In collaboration with
Oliver Wyman

Healthcare in a Changing Climate: Investing in Resilient Solutions

WHITE PAPER

JANUARY 2025

Images: Midjourney, Getty Images

Contents

Foreword

Shyam Bishen
Head, Centre for Health and Healthcare; Member of the Executive Committee, World Economic Forum

Terry Stone
Global Leader of Health and Life Sciences, Oliver Wyman

Climate change is a health emergency. We are on track for a world that is more than 2ºC warmer than today. This will result in an increased frequency of climate events including floods, droughts, heatwaves, wildfires and tropical storms, as well as longer-term changes such as saltwater intrusion from rising sea levels.

These manifestations will have a profound impact on people's health – with an estimated additional 14.5 million deaths and $12.5 trillion in economic costs between today and 2050. Vulnerable populations – the least responsible for the climate crisis – will bear the brunt of the consequences, primarily in less economically developed economies.

We need strong mitigation efforts to avoid the most severe impacts of climate change on nature, the economy and people. However, mitigation alone is not enough. The World Economic Forum's Climate and Health Initiative focuses on making healthcare systems more resilient and adaptable to the impacts of climate change. In this report, we focus on three key pillars – building the evidence for change, advocating for more resilient healthcare systems and incentivizing action.

We also illustrate solutions to prevent the most negative consequences of the impending climate crisis and look at opportunities in which the life sciences industry can play a pivotal role. The COVID-19 pandemic demonstrated that collaboration among policy-makers, industry leaders, academics and civil society can produce solutions that can be deployed rapidly and at scale. The lessons learned from this shock will need to be replicated and amplified to combat the health impact of climate change.

Regardless of the solutions, health systems and life sciences innovations need to be mobilized with great urgency, as does the capital required to develop a new portfolio of climate-related products and services. We are confident that the ideas presented through this analysis will inspire leaders to take the decisive, timely and collaborative actions needed.

Executive summary

By filling the $65 billion investment gap, 6.5 million lives could be saved and global economic losses reduced by $5.8 trillion.

R&D investments totalling $65 billion over the next five to eight years will be required to mitigate potential climate-related challenges –

less than

5%

of normal annual R&D spending by the pharmaceutical industry.

Climate change is already causing global public health challenges. Drought in eastern Africa has affected more than 10 million people.[1] Hurricanes in the southern United States have left hundreds dead and thousands homeless.[2,3] Mosquitoes are now spreading dengue fever in record numbers beyond their usual geographic range.[4,5]

The World Economic Forum's January 2024 report *Quantifying the Impact of Climate Change on Human Health*,[6] assessed the health and economic impacts of weather events aggravated by global warming, such as flooding, drought, tropical storms and rising sea levels. By 2050, these impacts are projected to cause an additional 14.5 million deaths and cost the global economy $12.5 trillion. On an annual basis, the losses are comparable to the gross domestic product of Singapore.

This report looks at the measures that the global economy can pursue to mitigate these anticipated impacts. Through investment in vaccines, medicines, medical devices, health-tech and climate services, 6.5 million lives could potentially be saved, global economic losses reduced by $5.8 trillion and one billion fewer disability-adjusted life years accrued (DALYs).

The active support of life sciences innovators will be crucial – and the prospect of such positive impacts should provide incentives for collaboration among governments, academia, civil society and the private sector.

The climate crisis will demand global coordination on an even greater scale than was needed during the COVID-19 pandemic. Research conducted for this report finds that a series of rapid, focused R&D investments totalling $65 billion over the next five to eight years will be required to mitigate potential climate-related challenges. This amounts to less than 5% of normal annual R&D spending by the pharmaceutical industry.

To effectively address the health and associated economic impacts of climate change, it is essential to develop innovative funding mechanisms and harmonized global regulatory frameworks that encourage investment in climate-driven health solutions. This will require coordinated action between life sciences innovators, different government agencies and nations, regulatory bodies and non-governmental organizations (NGOs), as well as health systems actors, investors and academia.

Integrating climate and health data will further support innovation, connecting scientists across health and environmental fields, while creating platforms and other digital tools to collect and circulate the data. Development of effective distribution systems and infrastructure to disseminate new treatment protocols and raise public awareness will be required to support the transition to resilient healthcare systems.

The brunt of climate-driven illnesses will be borne by the most vulnerable populations in less-developed economies. Part of the global healthcare challenge will be to tailor treatment protocols and services to local settings, bolster local health systems and address all social determinants of health. A comprehensive and coordinated approach is needed to upgrade the capacity of global health systems to treat diseases most aggravated by climate change.

1 Preparing for the climate-induced health crisis

Preparing for the climate crisis requires investing in resilient systems, boosting innovation and implementing enabling policies.

1.1 Quantifying the impact of future climate events on public health

Global warming is already causing significant increases in vector-borne diseases –

500 million

more people are likely to be exposed to such diseases by 2050.

High-priority strategies

A short five years from now, the global economy should have cut 45% of its annual greenhouse gas emissions,[7] in line with the 2015 Paris Agreement on climate. But as of today, maintaining flat emissions in the face of economic expansion is the principal achievement of the global community. Even if new low-carbon or no-carbon technology is fully scaled-up in the next two decades, policy-makers and the public need to prepare for the effects of more significant global warming — with some of the most severe impacts affecting human health.

Climate events such as flooding, heatwaves, tropical storms and wildfires are already having a significant impact on public health. The increasing frequency and intensity of these events – together with longer term trends such as desertification, rising sea levels and changing habitats for the vectors of disease – are likely to trigger a climate health emergency.

If the impact of biodiversity loss on health is also factored in, the consequences for human health will potentially be even greater. The complex links between climate change, biodiversity loss and human health warrant further research. For instance, global warming is already causing[8] significant increases in vector-borne diseases such as malaria, dengue fever, Zika, West Nile, Lyme disease and tick-borne encephalitis, with spikes in populations[9] of mosquitos, ticks and other vectors. Hotter and wetter weather means an increase in the breeding periods of vectors as well as an extension of their geographic range.

Already, there have been reported cases of dengue and malaria in North America and Europe and it is probable that those numbers will begin rising quickly.[10] This combination of factors is likely to expose 500 million more people to such diseases by 2050, as disease-carrying vectors begin to be found routinely in Europe and North America.*

Relationship between climate impacts and health outcomes

Understanding the cascading effects of climate events provides valuable insights into the cause-and-effect relationship between climate impacts and health outcomes, which involve both direct and indirect consequences from these events. More immediate impacts include death, physical injuries, malnutrition, respiratory and cardiovascular ailments and exposure to infectious diseases, including vector-borne malaria and dengue, plus diseases caused by contaminated water or food, such as cholera and dysentery.

Additional long-term and indirect impacts will likely include heat-stress associated risks[11] to maternal health that can lead to higher incidences of miscarriage, premature birth, low birth weights and potentially stunted infant growth.[12]

Stunted development will also be seen among children suffering from drought-related malnutrition. Further impacts include respiratory and cardiovascular diseases triggered by deteriorating air quality from wildfires or prolonged heatwaves.

Longer term, climate-related events will impact both individuals and societies. The stress, trauma and displacement caused by climate-related disasters can be expected to produce a surge in mental health illnesses,[13] including anxiety, depression

* Core datapoints in Chapters 1 and 2 of this report on climate-related impacts to mortality and economic costs by 2050 are sourced from: World Economic Forum. (2024). *Quantifying the Impact of Climate Change on Human Health*, written in collaboration with Oliver Wyman.

Floods will pose the highest acute risk of climate-induced mortality, forecast to account for

8.5 million

additional deaths by 2050.

Heatwaves are predicted to cause the highest global economic toll at an estimated

$7.1 trillion

by 2050, due to the loss in productivity.

and post-traumatic stress disorder. A rise in mental health conditions is a shared outcome of all the climate events studied in the original report.

Rising climate risks

Floods will pose the highest acute risk of climate-induced mortality, forecast to account for 8.5 million additional deaths by 2050.[14] The effect of rising ocean temperatures on the frequency and intensity of storms can already be seen in places such as the southern US, which has been hit by a series of severe hurricanes since 2020. This included a rare category 5 storm[15] in October 2024 and substantial loss of life from storm surges and flooding. High-tide flooding is now four to 10 times more frequent than it was 50 years[16] ago in coastal areas.

The Earth has already experienced a 20-centimetre rise in average sea levels since 1880[17] and the rate of increase is accelerating. This has huge implications for tens of millions of people, given that eight of the world's 10 largest cities are near coasts.[18]

Currently, about 40% of the global population lives within 100 kilometres of the coast,[19] increasing their exposure and vulnerability to rising sea levels and other coastal hazards such as severe storms; this puts populations at risk of being displaced. Rising sea levels[20] 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, among other health and economic impacts.[21]

Droughts, indirectly linked to extreme heat, are forecast to be the second-highest cause of mortality, with an anticipated 3.2 million additional deaths by 2050. Some 40 million people in Africa are already living in severe drought conditions. Even in more temperate climates, drought is on the rise: 40% of the lower 48 states in the US[22] have faced drought conditions for the past two years and 17% of the European Union (EU)[23] are facing drought conditions at the time of writing. As a result, high temperatures are threatening food and water security, causing a rise in malnutrition and diseases connected to contaminated water and food.

Prolonged heatwaves – a period of abnormally high temperatures relative to seasonal averages – have already killed tens of thousands and led to considerable morbidity and productivity losses. In Europe, for instance, more than 62,000 people died in the record heat between late May and early September 2022.[24] Heatwaves are predicted to cause the highest global economic toll at an estimated $7.1 trillion by 2050, due to the loss in productivity.

A rising number of wildfires worldwide is also connected to record heat which dries out foliage. Besides the destruction of property and loss of life and livestock, wildfires aggravate air pollution, which in turn exacerbates respiratory illness and cardiovascular diseases. Research suggests that air pollution will lead to 6 to 9 million premature deaths per year by 2060.[25]

1.2 Implications for population health and well-being, including global economic impact

Research suggests that air pollution will lead to

6-9 million

premature deaths per year by 2060.

Climate change and health inequities

People suffering the brunt of climate-related illnesses will be those in less economically developed regions lacking the resources to recover from climate-related disasters. For instance, the projected mortality rate in Africa is more than 20 times greater than in North and Central America and almost 14 times worse than in Europe.[26] Asia is also disproportionately affected, with mortality rates more than 13 times worse than North and Central America.

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. Economic losses in Africa are forecast to be twice that of North and Central America, although less severe than in Europe. Asia is expected to experience losses three times higher than North and Central America and 34% higher than Europe over the 2023-2050 period.

Low-income and hard-to-reach communities tend to live further from health services and facilities and face additional challenges to accessing health services, such as a lack of transport. These populations often must pay out-of-pocket costs for access for 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 aggravate inequities and ultimately solutions that address economic disparity are vital for building resilience to climate change.

> The projected mortality rate in Africa is more than 20 times greater than in North and Central America and almost 14 times worse than in Europe.

While the least economically developed countries are expected to experience more of the climate-related health impacts, they are the least responsible[27] for the emissions that cause global warming. Africa, which only produces about 2% to 3%[28] of global emissions, is already suffering a disproportionate amount of the impacts of climate change. However, the current imbalance may decrease over time as the effects of climate change begin to be felt increasingly in more economically developed regions.

Getting ahead of the crisis

> The public health threat from climate change will be a global crisis, far surpassing the devastation from COVID-19.

There is no doubt that the public health threat from climate change will be a global crisis, far surpassing the devastation from COVID-19. As with the pandemic, the ongoing strain on global resources from the scope of the emergency will challenge the resilience of public health systems and the healthcare industry worldwide.

Public health faces a crisis situation when the enabling environment does not support innovation. The challenge of addressing bacterial resistance to antibiotics is a good example. Since 2017 only 12 antibiotics[29] have been approved, 10 of which belong to existing classes with established mechanisms of antimicrobial resistance. The World Health Organization (WHO) describes[30] the pipeline of new antibiotics as "stagnant and far from meeting global needs."

The Forum's Agenda blog, *3 key priorities to avert a climate-driven health catastrophe by 2050*,[31] published in September 2024, lays out three steps which world leaders and health policy-makers could take to get ahead of the impending health crises:

1. Focus on making local healthcare systems climate-resilient.

2. Leverage private-sector innovation in healthcare, life sciences and academia, targeting climate-induced health challenges.

3. Allocate government resources and enact policies to enable a robust global response.

The findings of Chapter 3 in this report emphasize these recommendations for future policy.

Climate's public-private sector challenge

The pressing challenge of climate change necessitates the creation of climate-resilient global health systems, capable of safeguarding public health during large-scale and potentially lengthy health crises. Yet, even without climate events to contend with, the reality is that many health systems in less developed economies and even some in more developed ones would not currently be considered resilient. This represents an opportunity for the public and private sectors not only to prepare for climate change but also to close any existing gaps in healthcare with new and innovative capabilities.

The COVID-19 pandemic showed first-hand evidence of the lack of resilience after hospitals in almost every country were overwhelmed, both by demand for services and absenteeism among staff. To get ahead of the climate crisis, it is important to identify infrastructure vulnerabilities and the diseases and conditions that can be mitigated with proactive strategies.

For instance, pharmaceutical supply chains are vulnerable[32] to the effects of climate change. When supply chains are disrupted, getting treatments to patients becomes a major issue. Reaching patients can become difficult when roads are washed away, ships cannot leave ports and planes cannot take off due to extreme weather conditions. Even short delays can potentially affect the efficacy of medicines, lead to longer-term supply bottlenecks and ultimately prevent people from getting access to care.

Part of the solution lies in public-private partnerships – involving government, life science innovators and the healthcare sector – to prepare for making high-impact, longer-horizon investments in vaccines, treatments and infrastructure. There is still a window in which to get ahead of the crisis, but it is closing fast.

2 The potential to mitigate the health and economic impacts of climate change

Enhanced prevention, improved diagnostics and novel treatments could halve the impacts of climate change on health.

2.1 Assessing the health and economic impacts of interventions

This assessment is based on a detailed review of the underlying causes and available medical interventions for eight priority medical conditions and diseases, which are aggravated by climate-change impacts (see Appendix for detailed methodology). The assessment's focus is on identifying areas where medical innovation could make a meaningful impact.

Figure 1 presents a summary of the findings, for example demonstrating significant opportunities to improve prevention, particularly in the continued development of vaccines. In the case of dengue, excellent progress has been made, especially with the pre-qualification of the TAK-003 vaccine by WHO in 2024.[33] Further development could expand this success to vaccines for additional medical conditions.

Diagnostics would benefit from continued improvement, particularly the development of affordable, accurate and easy-to-use point-of-care tools. In resource-constrained settings, the lack of rapid and definitive diagnostic tests limits timely intervention and effective treatment, for example for heat-related diseases and asthma.

In terms of treatment, addressing drug resistance remains a pressing need because of poor treatment adherence and the limited effectiveness of therapies, which forces some patients to take the same medicine many times. This is a particularly widespread issue for infectious diseases, such as malaria.[34] All this underscores the need for new vaccines, drug development and improved strategies to ensure patients complete their treatment courses.

In addition to traditional life sciences interventions, new technologies offer substantial opportunities to reduce the climate impact on health. For example, desalination technology is important for reducing incidences of climate-related hypertension, while low-water sanitation solutions could reduce stunting-associated enteric diseases.

Finally, climate services for health[35] – such as collecting and using climate knowledge to enhance health solutions – could improve the effectiveness of medical responses to climate change. Such services can leverage a range of climate readings (e.g. temperature, precipitation, wind) and non-meteorological data (e.g. agricultural production, health trends, infrastructure mapping). This approach[36] enables robust risk and vulnerability analyses, as well as the development of long-term projections and scenarios. For instance,[37] leading climate services could potentially predict outbreaks of infectious diseases as early as two months in advance. When these predictions are integrated with healthcare services, they can significantly enhance preventive measures and prepare health systems to mitigate impacts, potentially resulting in a reduction of up to 25%[38] in the incidence of such diseases.

FIGURE 1 | **Unmet needs range across prevention, diagnosis and treatment**

	Prevention	Diagnosis	Treatment	Technology and services
Stunting	Creating vaccines and interventions to prevent malabsorption Addressing maternal health	Developing tools for early detection Implementing point-of-care nutritional deficiency testing	Assessing and improving impact of interventions on cognitive development	Tailoring education, nutrition, and psychosocial interventions Scaling low-water sanitation solutions
Generalized anxiety disorder	Exploring potential of preventive pharmacological solutions	Creating definitive diagnostics that capture disease heterogeneity	Creating safer interventions for treatment-resistant GAD[1] Scaling effective digital therapeutics	Identifying high-risk populations and individuals Collecting more diverse data sets
PTSD	Developing post-trauma interventions to prevent onset	Creating definitive diagnostics that capture disease heterogeneity	Developing improved alternatives to psychotherapy Scaling effective digital therapeutics	Identifying high-risk populations and individuals Collecting more diverse data sets
Malaria	Expanding vaccination for adults Ensuring durability and reliable efficacy of children's vaccine	Providing sufficient supply of diagnostics Improving RDT[2] sensitivity	Developing strategy for multi-drug resistance	Integrating digital tools for real-time monitoring Improving data and reporting tools
Dengue	Continuing roll-out of vaccines efficacious across all serotypes of dengue Development of single dose vaccines to improve adherence	Developing cheaper, easier diagnostics Improving serological and molecular diagnostics	Developing antiviral therapy	Integrating digital tools for real-time monitoring
Hypertension	Identifying genetic and biological risk markers	Increasing accuracy and speed of in-office diagnosis Improving at-home monitoring	Developing long-acting treatments Addressing treatment-resistant hypertension	Improving desalination technology
Heat-related diseases	Developing preventive pharmacological solutions Using wearables as heat sensors	Developing rapid, point-of-care diagnostic tools	Developing targeted treatments	Implementing real-time monitoring for population management
Asthma	Innovating on interventions to prevent initial onset	Developing definitive diagnostics Predicting asthma exacerbations and supporting self-management	Modifying underlying disease Creating patient-friendly alternatives to inhaler treatments	Implementing asthma risk surveillance and warning systems

1. Generalized anxiety disorder; **2.** Rapid diagnostic test

Source: World Economic Forum and Oliver Wyman analysis of current literature supplemented through expert interview.

2.2 The potential to reduce climate's impact on health by 2050

1 billion

DALYs by 2050 could be prevented through innovative prevention, diagnostics and treatment.

