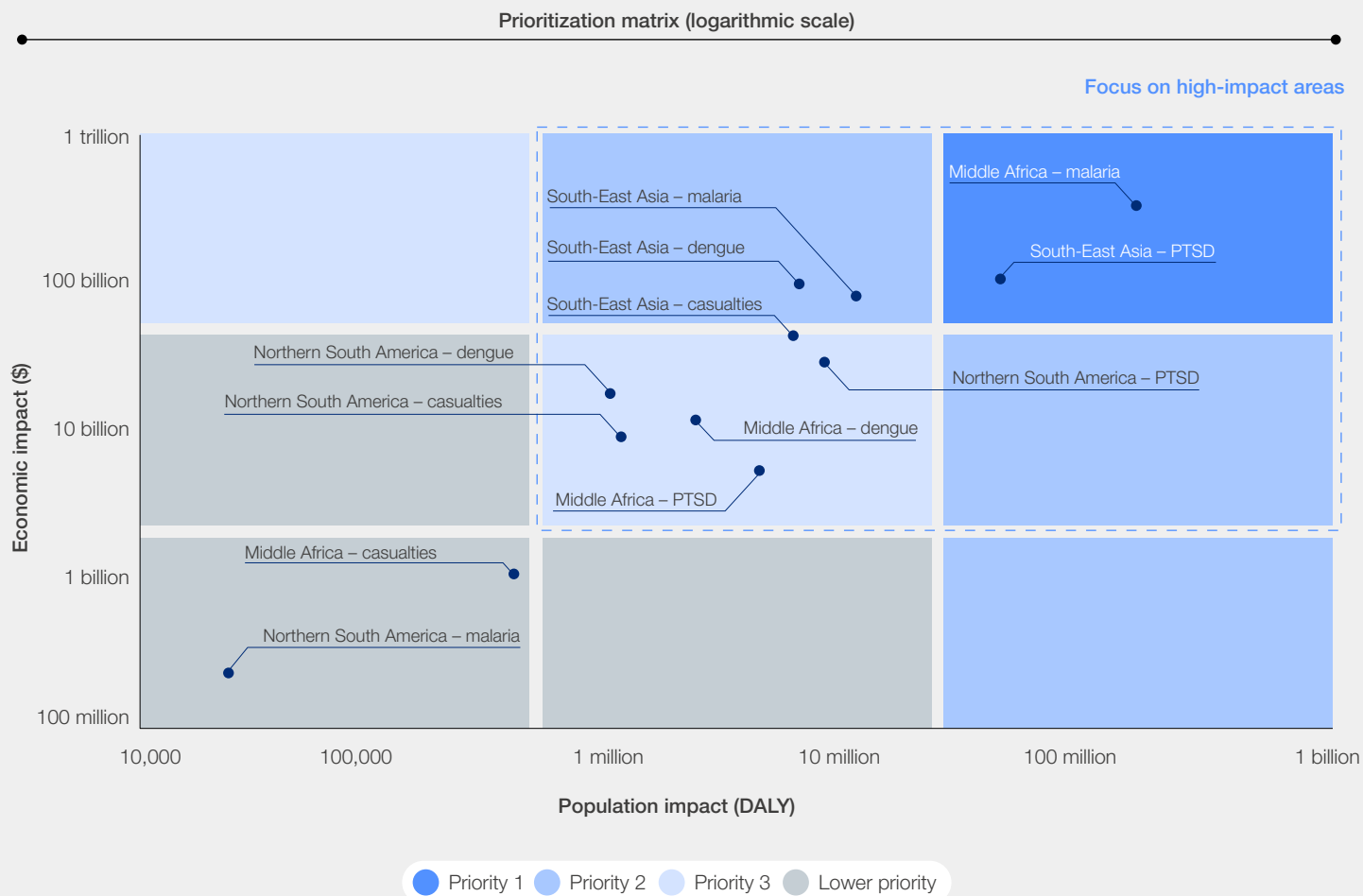
Looking at global flood and rainfall projections, it is evident that the frequency and intensity of these events are expected to increase. By 2050, South-East Asia is projected to face the highest impact, with extreme rainfall forecasts indicating an increase of 17% to 35% over current levels. Longer-term projections to the year 2100 suggest even more significant increases, ranging from 22% to 77% over current levels.<sup>35</sup>

### Quantifying future health and economic impacts by 2050

Floods and extreme rainfall have significant health outcomes, with malaria in central Africa and PTSD in South-East Asia being the two biggest impacts. Globally, the combined health impacts of these events are projected to cost approximately \$1.6 trillion to the healthcare system and affect 483 million DALYs.



FIGURE 11 | Projection of health outcomes triggered by floods by 2050, cumulative 2023-2050



Source: Oliver Wyman analysis

The financial burden and DALYs associated with floods and extreme rainfall are substantial. Fatalities and injuries resulting from these events are estimated to cost \$99 billion and affect 7.7 million DALYs. Malaria, a vector-borne disease that thrives in stagnant water, is projected to have a significant impact, costing approximately \$1 trillion and impacting 409 million DALYs. Additionally, the mental health consequences, particularly from PTSD, are anticipated to cost \$275 billion and affect 58 million DALYs.

Specifically, malaria in Central Africa is expected to have a significant economic impact, costing approximately \$345 billion to the healthcare system and impacting 151 million DALYs. Additionally, PTSD in South-East Asia is projected to add \$147 billion to healthcare system costs and impact 41 million DALYs. The traumatic experiences associated with floods and the subsequent loss

of homes and livelihoods contribute to the mental health challenges faced by individuals in this region.

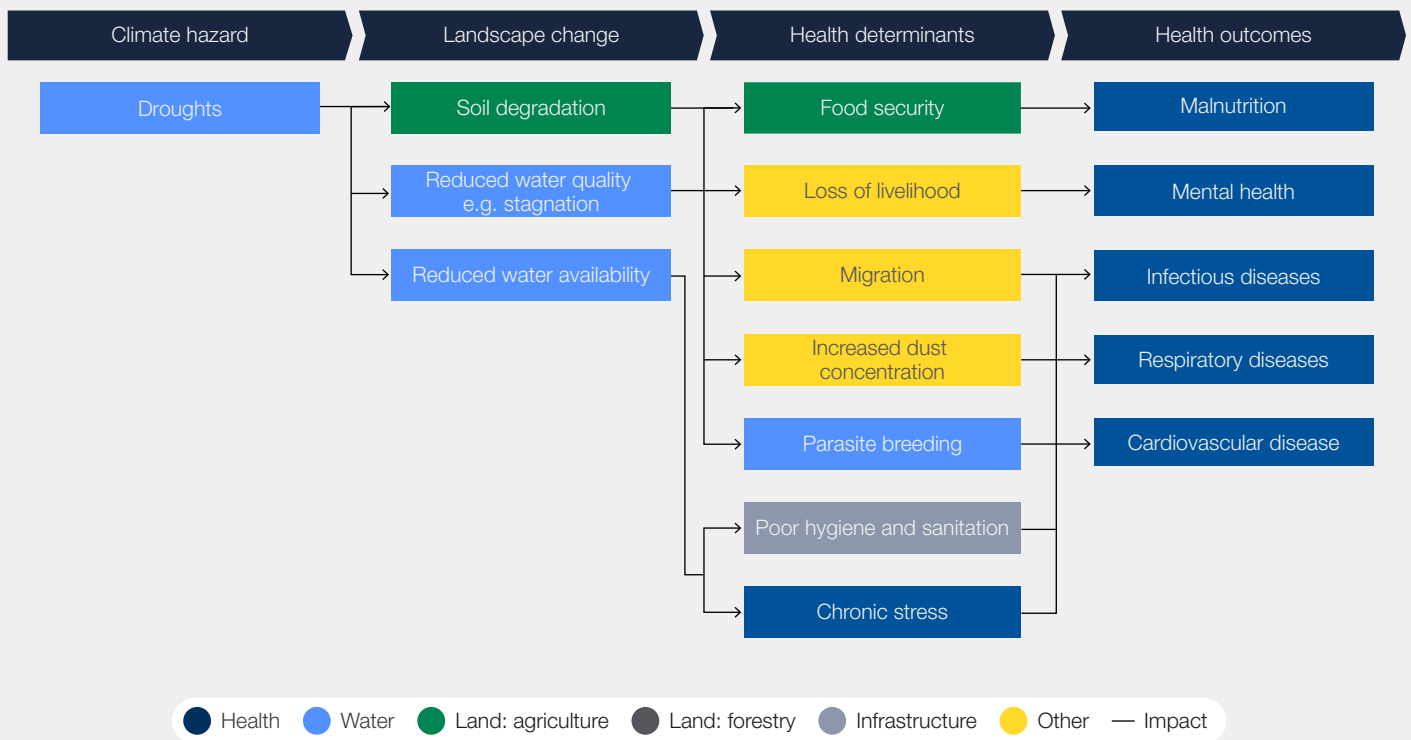
## Climate event 2: droughts

### Health outcomes

Drought, a prolonged period of abnormally low rainfall, disrupts the delicate balance of ecosystems and communities. Its impact extends far beyond water scarcity, affecting various aspects of human life and well-being. Some of the most concerning consequences of drought are the increase in malnutrition, mental health issues and infections, which arise from food insecurity, loss of livelihood and poor hygiene.



FIGURE 12 | Overview of droughts impact on health outcomes



**Note:** Spread of vector-borne diseases such as dengue also noted, but literature indicates cholera impact has a more prominent impact, e.g. Mali cholera epidemic (Tauxe et al. 1988).

**Sources:** Stanke et al., 2013; Berman et al., 2017; Bryan et al., 2020; IPCC Sixth Assessment Report (AR6); Center for Climate and Energy Solutions; Center for Disease Control and Prevention (CDC); World Health Organization; Oliver Wyman analysis

Droughts have a profound effect on food security and price stability, as they reduce crop yield through soil degradation and decrease the availability of food. The scarcity of water and its subsequent impact on agriculture often lead to widespread malnutrition. The condition, which is defined by a lack of adequate nutrients, multiplies the impact on affected communities and turns a short-term

disaster into a longer-term health concern of stunted growth among children and other medical disorders associated with vitamin deficiencies.

Not only is there not enough potable water for proper hydration. There is also not enough for cooking, bathing and other basic sanitation activities. This shortage leaves communities vulnerable to

the spread of diseases, such as cholera, typhoid and dysentery, that are associated with using contaminated water. Drought-induced migration can further exacerbate the transmission of diseases, straining healthcare systems and compounding public health challenges. The struggle to find food, loss of livelihood and the forced migration that often accompanies droughts can also have severe mental health implications, such as anxiety and stress.

Already affecting poorer nations more profoundly than richer ones, droughts disproportionately affect particularly vulnerable populations, including people living in poverty, the elderly, children, those with disabilities and individuals in occupations dependent on weather like farming. Even before a disaster, these groups often face limited access to food, clean water and healthcare. During droughts, their challenges become uniquely difficult as they also are isolated from larger populations and have limited mobility.

Addressing the multifaceted consequences and causes of drought requires a comprehensive approach that encompasses sustainable water management, disease prevention and control, agricultural resilience and mental health support. Investing in these areas will build more resilient communities with the tools to avoid or at least mitigate the devastating effects of drought on individuals and societies.

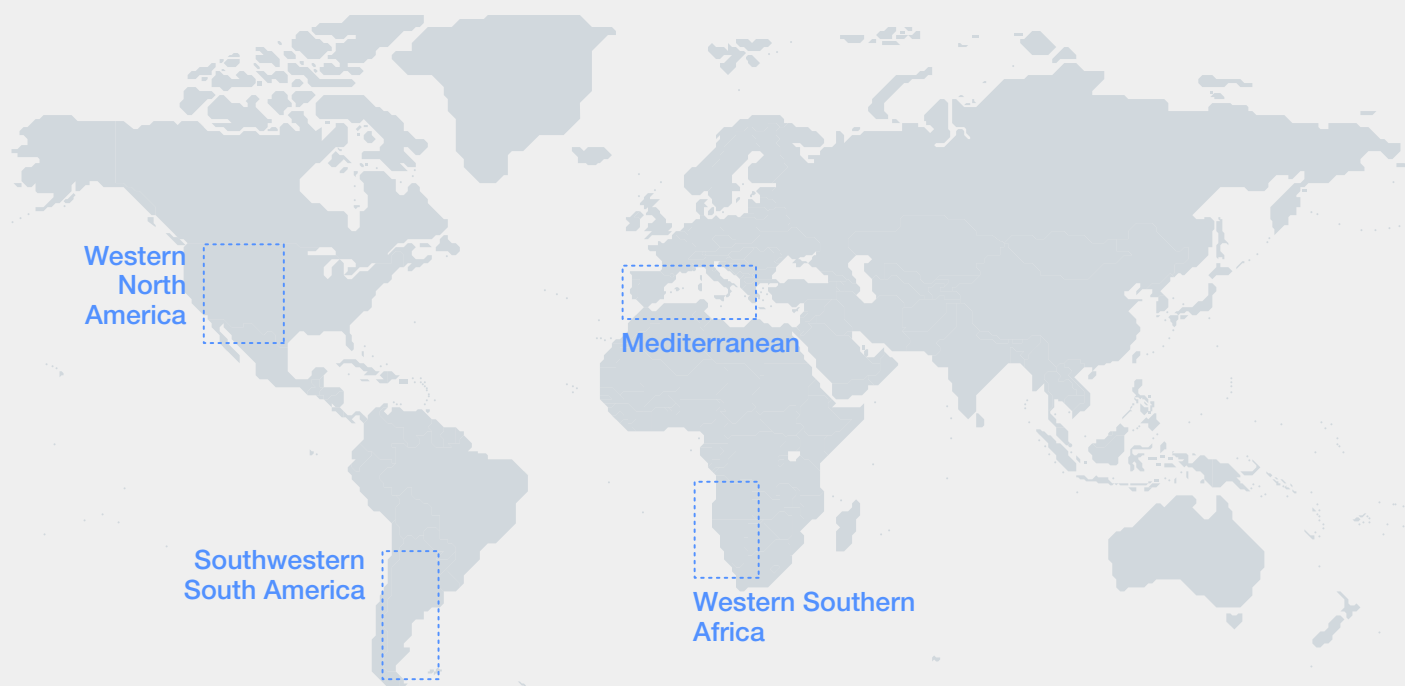
### Projecting the future incidence

The outlook for droughts is a cause for concern, as projections indicate an increase in their frequency and severity in several key regions. Extensive research has identified four regions as high-risk areas for droughts by 2050: southwestern Africa, the countries bordering the Mediterranean Sea, southwestern South America and western North America. These regions are particularly vulnerable to the impacts of climate change, including reduced rainfall and increased temperatures.

