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RESILIENCE BY DESIGN: Strengthening Health and Human Development in a Changing Climate

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Generali – UNDP Partnership

Generali and UNDP have a multi-year partnership aimed at supporting the financial resilience of vulnerable communities, SMEs and global value chains to climate and other risks. Under this, Generali and UNDP's Insurance and Risk Finance Facility (IRFF) are developing research and tools, incentivising the development of innovative insurance solutions, and advocating for holistic resilience solutions that blend risk transfer and management. The partnership blends Generali's insurance expertise with UNDP's long-term focus on financing and development.
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Acknowledgement
This report was produced by Assicurazioni Generali S.p.A. in partnership with UNDP, 2025.

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Foreword

Climate change is profoundly reshaping our society, altering patterns of vulnerabilities across regions and generations, placing growing stress on both public institutions and private sectors.
Among these, the role of insurance as social safety net is experiencing mounting pressure as climate change transforms the nature of uncertainty and risk. Over time, this may give rise to profound challenges of affordability and insurability, just when people are likely to need protection the most.

In health, rising temperatures layered onto already strained healthcare system may deepen existing healthcare protection gaps, with far-reaching consequences for people's wellbeing. Many of these impacts remain poorly understood and urgently demand further attention.

Addressing these challenges requires innovation and new mechanisms, grounded in multi-sectoral partnerships, since no single actor can respond effectively on their own.

The UNDP & Generali partnership shows how this work can be done in practice through risk assessments and modelling, but also through concrete proposals for adaptation and policies measures that respond to the growing need for enhanced healthcare systems.

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Introduction*

The global human development landscape today is increasingly shaped by turmoil and uncertainty, described in the 2021–2022 Human Development Report as an emerging "uncertainty complex"[1]. Global shocks, including pandemics, violent conflicts, and inflation, interact with long-term trends such as warming temperatures, reverberating through tightly interconnected economic, social, and ecological systems. The Covid-19 pandemic –and subsequent shocks-- triggered the first ever recorded global decline in the human development index, and recovery since then has been uneven and partial, with overall global progress well below pre-pandemic trends[2].

This shifting planetary reality, where acute shocks intersect with secular trends that elevate baseline risks[3], is fundamentally altering how risks manifest, interact, and impact people. Risks are increasingly systemic, cross-border, and intergenerational, with climate change exemplifying how inaction today locks in long-term vulnerabilities[4].

While insurance systems have long served as a stabilizing force in the face of uncertainty, the rapidly evolving nature of uncertainties and risks threaten insurers' ability to respond effectively. Higher risk and a progressive lack of mutualization will exacerbate issues of affordability, or even insurability. This, in turn, reduces people's ability to cope with uncertainty and place additional burdens on governments already facing fiscal constraints.

This paper assesses the context of re-shaped global uncertainties conditioned by climate change and explores how they are being mapped and modelled with new types of risk assessments, requiring an advancement of the models and data currently adopted for progressively coping with increased complexity. We focus on how emerging environmental risks endanger human development. In particular, rising temperatures, more frequent and severe heatwaves, and spread of climate-sensitive diseases are expected to drive a sharp increase in both acute and chronic health conditions, elevating both mortality and morbidity rates. Without proactive investment in adaptation strategies – complementing mitigation efforts, the compounded effects of climate change with other demographic trends, such as aging, could push healthcare systems toward unsustainable levels of stress, undermining public health. The analysis builds on results from the Generali climate risk model and highlights how climate change impacts the life and health insurance sector, as environmentally mediated morbidities and acute pathologies, such as vector borne disease and heat stress, expand what is already a severe healthcare protection gap.

In a rapidly changing world, sense-making and policymaking must remain closely aligned. In the case of climate change, we are still working to understand how shifts in geophysical variables will affect people and communities. At the same time, our systems must adapt to these new realities.