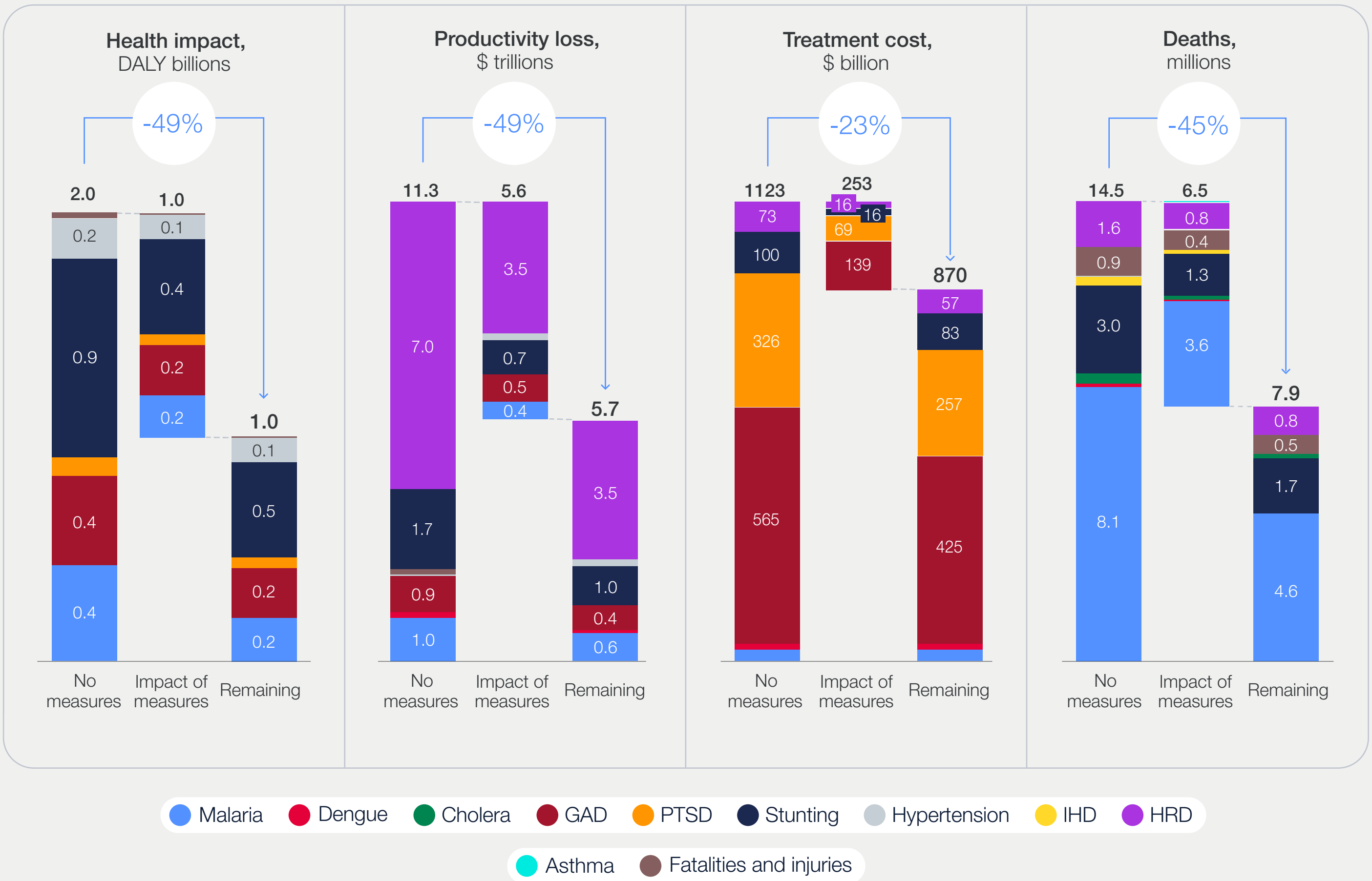
Developing solutions to address unmet medical needs for high-priority diseases offers a unique opportunity to significantly reduce the projected[39] impacts of climate change on both disease burden and economic losses by 2050 (see Appendix for detailed methodology) .

Figure 2 summarizes the human and economic impacts that are potential preventable, broken down into 11 diseases and health impacts: malaria, dengue fever, cholera, generalized anxiety disorder (GAD), post-traumatic stress disorder (PTSD), stunting, hypertension, ischemic heart disease (IHD), fatalities and injuries, heat-related diseases (HRD) and asthma.

By 2050, these impacts are projected to cause an additional 14.5 million deaths and cost the global economy $12.5 trillion cumulatively, through productivity losses and treatment costs – comparable to the gross domestic product of Singapore. However, through investment in vaccines, medicines, medical devices, health-tech and climate services, 6.5 million lives could potentially be saved, global economic losses reduced by $5.8 trillion and 1 billion fewer disability-adjusted life years accrued (DALYs) – cumulatively by 2050.

Innovative interventions from the life sciences sector — focused on prevention, diagnostics and treatment — could potentially avert up to 49% of the anticipated DALYs lost due to diseases exacerbated by climate change. More effective and accessible interventions, particularly for remote communities, can prevent disease incidences, facilitate faster and more effective treatments, reduce premature mortality, shorten recovery times and eliminate long-term health consequences. Collectively, these efforts could help prevent the loss of approximately 1 billion DALYs (cumulatively) by 2050.

FIGURE 2 **Health and economic impacts of climate change, potentially preventable by 2050 (cumulative)**



1. See Appendix for detailed methodology. **2.** Numbers may not sum precisely to totals due to rounding.

Source: World Economic Forum[40] and Oliver Wyman analysis of current literature supplemented through expert interview.

$253
billion
of treatment costs and

$5.6
trillion
of productivity losses could be avoided.

The introduction of innovative medical interventions also holds significant potential for reducing healthcare costs in affected regions. For instance, vaccination programmes often demonstrate a positive return on investment by lowering healthcare system costs associated with avoided treatments. Additionally, improved diagnostics can prevent delays and inaccuracies in treatment. More effective and affordable treatment options have demonstrated significant potential to reduce healthcare expenses, minimizing the need for repeat visits or costly intensive care procedures.

However, the introduction of innovative solutions will not serve as a panacea for healthcare costs. Significant spending will still be necessary to ensure access to new vaccines, diagnostics and treatments. Innovations from the life sciences sector addressing unmet medical needs could collectively help prevent up to 23% of healthcare costs, amounting to approximately $253 billion by 2050.

Stunting, a major concern for child health, could be mitigated by over 45%, preventing

1.3
million
deaths and saving over $753 billion in economic losses.

Preventing adverse health outcomes indirectly contributes to a higher GDP for the global economy. With fewer premature deaths and a decrease in days lost to illness or lower productivity, new interventions could prevent approximately $5.6 trillion in productivity losses by 2050.

Ultimately, life sciences interventions have the potential to prevent numerous deaths. By reducing disease incidences through prevention and ensuring timely and effective diagnostics and treatments, the severity of diseases can be reduced, hence lowering mortality rates. By 2050, this could result in the prevention of up to 45% of additional deaths from diseases exacerbated by climate change, translating to approximately 6.5 million lives saved.

Stunting, a major concern for child health, could be mitigated by over 45%, preventing 1.3 million deaths and saving over $753 billion in economic losses. Interventions targeting malaria could mitigate 180 million DALYs and prevent over 3.6 million deaths by 2050, while saving $450 billion in economic losses. Dengue, another vector-borne disease, could see a global impact reduction of 63%, preventing 66,000 deaths and saving $89 billion in economic losses. Heat-related illnesses, another growing threat due to climate change, could see a 50% reduction in deaths, saving over 800,000 lives and preventing $3.5 trillion in economic losses.

The effectiveness of such innovative life sciences interventions can be substantially improved if implemented together with advanced technologies and climate services. By utilizing enhanced digital tools that leverage data to predict disease outbreaks, communities and healthcare systems can achieve greater preparedness, enhancing the effectiveness of diagnostics and treatment, or preventing incidents altogether. Implementing these technologies and climate services alongside life sciences interventions could reduce health impacts by an additional 3.6% through 2050 — eliminating 74 million DALYs, $19 billion in treatment costs, $418 billion in productivity losses and 454,000 deaths by 2050.

These numbers highlight the urgent need to address climate-sensitive health challenges and the opportunity to significantly alleviate both human and economic burdens through targeted solutions. This opportunity to act is not only about saving lives but also about ensuring long-term economic sustainability. By reducing the disease burden and associated costs, governments and businesses can allocate resources more efficiently, leading to healthier, more productive populations. The long-term benefits of mitigating these diseases go beyond immediate healthcare savings – they include fostering better economic growth and reducing poverty in regions most vulnerable to climate impacts. Addressing these unmet medical needs with innovative climate and health solutions is critical to building resilient health systems and supporting sustainable development in a rapidly changing world.

2.3 Mitigation strategies for health and economic impacts – by diseases

3.6 million malaria deaths,

$3.5 trillion

of economic costs from heat-related disease and almost 400 million stunting DALYs are potentially preventable by 2050.

This section analyses the data for eight high-priority diseases: malaria, dengue fever, post-traumatic stress disorder (PTSD), generalized anxiety disorder (GAD), stunting, hypertension, heat-related diseases and asthma. A summary of the analysis is presented in Figure 3, while deep dives into these diseases are available in an Annex, published separately here by Oliver Wyman.

Malaria

Vector-borne infectious diseases such as malaria will be significantly exacerbated by climate change, which extends the range of several species of mosquitoes, increasing the geographical extent of the diseases they carry. Up to 8.4 billion people could be at risk of contracting malaria or dengue fever by the end of the century due to climate change.[41] Malaria alone is projected to cost an additional $1 trillion and add 409 million DALYs (cumulatively) by 2050 because of climate change.[42]

In central Africa alone, malaria is expected to cost the healthcare system around $345 billion and add 151 million DALYs by 2050. Notably, the impact of climate change on malaria is predicted to extend to more economically developed countries; in 2023, for the first time in 20 years, the US recorded cases of domestic malaria transmission, according to Johns Hopkins University.[43]

Addressing the priority unmet medical needs for malaria offers significant potential to reduce the health and economic impacts exacerbated by climate change. Analysis conducted for this report shows that introducing novel prevention methods (e.g. the development of single-use vaccines with associated improved patient adherence), diagnostics and treatments could prevent approximately 44% of the projected health and economic burdens linked to malaria proliferation. This could save up to 180 million DALYs, prevent nearly $450 billion in economic losses (including $6 billion in healthcare costs) and avert 3.59 million deaths.

FIGURE 3 | **Potentially preventable impacts – by diseases and health conditions**

Health outcomes	Diseases	DALY, %[2]	Potentially preventable impacts[1]: DALY, millions	Potentially preventable impacts[1]: $, billions	Potentially preventable impacts[1]: Deaths, thousands
Infectious diseases	Malaria	44%	180	450	3,590
	Dengue	63%	6	89	66
	Cholera[3]	49%	4	25	110
Mental health issues	Generalized anxiety disorder (GAD)	58%	220	139 (treatment costs); 671	19
	Post-traumatic stress disorder (PTSD)	60%	51	69 (treatment costs); 113	N/A
Malnutrition	Stunting	45%	397	753	1,298
Cardiovascular diseases	Hypertension	53%	103	37	54
	Ischemic heart disease[3]	49%	1	2	120
Fatalities and injuries	Fatalities and injuries[3]	49%	11	170	410
Heat-related diseases	Heat-related diseases	50%	3	3,522	803
Respiratory diseases	Asthma	57%	1	5	25
Total		49%	976	5,836	6,495

● Treatment costs ● Productivity loss

1. Excluding 8% average overlap between interventions. Totals rounded up to nearest percentage point, million, billion or thousand.

2. PTSD does not lead to premature mortality.

3. Preventable impacts for cholera, ischemic heart disease, and fatalities and injuries are assessed based on averages across diseases.

Source: World Economic Forum and Oliver Wyman analysis.

The impacts of various forms of malaria prevention can be seen in the following table:

TABLE 1 **Malaria prevention impact**

Prevention type	Typical measures	% impact prevented	DALYs prevented	Economic losses prevented	Deaths averted
Enhanced prevention	Develop adult vaccines Improve efficacy of paediatric vaccines	23%	96 million	$239 billion	1.92 million
Improved diagnostics	Develop better-performing rapid diagnostic tests (RDTs) Ensure their widespread availability	9%	36 million	$91 billion	730,000
Novel treatments	Particularly those targeting multi-drug-resistant malaria	12%	48 million	$120 billion	940,000
Total		**44%**	**180 million**	**$450 billion**	**3.59 million**

Source: World Economic Forum and Oliver Wyman analysis.

Dengue fever

Dengue fever driven by climate change is projected to cause 93,000 deaths,

7.9 million

DALYs and $118 billion of costs in Asia and Africa by 2050 – but 63% of these impacts can be prevented.

Dengue is projected to impose a significant health and economic burden by 2050. Asia will continue to bear the brunt, with 66,000 dengue-related deaths, 5.8 million DALYs and healthcare costs soaring to $105 billion.[44] The costs associated with dengue are mostly from hospitalizations, long-term care and productivity losses. Africa will also face severe impacts, with 28,000 deaths, 2.1 million DALYs and an economic cost of $13 billion.

The expansion of Aedes mosquito populations due to climate change and urbanization[45] is expected to accelerate dengue transmission, emphasizing the urgent need for global action to control the disease and reduce its impacts on public health and economies worldwide. Recent data from the European Centre for Disease Prevention and Control (ECDC)[46] already shows a rising trend in dengue cases outside endemic regions, with 2023 seeing a notable spike in Europe.

Addressing the priority unmet medical needs for dengue offers significant potential to reduce the health and economic impacts exacerbated by climate change. The analysis conducted for this report shows that introducing novel prevention methods, diagnostics and treatments could prevent approximately 63% of the projected health and economic burdens linked to dengue expansion. These advancements could save up to 5.6 million DALYs, prevent $89 billion in economic losses (including $3 billion in healthcare costs) and avert 66,000 deaths.

The impacts of various forms of dengue prevention can be seen in the following table:

TABLE 2 **Dengue prevention impact**

Prevention type	Typical measures	% impact prevented	DALYs prevented	Economic losses prevented	Deaths averted
Enhanced prevention	Continuing roll-out of vaccines efficacious across all serotypes of dengue Development of single dose vaccines to improve adherence	46%	4 million	$64 billion	48,000
Improved diagnostics	Develop affordable, easy-to-perform diagnostics Ensure their widespread availability	5%	0.5 million	$8 billion	6,000
Novel treatments	Antiviral treatments Including monoclonal antibodies as a potential short-term prevention method	12%	1.1 million	$17 billion	12,000
Total		**63%**	**5.6 million**	**$89 billion**	**66,000**

Source: World Economic Forum and Oliver Wyman analysis.

Continued roll-out of vaccines targeting all four serotypes in individuals both already exposed and unexposed to dengue would continue the excellent progress in this field,[47] reducing the incidence of the disease and preventing severe cases, particularly in endemic regions. Novel treatments, such as monoclonal antibodies could also play a role,[48] and are being studied as a potential short-term prevention method for high-risk groups.

Post-traumatic stress disorder (PTSD) and generalized anxiety disorder (GAD)

Climate-related events such as floods, storms and droughts are increasingly recognized as catalysts for mental health conditions,[49] such as post-traumatic stress disorder (PTSD) and generalized anxiety disorder (GAD). Acute disasters, such as floods and storms, expose individuals to traumatic experiences that can trigger PTSD, including loss of family members and friends, homes and livelihoods.

In regions such as South-East Asia, where floods are frequent and severe,[50] these events are expected to cause $147 billion in PTSD-related healthcare expenses and 41 million DALYs by 2050. Globally, PTSD from climate events is projected to cost $397 billion and cause 85 million DALYs, underscoring the need for targeted mental health interventions in disaster-prone regions.

Collectively, PTSD and GAD driven by climate change are expected to cause over

$1.8 trillion

in costs and over 460 million DALYs by 2050 – but roughly 60% of these impacts can be prevented.

Meanwhile, GAD often[51] develops in response to prolonged stress and uncertainty. The struggle[52] to find food, loss of livelihoods and forced migration due to droughts or the destruction caused by wildfires, as well as the threat of recurrence, can lead to chronic stress and anxiety, significantly contributing to the rise in GAD cases. The expected global impact of climate-related GAD is profound,[53] with projected costs of $1.5 trillion and health impacts of 378 million DALYs by 2050. More specifically, in the western US, generalized anxiety disorders linked to wildfires are estimated to cost $709 billion, with 36 million DALYs.

Addressing the priority unmet medical needs for PTSD and GAD offers significant potential to reduce the health and economic impacts exacerbated by climate change. The analysis shows that introducing novel prevention methods, diagnostics and treatments could prevent approximately 60% and 58% of the projected health and economic burdens linked to PTSD and GAD, respectively.

For PTSD, these preventive measures could save up to 51 million DALYs and prevent $113 billion in economic losses (including $69 billion in healthcare costs). For GAD, such measures could save up to 220 million DALYs, prevent $671 billion in economic losses (including $139 billion in healthcare costs) and avert 19,000 deaths. Together, these interventions represent key opportunities for public health advancement, with targeted investment essential to realize these benefits.

The impacts of various forms of PTSD and GAD prevention can be seen in the following tables:

TABLE 3 **PTSD prevention impact**

Prevention type	Typical measures	% impact prevented	DALYs prevented	Economic losses prevented	Deaths averted
Enhanced prevention	Develop post-trauma interventions to prevent PTSD onset	31%	26 million	$55 billion	N/A
Improved diagnostics	Create definitive diagnostics that capture disease heterogeneity	4%	4 million	$13 billion	N/A
Novel treatments	Develop improved alternatives to psychotherapy Develop scaled effective digital therapeutics	25%	21 million	$45 billion	N/A
Total		**60%**	**51 million**	**$113 billion**	**N/A**

Source: World Economic Forum and Oliver Wyman analysis.

TABLE 4 **GAD prevention impact**

Prevention type	Typical measures	% impact prevented	DALYs prevented	Economic losses prevented	Deaths averted
Enhanced prevention	Explore the potential of preventive pharmacological solutions	10%	37 million	$112 billion	3,000
Improved diagnostics	Create definitive diagnostics that capture disease heterogeneity	15%	59 million	$193 billion	5,000
Novel treatments	Develop safer interventions for “treatment-resistant” GAD Develop scaled effective digital therapeutics	33%	124 million	$366 billion	11,000
Total		**58%**	**220 million**	**$671 billion**	**19,000**

Source: World Economic Forum and Oliver Wyman analysis.