Global drought projections estimate an increase of up to 36% in drought occurrence by 2050 in some regions.<sup>36</sup> These projections are based on the frequency of drought days, which show a clear upward trend compared to current levels. For instance, in western Southern Africa, drought frequency is projected to increase by 20% to 25% by 2050, highlighting the growing risk faced by this region.

Looking further ahead, the long-term changes in drought patterns could be even more significant. In the Mediterranean, for example, the projected increase in drought frequency by 2100 varies widely, ranging from 20% to a staggering 110%. These projections underscore the urgent need for proactive measures to mitigate the impacts of drought and build resilience in these vulnerable regions.

FIGURE 13 Future projections of drought in high-risk areas



Sources: IPCC Sixth Assessment Report (AR6); UNCCD 2022; Cabot Institute for the Environment; Oliver Wyman analysis



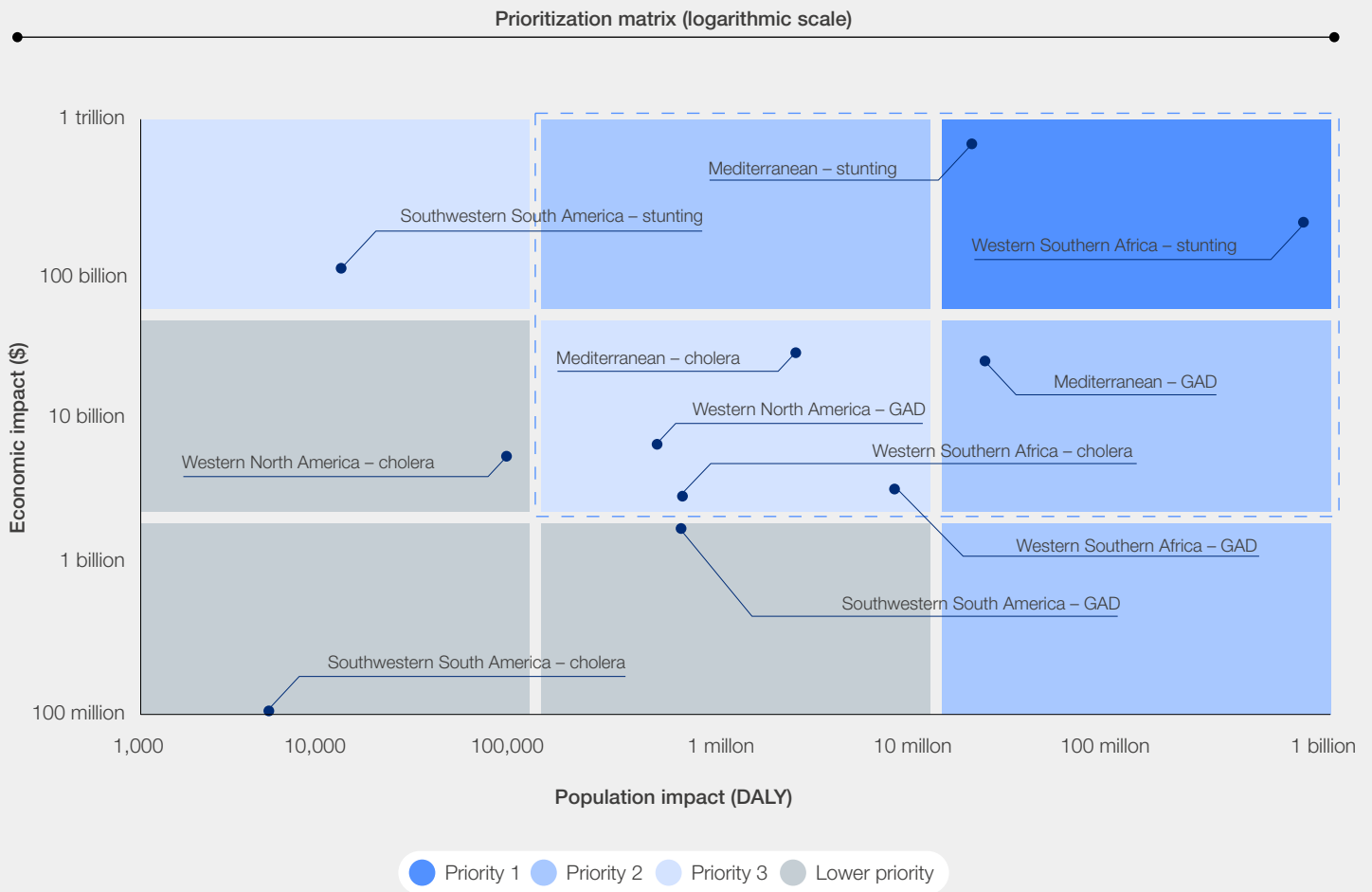
**Quantifying health and economic impacts by 2050**

The global impact of droughts on health outcomes is profound, with stunted development among

children, generalized anxiety disorder and cholera alone projected to cost the health system a staggering \$2.1 trillion and impact 1.1 billion DALYs by 2050.

FIGURE 14

**Projection of health outcomes triggered by droughts by 2050, cumulative 2023-2050**



Source: Oliver Wyman analysis





“Cholera, a waterborne disease that thrives in conditions of poor sanitation and hygiene often exacerbated by droughts, is estimated to cost health systems \$51 billion.

Stunting emerges as the most significant health outcome triggered by droughts, accounting for a substantial portion of the economic burden and DALYs. The cost to the health system from stunted development in children is estimated at \$1.8 trillion, with an impact of 887 million DALYs. This highlights the severe consequences of food insecurity and malnutrition resulting from drought-induced crop failures and reduced food availability.

Generalized anxiety disorder, a mental health disorder exacerbated by the stress and uncertainty associated with droughts, is projected to cost \$198 billion to the health system and impact 176 million DALYs. The psychological toll of droughts cannot be underestimated, and the long-term effects on mental well-being necessitate attention and support.

Cholera, a waterborne disease that thrives in conditions of poor sanitation and hygiene often exacerbated by droughts, is estimated to cost health systems \$51 billion and impact 8.1 million DALY. The scarcity of water resources and inadequate sanitation facilities increase the vulnerability of communities to infectious diseases, further straining healthcare systems.

When examining specific regions, undernutrition and stunting in the Mediterranean region and Western and Southern Africa emerge as the two largest health outcomes triggered by droughts. The Mediterranean region is anticipated to bear a cost of \$700 billion to the health system and experience an impact of 16 million DALYs from stunted development in children. Similarly, stunting

in Western and Southern Africa is projected to cost \$231 billion to the health system and impact a staggering 727 million DALYs.

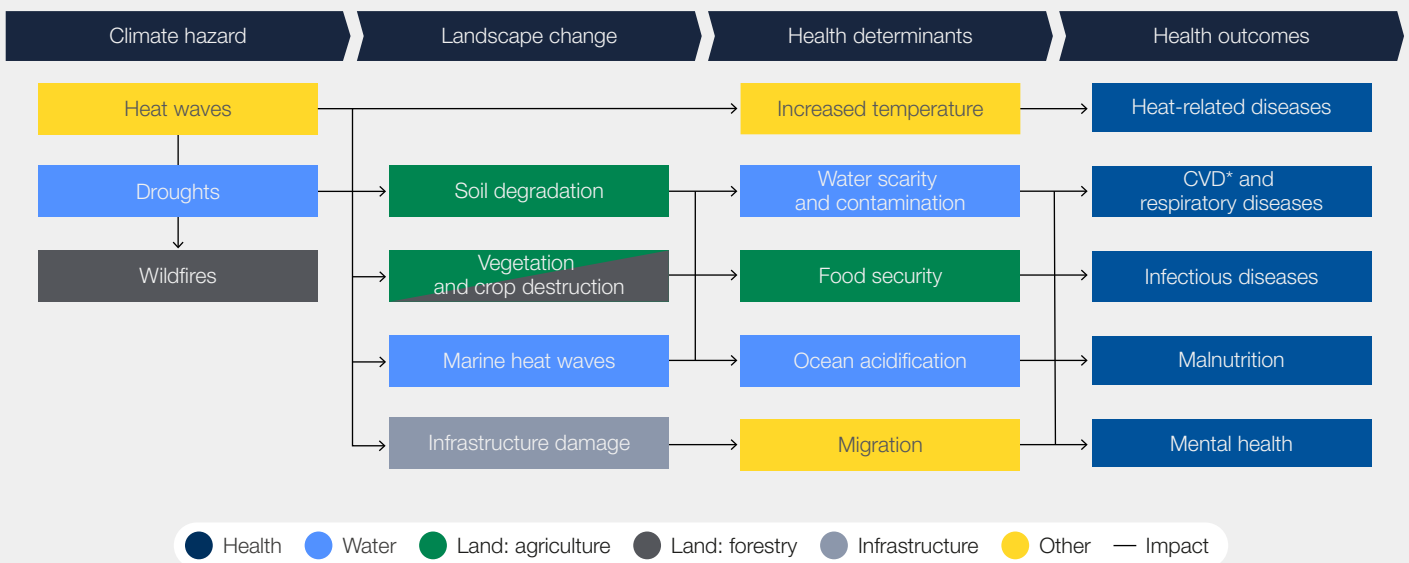
These figures underscore the urgent need for comprehensive strategies to address the health consequences of droughts. Investing in measures to enhance food security, mental health support, and access to clean water and sanitation can mitigate the economic and human toll of drought-induced health challenges and build resilience in vulnerable regions.

### Climate event 3: heat waves

#### Health outcomes

Amid the backdrop of global warming, heat waves – characterized by prolonged periods of exceptionally high temperatures often accompanied by heightened humidity levels – have become increasingly prevalent. These heat events disrupt the body’s inherent cooling mechanisms, giving rise to a spectrum of symptoms ranging from mild discomfort to severe, life-threatening conditions. Prolonged exposure to extreme heat can instigate a cascade of heat-related ailments, including everything from heat cramps, caused by excessive sweating and electrolyte imbalances, to heat exhaustion, typified by symptoms such as dizziness, weak pulse, nausea and fainting. At the extreme end, heatstroke, marked by core body temperatures surpassing 40°C, poses a critical threat, capable of inducing organ damage and fatalities.

FIGURE 15 Overview of heat waves impact on health outcomes



\*Cardiovascular diseases

Source: IPCC Sixth Assessment Report (AR6); PubMed; UN Environment Programme; Oliver Wyman analysis

Heat waves also have a profound impact on occupational health and workforce productivity, particularly in regions vulnerable to climate change. They also affect poorer populations disproportionately because of their often-limited access to air conditioning and large supplies of freshwater. Professions characterized by significant heat exposure, such as those in agriculture and construction industries, are particularly susceptible to the adverse effects of heat waves.

Beyond the direct implications of heat-related fatalities, the physiological strain induced by heat stress and dehydration further burdens the heart and respiratory system and can significantly amplify the risks of heart attacks, stroke and heart failure.