The paper identifies the necessity of improved data and research methods for assessing the causal human and health impacts of climate shocks and recognizes the importance of context-specific mitigation and adaptation strategies. Moreover, it offers examples of possible actions and policy responses, which depend on timely analysis of the links between climate change, mortality and morbidity. Finally, it underscores that this should not be a one-time effort but a continuous endeavor, laying out a future research agenda that seeks to reimagine collaboration between the public and insurance sectors. Because no single actor – be it the private sector, academia, the UN, or government – can fully address the challenges of a novel planetary reality, multistakeholder partnerships are essential. These are needed to better understand how emerging shocks are affecting all dimensions of life, anticipate foreseeable risks, and explore a new generation of policies and incentive mechanisms for safeguarding human security and advancing human development in a world facing deeper, more interconnected uncertainties.

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1 HUMAN DEVELOPMENT PROSPECTS IN A CHANGING PLANETARY REALITY

Inaction in the face of this crisis comes at a high cost to human development. Human health impacts from heat exposure, food insecurity, displacement, wildfire smoke, and climate-mediated vector-borne illnesses are all increasing[5]. Climate-related impacts to human health, livelihoods and ecological stability grow more pronounced each year[6] and, although meaningful progress has been made towards mitigating global greenhouse gas (GHG) emissions, our total emissions footprint is still growing, with warming likely to approach +3°C by end-of-century in the absence of sweeping collective action to transition away from fossil fuels[7].

To effectively anticipate, assess and adapt to the dangerous socioeconomic and ecological impacts of this magnitude of warming, improvements to our measurement and modeling of climate evolving trends and human development impacts must be made alongside coordinated, multilateral policy efforts.

Despite the sociopolitical inertia that impedes progress towards collective climate policy solutions, scientific progress allows us to more precisely quantify and predict our fragile relationship with the world around us. Rapidly evolving digital technologies, such as the evolution of sophisticated machine learning and artificial intelligence (AI), have fostered advances in climate modeling, environmental monitoring and quantitative assessment of human vulnerabilities across the globe. This ability to more precisely measure the interplay between human society and the global environment is essential for prescribing solutions and largely depends on leveraging new technical, scientific breakthroughs in the following realms of research.

One realm of substantial progress that leverages new computational methods is in the detection and attribution of the marginal causal influence that anthropogenic climate influence plays for individual climate shocks.

For example, following Hurricane Helene, which struck the southeast United States in September 2024 and caused nearly $80 billion of damage and an estimated 250 deaths (the third deadliest in U.S. history behind Maria and Katrina)[8], climate scientists were able to make precise estimates of the extent to which human-caused climate change worsened the severity of the storm. They found that climate change made associated total storm-related rainfall was roughly 10% heavier overall and over 50% heavier in some locations, relative to no-climate-change conditions[9]. Similarly, 3-day rainfall maxima were estimated to have been made up to 20 times more likely to occur (i.e. a 1-in-1000 years extreme rainfall event becoming a 1-in-50 event) in many storm-afflicted locations relative to “natural” climatological conditions (Figure 1)[10].

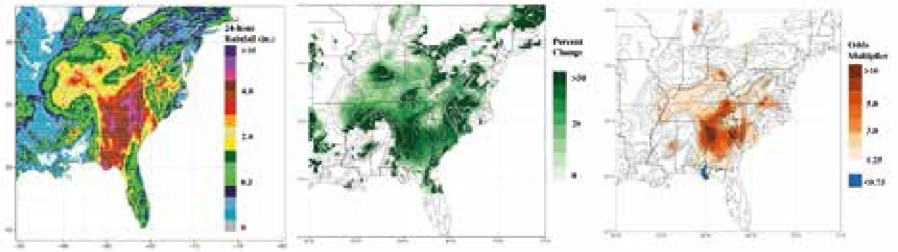

Figure 1. (adapted from Risser et al. 2024) (left) 24h rainfall accumulation maxima during Hurricane Helene between 25 and 29 September, 2024; (center) percent change in 24h accumulated rainfall maxima attributable to climate change; (right) change in the probability of occurrence for these 24h maxima attributable to climate change.

Additionally, the growing abundance and sophistication of “remotely-sensed” high-resolution earth surface imagery – most commonly collected by satellites – has revolutionized our ability to detect change across our planet in stunning detail. Researchers are able to track trends in deforestation to the scale of individual trees, crop failures at the scale of household fields, migrations of individual large mammals, and countless other human and environmental processes in real-time. Pairing these observations with regional climate models has facilitated the development of the most accurate globally-extensive historical datasets of past climate conditions, improved our ability to make rapid impact assessments following disasters, such as flood extents (Figure 2), and improved future risk projections.