Stunting in children driven by climate change is expected to cause around

$1.8 trillion

in costs and over 887 million DALYs by 2050 – but roughly 45% of these impacts can be prevented, including 1.3 million deaths.

Stunting

Stunting is caused by malnutrition or malabsorption of nutrients and is already a significant global health challenge, affecting millions of children under five in less economically developed economies. It is expected to be further exacerbated by climate change[54] as rising temperatures threaten food availability by reducing crop yields and raising the price of the limited supply. By 2050, assuming emissions are not reduced sufficiently, the global cost of stunted development in children is projected to be $1.8 trillion, impacting 887 million DALYs. Regional disparities are stark, with the Mediterranean region, West Africa and Southern Africa bearing the heaviest burdens.

In the Mediterranean region, stunting is expected to lead to economic losses of $700 billion including GDP losses and treatment costs, and affect 16 million DALYs. In West Africa and Southern Africa, it is projected to incur losses of $231 billion, affecting a staggering 727 million DALYs. The differential in number of DALYs versus the cost reflects the limited spending on healthcare in Africa because of lack of resources.

Addressing the priority unmet medical needs for stunting offers significant potential to reduce the health and economic impacts exacerbated by climate change. The analysis shows that introducing novel prevention and prenatal methods, diagnostics and treatments could prevent approximately 45% of the projected health and economic burdens linked to stunting. These measures could save up to 397 million DALYs, prevent $753 billion in economic losses, including $16 billion in healthcare costs and avert 1.3 million deaths. Together, these interventions and the need for targeted investments to develop them represent key opportunities for public health advancement.

The impacts of various forms of stunting prevention can be seen in the following table:

TABLE 5 **Stunting prevention impact**

Prevention type	Typical measures	% impact prevented	DALYs prevented	Economic losses prevented	Deaths averted
Enhanced prevention	Create vaccines and interventions to prevent malabsorption Address maternal health to prevent stunting	36%	322 million	$602 billion	1.04 million
Improved diagnostics	Improve early detection of stunting Implement point-of-care nutritional deficiency testing	6%	49 million	$101 billion	170,000
Novel treatments	Address the impact of interventions on cognitive development	3%	26 million	$50 billion	90,000
Total		**45%**	**397 million**	**$753 billion**	**1.3 million**

Source: World Economic Forum and Oliver Wyman analysis.

Hypertension driven by climate change is expected to cause around

$73 billion

in costs and 193 million DALYs – but 53% of these impacts can be prevented, including 54,000 deaths.

Hypertension

Hypertension is a major global health concern, even without climate change, with rates rising in parts of the globe. Global warming is likely to exacerbate that trend as rising sea levels contribute to saltwater intrusion into groundwater, increasing the concentrations of calcium, potassium and magnesium, which are associated with elevated blood pressure and cardiovascular risks. By 2050, the impact in Asia in particular is expected to be severe, with projected healthcare costs of $48.1 billion and an estimated burden of 127 million DALYs.[55]

Coastal areas with a low human development index are particularly vulnerable, with saltwater intrusion projected to contribute to more than 800,000 new hypertension cases by 2050 in these vulnerable coastal regions. This is linked to an economic toll on healthcare systems of an estimated $73 billion to address hypertension-related issues and an impact of approximately 193 million DALYs.

Addressing the priority unmet medical needs for hypertension offers significant potential to reduce the health and economic impacts exacerbated by climate change.

The analysis shows that introducing novel prevention methods, diagnostics and treatments could prevent approximately 53% of the projected health and economic burdens. These advancements could save up to 103 million DALYs, prevent $37 billion in economic losses, including $1 billion in healthcare costs and avert 54,000 deaths.

TABLE 6 **Hypertension prevention impact**

Prevention type	Typical measures	% impact prevented	DALYs prevented	Economic losses prevented	Deaths averted
Enhanced prevention	Identify genetic and biological risk markers	5%	9 million	$3 billion	5,000
Improved diagnostics	Increase accuracy and speed of in-office diagnosis Improve at-home monitoring	26%	51 million	$19 billion	27,000
Novel treatments	Develop long-acting treatments and those targeting "resistant hypertension"	22%	43 million	$15 billion	22,000
Total		**53%**	**103 million**	**$37 billion**	**54,000**

Source: World Economic Forum and Oliver Wyman analysis.

Heat-related disease driven by climate change is expected to cause around

$7.1 trillion

in costs and 6.5 million DALYs – but 50% of these impacts can be prevented, including 800,000 deaths.

Heat-related disease (HRD)

Heatwaves caused by climate change are projected to cause nearly 1.6 million deaths globally by 2050,[56] with approximately 70% of these fatalities concentrated in high-risk regions, particularly South-East Asia. The global economic losses associated with heat-related diseases are expected to reach $7.1 trillion, predominantly driven by productivity losses. South-East Asia alone is forecasted to account for $1.8 trillion of these costs, reflecting the region's disproportionate exposure to extreme heat and its significant public health challenges. In addition to the financial burden, heat-related diseases are anticipated to contribute to a loss of 6.5 million DALYs globally, with 3 million DALYs expected in South-East Asia.

Addressing the priority unmet medical needs for HRD offers significant potential to reduce the health and economic impacts exacerbated by climate change. The analysis shows that introducing novel prevention methods, diagnostics and treatments could prevent approximately 50% of the projected health and economic impacts linked to accelerating HRD. These preventive measures could save up to 3.2 million DALYs, avoid $3.5 trillion in economic losses (including $16 billion in healthcare costs) and avert 800,000 deaths.

The impacts of various forms of HRD prevention can be seen in the following table:

TABLE 7 **HRD prevention impact**

Prevention type	Typical measures	% impact prevented	DALYs prevented	Economic losses prevented	Deaths averted
Enhanced prevention	Develop preventive pharmacological solutions	30%	2 million	$2.1 trillion	490,000
Improved diagnostics	Develop rapid, point-of-care diagnostics Ensure their widespread availability	15%	0.9 million	$1 trillion	230,000
Novel treatments	Develop novel targeted treatments	5%	0.3 million	$339 billion	80,000
Total		**50%**	**3.2 million**	**$3.5 trillion**	**800,000**

Source: World Economic Forum and Oliver Wyman analysis.

Asthma driven by climate change is expected to cause around

$9.4 billion

in costs and 2.1 million DALYs – but 57% of these impacts can be prevented, including 25,000 deaths.

Asthma

Asthma is highly susceptible to environmental changes driven by climate change. The projected increase in wildfires will increase exposure to smoke from fires, which can trigger asthma, especially among those directly exposed to the fumes. Meanwhile, the wind erosion of dry and degraded soils during wildfires generates airborne particles, compounding the issue of poor air quality and intensifying respiratory challenges. Additionally, climate-driven changes are expected to lead to a higher prevalence of allergens, such as pollen, which in turn may further exacerbate asthma symptoms.

The western US is particularly vulnerable to climate impacts, where increasing wildfire frequency and intensity are expected to contribute to a further deterioration in air quality, posing severe respiratory health risks. By 2050, additional economic and health impacts of asthma related to wildfires are projected to be substantial, with North and Central America expected to incur $4.6 billion in economic impact and almost 400,000 DALYs.[57] Globally, asthma-related costs are estimated to reach $9.4 billion and an additional 2.1 million DALYs. The situation is compounded by data gaps in remote communities, where the health impacts remain under-documented, leaving these populations vulnerable to the consequences of poor air quality.

Addressing the priority unmet medical needs for asthma offers significant potential to reduce the health and economic impacts exacerbated by climate change. The analysis shows that introducing novel prevention methods, diagnostics and treatments could prevent approximately 57% of the projected health and economic burdens linked to asthma. These advancements could save up to 1.2 million DALYs, prevent $4.6 billion in economic losses (including $0.9 billion in healthcare costs) and avert 25,000 deaths. To achieve the full 57% potential for health improvement, strategic interventions must be a priority.

The impacts of various forms of asthma prevention can be seen in the following table:

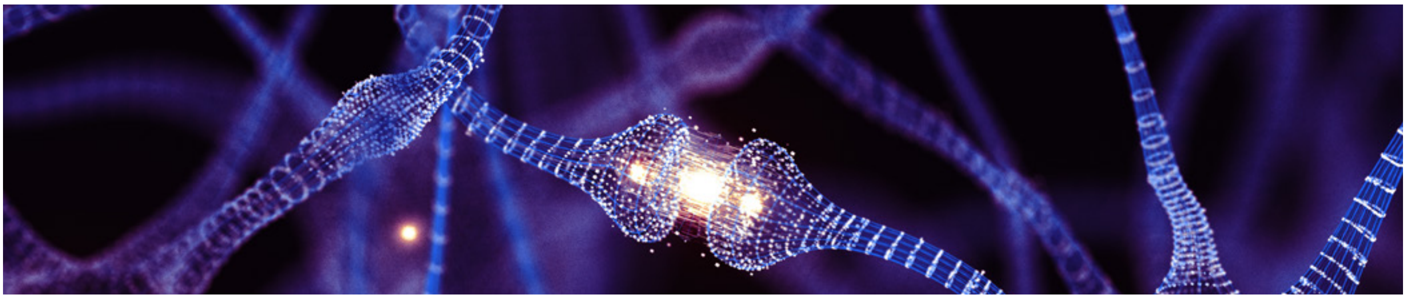
TABLE 8 **Asthma prevention impact**

Prevention type	Typical measures	% impact prevented	DALYs prevented	Economic losses prevented	Deaths averted
Enhanced prevention	Develop innovative interventions to prevent initial onset	14%	0.3 million	$1.1 billion	6,000
Improved diagnostics	Develop more definitive diagnostics and tools to predict asthma exacerbations Support dynamic self-management	30%	0.6 million	$2.6 billion	13,000
Novel treatments	Develop treatments targeting modification of the underlying disease Create patient-friendly alternatives to inhaler-based treatments	13%	0.3 million	$0.9 billion	6,000
Total		**57%**	**1.2 million**	**$4.6 billion**	**25,000**

Source: World Economic Forum and Oliver Wyman analysis.

3 Unlocking innovation across life sciences and technology

A strategic investment of $65 billion could achieve a 49% reduction in the health and economic impacts of climate change.



3.1 Pivotal role of life sciences innovators in climate and health solutions

Life sciences innovators have a pivotal role to play in the effort to mitigate the impact of climate change through targeted, long-term investments in R&D across vaccines, medicines, medical devices and healthcare technology. Research conducted for this report has identified 36 unmet medical needs in eight climate-aggravated medical conditions across prevention, diagnostics and treatment that could be addressed by life sciences innovation.

To achieve the 49% reduction in projected health and economic impacts of climate change, detailed above in Chapter 2, a strategic investment of $65 billion in innovative solutions over the next five to eight years is required (see Appendix for detailed methodology).

This investment amounts to less than 5% of what is currently spent annually by pharmaceutical,[58] medical devices and healthtech companies on R&D and demonstrates that substantial impact can be achieved even with more targeted investment.

Although leading companies are already investing in climate-resilient health, these companies may not expect profits[60] from these efforts but rather are responding to multilateral calls to reach global targets for NTDs, such as those in WHO's Neglected Tropical Disease Roadmap (2021-2030) and the Kigali Declaration, initiated in 2022. While these efforts are important, significantly greater scale is needed to boost R&D in climate-driven health conditions.

Life sciences innovators have also made progress in making their supply chains and operations more climate resilient, particularly after problems encountered during the COVID pandemic and efforts to address avian flu. This includes supplier diversification and adapting distribution channels to the physical impacts of climate change. Some companies are making product investments that improve distribution resilience.

This includes novel means of storage and transportation (e.g. using a plasma separation card to ship blood samples in a range of environmental conditions)[61] as well as improving the characteristics of the medicines themselves (e.g. investigating the thermostability of insulin for settings without stable cooling).[62]

3.2 Level of investment needed and estimated returns

Investing $65 billion over the next five to eight years could lead to savings of

$253 billion

in cumulative healthcare spending by 2050.

An investment of $65 billion over the next five to eight years would enable real gains to be made in treatments and healthcare. The amount, which is based on historical R&D costs for comparable solutions, represents a strategic step change in prioritizing medical conditions that will be impacted by climate change.

Investing $65 billion could lead to savings of $253 billion in cumulative healthcare spending by 2050, easing the financial strain on patients, insurance providers, public health budgets and healthcare professionals.

The anticipated decrease in the number of new cases and severity of health outcomes will result in fewer productive days lost due to illness and premature mortality. Such a reduction would have a substantial indirect economic impact, potentially preventing $5.6 trillion in GDP productivity losses cumulatively by 2050.

Considering these factors, the R&D costs associated with developing new solutions could yield returns of up to four times in terms of avoided healthcare costs and up to 90 times in terms of total economic loss avoidance by 2050. When compared with alternative investment opportunities, the potential savings in preventable healthcare costs alone is in line with average returns on investments in climate action.

By 2050, new interventions could potentially save up to one billion DALYs at an average R&D cost of $65 per prevented DALY. By comparison, the cost of averted DALYs for most health systems is estimated to range from $1,000 to $70,000,[63] depending on a country's human development index. From this perspective, investing in R&D to mitigate the health impacts of climate change represents a cost-effective and ethical approach.

3.3 Overcoming roadblocks that hinder development of new climate and health solutions

The main roadblocks limiting investment today include uncertain market demand, unclear return on investment and fragmented regulatory policies and incentives.

While the return on investment from innovation is clear for health systems, the same does not automatically apply to private-sector life science innovators.

The life sciences industry has deep roots in serving global society. It invests regularly in health equity and access to medicines. For example, some companies offer screening[64] and disease awareness programmes and health education[65] to facilitate disease prevention. Examples of efforts to improve healthcare access include providing medication donations[66] during disasters, partnering to improve distribution of treatments in Sub-Saharan Africa,[67] adopting tiered and capped[68] pricing models and funding mobile[69] healthcare clinics to improve healthcare access. However despite these important philanthropic investments, funding in R&D for climate-driven diseases remains insufficient.

The main roadblocks limiting investment today include uncertain market demand, unclear return on investment and fragmented regulatory policies and incentives. In addition, life sciences innovators face the complexity of climate health data integration, a lack of collaboration between climate and health scientists, cultural resistance to a new climate focus and low public and political awareness of the impact of climate on health.

Actions to eliminate or at least reduce these roadblocks to investment include the following:

- Creation of innovative funding mechanisms and business models to unlock R&D investments in climate-driven health problems.
- Collaboration between life sciences innovators and governmental organizations to improve harmonization of global policies and incentives.
- Investment in climate-health data platforms that predict disease patterns and outcomes to foster cross-sector collaborations and align company commitments.
- Joint efforts between industry and government to increase public awareness through media and community-focused campaigns.

FIGURE 4 | **Critical actions to overcome roadblocks to investment in climate and health innovation**

Roadblocks encountered	Description and rationale	Critical actions
Uncertain market demand and ROI	Many climate-driven diseases impact areas with limited healthcare budgets, leading to uncertainty about commercial viability and ROI, even as these diseases are expected to rise in developed countries.	Create innovative funding and business models to unlock R&D investments in climate and health areas.
Fragmented policies and incentives	Varied regulatory, financial and tax incentives across regions limit scalability. This fragmentation makes it difficult for the life sciences sector to develop cohesive, cross-border strategies for climate and health innovation.	Advocate for harmonized global policies and incentives to promote climate and health investments.
Complexity of climate-health data integration	The life sciences sector's ability to forecast disease patterns and design effective climate and health solutions is hindered by data infrastructure gaps that make it hard to connect climate variables with patient health data.	Invest in climate-health data platforms to predict disease patterns and outcomes.
Lack of collaboration between climate and health sectors	The life sciences sector often works in isolation from climate and environmental scientists, resulting in missed opportunities for cross-sector innovations addressing health and environmental issues.	Foster cross-sector collaborations to drive holistic climate and health innovation.
Cultural resistance to new climate focus	The life sciences sector often faces internal resistance to redirecting resources from traditional high-revenue therapeutic areas to climate-sensitive diseases. This resistance slows the adoption of climate-health strategies.	Align company climate and health through leadership commitment and awareness programmes.
Low public and political awareness	While climate change's impact on health is becoming more understood, public and political awareness remains relatively low, weakening advocacy efforts and delaying policy change.	Drive public campaigns and media engagement to elevate climate-health awareness.

Source: World Economic Forum and Oliver Wyman analysis.

At the beginning of the COVID pandemic, the US government guaranteed the purchase of vaccines from Pfizer and Moderna to establish the market the vaccine producers needed to justify the R&D programmes they created.

The accelerated approval by the FDA of COVID-19 vaccines demonstrates how flexible regulatory frameworks can expedite critical healthcare solutions.

Uncertainty of market demand and return on investment

One of the most significant roadblocks preventing life sciences investments in climate and health is the uncertainty of market demand and return on investment. Given the high risks[70] inherent with life sciences R&D, return on capital becomes a driving force for the industry. It often compels life sciences innovators to set priorities according to investor expectations rather than societal need. When philanthropic investments are made on health-equity concerns, although a positive step forward, R&D programmes are often not big enough to address the full needs of climate-driven diseases.

Ultimately, the decision to invest is based on a business case – and for many climate-exacerbated diseases, the traditional risk-return dynamic does not yield sufficient economic rewards. For example, mental health faces[71] significant funding challenges because of uncertain ROI. Only about 5%[72] of biopharma R&D budgets is dedicated to treatments despite estimates that over half the US population is diagnosed with a mental health condition during their lifetime.[73] Public funding[74] for academic mental health research tends to be limited, leading to low levels of early-stage research. At the same time, R&D costs are very high. Early-stage failure rates[75] of neuropsychiatric drugs are high and psychiatric studies often need to be large, which increases development costs and extends approval timelines.

Additionally, a number of climate-driven diseases such as stunting, malaria and dengue predominantly affect less economically developed regions with a perceived small market size[76] and marginal return on investment, even as cases rise globally. In the case of vaccines, for example, creating economies of scale in manufacturing can be challenging,[77] which further impairs ROI. Although climate-driven diseases are predicted to rise in both less and more economically developed countries, and new cases of vector-borne diseases in North America and Europe may trigger investment interest, the lack of visibility into the timing of commercial viability can dissuade companies from investing in these areas to make real progress.

Misalignment of risk and reward limits investments[78] or restricts their focus to small-scale philanthropic projects. While a positive step, these would benefit from the large-scale impact of projects in the commercial core business. Changes to funding approaches and global policies will have to be made to enable life sciences innovators to undertake strategic, large-scale investments in climate-exacerbated diseases.