Extreme heat can also aggravate conditions like arthritis, autoimmune diseases, migraines and respiratory-related ailments. While the scope of

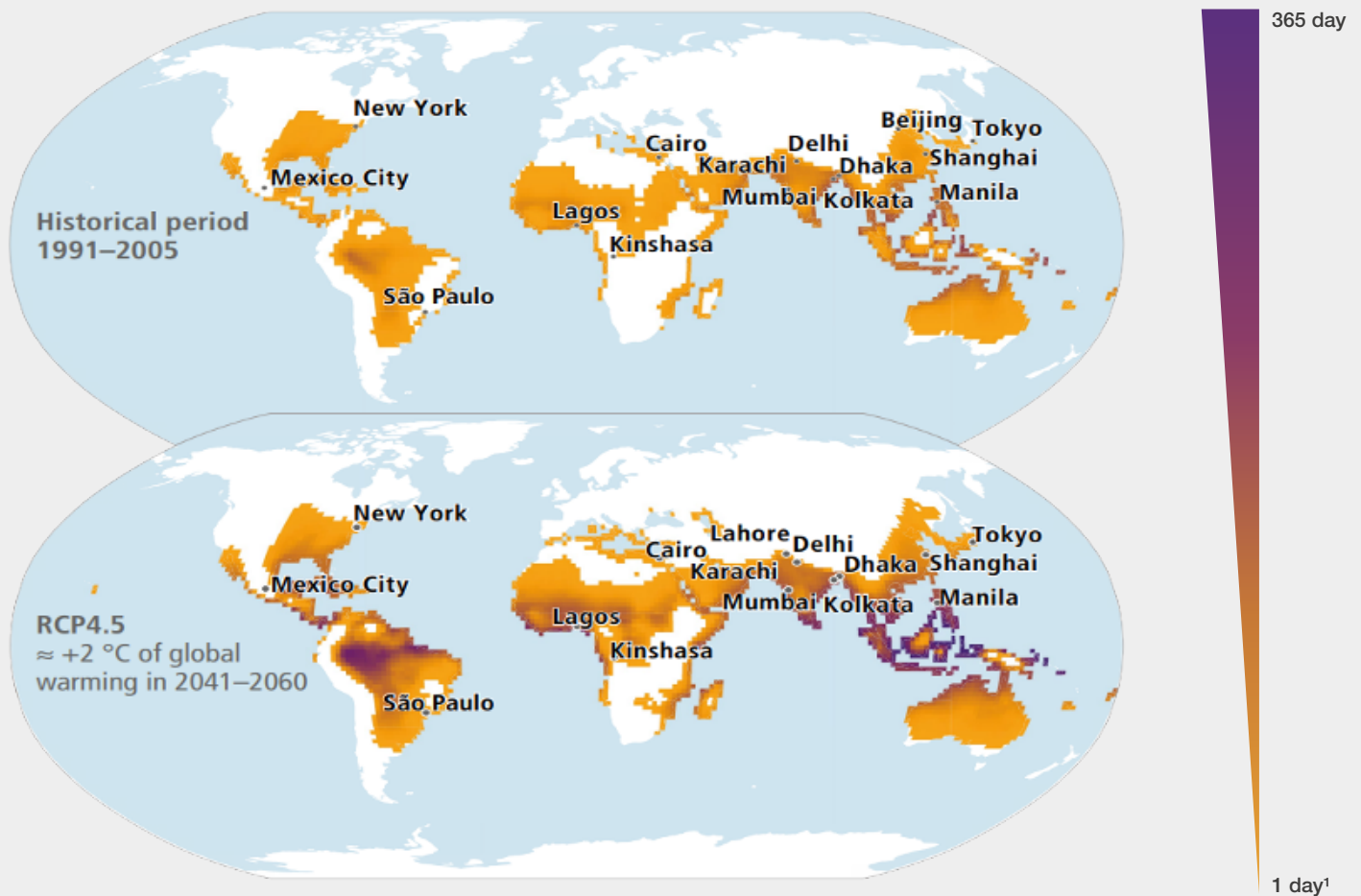
research on the specific correlations between heat waves and certain diseases remains limited, the overall impact of heat-related diseases has been extensively documented.

### Projecting the future incidence

Beyond the sheer pressures from climate change, heat waves have become more prevalent because of increasing urbanization. The urban heat island effect is the phenomenon caused by the fact that city buildings, roads, sidewalks and other infrastructure absorb and re-emit the sun's heat more than natural landscapes. It exacerbates already elevated temperatures within cities, disproportionately affecting marginalized communities without air conditioning, older people and those with disabilities, people experiencing homelessness and other vulnerable populations.

FIGURE 16 Five main regions have been identified in the literature as high-risk areas for increased heat waves by 2050

Overview of regions identified as high-risk areas for heat waves by 2050  
Historical and future projections of heat waves



Note: 1 Days per year when air temperature and humidity conditions pose a risk of death.

Sources: IPCC Sixth Assessment Report (AR6); Oliver Wyman analysis

“ Heat-related diseases resulting from heat waves are projected to place an astonishing \$7.1 trillion burden on healthcare systems worldwide.

Comprehensive global assessments underscore the heightened susceptibility of various regions to amplified heat wave risks, notably encompassing the US, Central America, southern and western Africa, the Middle East, India, South-East Asia and northern Australia. Projected estimations for 2050 reveal an alarming surge in heat wave exposure, with anticipated increments ranging from 12 to 38 times the current levels.

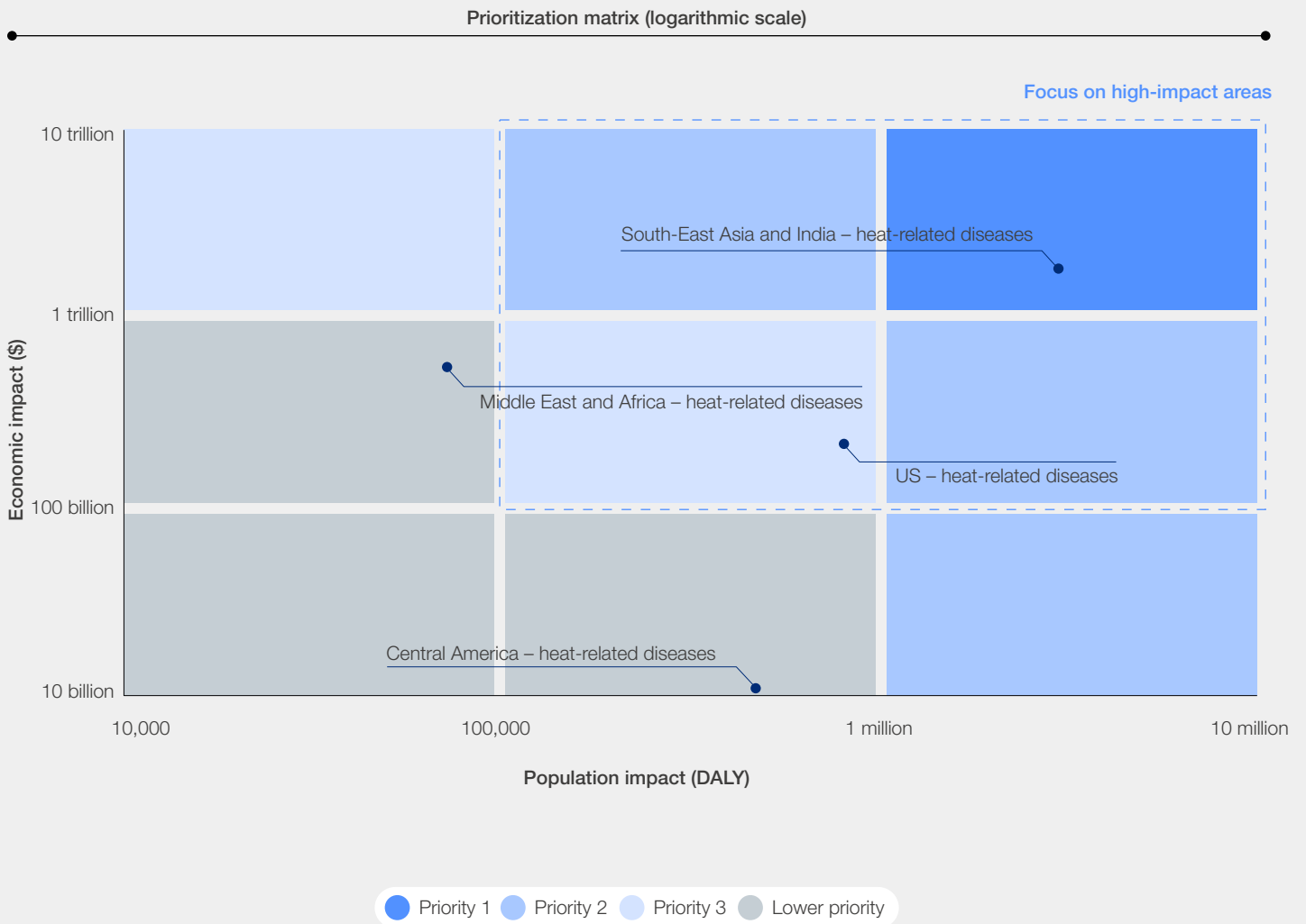
In the US alone, the projected heat wave exposure is expected to surge between 168 billion and 535 billion person-days, while in the Middle East and Africa, the exposure levels are projected to elevate within a range of 67 billion to 230 billion person-days. A person-day refers to the cumulative measure of the duration of heat exposure for an individual over a single day. It represents the combination of the number of people exposed to heat and the duration of their exposure, providing a unit of measurement to

assess the collective impact of heat waves on a population over a specific period.

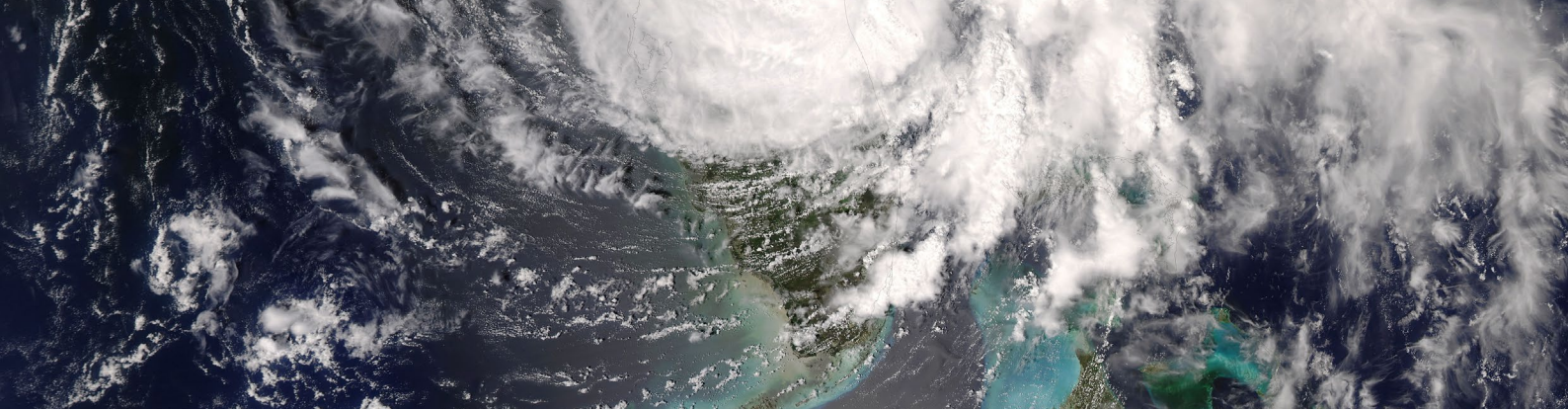
**Quantifying future health and economic impacts by 2050**

By the year 2050, heat waves are forecast to contribute to nearly 1.6 million fatalities, with approximately 70% of these deaths concentrated within identified high-risk regions. Notably, South-East Asia is poised to bear a significant brunt of this distressing toll. The collective impact of heat-related diseases resulting from heat waves is projected to place an astonishing \$7.1 trillion burden on the global economy, coupled with an adverse influence on 6.5 million DALYs. However, South-East Asia is anticipated to shoulder the most substantial burden, with heat-related diseases expected to dump a staggering \$1.8 trillion cost on to the healthcare system and affect 3.0 million DALYs.

FIGURE 17 Projection of health outcomes triggered by heat waves by 2050, cumulative 2023-2050



Source: Oliver Wyman analysis



## Climate event 4: tropical storms

### Health outcomes

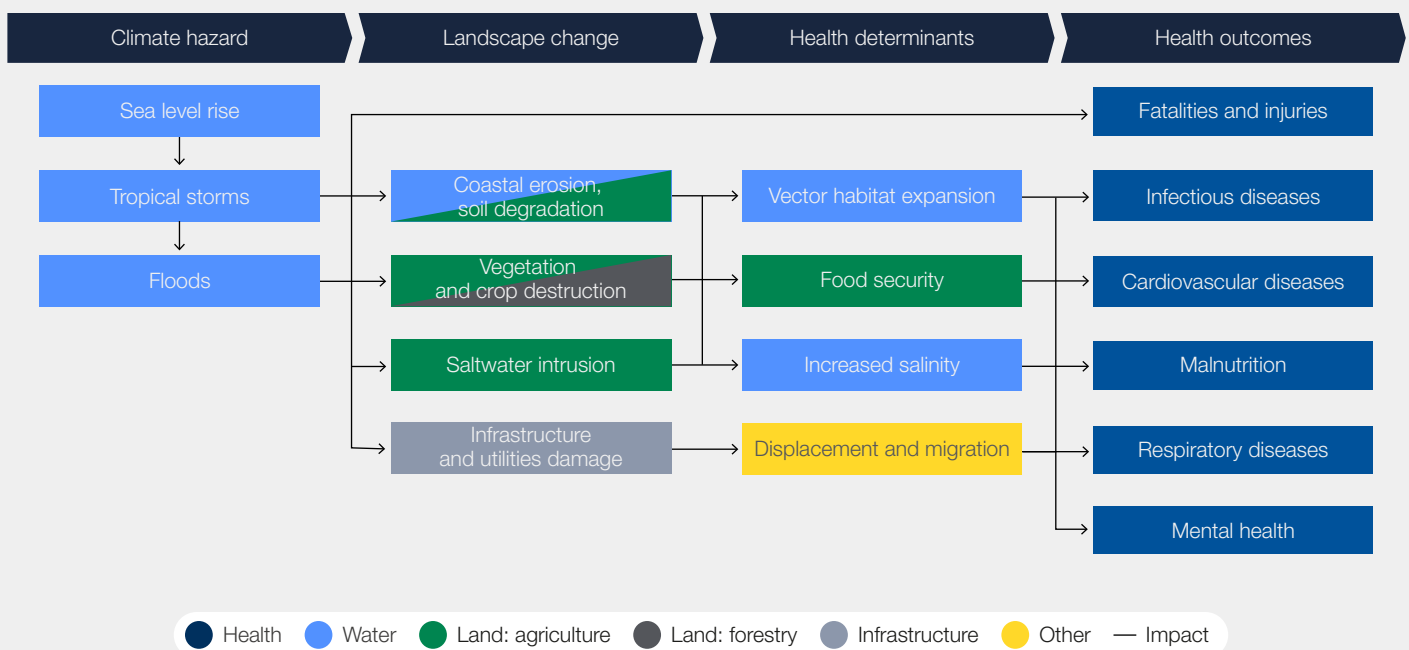
As defined by the WMO, hurricanes, cyclones and typhoons all refer to the same meteorological phenomenon: intense rainfall accompanied by maximum sustained wind speeds near the centre of the weather system surpassing 119 kilometres per hour. While hurricanes, typhoons and cyclones refer to the same type of weather system, the naming convention varies by geographical location.