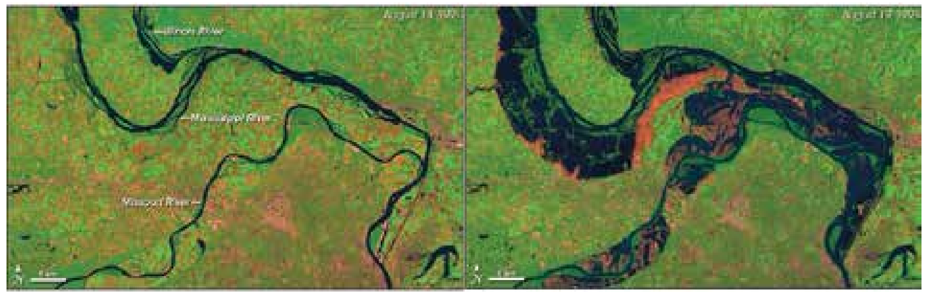

Figure 2. Examples of remotely sensed (satellite) NASA images showing the extent of inundation before (left panel) and after (right panel) a flood event in August 1993 near the confluence of the Missouri and Mississippi Rivers near St. Louis, Missouri, USA. (Source: Klemas 2015) Human Climate Horizons

Modern climate science and impact modeling has also enabled more accurate and precise quantification of different socioeconomic impacts that changing patterns of extremes and long-term climate

trends are having on human society. In collaboration with the Climate Impact Lab, UNDP’s Human Development Report Office has constructed an interactive online platform called Human Climate Horizons (HCH), that displays various such hazard exposure and impact projections at subnational scales (Figure 3)[11].

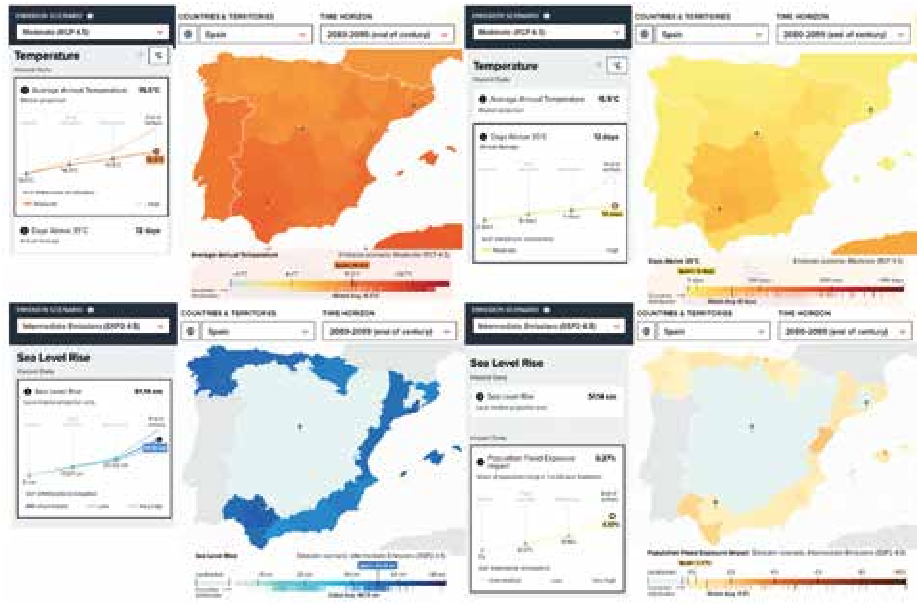

Figure 3. Examples of climate hazard exposure maps for Spain from the Human Climate Horizons Platform. All projections shown are for moderate emissions scenarios at end-of-century (2080-2099). (top-left) projected average annual temperature increase using CMIP5 data; (top-right) projected average annual change in number of days with max temperatures above 35°C using CMIP5 data; (bottom-left) projected sea level rise using CMIP6 data; (bottom-right) projected exposed population to coastal inundation using CMIP6 data.