For instance, at the beginning of the COVID pandemic, the US government guaranteed the purchase of vaccines from Pfizer[79] and Moderna[80] to establish the market the vaccine producers needed to justify the R&D programmes they created. But, unlike COVID, climate-related health issues often play out over many years.

By implementing innovative funding models and fostering partnerships with governments and impact investors, companies can share risks and unlock new sources of capital. To de-risk these investments, public-private partnerships are essential. One proven model is the GAVI Alliance,[81] which funds vaccines for low-income countries — a blueprint that could be expanded to cover climate-related diseases such as malaria and dengue. Between 2000 and 2023, the GAVI Alliance[82] vaccinated more than 1.1 billion children in 78 countries and prevented almost 19 million deaths.

Unpredictable and diverse regulation

Another major obstacle to unleashing life sciences innovation involves policy and drug regulation. This roadblock has an intimate cause and effect relationship with a lack of market uncertainty and return on investment, since regulation can reduce uncertainty and drive investments by establishing clear demand. Disjointed regulatory, financial and tax incentives make it difficult for companies to develop cohesive strategies that span multiple markets, limiting the reach and impact of innovative climate-health solutions.

For example,[83] unclear or unpredictable regulatory pathways and lack of technical and regulatory capacity in low- and middle-income countries hinder investment in malaria. Existing regulatory systems can be inadequate to drive more competitive markets or ensure widespread production of higher quality products at reduced costs. WHO's prequalification system (PQ)[84] plays a crucial role in providing regulatory guidance, but challenges in coordination[85] between WHO PQ and national regulatory bodies can delay product access.

Lack of regulatory precedent and established efficacy measures can also complicate the approval process and lead to further regulatory fragmentation. In mental health,[86] the novelty of tools such as digital therapeutics and devices for brain stimulation creates uncertainty around approval pathways. Overcoming these regulatory challenges,[87] when pursuing mental health innovations, is further exacerbated by reliance on subjective psychiatric endpoints and a nascent understanding of the molecular drivers of mental health conditions.

The accelerated approval by the US Food and Drug Administration (FDA) of COVID-19 vaccines[88] demonstrates how flexible regulatory frameworks can expedite critical healthcare solutions. During COVID, regulators and the biopharmaceutical industry worked together to reduce red tape to accelerate the development, evaluation, authorization and supply of vaccines. These regulatory arrangements[89] were a key factor in enabling rapid patient access to vaccines and limiting COVID's most negative impacts to less than two years.[90] This experience provided important lessons on how regulatory systems may be adapted to support innovation and timely patient access to vaccines at all times, not just during emergencies.

Government incentives for investment in rare diseases

The rare disease landscape offers a clear example of how coordinated policy and regulatory action can transform a previously unattractive investment therapeutic area into one of high innovation and growth. Historically, rare or "orphan" diseases were considered financially unattractive[91] for pharmaceutical companies to invest in due to their small patient populations, making it difficult to recoup the high costs associated with drug development. To address these challenges, governments have introduced a variety of incentives to stimulate investment in orphan drugs, including the Orphan Drug Act in the US (see Box 1).

BOX 1

Orphan Drug Act – turning risk into opportunity

The Orphan Drug Act (ODA), signed into US law in 1983, provides financial incentives to pharmaceutical companies to develop drugs for rare diseases that affect a limited population of Americans. Since the ODA was passed, the orphan drug market, once seen as unviable, has become a major growth sector[92] in pharmaceuticals, valued at over $170 billion[93] globally by 2023.

By the end of 2024, it is expected[94] to reach $204 billion and grow with a CAGR of approximately 8.8% to reach $340 billion by 2030. Venture capital and private equity investment into rare disease biotech firms has increased significantly,[95] as investors see the potential for high returns through these incentives.

The ODA provides pharmaceutical companies with key benefits,[96] including seven years of market exclusivity for drugs developed for approved orphan diseases, tax credits for clinical trial expenditures, fee waivers and access to research grants through the Office of Orphan Development. These incentives are aimed at reducing financial risk and increasing the potential return on investment for drug developers.

In the US, the number of FDA-approved orphan drugs skyrocketed after the ODA was passed (see Figure 5). Over 599 approvals were achieved by mid-2020,[97] representing a significant jump from only 38 approvals prior to the ODA. Notably, in 2023, 51% of novel FDA-approved drugs[98] were orphan drugs compared to 20% in 1985, demonstrating the growing importance of orphan drugs in the pharmaceutical pipeline. In terms of health impact, the potential years of life lost to rare diseases before age 65 declined by 3.3% annually from 1999 to 2007, compared to an estimated 0.9% annual increase without new drug approvals.

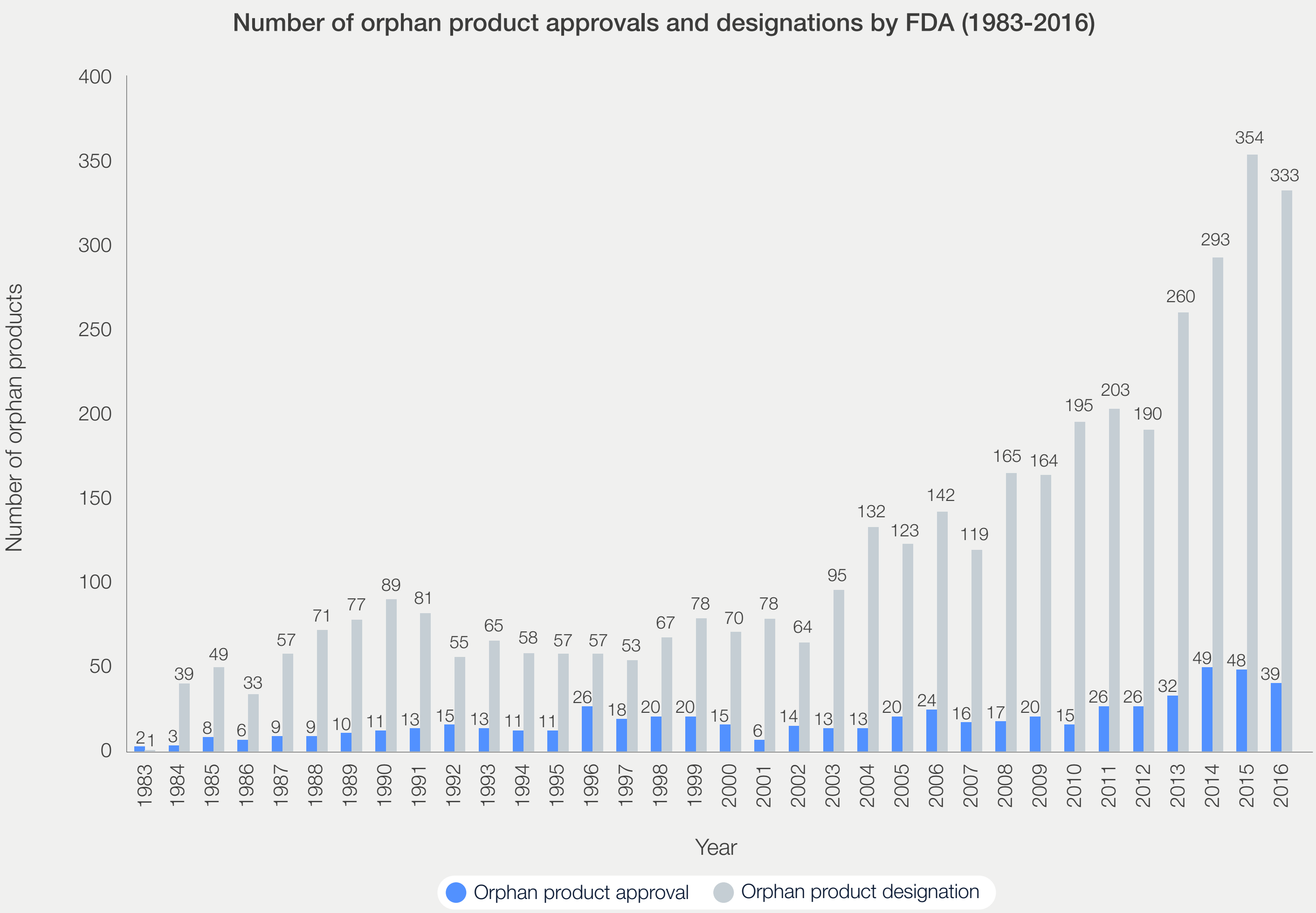
The ODA also had implications for medical devices as it spurred follow-on regulation, including the introduction of the class of humanitarian use devices (HUDs)[100] from the FDA. This allows manufacture of medical devices with less proof of efficacy if these devices serve a small number of impacted individuals. However, orphan device regulation remains limited[101] globally and, as a result, so do innovations to meet needs in these areas.

More recently, the FDA instituted an accelerated approval pathway for drugs that fill an unmet medical need within serious conditions. Additionally, companies have been offered exemptions from mandatory drug discounts implemented with the Affordable Care Act (ACA) if the product has orphan designation. Similar frameworks[102] have followed in other market, such as the European Union's Orphan Regulation of 2000. These policies are designed to lower the financial risks and enhance the potential profitability for drug developers, encouraging them to enter this niche field.

These efforts have led to transformative outcomes[103] and demonstrate how thoughtful regulatory support and financial incentives can transform an underfunded, high-risk area such as rare diseases into a high-investment sector, resulting in both economic growth and life-saving treatments for patients.

The ODA provides pharmaceutical companies with key benefits, including seven years of market exclusivity, tax credits for clinical trials, fee waivers and access to research grants.

FIGURE 5 | **Impact of Orphan Drug Act on rare disease investment in the US**



Source: Rana, P. and Chawla, S.[99]

Complexity of climate-health data integration

The complexity of climate-health data integration, which involves integrating climate information into routine decision-making in the health sector, is another significant roadblock.

One complication is the diversity of regulations governing data privacy and security. Rules such as Europe's General Data Protection Regulation (GDPR),[104] the US's Health Insurance Portability and Accountability Act[105] and China's Personal Information Protection Law[106] impose varying privacy standards.

Although these regulations are an important step in data security and digital privacy, they make cross-border data sharing and integration challenging.

Building and investing in advanced climate-health data platforms[107] that integrate diverse data sets would enable better forecasting[108] of climate-driven diseases, improving response times and leading to more targeted interventions.[109] Investment in AI-driven platforms that link environmental, biodiversity and health data can help identify disease patterns influenced by climate change, enabling pharmaceutical companies to proactively develop solutions. For instance, the Global Virome Project,[110] which unites climate and health experts to predict zoonotic disease outbreaks, serves as a model that could be adapted for climate-sensitive diseases. With better predictive tools, companies can design more effective solutions that address both emerging health risks and longer-term public health impacts.

In 2023, private and public sector thought leaders, including WHO, the World Meteorological Organization, the Wellcome Trust and the Rockefeller Foundation, agreed on a three-year action agenda[111] to integrate climate and health data and surveillance systems. This includes identifying high-priority gaps and initial requirements for the integration of climate and weather information into health information systems.

With better predictive tools, companies can design more effective solutions that address both emerging health risks and longer-term public health impacts.

Lack of collaboration among scientists working in life sciences, environment and climate makes it difficult to coordinate research efforts and drive holistic climate-health innovations.

Another example is Burjeel Holdings, which has launched the Center for Climate and Health[112] to introduce advanced screening for climate-sensitive triggers, such as air pollution and extreme heat. Data collections can help clarify links between climate-driven environmental changes and patient symptoms to develop better clinician guidelines and life sciences innovations; they can also highlight the scale and gravity of the impact of climate on health to increase public awareness.

Lack of cross-sector collaboration

The lack of collaboration among scientists working in life sciences, environment and climate makes it difficult to coordinate research efforts and drive holistic climate-health innovations. Operating in silos leads to missed opportunities for developing holistic solutions that address both health and environmental challenges. By fostering partnerships between these sectors, the life sciences industry can pool its scientific expertise[113] with environmental insights to create solutions that address the interconnected issues of climate change and health outcomes.

Cross-sector collaboration would also bring together different perspectives, encouraging innovations that can address systemic issues, such as environmental influence on disease patterns. The US Centers for Disease Control and Prevention (CDC) have recently developed a guide[114] for collaboration on climate and health that supports health department staff in conducting cross-sector outreach for climate adaptation planning. This is a promising initiative, but additional efforts are required globally to support lasting outcomes.

Cultural resistance

Like most organizational transitions, many life sciences innovators face challenges in securing the buy-in to shift to a more climate-centric agenda and line-up of products and services. To overcome this roadblock, leadership commitment is crucial. Senior leaders in companies[115] across the life sciences industry have made commitments to climate mitigation efforts, such as net zero emissions, but commitments to climate adaptation are not yet common.

A more widespread and targeted commitment to adaptation would enable a cultural transformation, where climate-health is not seen as diverting resources from core business, but as an essential new frontier with long-term growth opportunities.

Low public awareness

Climate change's impact on health is becoming more understood, but public and political awareness remains relatively low, weakening advocacy efforts and delaying policy change. However, public campaigns and media engagement could help to address this. Life sciences innovators are in a position to drive public awareness, particularly with the increasing focus on climate-related financial disclosures[116] and pressure[117] for companies to engage in good corporate citizenship programmes.[118]

Regulatory bodies can also play a significant role in promoting awareness. For example, the COVID-19 pandemic demonstrated how rising death rates fuelled public demand for vaccines and other health interventions. A similar dynamic could arise if hospitals or governments were required to disclose climate-related health impacts, such as mortality from extreme heat or asthma exacerbations.

Finally, investors can also play a role by supporting media campaigns and public initiatives that highlight the critical connection between climate and health.

3.4 Life sciences innovation for health systems resilience and equity

One in 12

hospitals worldwide – 16,245 facilities – may be forced to close due to extreme weather events by the end of the century.

As life sciences innovators make efforts to develop, manufacture and deliver a new portfolio of climate-driven health treatments, other public and private health partners can take steps to ensure these efforts reach their target population by addressing health equity problems, diversifying supply chains and bolstering health services and infrastructure. Climate change introduces novel vulnerabilities to health systems and public health efforts that need to be addressed proactively. One in 12 hospitals worldwide – 16,245 facilities – may be forced to close[119] due to extreme weather events by the end of the century.

Health system resistance can be supported by life sciences prevention, diagnostics and innovative climate services

Climate-resilient infrastructure[120] — such as hospitals with heat regulation systems and storm-resistant designs — will be important for maintaining safe environments for patients and clinicians. A climate health impact resilience framework can help hospitals, clinics, the life sciences industry and the public sector map how to coordinate efforts to resist and recover from climate crises. The resilience framework comprises two phases (see Figure 6):

- **Health system resistance** – comprising avoidance (mitigation) and containment (adaptation).
- **Health system recovery** – comprising stabilization (first response) and return to health (treatment).

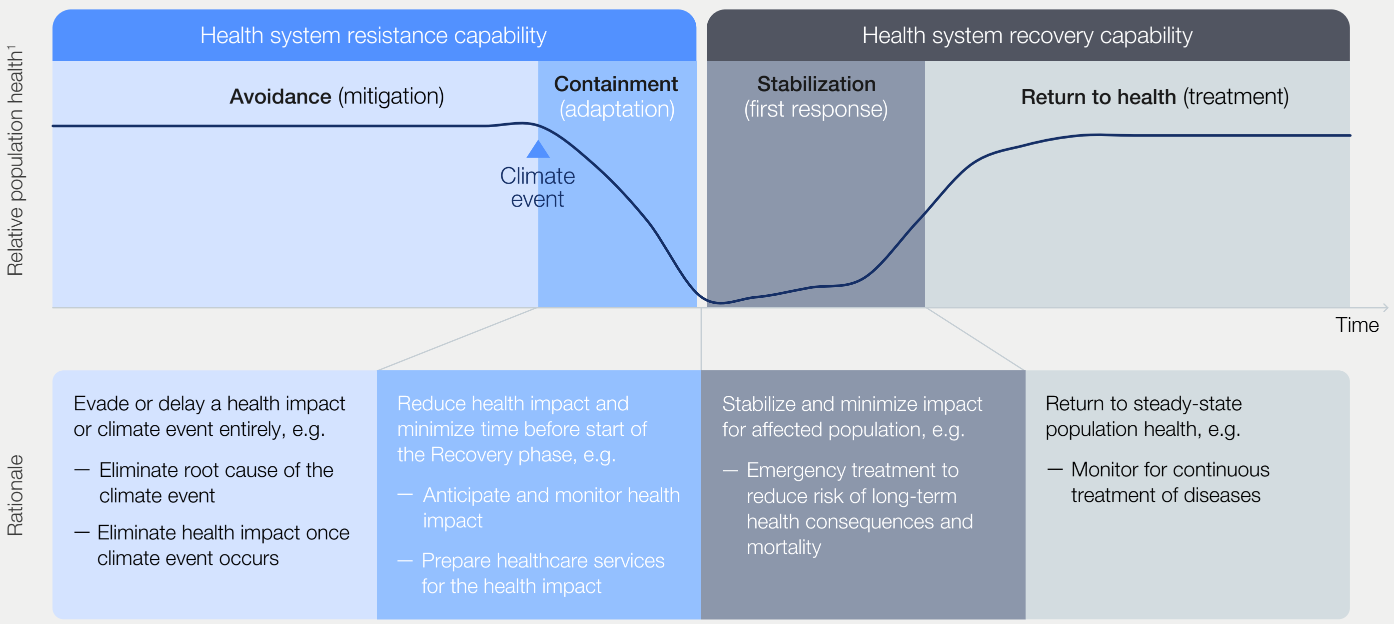
In addition to resilient infrastructure, fostering community-health efforts[121] through initiatives focused on patient education and preventive care (particularly in chronic disease management)[122] is important for reducing strain on the healthcare system so there is capacity during and after climate events. These steps would also create a healthier population that is less vulnerable to the impacts of climate change.

Expanding home care and outpatient services would allow patients to manage care outside a hospital setting, further easing pressure on resources. Finally, approaches to enable appropriate physician adoption of emerging life sciences innovation, such as collecting and incorporating[123] physician feedback, could improve prevention and diagnostic efforts.

Critically, life sciences innovation can contribute to the resistance of health systems through the novel prevention approaches, diagnostics and tech and climate services detailed in Chapter 2 of this report.

FIGURE 6 **Climate health impact resilience framework**

When presented on a time scale, a resilience framework helps to identify and map solutions for avoidance, containment, stabilization and return to health



1. Vs. steady state without climate event

Source: World Economic Forum and Oliver Wyman analysis

> Early warning systems for climate events and disease outbreaks are important, but they must be tailored to local settings, taking into account how different populations access and receive information.