Tropical storms are classified by their level of severity, according to the Saffir-Simpson scale,

based on wind speed and the extent of anticipated damage upon landfall. There are five categories. category one represents storms with relatively lower wind speeds and minimal landfall damages, while category five denotes storms with extremely high wind speeds and severe landfall damage.

The health implications of storms are far-reaching, with immediate concerns centred around direct fatalities and injuries. Physical harm can arise from flying debris, falling objects, structural collapses and flooding, which often result in fatalities. Exposure to storms can also contribute to a range of mental health issues, including heightened anxiety, depression and PTSD.

FIGURE 18 Overview of tropical storms' impact on health outcomes



Sources: IPCC Sixth Assessment Report (AR6), PubMed, UNEP, Oliver Wyman analysis

Conditions in the wake of storms, such as power outages, contaminated water from stored chemicals or gasoline, downed power lines, impassable roadways, collapsed structures and food shortages, often lead to other public health-related crises. These include waterborne diseases and disruption

of healthcare services. Certain studies have highlighted the connections between storms and respiratory diseases, which are often exacerbated by power outages that make it difficult to use medical equipment.



Older people, children, people experiencing homelessness, individuals with disabilities, people without transport and those with chronic health conditions are particularly susceptible to the destruction and physical risks from storms. These populations may face greater challenges than the general population evacuating the area in the storm's path or finding adequate shelter. The potential loss of electricity increases their vulnerability, and their physical and emotional well-being can be significantly damaged by this sense of helplessness.

### Projecting the future incidence

Asia, North and Central Americas, and the South-West Pacific Ocean region have experienced the highest incidence of storms over the past 50 years, according to the WMO Atlas of Mortality.

Due to the concentration of people living near the coast in low-lying areas, Asia has witnessed the highest number of disasters and loss of life, accounting for approximately 90% of deaths globally. Within Asia, countries such as Bangladesh, Myanmar and India lead in terms of fatalities linked to storms.

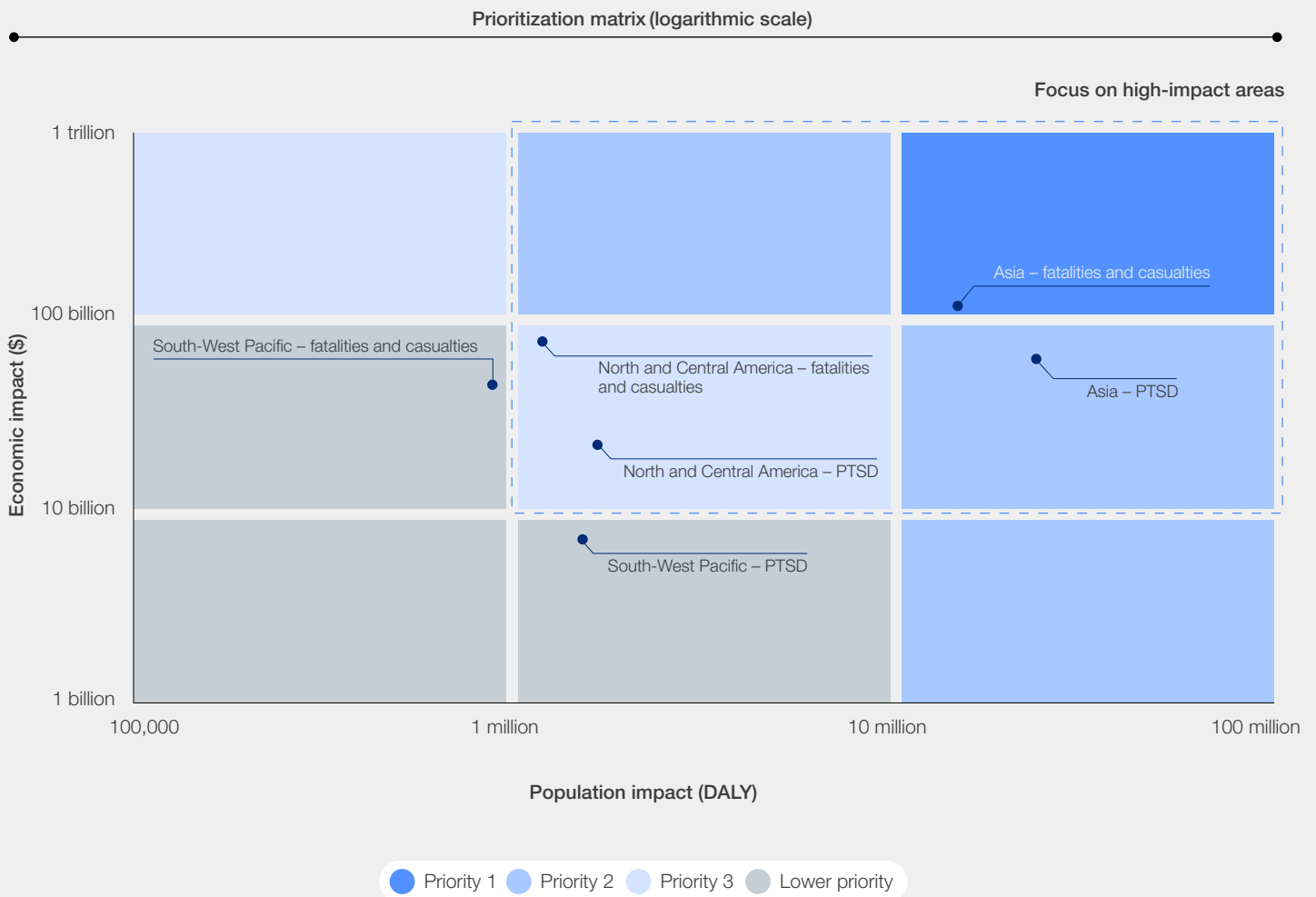
It is imperative to recognize that the true toll of storms may be underestimated because of the lack of comprehensive data capturing indirect effects. This is particularly true for low-income and other vulnerable populations.

The future trajectory of tropical storms is cause for substantial concern. Projections suggest an approximate 10% to 15% increase in the number of storms per year by 2050, with a staggering 90% of these events expected to occur in Asia, North and Central America, and the southwest Pacific Ocean regions. These projections underscore the critical imperative for implementing robust preparedness and mitigation measures within these areas, emphasizing the urgent need for proactive strategies to effectively manage the escalating risks posed by severe storms.

### Quantifying future health and economic impacts

By 2050, the impacts of storms on both health and local economies are anticipated to be substantial, particularly in Asia. The health outcomes triggered by storms, including fatalities, PTSD and other serious injuries and illnesses, are projected to cost the global health system approximately \$369 billion and impact 44 million DALYs.

FIGURE 19 Projection of health outcomes triggered by storms by 2050, cumulative 2023-2050



Source: Oliver Wyman analysis



Asia is expected to be the most affected region, with PTSD alone estimated to cost \$85 billion to the health system and impact 24 million DALYs. Casualties in Asia are projected to add \$121 billion to health system costs and 15 million DALYs.

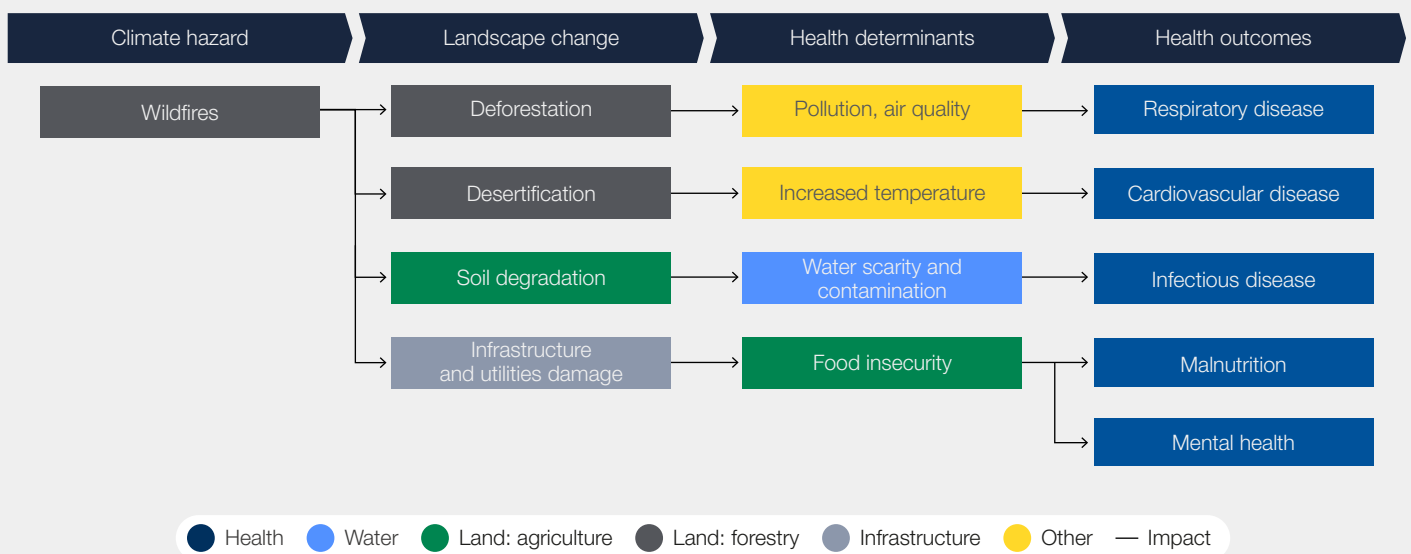
With the anticipated increase in the frequency of severe storms, regions most affected must take proactive measures and invest in healthcare systems to fortify their resilience and mitigate the devastating impact of these natural disasters. Additionally, international collaboration and knowledge sharing can contribute to more effective storm response and recovery efforts.

### Climate event 5: wildfires

#### Health outcomes

The profound impact of wildfires on human health and the environment is undeniable. Besides the sheer destructive force of wildfires, the release of hazardous pollutants and particulate matter during these events significantly increases the risk of respiratory and cardiovascular diseases.

FIGURE 20 Overview of wildfire impact on health outcomes



Sources: IPCC Sixth Assessment Report (AR6), PubMed, UNEP, Oliver Wyman analysis

“ The highest-risk regions for wildfires include the Amazon, Mediterranean Europe, the Arctic tundra, Western Australia and the Western US.

Exposure to smoke from fires can trigger respiratory ailments, notably asthma, especially among those directly exposed to the fumes. Simultaneously, the wind erosion of dry and degraded soils during wildfires generates airborne particles, compounding the issue of poor air quality and intensifying respiratory challenges. Moreover, the intense heat and dehydration induced by wildfires can further worsen cardiovascular conditions, potentially leading to heightened blood pressure and blood viscosity, thereby increasing the vulnerability to ischemic heart diseases (IHD).

The far-reaching consequences of wildfires extend beyond physical health, encompassing the profound social and psychological impacts resulting from the loss of livelihoods, food insecurity and displacement. These factors significantly contribute to heightened stress and anxiety levels among affected populations, often leading to the development of generalized anxiety disorders.

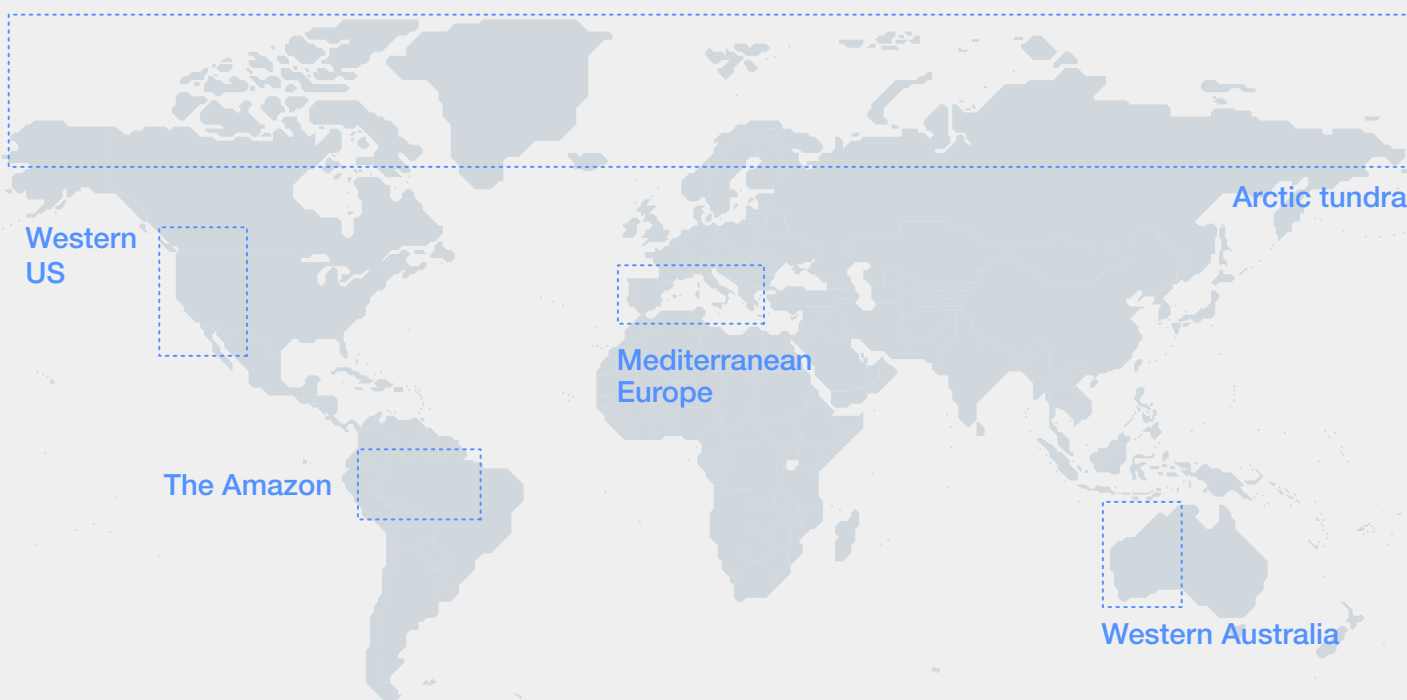
Wildfires pose a significant risk to various populations, including firefighters, low-income individuals, older adults and other vulnerable,

less mobile groups. They can have devastating consequences for people with disabilities, hospitalized individuals and local tribes living in forested areas.

### Projecting the future incidence

Over the past decade, the frequency of wildfires has surged across almost every continent globally, except Antarctica, including the Amazon, the Arctic, Australia, the Western US, Southern Europe and parts of Africa and Asia. This notable escalation in wildfires is primarily attributed to extraordinary air temperature anomalies. On a global scale, an average of 56,000 square kilometres of land falls prey to annual wildfires, with the most intense fires documented in the Amazon rainforest, deciduous forests in Africa, and northern Australia.<sup>37</sup> Scientific literature has pinpointed certain areas at a higher risk of experiencing more fires in general, fires that involve significant acreage and persistent weather conditions that encourage fires. Notably, these high-risk regions include the Amazon, Mediterranean Europe, the Arctic tundra, Western Australia and the Western US.

FIGURE 21 Future projections of wildfire in high-risk areas



Source: IPCC Sixth Assessment Report (AR6), OECD, PubMed, UNEP, Oliver Wyman analysis

As seen with the other climate events, the likelihood of an increasing number of catastrophic wildfires is anticipated to surge by 20% to 33% by 2050. In the Western US, estimates suggest that 20,000 to 22,000 square kilometres of forest could succumb

to wildfires by 2050, while in Mediterranean Europe, 2,200 to 2,500 square kilometres of forest could face similar challenges, indicating the urgent need for comprehensive and strategic wildfire management initiatives.

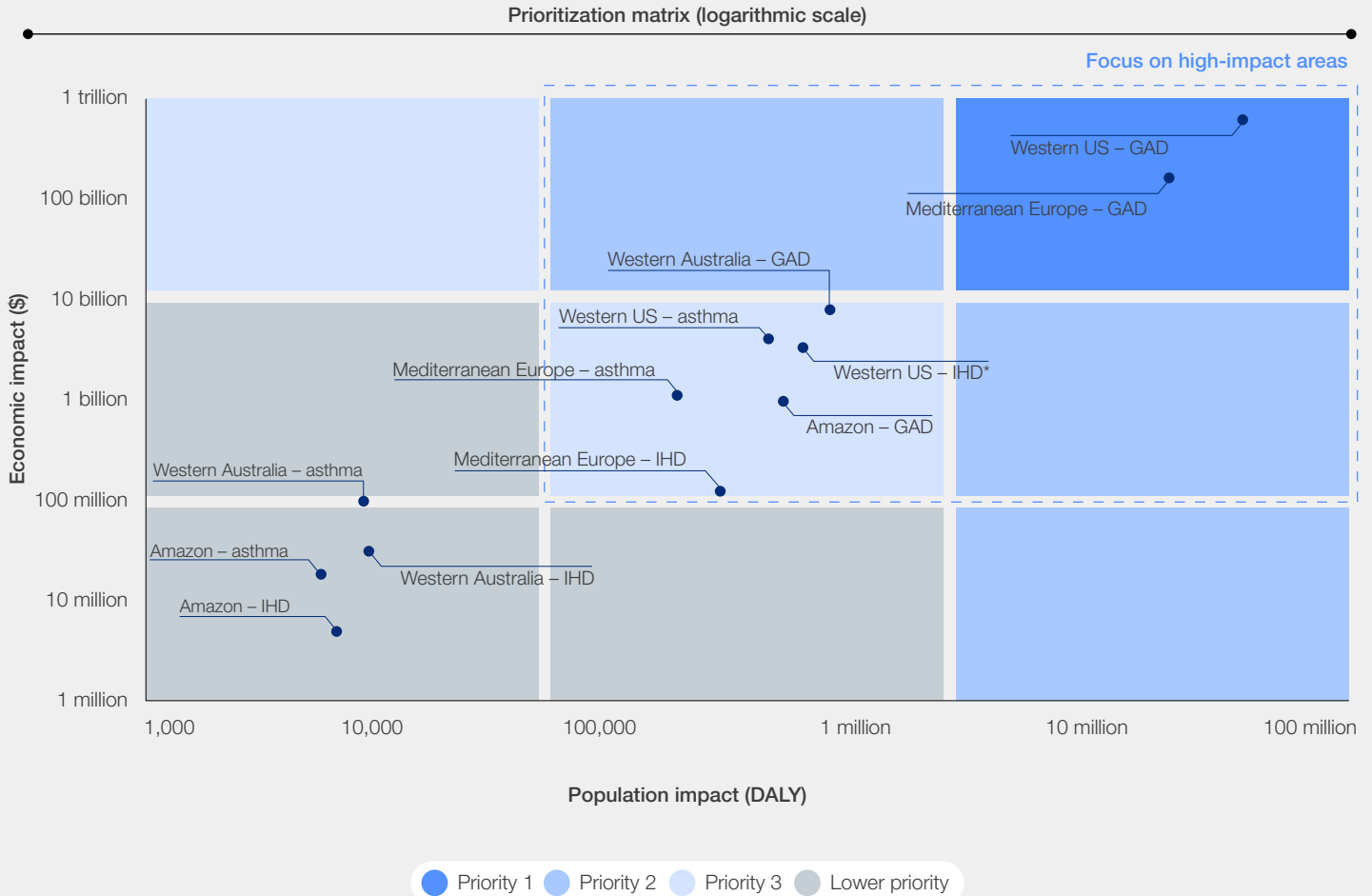
### Quantifying future health and economic impacts

The far-reaching socioeconomic implications of wildfires are substantial, especially concerning the strain they place on global healthcare systems.

Health outcomes linked to wildfires, including asthma, ischemic heart diseases and generalized anxiety disorders, present a significant burden on healthcare systems worldwide.

FIGURE 22

Projection of health outcomes triggered by wildfires by 2050, cumulative 2023-2050



Source: Oliver Wyman

Projections indicate that these health outcomes could add as much as \$1.3 trillion, with a total of 207 million DALYs. Specifically, asthma is anticipated to incur costs amounting to \$9.4 billion and 2.1 million DALYs, while ischemic heart diseases are projected to cost \$5.6 billion and add 2.9 million DALYs. However, the most substantial economic and population impacts are tied to generalized anxiety disorders.

The prevalence of this type of mental illness resulting from wildfires is estimated to generate a monumental cost of \$1.3 trillion and 202 million DALYs. More specifically, in the Western US, generalized anxiety disorders are estimated to cost \$709 billion, with 36 million DALYs, while in

Mediterranean Europe, it is projected to incur costs of \$166 billion, with 18 million DALYs.

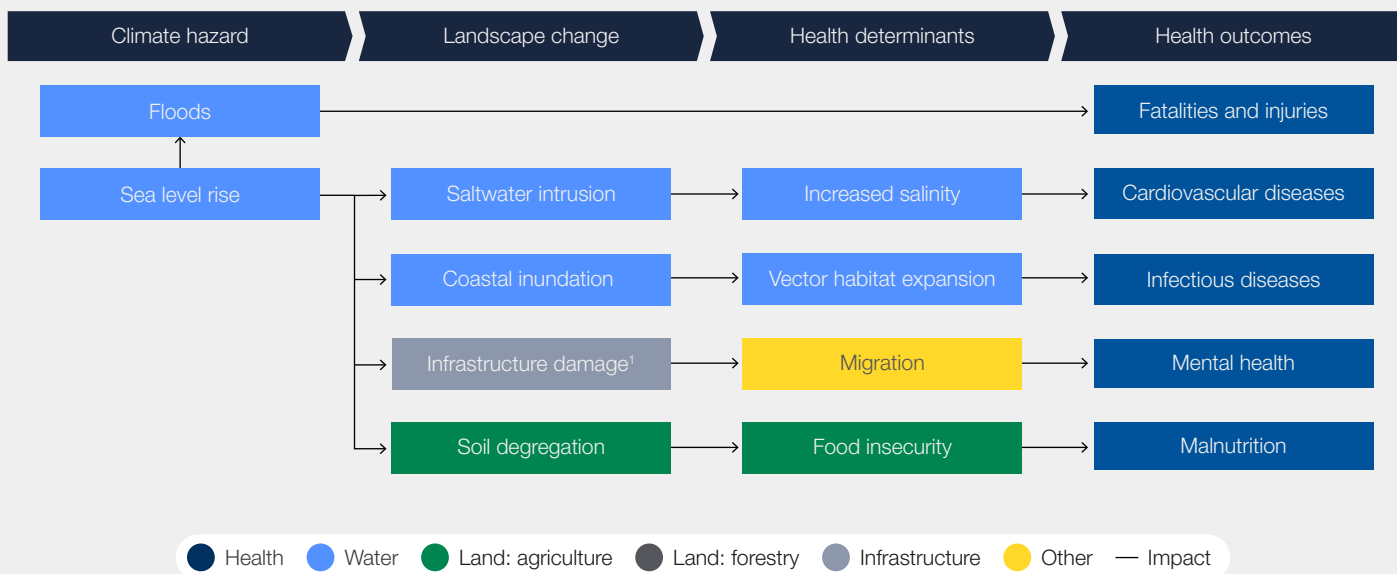
### Climate event 6: sea level rise

#### Health outcomes

Sea level rise is not only a threat to those living in coastal areas and the infrastructure, but it also has significant implications for human health among a broader population. Increased groundwater salinity and the expansion of vector habitats are two key factors that can trigger a rise in cardiovascular and infectious diseases.



FIGURE 23 | Overview of sea level rise impact on health outcomes



**Note: 1** Coastal inundation leading to death due to drowning or suffocation not included as a long-term health impact due to disease focus areas, i.e. cardiovascular, respiratory, infectious disease, malnutrition and mental health. This risk will be captured in the floods section.

**Sources:** IPCC Sixth Assessment Report (AR6), NCEH, National Institute of Health, Oliver Wyman analysis

Rising sea levels lead to saltwater intrusion, resulting in higher concentrations of calcium, potassium and magnesium in groundwater. This can contribute to an increase in hypertension and related cardiovascular illnesses.

Additionally, coastal inundation creates favourable conditions for the expansion of water-based habitats of disease-carrying vectors like mosquitoes, potentially leading to higher transmission rates of infectious diseases such as malaria.

Apart from the physical health risks, the mental health implications of sea level rise should not be overlooked. The gradual rise in sea level can contribute to depression related to climate

change due to the potential for displacement of communities and flooding events. The loss of homes, livelihoods and social support systems can lead to increased stress, anxiety and depression among affected individuals.

Rising sea levels pose a significant threat to low-income coastal communities, especially individuals engaged in farming. These populations are disproportionately affected by increased flooding, erosion and saltwater intrusion on farms and freshwater supplies. Coastal communities are likely to face displacement and loss of livelihoods, while farmers in low-lying regions are likely to experience reduced agricultural productivity.