Health system recovery can be supported by life sciences treatment and innovative climate services

To enable health systems to recover and function after climate shocks, alternative care delivery approaches such as telemedicine and mobile health units[124] can be implemented to establish dynamic front-line locations and deploy workers to deliver care during and after crises.

The health system could also benefit from adapting to the shifting disease landscape. Re-tasking non-physicians and investing in targeted clinician training are important strategies for expanding capacity during the recovery phase, particularly in mental health, where resources are often constrained. Training programmes could focus on equipping healthcare workers to handle the shifting burden of disease in different regions, through education in the most effective treatments for various crisis scenarios, as well as preparing them for resource shortages and the need to triage core operations that may be in greater demand during recovery.

Supporting workforce well-being is a key part of sustaining health system recovery. By providing mental health resources and offering flexible work options, health systems can help clinicians manage stress and continue delivering care during crises. Cross-system collaboration[125] and resource-sharing across industries can enhance readiness[126] and ensure a coordinated response when governmental interventions may be delayed.

Critically, life sciences innovation can contribute to the recovery of health systems through the novel prevention approaches, diagnostics and tech and climate services detailed in Chapter 2 of this report.

Addressing health equity is a pre-requisite to delivering impact across resistance and recovery

Health systems and other critical private and public partners must join life sciences innovators in efforts to tackle health equity problems. When considering life sciences innovations, it is also important to address and account for social determinants of health,[127] such as economic stability, access to and quality of education, and the social and community context. Climate change will intensify disparities in access to prevention, diagnosis, treatment and climate technology and services. Closing these access gaps across diseases is essential for equitable public health outcomes.

Coordinated efforts such as early warning systems for climate events and disease outbreaks are important,[128] but they must be tailored to local settings, taking into account how different populations access and receive information. Public health measures, in parallel with life sciences efforts, can address the health risks of rising heat levels, for example, by providing cooled shelters for those facing energy poverty and adopting urban planning strategies, such as expanding green spaces, to protect vulnerable populations in areas prone to the heat island effect.

Insurance coverage that allows workers to safely miss work during extreme heat events, such as that provided by the India Extreme Heat Income Insurance Initiative,[129] can further protect at-risk populations.

Ultimately, coordinated action across the health system, the life sciences industry and other private and public players can reduce the projected health and economic impacts of climate change.

3.5 Avenues for further research: how climate affects non-communicable diseases

There are still many unanswered questions regarding the impact of climate change on health. It is particularly important to understand the relationship between climate change and non-communicable diseases (NCDs). Climate change will aggravate NCDs, already responsible for more deaths than any other cause on the planet.[130] For instance, researchers studying Brazil and Australia[131] found that for every 1°C increase in temperature, the estimated risk of hospitalization for renal diseases lasting up to seven days increased by almost 1%. For children, women and those over 80 years old, the risks are even higher.

There will also be a higher risk of exposure to air pollution from wildfires and the continued burning of fossil fuels that emit carcinogenic gases such as nitrogen dioxide and sulphur dioxide. For example, air pollution is believed to be responsible for approximately 14% of lung cancer cases worldwide.[132] A meta-analysis involving numerous lung cancer cohort studies over the past 25 years found that each 10 μ/m3 increase in PM2.5 exposure is associated with another 14% average increase in lung cancer mortality.

There could be a higher incidence and higher mortality rate from chronic disease, as already stretched public health resources are switched from regular surveillance and health promotion activities to combating the climate-health crisis. This is a phenomenon caused by excess demand, as seen during the COVID-19 pandemic.[133]

Diabetes is a non-communicable disease that could be aggravated by climate change, because of diabetics' impaired responses to heat stress. This includes compromised vasodilation and sweating, diabetes-related comorbidities and chronic low-grade inflammation.[134] Diabetics are also more susceptible to many pathogens because of their altered immune systems.[135]

It is important to understand the interplay between diseases and to consider how climate-related stresses could disproportionately affect more compromised populations, including those with NCDs. For example, diabetes, obesity and hypertension often coexist[136] and could increase the likelihood of climate-driven health complications. COVID sufferers with comorbidities are also more likely to be hospitalized and develop worse symptoms.[137]

Conclusion

Investing $65 billion in prevention, diagnostics and treatment could avoid almost half the impact of climate change on deaths, health and productivity by 2050.

Governments and industry need to join forces now to mobilize global public health systems and unleash life sciences innovation to stay ahead of the advancing crisis. Such investment will save lives and prevent economic losses.

A worldwide coordinated effort is needed to mitigate the health impacts of climate change, similar to the effort that enabled the global economy to move past the COVID-19 pandemic. The climate crisis will be slower to unfold, but even more deadly. Support should revolve around building a viable economic model for sustainable interventions that relies on multilateral financing mechanisms, with global public-private partnerships to fund the needed R&D and build the health infrastructure to disseminate treatment and care, while delivering an ambitious public education campaign.

A coordinated response could significantly reduce negative health and economic consequences through strategic, consistent investment. It is possible to avoid almost half the health impacts and productivity losses projected to occur by 2050 in eight key climate-driven disease areas, along with 45% of deaths and 23% of healthcare costs. This could be achieved with approximately $65 billion of investment into innovative prevention, diagnostics and treatment over the next five to eight years. The only thing needed is the determination to get ahead of the problem.

Appendix: Methodology and assumptions

Overview

Several major reports – including ones from The White House, World Bank and Lancet Countdown – make similar arguments underscoring and collectively reinforcing the significant climate change-driven health risks highlighted in this report.

For instance, the Lancet Countdown estimates that heat exposure, intensified by climate change, has resulted in $863 billion in global income losses over the past eight years. It also predicts increasing heat-related labour losses and deaths. Furthermore, the Lancet Countdown projects that over 500 million additional people will face food insecurity due to climate-driven heatwaves and droughts, along with a more than 30% increase in dengue transmission potential by mid-century. It also predicts an expansion of malaria transmission areas and a longer transmission season. These figures support the projections around climate-linked health and economic impacts of heat-related disease, stunting, malaria and dengue that are used as the basis of this report – including $7.1 trillion in economic losses from heat-related diseases and 900 million DALYs from stunting by 2050.

The World Health Organization (WHO) forecasts 250,000 additional annual deaths by the 2030s, which is directionally in line with assumptions used in the calculations described below. The World Bank projects 21 million climate-related deaths by 2050, compared to the figure of 14.5 million found in this report and the World Economic Forum's January 2024 report, *Quantifying the Impact of Climate Change on Human Health*. The difference arises mainly from the exclusion of diarrhoea-related deaths, as they are influenced by complex factors beyond climate change, such as poor sanitation, lack of clean water, malnutrition and socioeconomic conditions. Together, these reports reinforce the focus on key disease areas in the current report and the scale of the impending crisis.

The report's methodology follows a three-step approach as follows (see Figure A1):

1. Assess the burden of diseases most aggravated by climate change.

2. Prioritize unmet needs for those diseases.

3. Develop a climate and health investment case for the priority unmet needs.

The assessment of health and economic impact leverages the climate-related health impact matrix described initially in the Forum's *Quantifying the Impact of Climate Change on Human Health* report. It is based on an overview of climate databases and meteorological forecasts, as well as research insights from more than 50 scientific and medical studies. The health matrix establishes connections between climate events and heightened disease prevalence and its health and economic impacts.

In this follow-up report, the analysis went a step further to assess what could be done to reduce these impacts. The starting point was an analysis of the highest-affected disease areas and their related unmet medical needs that result in unfavourable health outcomes. The unmet medical needs and their priority were validated through consultations with 14 leading academic experts, researchers and clinicians from institutions such as the Swiss Tropical and Public Health Institute, the Planetary Health Alliance, Yale University, the New York Academy of Medicine and the US Department of Health and Human Services. This ensured alignment with real-world challenges across geographies.

The most pressing unmet medical needs were then prioritized to identify innovation opportunities for the life sciences sector and to evaluate their potential to reduce the health and economic impacts of climate change. This analysis informed the development of investment cases for each unmet need, by comparing required investments with the monetary and human value of expected health and economic benefits.

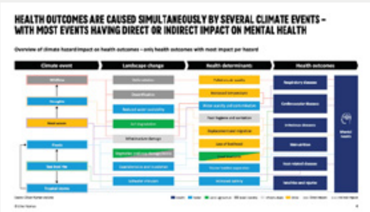
FIGURE A1 **Step-wise approach to assess the burden of climate-related diseases, analyse unmet needs and prioritize investments to mitigate health impacts**

1

Assessment of the burden of disease

Leverage health outcomes model from the 2024 report[1] to identify highest climate impacts on health across geographies

Engage experts to highlight priority diseases not covered in the 2024 report[1]



10-15 health outcomes with highest burden across geographies

2

Prioritization of unmet needs

Identify medical interventions and unmet medical needs for the selected health outcomes, by region

Prioritize unmet needs based on existing and pipeline solutions, associated size of health outcomes and commercial potential

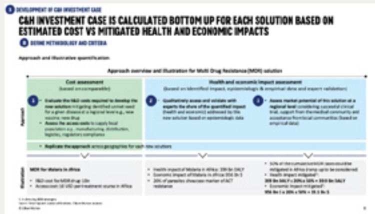
Prioritized list of high impact unmet needs by disease and region

3

Development of climate and health investment case

Assess life sciences sector **potential to address unmet needs**

Develop a **high-level investment case** to assess commercial viability and health improvement potential



Commercial and ethical ROI assessment for prioritized unmet needs

1. World Economic Forum and Oliver Wyman, *Quantifying the Impact of Climate Change on Human Health*, 2024.

Source: World Economic Forum and Oliver Wyman analysis.

1 Starting point: highest burden climate-induced diseases

The first step used the Forum's climate-related health impact matrix to identify the diseases, regions and populations most affected by rising temperatures and climate change. This focused on the impact of six major climate events that increase in severity and frequency because of global warming – flooding, droughts, heatwaves, tropical storms, wildfires and rising sea levels. These events also cause significant environmental and economic damage, including destruction of agriculture, deforestation, desertification, coastal erosion, water scarcity and soil degradation.

Data linking the effects of these weather events on health outcomes and determinants was gathered from various sources, including WHO's climate change framework, the UN's Intergovernmental Panel on Climate Change (IPCC), the World Meteorological Organization (WMO) and over 50 medical and scientific research publications.

The final list consisted of eight priority diseases: vector-borne diseases (malaria and dengue), mental health disorders (GAD, PTSD), stunting, heat-related illnesses, hypertension and asthma.

2 Prioritization of unmet medical needs by disease

The second step involved identifying current therapies and unmet medical needs for the priority diseases across geographies (see Figure A2). These were based on the availability of existing and pipeline solutions, the scale of the health impact and their commercial potential.

The approach began with a thorough analysis of each priority disease, detailing its etiology and pathophysiology. This included explanations of the underlying causes, biological mechanisms, symptoms and diagnostic processes. The progression and prognosis of each disease were outlined, alongside preventive measures and risk factors. Regional variations in disease manifestation were also examined to ensure a comprehensive understanding of the health outcomes in different geographies.

FIGURE A2 **Phased approach to describe the disease, assess treatments and prioritize unmet needs with the largest impact potential**

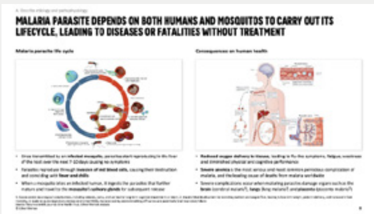
2

Prioritization of unmet needs

A Describe etiology and pathophysiology

Provide disease overview, explaining causes, biological mechanisms, symptoms and diagnostics

Detail **prognosis and evolution** of the disease, preventive measures and risk factors, differences across geographies



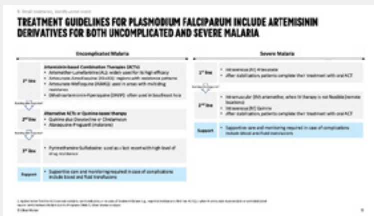
↓

Disease overview, etiology and pathophysiology

B Detail treatments and identify unmet needs

Review existing clinical guidelines and R&D pipeline covering medications, medical devices and digital solutions

Identify unmet needs for high burden disease along prevention, diagnostics and treatment



↓

Overview of existing and emerging medical interventions and corresponding unmet needs

C Assess and prioritize unmet needs

Prioritize high impact unmet needs based on their potential to reduce the burden of disease and improve quality of life

Leverage scientific literature and press releases and validate with scientific and medical experts

↓

Prioritized list of unmet needs with highest impact potential

Source: World Economic Forum and Oliver Wyman analysis.

Next, a review of the currently available treatments was conducted, focusing on prevention protocols, diagnostics, treatments, public health services such as early warning systems, and testing and ongoing research across pharmaceutical companies. This analysis revealed gaps in the prevention, diagnosis and treatment of high-burden diseases, highlighting areas where effective solutions are either lacking or underdeveloped. As a result, 99 unmet needs were identified across eight priority diseases.

Finally, these 99 unmet medical needs were prioritized based on their potential to significantly reduce negative disease outcomes and improve quality of life, while reducing the overall economic impact and providing sufficient incentives to foster investment and innovation.

To ensure alignment with real-world challenges, input was sought from academic experts, researchers and clinicians. Given the complexity and variations in the scientific and medical literature, these consultations were crucial in validating the findings and ensuring that both the prioritization of unmet medical needs and assumptions for investment case development were accurate and actionable.

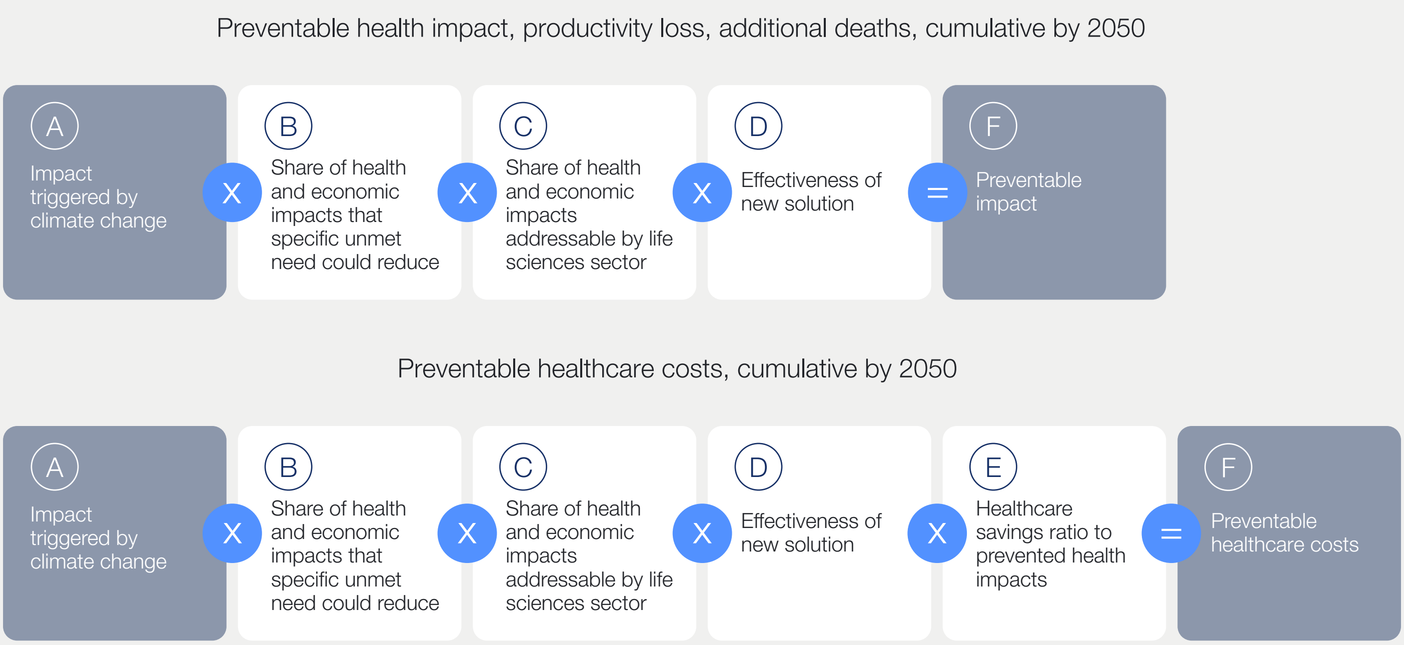
3 Building investment cases for how to address unmet medical needs and produce step-change impact reductions

From the prioritized list of unmet needs, 36 were identified as high- and medium-high impact and selected for investment case assessment. The investment case was broken down into its components, namely preventable impact and the required investments. This supported the assessment of financial and ethical returns on investments in climate and health.

3.1 Estimating the potential to reduce the impact of climate change on health

To calculate the preventable health impacts, productivity loss and additional deaths, three parameters (B-D) were considered. To calculate the preventable healthcare costs, an additional parameter (E) was included to capture healthcare costs associated with the delivery of innovative medical interventions. This approach was replicated for each of the 36 high-priority unmet needs. Overall, preventable impact quantification relied on the parameters detailed below (see Figure A3).

FIGURE A3 **Approach for quantifying preventable impacts for an unmet need**



Source: World Economic Forum and Oliver Wyman analysis.

A. Impact triggered by climate change

The quantified impact of climate change on human health from the Forum's *Quantifying the Impact of Climate Change on Human Health* served as a starting point for assessing preventable health and economic impacts at a disease level for each of the six regions as per the WMO's classification: Africa, Asia, South America, South-West Pacific, Europe and North America, Central America and the Caribbean. For example, malaria is expected to cause an additional health impact of 399 million DALYs, productivity losses of $926 billion, treatment costs of $31 billion and 8 million additional deaths in Africa by 2050.

B. Share of health and economic impacts that specific unmet need could reduce

This coefficient represents the portion of the health and economic outcome that could be prevented if the unmet needs were fully addressed. This may include the share of patients with treatment-resistant diseases, undiagnosed or misdiagnosed cases, or incidences occurring in areas where vaccination is justified. For example, developing a treatment for multi-drug-resistant malaria could address from 35% to 46% of cases where current treatments fail to eliminate the malaria parasite, depending on the region.