### Projecting the future incidence

Global sea levels are projected to rise significantly by the year 2100, with estimates ranging from 0.3 to 1.1 metres compared to current levels, depending on emissions scenarios. This increase in sea levels will have a profound impact on coastal populations, potentially doubling the number of

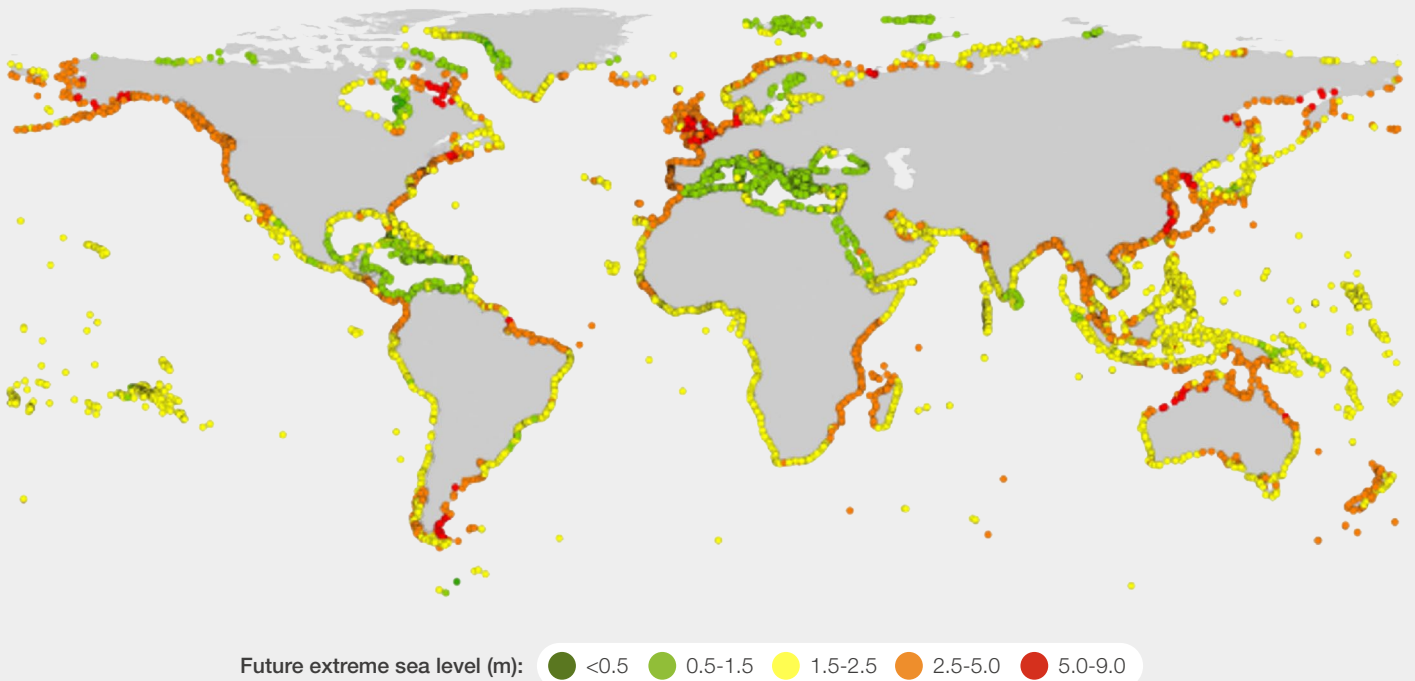
people exposed to sea level rise. While the exact estimates vary for different regions at risk, research suggests that the greatest impact on human health will be felt in low human development index (HDI) coastal areas. These regions often face challenges in terms of migration, mitigation, adaptation and support, making them more vulnerable to the health impacts of sea level rise.

FIGURE 24

### All coastal areas are high-risk areas for sea level rise by 2050 and 2100; areas with low HDI will see the highest health impacts

Overview of coastal regions identified as high-risk areas for sea level rise by 2050 and 2100

#### Future projections of sea level rise in high-risk areas



Sources: Kirezci et al., Nicholls et al., Romanello et al., Oliver Wyman analysis

To better understand potential health risks, it is important to consider the population at risk. This approach considers the socioeconomic factors and the ability of regions to effectively respond to the challenges posed by rising sea levels. Currently, approximately 40 million people in low HDI coastal areas are exposed to sea level rise risks. However, this number is projected to increase significantly to 96.5 million by the year 2050 as more people continue to move to the coasts and more coast is affected by rising sea levels.<sup>38</sup>

### Quantifying future health and economic impacts

Sea level rise is expected to have a significant impact on coastal areas, particularly in terms of hypertension-related health outcomes. By the year 2050, the rise in sea levels is projected to contribute to an increase of more than 800,000 in hypertension cases in low HDI coastal areas.





FIGURE 25 | Projection of health outcomes triggered by sea level rise by 2050, cumulative 2023-2050



Source: Oliver Wyman analysis

The consequences of hypertension in these vulnerable coastal regions are not only limited to individual health but also have significant economic implications. It is estimated that the healthcare system will bear a cost of approximately \$73 billion

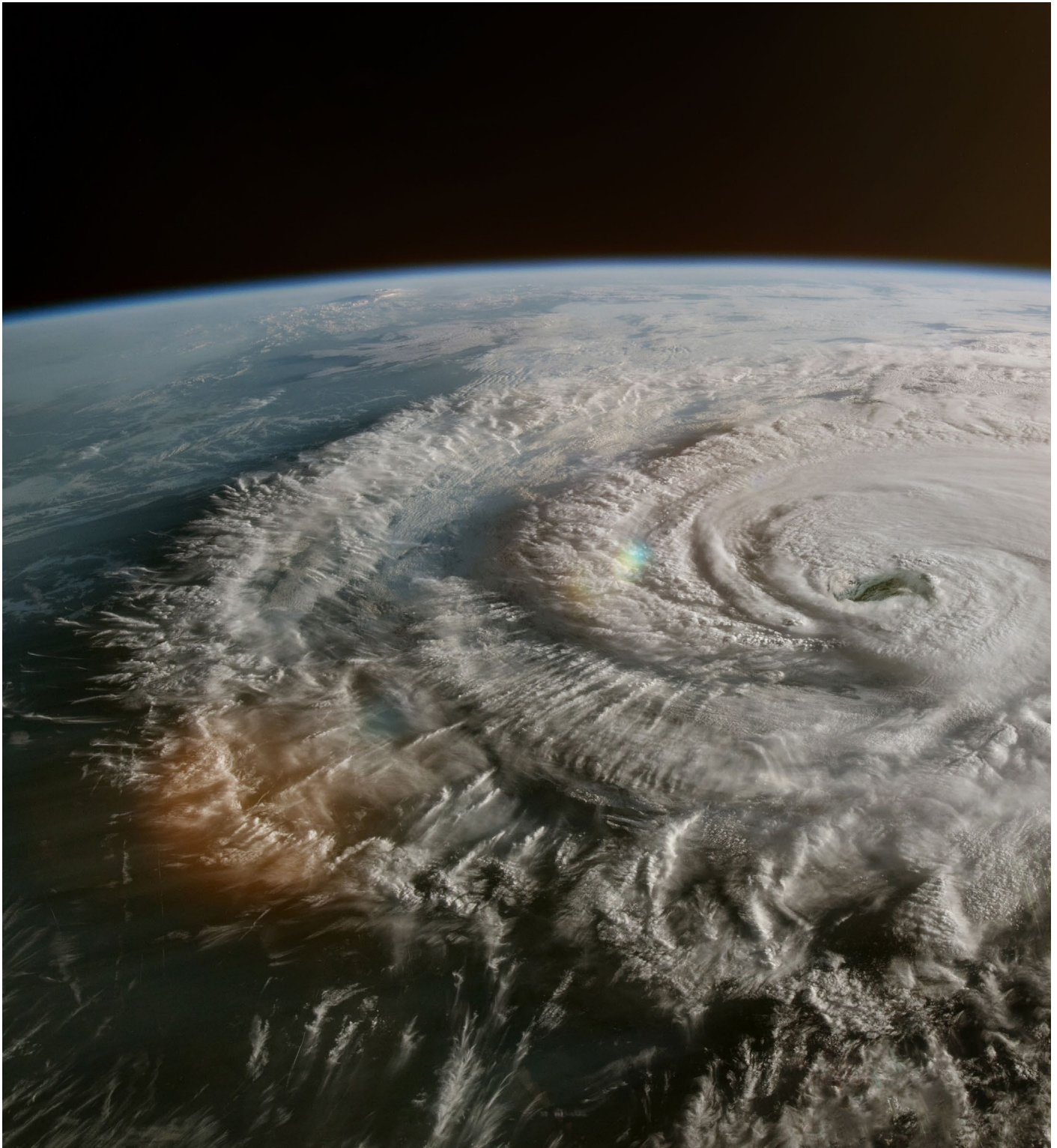
in addressing hypertension-related issues in low HDI coastal areas. Additionally, the impact on DALYs is projected to be substantial, affecting approximately 193 million DALYs.



3

# Building climate-resilient health systems

Healthcare executives and policy-makers need to focus on prevention, recovery and innovation.



### 3.1 Resistance and recovery, the two key pillars for sustainable health systems

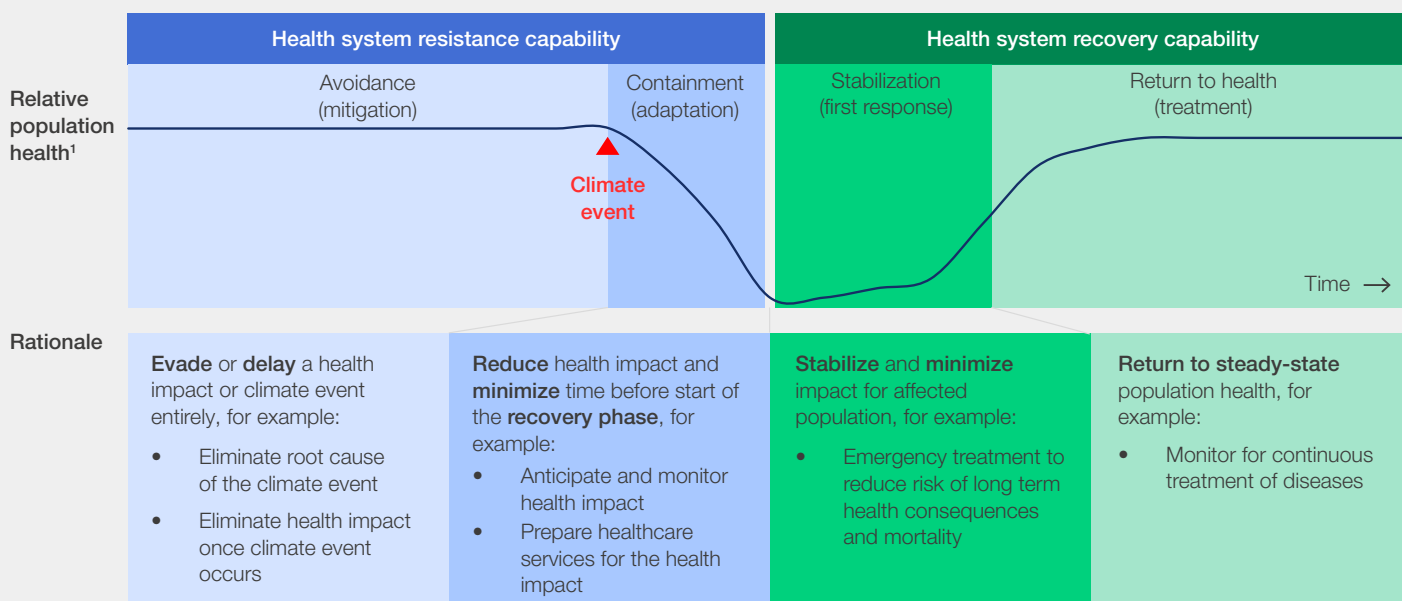
#### A framework for developing solutions

Healthcare leaders worldwide need to encourage models of care and flexible infrastructures to build resilience for the anticipated increases in climate-related morbidity and mortality. They must also support regional policy-makers to address adapted strategic plans emphasizing healthcare system capacity and agility. Due to the substantial risk that climate change poses to local, regional and global

health, it is important to explore solutions that address the needs of the healthcare infrastructure and resources at all three levels.

The climate-resilient health systems framework (see Figure 26) foresees that healthcare systems will need to develop or improve on two important areas: 1) **resistance**, the ability to prevent, reduce or delay climate change's impact on humans, and 2) **recovery**, providing fast stabilization of the affected populations and healthcare infrastructure and effective treatment of long-term consequences.

FIGURE 26 Climate-resilient health systems framework



Note: 1 Versus steady-state without climate event.

Source: Oliver Wyman analysis

#### Making health systems resistant to climate change

To construct a climate-resilient healthcare sector and delivery system, communities must focus on effectiveness and accessibility as top strategic objectives. These can include adaptation planning, infrastructure resilience, disease surveillance and response, capacity building, innovative research and development, continuous evidence gathering and policy integration.

As described in chapter 2, health outcomes based on climate events were researched, and adaptation/preparedness measures were identified to address these outcomes. These can include forecasting activities such as novel therapeutic and diagnostic development or ensuring enhanced access and production capacities in anticipation of increased demand for the treatment of climate-related conditions. A key way to implement preventative measures is also to increase capacity building, knowledge transfer and community involvement, especially for vulnerable and hard-to-reach populations.



“ Technology and media can play a big role during disasters, helping stakeholders set up early warning systems for affected communities.

### Enhancing the capability of health systems to recover from climate impacts

The second element of resilience is the ability to recover fast from climate events. Health systems need the ability to stabilise shocks and crisis situations and recover from both acute and longer-term climate events and related health impacts. Prioritizing recovery to a pre-disaster state ensures that health systems can address ongoing community needs as well as manage the health consequences of climate events. This can include the development of innovative treatments for infectious diseases, drug delivery innovations and preparedness planning of emergency services in anticipation of climate events.

Together, these two pillars form the foundation of climate-resilient health systems. By combining proactive resistance measures with robust recovery strategies, health systems can more effectively mitigate the impact of climate change on public health, safeguard the well-being of communities and promote a sustainable healthcare infrastructure.

Additionally, by implementing solutions that increase resilience, healthcare systems can enhance their ability to respond to disasters and ensure continuity of care in the face of climate challenges.

### Developing innovative solutions

Developing solutions for climate-resilient health systems will require coordination among all stakeholders and the identification of risk factors. These include sharing data and knowledge on conditions and impacts as well as active collaboration across private sectors, both geographically and by focus area.

#### The importance of early warning systems

Technology and media can play a big role during disasters, helping stakeholders set up early warning systems and pushing out alerts and educational materials to affected communities. For instance, the deployment of the Hot Weather-Health Watch/

Warning System in the United States from 1995 to 1998 provided early warning in the instance of heat waves and helped save hundreds of lives for a fractional dollar cost.<sup>39</sup>

More recent digital public health campaigns around vaccinations offer another example of how organizations can reach large numbers of people as they did during COVID-19.<sup>40</sup> Companies, such as Google, are pitching in to provide crisis alerts and forecasts for floods, wildfires and hurricanes.<sup>41</sup>

For many diseases, including malaria and dengue, there is always an urgent need for reliable and rapid diagnostic tests. As warmer temperatures and increased humidity encourage the growth and spread of mosquito populations, community data collection, accurate geographic information system forecasting and mosquito monitoring, can help indicate a future outbreak. These early warning systems trigger timely public health responses that can include larvae control, released male Wolbachia-infected mosquitoes, distribution of bed nets, diagnostic availability, preventative and treatment therapeutics.

#### Role of healthcare and life sciences organizations

As major stakeholders and primary solutions providers, companies in the health and life sciences industry need to recognize the importance of ongoing innovative research and development to meet the growing demand for solutions to diseases and conditions aggravated by climate change, such as infectious and vector-borne diseases as well as respiratory and cardiovascular ailments. Collaboration with healthcare providers and regulatory bodies is also essential to ensure the timely availability and uptake of these solutions.

In turn, pharmaceutical and medical device and technology companies will require sound economic incentives and stable funding over the long term to help them commit the necessary resources to research and development for medicines and vaccines for underdeveloped or even undeveloped markets. They may also need support to ensure sufficient production capacity to avoid shortages – a problem that developed during past epidemics.



At the same time, focus on new preventative smart solutions and increased speed to market are needed, including work on improved diagnostics, monitoring devices and drug delivery systems to ensure coverage for climate-related conditions such as heat-related diseases and infections, respiratory

and cardiovascular ailments and infectious diseases. These advancements will enable early detection and intervention, leading to better health outcomes. Increasing access to technology and reducing its cost will be critical to addressing health impact in developing countries.

FIGURE 27 Overview of solution approaches employed by various healthcare providers

	Resistance		Recovery	
	Avoidance	Containment	Stabilization	Return to health
Hospitals and clinics	<ul style="list-style-type: none"> <li>Preventive education for vulnerable population</li> <li>Preventive treatments for patients at risk where applicable</li> </ul>	<ul style="list-style-type: none"> <li>Diagnostic tools and procedures (e.g. to identify mental issues)</li> <li>Access to patients (e.g. with mobile clinics in emerging countries)</li> </ul>	<ul style="list-style-type: none"> <li>Broad offering of treatment options</li> <li>Continuous resource training and up-skilling with latest treatment</li> <li>Preparedness plan of emergency services</li> </ul>	
Pharma	<ul style="list-style-type: none"> <li>Access to effective vaccines and preventive medicine (e.g. for malaria)</li> <li>Research of innovative preventive treatments</li> </ul>		<ul style="list-style-type: none"> <li>Access to medication for various medical conditions and related complications</li> <li>Research of innovative treatments for unmet needs (e.g. against resistant pathogens)</li> </ul>	
Medtech	<ul style="list-style-type: none"> <li>Preventive smart solutions (e.g. wearable sensors for heat stress prevention, outbreaks prediction)</li> </ul>	<ul style="list-style-type: none"> <li>Improved diagnostics (e.g., quick, portable, more precise)</li> <li>Monitoring devices for diagnostics (e.g. wearables, apps)</li> </ul>	<ul style="list-style-type: none"> <li>Drug delivery innovation (e.g. automated delivery, long-lasting medication)</li> <li>Health monitoring devices to track treatment efficiency and complications</li> </ul>	
Public sector (e.g. MoH)	<ul style="list-style-type: none"> <li>Regular public awareness campaigns on health risks and response strategy</li> <li>Climate forecasting systems to issue warnings and prepare adequate system response</li> </ul>	<ul style="list-style-type: none"> <li>Community empowerment (e.g. education, volunteers' organization, leaders' involvement)</li> <li>City infrastructure (e.g. shadowed areas and green zones to reduce heat island effect)</li> </ul>		<ul style="list-style-type: none"> <li>Public sector coordination and response plan</li> <li>Public measures to protect population from potential health impact (e.g. larviciding for vector control)</li> </ul>
Intergovernmental organizations (e.g. WHO)	<ul style="list-style-type: none"> <li>Knowledge creation and sharing to increase stakeholder awareness of health risks and response strategies</li> </ul>	<ul style="list-style-type: none"> <li>Support vulnerable communities directly on the ground</li> <li>Knowledge transfer to local communities</li> </ul>		<ul style="list-style-type: none"> <li>Coordination with gov agencies, other NGOs and international organizations for effective response to climate impact on health</li> </ul>

Source: Oliver Wyman analysis

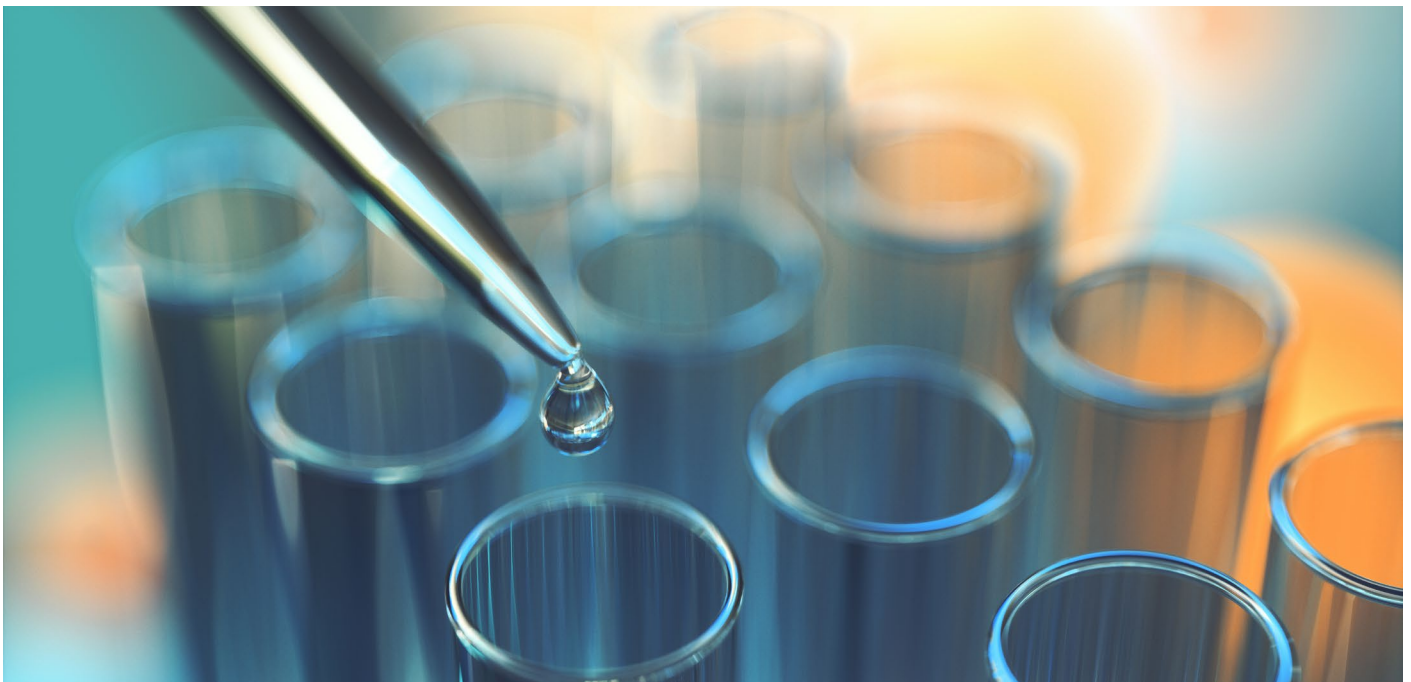
### 3.2 Why policies and incentives need to change to enable climate-resilient health systems

#### The role of governments and the public sector to drive innovation and support the transition

Public sector participation is vital when it comes to raising awareness about health risks associated with climate change. For instance, support from agencies such as the Centers for Disease Control and Prevention (CDC) in the US was instrumental in developing robust public awareness campaigns during the COVID-19 pandemic.<sup>42</sup>

Similar approaches are ongoing and encouraged to address climate-related health impact visibility and awareness from both the public and private sectors. Examples include the WHO [Alliance for Transformative Action on Climate and Health](#) (ATACH), the WHO National Adaptation Plans (NAP),<sup>43</sup> [Fridays for Future](#), the [ClimaHealth](#) platform by the WHO and WMO, as well as important work carried out by the Rockefeller Foundation, Wellcome Trust, ClimateWorks Foundation, the Forum for the Future and the Global Institute for Disease Elimination.<sup>44</sup>





**“ Coordination between public and private sectors is pivotal to ensure funds are invested where most needed and not only where the return is the best.**

Government support is a key factor, as demonstrated during the pandemic. The public sector was vital in keeping hospitals and clinics operating through subsidies and underwriting the cost of protective gear and medicines.<sup>45</sup> The US government spent more than \$30 billion to support research, development and production of the COVID-19 vaccine.<sup>46</sup>

Another area where public support is required is in necessary infrastructure upgrades to ensure their resilience in the face of climate- and weather-related challenges. This will be especially vital in high-risk geographies.

The public sector's involvement tends to ensure a comprehensive approach to health preparedness in which innovation, paired with private-sector involvement, becomes a driving force behind timely responses to evolving health challenges. Rapid and effective collaboration will be key to meeting the challenges of climate-related health conditions.

Even so, private-sector financing is crucial given the variety of capital sources from which it can draw, including sources not usually available to governments or non-governmental organizations (NGOs). For example, in 2020, Bank of America issued a \$1 billion environmental, social and governance (ESG) bond to lend to not-for-profit hospitals, nursing homes and manufacturers of healthcare equipment.<sup>47</sup>

Additionally, the private sector is armed with operational know-how regarding the production and delivery of therapeutics. This expertise enables private entities to provide a range of proactive responses to evolving health challenges. The remarkable aspect is often the scalability of these solutions, transcending industry boundaries and geographic borders. Making use of their access to substantial financial capital and commercial

and manufacturing savvy, the private sector can emerge as a catalyst in creating and scaling innovative solutions to address the health impact of climate change.

Yet companies will also face challenges, at least initially, that may limit an innovation's commercial viability. To overcome these hurdles, government incentives can be instrumental in encouraging private-sector involvement in undertaking difficult but necessary projects. This is where the strategic allocation of funds becomes a defining force for resilience, and coordination between public and private sectors is pivotal to ensure that funds are invested where most needed and not only where the return is the best.

Incentives act as a bridge, encouraging this collaboration and amplifying efforts to address the health implications of climate change on a broader scale. A workable comparison would be with their use to cultivate new therapeutics to treat rare diseases. These conditions affect roughly 4% of the global population and require a multiyear development and approval process.<sup>48</sup> Many of these diseases do not have a treatment today and would not be addressed at all without technological advancements, an increase in the number of cases, or external incentives.

Chagas is a vector-borne disease that mainly afflicts low-income communities in the Americas. It affects up to seven million people today and causes 14,000 deaths annually. There would probably not be a treatment for it were it not for the US Orphan Drug Designation programme, which was used several years ago to underwrite the development of benznidazole.<sup>49</sup> The US Food and Drug Administration (FDA) granted it priority review and orphan product designation. Due to the disease being vector-borne, the number of Chagas cases is expected to rise due to the changing climate.

## Incentives to drive private sector participation

Four crucial incentives will drive action by the private sector: direct economic incentives, financial enablement, regulation and awareness.

Direct economic incentives play a crucial role in motivating the private sector to enhance preparedness for climate change. These incentives encompass such tools as tax credits, subsidies, research grants and implementation grants. Governments, NGOs and financial institutions can use these direct economic incentives to channel funds towards initiatives aimed at mitigating the impact of climate change on health. The Bill & Melinda Gates Foundation and similar NGOs often assume the role of allocating funds, aggregating resources from diverse sources and strategically directing them to private sector projects deemed impactful and prudent.