C. Share of health and economic impacts addressable by life sciences sector

This coefficient is based on four parameters:
1) Required R&D time, 2) Innovation adoption rate,
3) Access to healthcare and technology, and
4) Health and economic impact trajectory:

1) Required R&D time – defined as the number of years necessary to develop a new vaccine, medtech device, drug or digital therapeutic app. R&D time was estimated by considering an accelerated development pathway, reflecting the urgency recognized by the life sciences community and regulatory bodies. For every intervention type across vaccines, diagnostics, treatment and digital therapeutics, the average development time for new solutions was calculated, incorporating historical benchmarks alongside accelerated timelines observed during the COVID-19 pandemic.

– **Vaccines:** R&D timeline of six years was considered for all innovative vaccines, as an average between the historical R&D timeline (10 years) and accelerated timeline observed during the COVID-19 pandemic (one year).

– **Diagnostics:** R&D timeline of three years was considered for all innovative diagnostic kits, as an average between historical R&D timeline for medical devices (five years) and accelerated timeline observed during the COVID-19 pandemic (three months for diagnostic tests).

– **Drugs:** R&D timeline of six years was considered for all innovative drugs, as an average between historical R&D timeline (10.5 years) and accelerated timeline observed during the COVID-19 pandemic (one year for new vaccine development).

– **Digital therapeutics:** R&D timeline of two years was considered for all innovative digital therapeutics, based on the historical R&D timeline for healthcare app (18 months development and six months for approval following Premarket Notification 510(k) procedure).

2) Innovation adoption rate – defined as the share of disease incidences that gets treated by the new intervention each year upon completion of the R&D process. This captures both physician adoption and patient uptake rates. It is eventually capped by the degree of access to healthcare and technology. The adoption rate was assessed based on historical adoption.

– **Vaccines:** The adoption rate of the COVID-19 vaccine was considered as a benchmark, reaching 10% of global population in the launch year, 49% two years after launch, 63% three years after launch and 65% four years after launch. The same timeline was assumed for all innovative vaccines. From year five after launch onwards, an additional 2% growth of adoption rate was assumed, similar to the incremental growth of adoption rate in year four after COVID-19 vaccine launch (increase from 63% to 65%).

– **Medical technology diagnostic devices:** The adoption rate of malaria rapid diagnostic tests (RDTs) in Africa was used as a benchmark. Malaria RDTs are not a novel solution; however from 2010-2019 a major effort was made to widen their availability, resulting in an increase in usage from 36% to 87%. As such, an average 5% annual increase in adoption rate was assumed for all innovative diagnostic kits.

– **New treatments:** The adoption rate of new drugs by physicians was considered as a benchmark. Studies for innovative cardiovascular drugs have demonstrated that 35% of physicians start prescribing the new drug in the first 18 months after it is introduced into the market. As such, an average 21% annual increase in adoption rate for each consecutive year after drug launch was assumed for all innovative treatments.

3) Access to healthcare and technology – defined as the maximum share of annual disease incidences which could be reached by the new intervention by 2050. For most interventions, the innovation adoption rate is eventually limited by the level of healthcare access in the region.

- **Economically developed regions:** Findings from North America were treated as the benchmark, indicating that 8.4% of US census areas do not have an ambulatory care facility. Hence, it was assumed that for developed countries 92% of incidences could be effectively reached by innovative life sciences solutions.

- **Less economically developed regions:** For these regions, a forward-looking estimate was applied. Current global access to healthcare of 61% was assumed to be average, based on the share of rural (44%) and urban (78%) populations with access to healthcare services. To account for the expected increase in healthcare access by 2050, an average of between 61% current global access to healthcare and 92% current access to healthcare in developed countries was applied.

- **Digital therapeutics:** For these, a different approach was used. The maximum share of incidences that an innovative intervention could reach was limited by the degree of smartphone penetration rates in corresponding regions, ranging from 38% in Africa to 74% in North America.

4) Health and economic impact trajectory – defined as the amount of DALYs, economic losses and deaths expected to be caused by climate change each year until 2050, derived from the Forum's *Quantifying the Impact of Climate Change on Human Health*. Four factors were combined to estimate the share of health and economic impacts that could be prevented by the new solutions developed by the life sciences sector until 2050:

- **Required R&D time** was used as a delay before any impact could be reduced.

- **Year-on-year innovation adoption rate** was applied to year-on-year health and economic impact trajectories.

- **Access to healthcare and technology** marked the maximum adoption rate that could be achieved by 2050.

- **This combination of factors** allowed us to assess what proportion of year-by-year health impacts, economic losses and additional deaths could be prevented.

D. Effectiveness of new solutions

New interventions are not anticipated to reach 100% effectiveness. Therefore, medical literature was reviewed to identify the efficacy of innovative solutions in ongoing trials and averaged with the effectiveness of existing solutions. The following scenarios were considered:

- **Ongoing trials:** In the case of ongoing trials with quantified efficacy outcomes, the effectiveness of an innovative solution was considered as the average between the existing intervention effectiveness and the efficacy highlighted in trials. This approach takes into account existing effectiveness but also acknowledges improved clinical efficacy demonstrated in trials. For example, with a new malaria drug targeting multi-drug resistance, an average effectiveness was calculated between current malaria drug effectiveness (from 54% in Asia to 65% in Africa) and best-practice efficacy observed in ongoing trials (100%).

- **Replicating existing solutions:** Where innovation replicates existing solutions in a new environment, the effectiveness of the existing solution was utilized. For example, this approach has been used to assess the potential effectiveness of a new preventive pharmacological solution for generalized anxiety disorder, where an effective treatment already exists, with an effectiveness of 56%.

- **No trials:** Finally, when no trials exist or no efficacy outcomes are demonstrated, a comparable intervention developed for another disease from a comparable therapeutic area was considered as a benchmark. For example, the potential efficacy of digital therapeutics in addressing generalized anxiety disorder is assumed to be 57%, in line with effectiveness of self-management apps in reduction of PTSD symptoms.

E. Healthcare savings ratio to prevented health impacts

Prevention of health impacts directly leads to a reduction in productivity losses and premature deaths, but it has a lower effect on reduction of healthcare costs. Access to new solutions is costly and often requires supply chain and medical infrastructure to deliver the health impact, resulting in extra costs for the healthcare system. For example, while a vaccine may avert adverse health outcomes, substantial healthcare costs are still required to deliver the injections, often in larger volumes than actual incidences in the area. Therefore, only a share of healthcare costs needed to treat the health impacts of climate change could be saved. A healthcare savings ratio was applied to estimate the prevented health impacts.

- **Vaccines:** A comparison of costs identified that vaccinating for influenza can be 32% cheaper than treatment – a savings ratio that was applied to all prevention interventions.

- **New diagnostics:** The introduction of new medtech devices has, in some instances, led to an overall increase in healthcare costs – up to an additional 40%. When considering the ratio of prevented health impacts, this implies around a 70% reduction in total healthcare costs for every diagnosed and subsequently treated case.

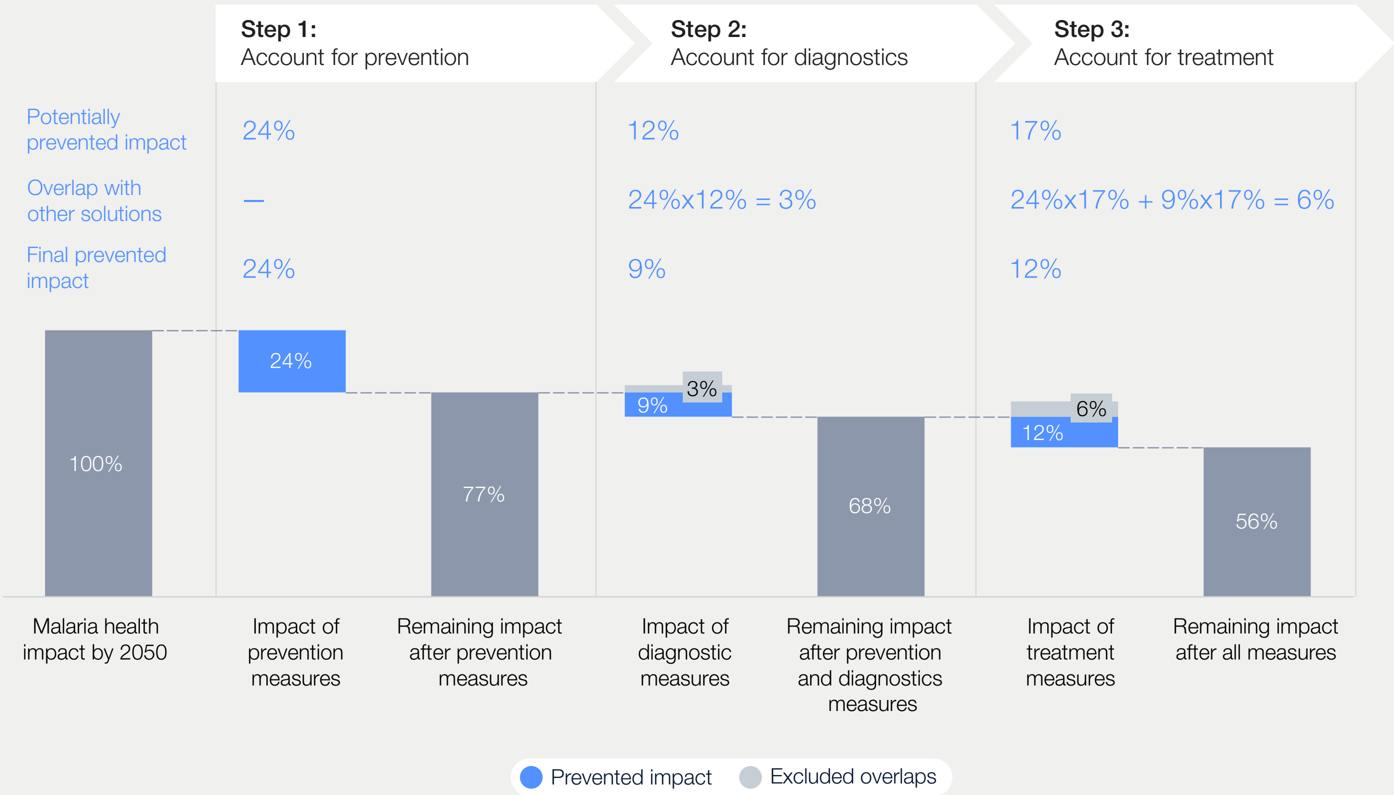
– **New treatments:** Transitioning to a more cost-efficient drug also incurs costs, with some studies indicating up to 31% saving per case treated.

F. Preventable health and economic impacts

The parameters described above were applied in combination to calculate the preventable health and economic impacts across the eight high-priority diseases in scope.

Overlaps between solutions were factored in to avoid double-counting of health and economic impacts. For instance, effective population vaccination could significantly reduce the incidence of the disease, thereby limiting the additional potential for diagnostics or treatments (see Figure A4).

FIGURE A4 **Approach for quantifying overlap between interventions (example for malaria)**



Source: World Economic Forum and Oliver Wyman analysis.

A sequential approach was developed to exclude overlaps from the quantification, as follows:

– **Step 1:** Prevention measures were applied to the entire health and economic impact. In the example above, the introduction of new vaccines could prevent up to 24% of the health impacts by 2050.

– **Step 2:** Diagnostic measures were then considered for the impact post-prevention, addressing the remaining 77% of the entire health and economic impact for malaria. The prevented impact from new diagnostics for malaria goes down from 12% in the absence of prevention measures, to 9% when the impact of prevention measures is considered.

– **Step 3:** Following a similar logic, treatment measures are applied to the impact post-prevention and diagnostics, addressing the remaining 68% of the entire impact. The prevented impact from new treatment for malaria goes down from 17% in the absence of prevention and diagnostic measures, to 12% when the impact of these measures is considered.

As a result, overlaps account on average for 8.4% of health and economic impacts across diseases until 2050. Overlaps were excluded from the final outcomes presented in this report.

3.2 Assessing the costs

Developing new interventions to address high-priority unmet needs would require up to $65 billion of investment in research and development in the coming five to eight years. For each intervention type, the number of required interventions was multiplied by historical average R&D costs.

- **Vaccine** development costs represent 8% of total R&D costs. Historical development costs have been up to $1 billion per vaccine. Vaccines are deemed crucial for addressing climate challenges, including those for malaria, dengue fever and enteric infections contributing to malabsorption in stunting.

- **Drug** development costs represent 89% of total R&D costs. Developing new drugs, such as those combating treatment resistance is often the most expensive endeavour, with costs up to $2.8 billion depending on the therapeutic area and accounting for the risks associated with drug development failures.

- **Diagnostic device** development costs represent 1% of total R&D costs. Development costs for new diagnostic medtech devices are up to $54 million per device.

- **Digital therapeutic** development costs represent less than 1% of total R&D costs. Digital therapeutics typically have the lowest development costs, up to $425,000 per application.

3.3 Model limitations

The quantification approach developed in this report provides a solid foundation, encouraging further research assessing new solutions preventing the impact of climate change on human health. Further research could enhance the precision of the assessment, by addressing some of the following limitations of the report:

- **Extrapolation of data:** Given the lack of existing data, averages were used to finesse the projection. Additionally, extrapolations were developed across comparable medical interventions when no data was available. A sensitivity analysis was performed to measure the variance of outcomes, however additional research and the use of Monte Carlo analysis could be leveraged to further enhance the quantification.

- **Parameters used:** A similar set of assumptions was applied to assess the impact that could be prevented across DALYs, economic losses and additional deaths. However, some innovative interventions could be more effective in preventing, for example, additional mortality rather than reducing health impacts or saving economic losses. Further research could focus on assessing how innovative interventions could affect these impacts separately.

- **Limited region-specific data:** Region-specific estimates were utilized wherever available, focusing on one of six regions as per WMO's classification (Africa, Asia, South America, South-West Pacific, Europe and North America, Central America and the Caribbean). In some instances where region-specific research was lacking, global averages or findings from comparable regions were used. Further research could focus on detailing prevented health and economic impacts in selected regions of interest.

- **R&D timelines:** The analysis assumed that all new research initiatives would commence in 2024-2025. Further research could include the assessment of the probability of success for existing pipeline solutions.

- **Reliance on historical evidence:** Historical data was utilized to assess model parameters, including innovation adoption rate and efficacy of solutions. Going forward, the potential degree of urgency associated with addressing health and economic impacts of climate change could speed up adoption rates. Similarly, R&D could result in a significant increase in efficacy of potential interventions, not yet captured by existing solutions or ongoing trials. Detailed assessment of how these parameters might evolve could enhance the quantification of preventable health and economic impacts.

- **Focus on human impacts related to climate change:** The prevented impact assessment in this report was focused on additional health and economic impacts caused by climate change. However, new interventions could help prevent a portion of health and economic impacts not linked to climate change. Assessing such potential in further research could create additional evidence that supports the importance of investing in highlighted interventions.

Contributors

Lead authors

Shyam Bishen
Head, Centre for Health and Healthcare;
Member of the Executive Committee, World Economic Forum

Fernando Gomez
Head, Resource Systems and Resilience, World Economic Forum

Sven Braun
Partner, Private Capital and Life Sciences, Oliver Wyman

Oliver Eitelwein
Partner, Health and Life Sciences, Oliver Wyman

Judith Moore
Head, Healthcare Access & Outcomes, World Economic Forum

Matthew Watkins,
Lead, Climate & Health, World Economic Forum

Project team

Thibault Wautier
Principal, Health and Life Sciences, Oliver Wyman

Maxim Bochkov
Associate, Climate and Sustainability, Oliver Wyman

Daniella Diaz Cely
Specialist, Climate and Health, World Economic Forum

Clio Meghir
Associate, Health and Life Sciences, Oliver Wyman

Acknowledgements

The World Economic Forum and Oliver Wyman would like to extend their gratitude to the following individuals for their valuable contributions to this report. We would additionally like to sincerely thank the World Economic Forum private sector partners that contributed to this report. Due to the confidential nature of business strategy discussions, we do not list here contributing companies by name. The paper does not necessarily reflect the views of these individuals and/or their organizations. Expert advice is purely consultative in nature and does not imply any association with the takeaways or conclusions presented within this paper.

Emad Al Nemnem
Head of Pulmonary Department,
Burjeel Medical City

Ana Margarida Alho
Policy Officer, European Commission's Health Emergency Preparedness and Response Authority

Fiona Charlson
Associate Professor and NHMRC Research Fellow, Queensland Centre of Mental Health Research and School of Public Health, University of Queensland

Mohammad Fityan
Chief Medical Officer, Designated Institutional Official, Consultant Internal Medicine and Obesity Medicine, Burjeel Holdings

Lynne Gaffikin
Adjunct Professor, Stanford University School of Medicine, Department of Obstetrics and Gynecology

Ann Kurth
President, New York Academy of Medicine

Lais Miachon Silva
Programme Manager for Climate Change and Nutrition, Micronutrient Forum

Adetoun Mustapha
Adjunct Researcher, Nigerian Institute of Medical Research

Suzanne Steinbaum
Preventative Cardiologist, Private Practice

Fabrizio Tediosi
Group Leader, Swiss Tropical and Public Health Institute (Swiss TPH)

Vanessa A. Zuzarte Luís
Chief Scientist, SGS Global Biosciences Center

Production

Bianca Gay-Fulconis
Designer, 1-Pact Edition

Jonathan Walter
Editor

Pat Wechsler
Editorial Director, Oliver Wyman

Endnotes

1. Haile, G., Tang, Q., Sun, S., Huang, Z., Zhang, X. & Liu, X. (2019). Droughts in East Africa: Causes, impacts and resilience. *Earth-Science Reviews*, vol. 193, pp. 146-161. https://www.sciencedirect.com/science/article/abs/pii/S0012825218303519.
2. Vox. (2024). *The latest on Hurricanes Milton and Helene*. https://www.vox.com/climate/374867/hurricane-milton-helene-death-toll-flooding-outages-live-updates.
3. Griffith, C. (2022). *Thousands of People Made Homeless in Hurricane Ian's Aftermath*. Invisible People. https://invisiblepeople.tv/thousands-of-people-made-homeless-in-hurricane-ians-aftermath/.
4. Langlois, J. (2024). *Dengue fever is — unfortunately — having a banner year. Can it be quelled?* Goats and Soda, NPR. https://www.npr.org/sections/goats-and-soda/2024/07/23/g-s1-12674/dengue-mosquitoes-climate-virus-americas.
5. Centers for Disease Control and Prevention (CDC). (2024). *Increased Risk of Dengue Virus Infections in the United States*. https://emergency.cdc.gov/han/2024/han00511.asp.
6. World Economic Forum. (2024). *Quantifying the Impact of Climate Change on Human Health*. https://www.weforum.org/publications/quantifying-the-impact-of-climate-change-on-human-health/.
7. United Nations (UN). (2024). *For a livable climate: Net-zero commitments must be backed by credible action*. https://www.un.org/en/climatechange/net-zero-coalition.
8. Thomson, M. & Stanberry, L. (2022). Climate Change and Vectorborne Diseases. *The New England Journal of Medicine*, vol. 387, no. 21. https://www.nejm.org/doi/full/10.1056/NEJMra2200092.
9. Surprenant, A. (2024). *How climate change affects vector-borne diseases*. Wellcome. https://wellcome.org/news/how-climate-change-affects-vector-borne-diseases.
10. Sources:
    - European Centre for Disease Prevention and Control. (2024). *Dengue worldwide overview*. https://www.ecdc.europa.eu/en/dengue-monthly.
    - Johns Hopkins Bloomberg School of Public Health. (2023). *What to Know About Malaria in the U.S*. https://publichealth.jhu.edu/2023/malarias-comeback-in-the-us.
11. Bonell, A., Sonko, B., Badjie, J., Samateh, T., Saidy, T., Sosseh, F., Sallah, Y., Bajo, K., Murray, K.A., Hirst, J., Vicedo-Cabrera, A., Prentice, A.M., Maxwell, N.S. & Haines, A. (2022). Environmental heat stress on maternal physiology and fetal blood flow in pregnant subsistence farmers in The Gambia, west Africa: an observational cohort study. *The Lancet Planetary Health*, vol. 6, no. 12. https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(22)00242-X/fulltext.
12. Shankar, K., Ali, S.A., Ruebel, M.L., Jessani, S., Borengasser, S.J., Gilley, S.P., Jambal, P., Yazza, D.N., Weaver, N., Kemp, J.F., Westcott, J.L., Hendricks, A.E., Saleem, S., Goldenberg, R.L., Hambidge, K.M. & Krebs, N.F. (2023). Maternal nutritional status modifies heat-associated growth restriction in women with chronic malnutrition. *PNAS Nexus*, vol. 2, no. 1. https://pmc.ncbi.nlm.nih.gov/articles/PMC9896899/.
13. World Health Organization (WHO). (2022). *Mental health and Climate Change: Policy Brief*. https://www.who.int/publications/i/item/9789240045125.
14. Eitelwein, O., Fricker, R., Green, A. & Racloz, A. (2024). *The Impact Of Climate Change On Human Health*. Oliver Wyman. https://www.oliverwyman.com/our-expertise/insights/2024/jan/quantifying-climate-change-impact-on-human-health.html.
15. Breen, K. (2024). *Hurricane Milton was fastest on record to intensify into Category 5 in the Gulf of Mexico: "Historic storm"*. CBS News. https://www.cbsnews.com/news/hurricane-milton-florida-landfall-records/.
16. Lindsey, R. (2023). *Climate Change: Global Sea Level*. Climate.gov. https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level.
17. Lindsey, R. (2023). *Climate Change: Global Sea Level*. Climate.gov. https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level.
18. UN Atlas of the Oceans. (2016). *Human Settlements on the Coast*. https://www.oceansatlas.org/subtopic/en/c/114/.
19. United Nations (UN) & The European Space Agency (ESA). (2007). *Percentage of Total Population Living in Coastal Areas*. https://www.un.org/esa/sustdev/natlinfo/indicators/methodology_sheets/oceans_seas_coasts/pop_coastal_areas.pdf.
20. Eitelwein, O., Fricker, R., Green, A. & Racloz, A. (2024). *The Impact Of Climate Change On Human Health*. Oliver Wyman. https://www.oliverwyman.com/our-expertise/insights/2024/jan/quantifying-climate-change-impact-on-human-health.html.
21. Mueller, W., Zamrsky, D., Essink, G.O., Fleming, L.E., Deshpande, A., Makris, K.C., Wheeler, B.W., Newton, J.N., Venkat Narayan, K.M., Mohd Naser, A. & Gribble, M.O. (2024). Saltwater intrusion and human health risks for coastal populations under 2050 climate scenarios. *Scientific Reports*, vol. 14. https://www.nature.com/articles/s41598-024-66956-4.
22. Campbell, L. (2023). *Study finds states facing worse drought have more comprehensive drought planning*. National Drought Mitigation Center (NDMC). https://drought.unl.edu/Publications/News.aspx?id=400.
23. Frost, R. (2024). *Regular droughts could become the Mediterranean's 'new normal' due to climate change*. Euronews. https://www.euronews.com/green/2024/02/21/regular-droughts-could-become-the-mediterreneans-new-normal-due-to-climate-change.

24. Ballester, J., Quijal-Zamorano, M., Méndez Turrubiates, R.F., Pegenaute, F., Herrmann, F.R., Robine, J.M., Basagaña, X., Tonne, C., Antó, J.M. & Achebak, H. (2023). Heat-related mortality in Europe during the summer of 2022. *Nature Medicine*, vol. 29. https://www.nature.com/articles/s41591-023-02419-z.

25. Organisation for Economic Co-operation and Development (OECD). (2016). *The Economic Consequences of Outdoor Air Pollution*. https://www.oecd.org/en/publications/the-economic-consequences-of-outdoor-air-pollution_9789264257474-en.html.

26. Sources:
   - Eitelwein, O., Fricker, R., Green, A. & Racloz, A. (2024). *The Impact Of Climate Change On Human Health*. Oliver Wyman. https://www.oliverwyman.com/our-expertise/insights/2024/jan/quantifying-climate-change-impact-on-human-health.html.
   - World Economic Forum. (2024). *Quantifying the Impact of Climate Change on Human Health*. https://www.weforum.org/publications/quantifying-the-impact-of-climate-change-on-human-health/.

27. Bhargawa, R. & Bhargava, M. (2023). *The climate crisis disproportionately hits the poor. How can we protect them?* World Economic Forum. https://www.weforum.org/stories/2023/01/climate-crisis-poor-davos2023/.

28. United Nations (UN). (2006). *United Nations Fact Sheet on Climate Change. Africa is particularly vulnerable to the expected impacts of global warming*. https://unfccc.int/files/press/backgrounders/application/pdf/factsheet_africa.pdf.

29. World Health Organization (WHO). (2022). *Lack of innovation set to undermine antibiotic performance and health gains*. https://www.who.int/news/item/22-06-2022-22-06-2022-lack-of-innovation-set-to-undermine-antibiotic-performance-and-health-gains.

30. World Health Organization (WHO). (2022). *Lack of innovation set to undermine antibiotic performance and health gains*. https://www.who.int/news/item/22-06-2022-22-06-2022-lack-of-innovation-set-to-undermine-antibiotic-performance-and-health-gains.

31. Bishen, S. & Eitelwein, O. (2024). *3 key priorities to avert a climate-driven health catastrophe by 2050*. World Economic Forum. https://www.weforum.org/stories/2024/09/3-key-priorities-to-avert-a-climate-health-catastrophe-by-2050/.

32. Forrest, F. (2023). *The impact of climate change on the pharma supply chain*. Pharmaceutical Technology. https://www.pharmaceutical-technology.com/sponsored/the-impact-of-climate-change-on-the-pharma-supply-chain/.

33. Tricou, V., Yu, D., Reynales, H., Biswal, S., Saez-Llorens, X., Sirivichayakul, C., Lopez, P., Borja-Tabora, C., Bravo, L., Kosalaraksa, P., Martinez Vargas, L., Alera, M.T., Rivera, L., Watanaveeradej, V., Dietze, R., Fernando, L., Wickramasinghe, V. P., Duarte Moreira Jr, E., Fernando, A.D., Gunasekera, D., Luz, K., Oliveira, A.L., Tuboi, S., Escudero, I., Hutagalung, Y., Lloyd, E., Rauscher, M., Zent, O., Folschweiller, N., LeFevre, I., Espinoza, F. & Wallace, D. (2024). Long-term efficacy and safety of a tetravalent dengue vaccine (TAK-003): 4·5-year results from a phase 3, randomised, double-blind, placebo-controlled trial. *The Lancet Global Health*, vol. 12, issue 2. https://www.thelancet.com/journals/langlo/article/PIIS2214-109X(23)00522-3/fulltext.

34. Bassetti, M., Russo, A., Carnelutti, A., La Rosa, A. & Righi, E. (2018). Antimicrobial resistance and treatment: an unmet clinical safety need. *Expert Opin Drug Saf, PubMed*, vol. 17, no. 7, pp. 669-680. https://pubmed.ncbi.nlm.nih.gov/29897796/.

35. World Meteorological Organization (WMO). (2023). *2023 State of Climate Services: Health*. https://library.wmo.int/records/item/68500-2023-state-of-climate-services-health.

36. World Meteorological Organization (WMO). (2023). *2023 State of Climate Services: Health*. https://library.wmo.int/records/item/68500-2023-state-of-climate-services-health.

37. Bracher, J. (2023). *Could a new tool stop a dengue outbreak before it even starts?* Wellcome. https://wellcome.org/news/digital-tool-prevent-dengue-outbreak.

38. Bracher, J. (2023). *Could a new tool stop a dengue outbreak before it even starts?* Wellcome. https://wellcome.org/news/digital-tool-prevent-dengue-outbreak.

39. Eitelwein, O., Fricker, R., Green, A. & Racloz, A. (2024). *The Impact Of Climate Change On Human Health*. Oliver Wyman. https://www.oliverwyman.com/our-expertise/insights/2024/jan/quantifying-climate-change-impact-on-human-health.html.

40. World Economic Forum. (2024). *Quantifying the Impact of Climate Change on Human Health*. https://www.weforum.org/publications/quantifying-the-impact-of-climate-change-on-human-health/.

41. Colón, F. (2022). *World at risk: how malaria, dengue could spread due to climate change*. Wellcome. https://wellcome.org/news/world-risk-malaria-dengue-spread-climate-change.

42. Eitelwein, O., Fricker, R., Green, A. & Racloz, A. (2024). *The Impact Of Climate Change On Human Health*. Oliver Wyman. https://www.oliverwyman.com/our-expertise/insights/2024/jan/quantifying-climate-change-impact-on-human-health.html.

43. Johns Hopkins Bloomberg School of Public Health. (2023). *What to Know About Malaria in the U.S*. https://publichealth.jhu.edu/2023/malarias-comeback-in-the-us.

44. Eitelwein, O., Fricker, R., Green, A. & Racloz, A. (2024). *The Impact Of Climate Change On Human Health*. Oliver Wyman. https://www.oliverwyman.com/our-expertise/insights/2024/jan/quantifying-climate-change-impact-on-human-health.html.

45. Know Dengue. (2023). *Urbanisation is helping fuel the spread of dengue*. https://www.knowdengue.com/article/urbanizations.

46. European Centre for Disease Prevention and Control (ECDC). (2024). *Worsening spread of mosquito-borne disease outbreaks in EU/EEA, according to latest ECDC figures*. https://www.ecdc.europa.eu/en/news-events/worsening-spread-mosquito-borne-disease-outbreaks-eueea-according-latest-ecdc-figures.

47. Halstead, S. (2024). Three Dengue Vaccines — What Now? *The New England Journal of Medicine*, vol. 390, no. 5, pp. 464-465. https://www.nejm.org/doi/full/10.1056/NEJMe2314240.

48. Jiansheng Lu et al. (2022). A human monoclonal antibody to neutralize all four serotypes of dengue virus derived from patients at the convalescent phase of infection. *Virology*, vol. 576, pp74-82. https://www.sciencedirect.com/science/article/pii/S004268222200160X.

49. Walinski, A., Sander, J., Gerlinger, G., Clemens, V., Meyer-Lindenberg, A. & Heinz, A. (2023). The Effects of Climate Change on Mental Health. *Deutsches Ärzteblatt International, PubMed Central*, vol. 120, no. 8, pp. 117-124. https://pmc.ncbi.nlm.nih.gov/articles/PMC10154789/.

50. Eitelwein, O., Fricker, R., Green, A. & Racloz, A. (2024). *The Impact Of Climate Change On Human Health*. Oliver Wyman. https://www.oliverwyman.com/our-expertise/insights/2024/jan/quantifying-climate-change-impact-on-human-health.html.

51. Meek, W. (2024). *Generalized Anxiety Disorder: Causes and Risk Factors*. Verywell Mind. https://www.verywellmind.com/gad-causes-risk-factors-1392982#toc-how-life-experiences-contribute-to-gad.

52. Walinski, A., Sander, J., Gerlinger, G., Clemens, V., Meyer-Lindenberg, A. & Heinz, A. (2023). The Effects of Climate Change on Mental Health. *Deutsches Ärzteblatt International, PubMed Central*, vol. 120, no. 8, pp. 117-124. https://pmc.ncbi.nlm.nih.gov/articles/PMC10154789/.

53. Eitelwein, O., Fricker, R., Green, A. & Racloz, A. (2024). *The Impact Of Climate Change On Human Health*. Oliver Wyman. https://www.oliverwyman.com/our-expertise/insights/2024/jan/quantifying-climate-change-impact-on-human-health.html.

54. Eitelwein, O., Fricker, R., Green, A. & Racloz, A. (2024). *The Impact Of Climate Change On Human Health*. Oliver Wyman. https://www.oliverwyman.com/our-expertise/insights/2024/jan/quantifying-climate-change-impact-on-human-health.html.

55. Eitelwein, O., Fricker, R., Green, A. & Racloz, A. (2024). *The Impact Of Climate Change On Human Health*. Oliver Wyman. https://www.oliverwyman.com/our-expertise/insights/2024/jan/quantifying-climate-change-impact-on-human-health.html.

56. Eitelwein, O., Fricker, R., Green, A. & Racloz, A. (2024). *The Impact Of Climate Change On Human Health*. Oliver Wyman. https://www.oliverwyman.com/our-expertise/insights/2024/jan/quantifying-climate-change-impact-on-human-health.html.

57. Eitelwein, O., Fricker, R., Green, A. & Racloz, A. (2024). *The Impact Of Climate Change On Human Health*. Oliver Wyman. https://www.oliverwyman.com/our-expertise/insights/2024/jan/quantifying-climate-change-impact-on-human-health.html.

58. Evaluate. (2024). *World Preview 2024 – Pharma's Growth Boost*. https://www.evaluate.com/thought-leadership/world-preview-2024-report/.

59. Alvarado, D. (2022). *Novartis to invest $250M in tropical disease drug research*. Biopharma Dive. https://www.biopharmadive.com/news/novartis-kigali-neglected-tropical-disease-drug-research/625928/.

60. Grover, N. & Rigby, J. (2022). *GSK, Novartis pledge funds for diseases that mostly affect the poor*. Reuters. https://www.reuters.com/business/healthcare-pharmaceuticals/gsk-novartis-pledge-funds-diseases-that-mostly-affect-poor-2022-06-23/.

61. Roche. (2023). *A year of meaningful impact. Annual report*. https://www.roche.com/investors/annualreport23.

62. Blair, H.A. (2024). Insulin Icodec: First Approval. *BioDrugs, PubMed*, vol. 38, no. 5, pp. 717-724. https://pubmed.ncbi.nlm.nih.gov/39031321/.

63. Daroudi, R., Akbari Sari, A., Nahvijou, A. & Faramarzi, A. (2021). Cost per DALY averted in low, middle- and high-income countries: evidence from the global burden of disease study to estimate the cost-effectiveness thresholds. *Cost Effectiveness and Resource Allocation, PubMed Central*, vol. 19, no. 7. https://pmc.ncbi.nlm.nih.gov/articles/PMC7863358/.

64. Roche. (2022). *Limited awareness and access to cervical cancer diagnosis and treatment*. https://www.roche.com/stories/fighting-cervical-cancer.

65. Fresenius Kidney Care. (2024). *Resources For Living Well With Kidney Disease*. https://www.freseniuskidneycare.com/tools-and-resources.

66. Fresenius Medical Care. (2017). *How We Respond to Disasters*. https://fmcna.com/content/dam/fmcna/live/company/documents/FMCNA_PR_DisasterOverview_2017.pdf.

67. Novo Nordisk. (2023). *Novo Nordisk announces new partnership to supply human insulin to millions of people living with diabetes in the African continent*. https://www.novonordisk.com/content/nncorp/global/en/news-and-media/latest-news/new-partnership-to-supply-human-insulin.html.

68. Novo Nordisk. (2024). *Our position on medicine pricing*. https://www.novonordisk.com/sustainable-business/access-and-affordability/pricing-position.html.

69. Roche. (2024). *Phelophepa Healthcare Train*. https://www.roche.co.za/about/sustainability/phelophepa-healthcare-train.

70. Deloitte. (2023). *2023 Global Life Sciences Outlook*. https://www.deloitte.com/na/en/Industries/life-sciences-health-care/perspectives/global-life-sciences-sector-outlook.html.

71. Gupta, A., Dialynas, C., McLaughlin, M. & Richie, J. (2024). *Advancing Innovative Treatments for Mental Health Care*. Milken Institute. https://milkeninstitute.org/sites/default/files/2024-04/AdvancingInnovativeTreatmentsMentalHealthCare.pdf.

72. Gupta, A., Dialynas, C., McLaughlin, M. & Richie, J. (2024). *Advancing Innovative Treatments for Mental Health Care*. Milken Institute. https://milkeninstitute.org/sites/default/files/2024-04/AdvancingInnovativeTreatmentsMentalHealthCare.pdf.

73. Gupta, A., Dialynas, C., McLaughlin, M. & Richie, J. (2024). *Advancing Innovative Treatments for Mental Health Care*. Milken Institute. https://milkeninstitute.org/sites/default/files/2024-04/AdvancingInnovativeTreatmentsMentalHealthCare.pdf.

74. Gupta, A., Dialynas, C., McLaughlin, M. & Richie, J. (2024). *Advancing Innovative Treatments for Mental Health Care*. Milken Institute. https://milkeninstitute.org/sites/default/files/2024-04/AdvancingInnovativeTreatmentsMentalHealthCare.pdf.

75. Gupta, A., Dialynas, C., McLaughlin, M. & Richie, J. (2024). *Advancing Innovative Treatments for Mental Health Care*. Milken Institute. https://milkeninstitute.org/sites/default/files/2024-04/AdvancingInnovativeTreatmentsMentalHealthCare.pdf.

76. Mao, W., Cooke, R., Silimperi, D., Urli Hodges, E., Ortiz, E. & Udayakumar, K. (2023). Scaling malaria interventions: bottlenecks to malaria elimination. *BMJ Global Health*, vol. 8, no. 11. https://pmc.ncbi.nlm.nih.gov/articles/PMC10649629/#R6.