Finance enablement levers serve as another mechanism to drive private sector behaviour. This category includes tools like loan subsidies and government guarantees. The aim of this strategy is to enable private capital owners to invest in projects geared towards reducing the climate impact on health. By offering these levers, governments partially offset investor risks associated with uncertainty about future development scenarios and potential technology limitations, making it more attractive for private entities to invest in health-focused climate initiatives.

The use of regulation is another potential motivator for the private sector and can involve stricter

rules that, for instance, mandate the use of a new product or a loosening to encourage participation. For instance, these levers could include fast approval processes for necessary treatments, patent protection and clinical trial support to spur innovation.

There is also an opportunity for more disclosure requirements on climate-related health impacts, which often lead to public pressure for government and private sector action. That was the case during the COVID-19 pandemic when rising, publicly-announced death rates prompted demands for a vaccine and incentivized people to get vaccinated once it was available. Hospitals, for example, could be required to report mortality from certain climate-related diseases for tracking purposes.

Obligatory health-impact reduction targets could further provide requirements to prepare for the health impact of climate change. This could also be part of a broader topic of addressing social determinants of health, which is already required within the Medicare programme in the US.<sup>50</sup> Regulation levers like targets can propel the private sector towards proactive measures in preparing for climate-change-induced health impact.

Finally, awareness itself serves as a powerful incentive. This involves the preparation of public reports that prioritize areas with the highest impact, shedding light on critical health challenges of climate change. Broad dissemination of information and best practices not only raise awareness about pressing health issues, but they cultivate a collaborative environment where diverse entities can unite to tackle the evolving challenges.



TABLE 1 | Tools to incentivize adequate and timely private-sector investment

Category	Incentive types	Institution	Description	Examples
Direct economic incentives	Tariffs, taxes and subsidies	Governments	Reducing taxes or introducing subsidies for products that have a proven effect on addressing climate health impact	US Orphan Drug Act (1983) provides companies with up to 50% tax credits to cover research costs for orphan diseases. <sup>51</sup>
	Research or implementation grants	Governments/NGOs/supranational	Research grant for innovative solutions search to climate change impact on health	The US National Institute of Environmental Health Sciences (NIEHS) provides exploratory grants of up to \$2.3 million to examine the health impacts of climate change and to develop solutions. <sup>52</sup>
	Direct funds	Governments/NGOs/supranational	International fund for disease outbreak control in priority areas	The Global Fund allocates up to \$5 billion annually to fight malaria, human immunodeficiency virus (HIV) and tuberculosis (TB) through a partnership funding model. <sup>53</sup>
Finance enablement	Loan subsidies	Governments/supranational	Government-subsidized free-interest loans for selected climate change health impact solutions	European Green Deal Investment Plan includes €25-30 billion public sector loan facility. <sup>54</sup>
	Government guarantees	Governments	Government guarantees for innovative solution start-ups who are seeking to attract funding	The government of Sweden offers more than \$2 billion worth of guarantees for large green industrial investment projects. <sup>55</sup>
Awareness building	Public reports	NGOs/supranational	Report by an NGO with climate health impact prioritization, targets definition and recommended actions	The WHO's 2014 report, <i>Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s</i> . <sup>56</sup>
	Conferences	NGOs/supranational	Annual summit on climate health impact to discuss latest innovations and progress	American Meteorological Society Annual Conference on Environment and Health. <sup>57</sup>
Regulation	Reporting/disclosure requirements	Governments/NGOs/supranational/payers	Requirement for hospitals to disclose statistics on morbidity and mortality rates for selected climate-related diseases	EU Corporate Sustainability Reporting Directive: carbon footprint reporting requirements. <sup>58</sup>
	Obligatory impact reduction targets	Governments/supranational	Requirement for hospitals to establish targets on reduction of mortality for selected climate-related diseases	UK legally binding net-zero target under the Climate Change Act 2008. <sup>59</sup>
	Simplified approval process	Governments	Priority review and support with clinical trial support to improve success chances and reduce time to market	United States Food and Drug Administration (FDA) Tropical Disease Priority Review Voucher System reduces review process from 10 to six months for prioritized treatments. <sup>60</sup>





### **Best practices for a life sciences and public sector collaboration on climate**

There have been some important precedents set on how to tackle major public health crises that can now provide powerful tools for tackling the health impact of climate change. In the US, the Orphan Drug Act of 1983 is a pivotal example of healthcare legislation that specifically addresses the pharmaceutical industry's problem of reaching a profitable commercial scale when a market's size is limited and anticipated sales will not cover development costs.<sup>61</sup> It introduced compelling incentives, including a seven-year market exclusivity for drugs treating orphan diseases, irrespective of patent status.

To further stimulate research and development, the law offers tax credits of up to 50% for associated expenses. The United States Food and Drug Administration (FDA) plays a crucial role by providing grants for clinical testing of orphan disease treatments and assisting in framing investigation protocols. Additionally, FDA user fees were waived to facilitate the development of treatments for such diseases.

In 2007, the FDA introduced priority review vouchers (PRVs) as a strategic tool to encourage pharmaceutical companies to invest in treatments for neglected diseases.<sup>62</sup> This voucher, granted to a producer, expedites the FDA's review process for one of their drugs – reducing it from the standard 10 months to just six months. The Tropical Disease Priority Review Voucher System, a part of this initiative, spotlights diseases like malaria, cholera and dengue, aiming to address health issues predominantly affecting regions exposed to climate change.<sup>63</sup>

This approach accelerates the development and approval of treatments for prioritised diseases. It also strategically directs pharmaceutical efforts towards areas that may have otherwise been overlooked, showcasing the potential of policy-driven incentives in shaping the pharmaceutical landscape for improved global health outcomes.

This could prove to be an important tool for climate-related health issues.

The European Union's Horizon Europe 2027 is a critical funding programme for research and innovation in health, technology and other sectors. It boasts an impressive €95.5 billion budget.<sup>64</sup> The health cluster within the Horizon Europe programme is dedicated to enhancing and safeguarding people's health and well-being through innovative research solutions.<sup>65</sup>

In particular, the programme focuses on environmental and social health determinants and understanding and counteracting the impact of environmental stressors on human health. By allocating resources to delve into the intricate relationship between environmental factors and health outcomes, Horizon Europe's health initiatives aim not just to address the symptoms but to proactively develop innovative solutions. The funding mechanism in Horizon Europe is based on the principle of co-financing.

### **Public-private partnerships and successful models of cross-sector collaborations**

Countries, particularly middle-income ones, face common challenges such as limited primary care capacity, outdated infrastructure and high out-of-pocket payments – all of which could hinder climate-related disease treatment. New pathways must be considered to overcome these hurdles and implement innovative solutions. Public-private partnerships offer a promising avenue. These long-term contracts enable the provision of health facilities, equipment and healthcare services. Under these arrangements, the private partner participates in designing, implementing and funding the project. The private partner handles healthcare services delivery and the provision of managerial and operational expertise, while the public partner focuses on defining and monitoring compliance with contractual objectives. While they can impose



“ COVAX, an initiative to ensure equitable access to COVID-19 vaccines globally, is an example of an effective public-private response to a health crisis.

future budgetary burdens, careful consideration in designing, planning and monitoring these contracts can bridge the funding gap and yield positive outcomes for health budgets.

COVAX is an example of an effective public-private response to a health crisis. It is a global initiative designed to ensure equitable access to COVID-19 vaccines worldwide.<sup>66</sup> It was co-led by Gavi, the Vaccine Alliance to improve access to new and underused vaccines for children living in poor nations, the WHO and the Coalition for Epidemic Preparedness Innovations. COVAX brought together governments, global health organizations, manufacturers, scientists, the private sector, civil society and philanthropy to provide innovative and equitable access to COVID-19 diagnostics, treatments and vaccines. All participating countries were to have equal access to these vaccines once they were developed.

The Coalition for Epidemic Preparedness Innovations (CEPI) is an innovative global partnership between public, private, philanthropic and civil society organizations. It was launched at the Forum's Annual Meeting in Davos 2017 based on the recognition that a proactive and coordinated effort would be required to develop and deploy new vaccines to prevent future epidemics. Its mission is to expedite the advancement of vaccines and other biological countermeasures in response to epidemic and pandemic threats, ensuring widespread public accessibility.

Another example is the World Economic Forum's, Giving to Amplify Earth Action (GAEA) – an initiative that forges new public, private and philanthropic partnerships (PPPPs) to help unlock financing needed to reach net zero. It helps to prioritize interventions and design PPPP funding models. Piloting and improving PPPP models will eventually help develop an effective operating model that can handle larger projects.

Similar models will be crucial in addressing climate-related health impacts. Public-private partnerships should be integrated into governmental health financing, purchasing and organizational strategies. This approach empowers businesses to engage in health-focused climate action.

## Exploring the known unknowns: future considerations and potential avenues for research

Recently, several non-profit organizations, such as Wellcome, the Rockefeller Foundation and the WHO, have invested in research that is shedding light on various aspects of climate change's impact on human health – some of which this report incorporated.<sup>67,68,69</sup> Each framework offers a unique

way to structure the health impact of climate change and assess the impact at different levels of effect (e.g. climate event vs certain disease level), although all data suggest that the impact of climate change will be deadly, especially for certain populations.

This report has attempted to build the first comprehensive framework to chart and quantify the overall effects on humans and the economy as a tool for policy-makers and the healthcare industry, recognizing the need for consistent data, cohesion and collaboration.

Marked by complex interdependencies and cascading effects, unravelling these intricacies requires further dedicated research. Harmonizing frameworks can form a unified foundation that will allow for a more robust understanding of the complex dynamics between climate change and its effects on human health in future analyses.

Several aspects of the impact of climate change on human health still remain unquantified. For example, it's unclear how the increased spread of certain climate-related diseases will impact the frequency and severity of other diseases. The effect of climate change on underlying comorbidities is also an area requiring more research, such as the strain of exposure to sustained heat waves and its relation to hypertension or mobility and access to treatment of dialysis or cancer patients during heat stress. There is also a lack of clarity on the compounded effects of consecutive or simultaneous climate events on morbidity and mortality rates. Quantifying these uncertainties is essential for effective planning and response strategies.

Data gaps also exist for remote communities. For instance, the life expectancy of asthma patients in some Latin American and African countries remains scarcely documented. Quantifying the health impacts in these regions often relies on estimates derived from more extensively studied geographies and populations. This lack of specific research hampers the ability to tailor interventions and preparedness strategies for these communities, leaving them vulnerable to the health repercussions of a changing climate.

Bridging this research divide is essential for creating targeted and effective measures that account for the unique health challenges faced by these often neglected regions. One way to generate community support and engagement can be through outreach to the younger population and future leaders through organizations such as the Global Shapers Community.<sup>70</sup> With malaria associated with climate change on the rise, this preventative option will save many lives worldwide. Making more efficient and affordable versions of existing treatments will contribute significantly to the global economy's ability to mitigate as much as possible climate change's impact on health.

# Conclusion

**Climate change is a health emergency.** This report's projections of morbidity and mortality from climate-intensified natural disasters, cumulatively close to 15 million deaths, more than two billion healthy life years lost, and \$12.5 trillion in economic losses by 2050 bring into focus the dimensions of the crisis. The risk from global warming threatens to destabilize both the healthcare ecosystems and the planet.

The clarion call to action must be for governments and industry to try to avoid this future by actively cutting GHG emissions today. In parallel, policy-makers and the health and life sciences sector must begin to envision and prepare for a future of severe and frequent natural disasters and the dire impacts on communities and regions that accompany them.

For the healthcare industry, this must be a moment of reflection. What should its role be in this future, and how can it make its infrastructure, workforce and operations more resilient to the inevitable pressures from the climate crisis? The importance and fragility of healthcare workers must not be underestimated. Working tirelessly in the face of overwhelming numbers of patients and inadequate staffing and supplies, this workforce will need to be physically and mentally prepared with the adequate tools, infrastructure and resources both immediately and in the long term. The health emergency around climate change will prove relentless, with the added potential of physical destruction, power interruption and supply chain collapses.

The health and life sciences industry needs to continue setting priorities and strategies today for

this future, establishing avenues for collaboration within industry, government and all other impacted stakeholders. Having the quantification of the scope of disaster is a critical step towards risk assessment and preparation. The next step is to understand how well current systems would cope with this level of stress and pressure. Healthcare systems must embed climate-change resilience mechanisms to resist impact and recover fast if resistance is insufficient. Conducting regular stress tests in the healthcare sector, similar to those implemented in banking after the 2008 financial crisis, could be helpful to check the status quo. Solutions will need to be tailored to regional needs and populations served, recognizing that some of the hardest hit areas will be those with the fewest resources.

Governments and policy-makers are recognizing the imminent threats to global health from climate change. COP28 featured the first-ever "Health Day" and saw more than 120 nations sign a Declaration on Climate and Health, pledging to be proactive about the looming threat. More than \$1 billion was committed to health-related projects to mitigate the impact of climate change.

Yet much more is needed given the pervasiveness and severity of the climate problem. Mitigating it will require a high degree of global cooperation to develop solutions that fortify the global health infrastructure, not to mention a willingness to commit resources early. So far, governments and industry have been slow to step up.

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