77. Orphanet. (2024). *About Orphan Drugs*. https://www.orpha.net/en/other-information/about-orphan-drugs?stapage=countries.

78. Benesty, J., Serazin, E., Short, H. & Zheng, S. (2024). *Addressing Challenges at the Intersection of Climate and Health*. Boston Consulting Group (BCG). https://www.bcg.com/publications/2024/addressing-challenges-intersection-of-climate-and-health.

79. Pfizer. (2020). *Pfizer and BioNTech Announce an Agreement with U.S. Government for up to 600 Million Doses of mRNA-based Vaccine Candidate Against SARS-CoV-2*. https://www.pfizer.com/news/press-release/press-release-detail/pfizer-and-biontech-announce-agreement-us-government-600.

80. Sagonowsky, E. (2020). *After nearly $1B in research funding, Moderna takes $1.5B coronavirus vaccine order from U.S*. Fierce Pharma. https://www.fiercepharma.com/pharma/after-nearly-1b-research-funding-moderna-takes-1-5b-coronavirus-vaccine-order-from-u-s.

81. Gavi, the Vaccine Alliance. (2024). https://www.gavi.org/.

82. Gavi, the Vaccine Alliance. (2024). https://www.gavi.org/.

83. Mao, W., Cooke, R., Silimperi, D., Urli Hodges, E., Ortiz, E. & Udayakumar, K. (2023). Scaling malaria interventions: bottlenecks to malaria elimination. *BMJ Global Health*, vol. 8, no. 11. https://pmc.ncbi.nlm.nih.gov/articles/PMC10649629/#R10.

84. World Health Organization (WHO), WHO Regulation and Prequalification Department. (2023). *PQT Unit*. https://cdn.who.int/media/docs/default-source/health-products-policy-and-standards/19_prequalification-processes-and-activities-overview---lawrence-nzumbu.pdf.

85. Mao, W., Cooke, R., Silimperi, D., Urli Hodges, E., Ortiz, E. & Udayakumar, K. (2023). Scaling malaria interventions: bottlenecks to malaria elimination. *BMJ Global Health*, vol. 8, no. 11. https://pmc.ncbi.nlm.nih.gov/articles/PMC10649629/#R10.

86. Gupta, A., Dialynas, C., McLaughlin, M. & Richie, J. (2024). *Advancing Innovative Treatments for Mental Health Care*. Milken Institute. https://milkeninstitute.org/sites/default/files/2024-04/AdvancingInnovativeTreatmentsMentalHealthCare.pdf.

87. Gupta, A., Dialynas, C., McLaughlin, M. & Richie, J. (2024). *Advancing Innovative Treatments for Mental Health Care*. Milken Institute. https://milkeninstitute.org/sites/default/files/2024-04/AdvancingInnovativeTreatmentsMentalHealthCare.pdf.

88. Parums, D.V. (2021). Editorial: First Full Regulatory Approval of a COVID-19 Vaccine, the BNT162b2 Pfizer-BioNTech Vaccine and the Real-World Implications for Public Health Policy. *Medical Science Monitor, PubMed Central*, vol. 27. https://pmc.ncbi.nlm.nih.gov/articles/PMC8434768/.

89. Kuter, B.J., Offit, P.A. & Poland, G.A. (2021). The development of COVID-19 vaccines in the United States: Why and how so fast? *Vaccine, PubMed Central*, vol. 39, no. 18, pp. 2491-2495. https://pmc.ncbi.nlm.nih.gov/articles/PMC7997594/.

90. Giattino, C., Ritchie, H., Ortiz-Ospina, E., Hasell, J., Rodés-Guirao, L. & Roser, M. (2024). *Excess mortality during the Coronavirus pandemic (COVID-19)*. OurWorldInData.org. https://ourworldindata.org/excess-mortality-covid?country=IND~USA~GBR~CAN~DEU~FRA.

91. European Union, EUR-Lex. (2006). *COMMISSION STAFF WORKING DOCUMENT EVALUATION Joint evaluation of Regulation (EC) No 1901/2006 of the European Parliament and of the Council of 12 December 2006 on medicinal products for paediatric use and Regulation (EC) No 141/2000 of the European Parliament and of the Council of 16 December 1999 on orphan medicinal products*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020SC0163.

92. Parrish, M. & Waddick, K. (2023). *Pharma's rare disease rush*. PharmaVoice. https://www.pharmavoice.com/news/pharmas-rare-disease-rush/690686/.

93. Fortune Business Insights. (2024). *Orphan Drugs Market Size, Share & Industry Analysis, By Therapy Area (Oncology, Hematology, Neurology, Endocrinology, Cardiovascular, Respiratory, Immunotherapy, Infectious Diseases and Others), By Drug Type (Biologics and Non-Biologics), By Distribution Channel (Hospital Pharmacy, Retail Pharmacy, Online Pharmacy and Others) and Regional Forecast, 2024-2032*. https://www.fortunebusinessinsights.com/industry-reports/orphan-drugs-market-100088.

94. Visiongain Reports Ltd. (2024). *Rare Diseases market is projected to grow at a CAGR of 8.8% by 2034: Visiongain*. https://www.globenewswire.com/news-release/2024/06/06/2894923/0/en/Rare-Diseases-market-is-projected-to-grow-at-a-CAGR-of-8-8-by-2034-Visiongain.html.

95. Vinci, L. (2022). *New Report Shows 28% Increase in YoY Funding for Rare Disease Drug Development in 2021*. Global Genes, Business Wire. https://www.businesswire.com/news/home/20220112005794/en/New-Report-Shows-28-Increase-in-YoY-Funding-for-Rare-Disease-Drug-Development-in-2021.

96. Pearson, C., Schapiro, L. & Pearson, S.D. (2022). *The Next Generation of Rare Disease Drug Policy: Ensuring Both Innovation and Affordability*. Institute for Clinical and Economic Review (ICER). https://icer.org/wp-content/uploads/2022/04/ICER-White-Paper_The-Next-Generation-of-Rare-Disease-Drug-Policy_040722.pdf.

97. Pearson, C., Schapiro, L. & Pearson, S. (2022). *The Next Generation of Rare Disease Drug Policy: Ensuring Both Innovation and Affordability*. Institute for Clinical and Economic Review. https://icer.org/wp-content/uploads/2022/04/ICER-White-Paper_The-Next-Generation-of-Rare-Disease-Drug-Policy_040722.pdf.

98. Lucas, F. & Tomassi, M. (2024). *Optimizing Pricing And Access For Rare Disease Drugs*. Oliver Wyman. https://www.oliverwyman.com/our-expertise/perspectives/health/2024/april/optimizing-pricing-and-access-for-rare-disease-drugs.html.

99. Rana, Proteesh and Chawla, Shalini. (2018). Orphan drugs: Trends and issues in drug development. *Journal of Basic and Clinical Physiology and Pharmacology*, 29(5), 10.1515/jbcpp-2017-0206. https://www.researchgate.net/publication/324484571_Orphan_drugs_Trends_and_issues_in_drug_development.

100. The University of Arizona. (2024). *Humanitarian Use Devices*. https://research.arizona.edu/compliance/human-subjects-protection-program/collaborative-activities-banner-health/humanitarian-use.

101. Dooms, M. (2023). Orphan medical devices have come a long way. *Orphanet Journal of Rare Diseases, PubMed Central*, vol. 18. https://pmc.ncbi.nlm.nih.gov/articles/PMC10077604/.

102. Aartsma-Rus, A., Dooms, M., Le Cam, Y., OD Expert Group & Copenhagen Economics. (2021). Orphan Medicine Incentives: How to Address the Unmet Needs of Rare Disease Patients by Optimizing the European Orphan Medicinal Product Landscape Guiding Principles and Policy Proposals by the European Expert Group for Orphan Drug Incentives (OD Expert Group). *Frontiers in Pharmacology, PubMed Central*, vol. 12. https://pmc.ncbi.nlm.nih.gov/articles/PMC8717920/.

103. Pearson, C., Schapiro, L. & Pearson, Steven. (2022). *The Next Generation of Rare Disease Drug Policy: Ensuring Both Innovation and Affordability*. Institute for Clinical and Economic Review (ICER). https://icer.org/wp-content/uploads/2022/04/ICER-White-Paper_The-Next-Generation-of-Rare-Disease-Drug-Policy_040722.pdf.

104. European Commission. (2024). Data protection in the EU. https://commission.europa.eu/law/law-topic/data-protection/data-protection-eu_en.

105. Centers for Disease Control and Prevention (CDC). (2024). *Health Insurance Portability and Accountability Act of 1996 (HIPAA)*. https://www.cdc.gov/phlp/php/resources/health-insurance-portability-and-accountability-act-of-1996-hipaa.html.

106. Deloitte. (2020). *The China Personal Information Protection Law (PIPL)*. https://www2.deloitte.com/cn/en/pages/risk/articles/personal-information-protection-law.html.

107. World Meteorological Organization (WMO). (2024). *Climate and health data must be integrated*. https://wmo.int/media/news/climate-and-health-data-must-be-integrated.

108. von Hammerstein, C., Ahlawat, H., Craven, M., Wilson, M., Walker, O., Coghlan, B., Arora, D., Galvão, G.L., Moreira, M.S., Barreto, M., Vieira, P.G., van der Horst, K. & Ergüín, P.N. (2024). *Health-related climate adaptation: How to innovate and scale global action for local needs*. McKinsey Health Institute. https://www.mckinsey.com/mhi/our-insights/health-related-climate-adaptation-how-to-innovate-and-scale-global-action-for-local-needs.

109. Desai, A.N., Kraemer, M.U.G., Bhatia, S., Cori, A., Nouvellet, P., Herringer, M., Cohn, E.L., Carrion, M., Brownstein, J.S., Madoff, L.C. & Lassmann, B. (2019). Real-time Epidemic Forecasting: Challenges and Opportunities. *Health Security, PubMed Central*, vol. 17, no. 4. https://pmc.ncbi.nlm.nih.gov/articles/PMC6708259/.

110. Global Virome Project. (2021). *A collaborative scientific initiative to discover zoonotic viral threats & stop future pandemics*. https://www.globalviromeproject.org/.

111. World Meteorological Organization (WMO). (2024). *Climate and health data must be integrated*. https://wmo.int/media/news/climate-and-health-data-must-be-integrated.

112. Burjeel Holdings. (2024). *Burjeel Holdings Launches New Initiative Focusing on Climate-Related Health Impacts*. https://burjeelholdings.com/news-and-media/burjeel-holdings-launches-new-initiative-focusing-on-climate-related-health-impacts/.

113. Roy, E.D., Morzillo, A.T., Seijo, F., Reddy, S.M.W., Rhemtulla, J.M., Milder, J.C., Kuemmerle, T. & Martin, S.L. (2013). The Elusive Pursuit of Interdisciplinarity at the Human—Environment Interface. *BioScience*, vol. 63, no. 9, pp. 745-753. https://academic.oup.com/bioscience/article/63/9/745/260778.

114. Centers for Disease Control and Prevention (CDC). (2019). *Climate and health: a guide for cross-sector collaboration*. https://stacks.cdc.gov/view/cdc/82203.

115. Sources:
    - Fresenius. (2022). *Climate target set: Fresenius to be climate neutral by 2040*. https://www.fresenius.com/node/6322.
    - Roche. (2024). *Minimise the environmental footprint*. https://www.roche.com/about/sustainability/fighting-climate-change.
    - Novo Nordisk. (2024). *Zero environmental impact*. https://www.novonordisk.com/sustainable-business/zero-environmental-impact.html.

116. IBM. (2024). *What is the TCFD?* https://www.ibm.com/topics/tcfd.

117. Buckup, S. (2019). *Stakeholders have been neglected for too long - but these CEOs want to change that*. World Economic Forum. https://www.weforum.org/stories/2019/11/corporate-citizens-must-become-global-catalysts/.

118. McClimon, T. J. (2024). *The Current And Future State Of Corporate Citizenship*. Forbes. https://www.forbes.com/sites/timothyjmcclimon/2024/04/22/the-current-and-future-state-of-corporate-citizenship-2024/.

119. Cross Dependency Initiative (XDI). (2023). *2023 XDI Global Hospital Infrastructure Physical Climate Risk Report*. https://xdi.systems/news/2023-xdi-global-hospital-infrastructure-physical-climate-risk-report.

120. World Health Organization (WHO). (2024). *Building climate-resilient health systems*. https://www.who.int/teams/environment-climate-change-and-health/climate-change-and-health/country-support/building-climate-resilient-health-systems/climate-resilient-and-sustainable-technologies-and-infrastructure.

121. Jack, H.E., Arabadjis, S.D., Sun, L., Sullivan, E.E. & Phillips, R.S. (2016). Impact of Community Health Workers on Use of Healthcare Services in the United States: A Systematic Review. *Journal of General Internal Medicine, PubMed Central*, vol.32, issue 3, pp. 325-344. https://pmc.ncbi.nlm.nih.gov/articles/PMC5331010/.

122. Levine, S., Malone, E., Lekiachvili, A. & Briss, P. (2019). *Health Care Industry Insights: Why the Use of Preventive Services Is Still Low*. Centers for Disease Control and Prevention (CDC). https://www.cdc.gov/pcd/issues/2019/18_0625.htm.

123. James, T.A. (2023). *Physicians at the Forefront of Health Care Technology Innovation*. Harvard Medical School. https://postgraduateeducation.hms.harvard.edu/trends-medicine/physicians-forefront-health-care-technology-innovation.

124. World Health Organization (WHO). (2019). *Delivering health in some of the worlds' worst crises through mobile clinics and medical teams*. https://www.who.int/news-room/feature-stories/detail/delivering-health-in-some-of-the-worlds-worst-crises-through-mobile-clinics-and-medical-teams.

125. Kim, S., Goh, Y. & Kang, J.H.B. (2022). Moving toward a common goal via cross-sector collaboration: lessons learned from SARS to COVID-19 in Singapore. *Globalization and Health*, vol. 18, no. 82. https://globalizationandhealth.biomedcentral.com/articles/10.1186/s12992-022-00873-x#citeas.

126. Haldane, V., De Foo, C., Abdalla, S.M., Jung, A.S., Tan, M., Wu, S., Chua, A., Verma, M., Shrestha, P., Singh, S., Perez, T., Tan, S.M., Bartos, M., Mabuchi, S., Bonk, M., McNab, C., Werner, G.K., Panjabi, R., Nordström, A. & Legido-Quigley, H. (2021). Health systems resilience in managing the COVID-19 pandemic: lessons from 28 countries. *Nature Medicine*, vol. 27, pp. 964-980. https://www.nature.com/articles/s41591-021-01381-y#citeas.

127. Centers for Disease Control and Prevention (CDC). (2024). *Social Determinants of Health*. https://www.cdc.gov/public-health-gateway/php/about/social-determinants-of-health.html.

128. United Nations Environment Programme (UNEP). (2024). *Climate Information and Early Warning Systems*. https://www.unep.org/topics/climate-action/climate-transparency/climate-information-and-early-warning-systems.

129. Rockefeller Foundation. (2023). *The Rockefeller Foundation Announces Support for the India Extreme Heat Income Insurance Initiative as Part of the Global Climate Resilience Fund for Women*. https://www.rockefellerfoundation.org/news/the-rockefeller-foundation-announces-support-for-the-india-extreme-heat-income-insurance-initiative-as-part-of-the-global-climate-resilience-fund-for-women/.

130. World Health Organization (WHO). (2023). *Noncommunicable diseases*. https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases.

131. Wen, B., Xu, R., Wu, Y., de Sousa Zanotti Stagliorio Coêlho, M., Hilario Nascimento Saldiva, P., Guo, Y. & Li, S. (2022). Association between ambient temperature and hospitalization for renal diseases in Brazil during 2000–2015: A nationwide case-crossover study. *The Lancet Regional Health – Americas*, vol. 6. https://www.thelancet.com/journals/lanam/article/PIIS2667-193X(21)00097-1/fulltext.

132. Berg, C.D., Lam, S., Aggarwal, C., Bernicker, E., Boffetta, P., Cavic, M., Dowell, J., Duffy, R., Elkins, I., Gerber, D., Huber, R.M., Liu, S., Mezquita, L., Myers, R., Nixon, J.E., Oettel, K., Patel, S., Penell, N., Rivera, M. P., Roy, U.B., Sanborn, R., Spigel, D., Traynor, A., Velcheti, V. & West, H.J. (2022). *Air Pollution and Lung Cancer - The IASLC Position Statement*. International Association for the Study of Lung Cancer (IASLC). https://www.iaslc.org/iaslc-news/press-release/air-pollution-and-lung-cancer-iaslc-position-statement.

133. Hacker, K.A., Briss, P.A., Richardson, L., Wright, J. & Petersen, R. (2021). COVID-19 and Chronic Disease: The Impact Now and in the Future. *Centers for Disease Control and Prevention (CDC)*, vol. 18. https://www.cdc.gov/pcd/issues/2021/21_0086.htm.

134. Meo, S.A. & Meo, A.S. (2024). Climate Change and Diabetes Mellitus – Emerging Global Public Health Crisis: Observational Analysis. *Pakistan Journal of Medical Sciences, PubMed Central*, vol. 40, no. 4, pp. 559-562. https://pmc.ncbi.nlm.nih.gov/articles/PMC10963985/.

135. van Niekerk et al. (2021). Diabetes and susceptibility to infections: Implication for COVID-19. *Immunology*, Nov;164(3):467-475. https://pubmed.ncbi.nlm.nih.gov/34115881/.

136. Petrie, J.R., Guzik, T.J. & Touyz, R.M. (2018). Diabetes, Hypertension and Cardiovascular Disease: Clinical Insights and Vascular Mechanisms. *Canadian Journal of Cardiology*, vol. 34, no. 5, pp. 575-584. https://pmc.ncbi.nlm.nih.gov/articles/PMC5953551/.

137. U.S. Centers for Disease Control and Prevention (CDC). (2024). *Underlying Conditions and the Higher Risk for Severe COVID-19*. https://www.cdc.gov/covid/hcp/clinical-care/underlying-conditions.html.

COMMITTED TO IMPROVING THE STATE OF THE WORLD

The World Economic Forum, committed to improving the state of the world, is the International Organization for Public-Private Cooperation.

The Forum engages the foremost political, business and other leaders of society to shape global, regional and industry agendas.

World Economic Forum
91–93 route de la Capite
CH-1223 Cologny/Geneva
Switzerland

Tel.: +41 (0) 22 869 1212
Fax: +41 (0) 22 786 2744
contact@weforum.org
www.weforum.org