New data and methods have also allowed researchers to better estimate coastal flooding and future inundation risk from rising sea levels, indicating that roughly three times more people than previously thought are likely to be exposed to annual flooding by end-of-century, ranging from 190 to 630 million people under low- and high-GHG emissions pathways, respectively[12]. In another example, scientists assessed satellite images that capture nighttime light illuminance from the Earth’s surface to assess the extent and duration of electricity outages, which resulted in thousands of excess deaths and additional morbidity in Puerto Rico following Hurricane Maria’s devastating traverse across the island[13].

Moving forward, tailoring risk assessments to specific regions with increasing accuracy and spatial precision is pivotal for facilitating local, bottom-up planning and adaptation.

Localizing and enhancing estimates of human development

As the frontier of climate hazard models and environmental assessment methods advances, it is imperative that concomitant improvements be made in our ability to evaluate and track socioeconomic conditions and human development progress in a more granular manner. Traditionally, the Human Development Index (HDI), a quintessential indicator reflecting human capabilities with respect to health, educational and monetary resources, is estimated solely at the national scale, updated annually. While tracking human development at the national scale is important and insightful, it inherently masks inequities within country borders, which has been shown to be increasing, on average, while between-country inequality has been declining in recent decades[14].

Pioneering new ways by which we can track human development indicators like the HDI at increasingly fine-scale spatial scales is key to illuminating development disparities. UNDP and its research partners have recently applied a unique method of predictive modeling to construct a set of hyperlocal HDI estimates using high resolution satellite imagery along with novel machine learning methods[15]. Applying this approach to human development metrics enabled the construction of a global grid of predicted HDI values at a resolution of 0.1° (~10km) (Figure 4).

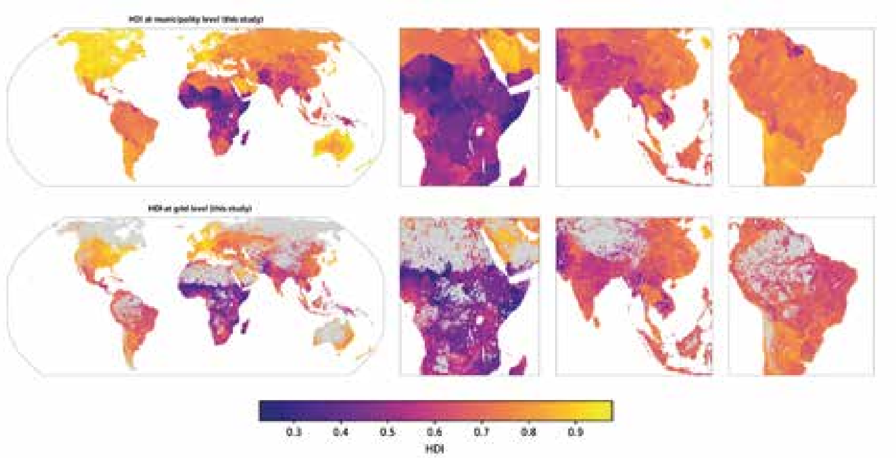

Figure 4. Downscaled estimates of the 2019 Human Development Index at the municipality (ADM2) level (top panel) and at a 0.1 x 0.1° (~10 x 10km at the equator) uniform land grid using the MOSAIKS machine learning technique. (Source: Sherman et al. 2023)

Although the fine-grained estimates of HDI presented above are not perfect, the approach represents a critical breakthrough in our ability to utilize new datasets and technologies to enhance assessments of human livelihoods.

While such novel methods of data collection and modeling techniques provide us with granular new snapshots of environmental hazards and socioeconomic conditions, most important to policymaking and human development is our ability to understand the linkages between these two realms.

To help elucidate this, newly available, highly granular datasets for enviro-climatic hazards and human development shed light as to how they impact human development, health and wellbeing. Consider a collection of maps showing physical exposure to a suite of environmental and climate hazards, such as severe storms, extreme heat, droughts etc. Intersecting these with downscaled predictions of HDI can illuminate subregions of the globe that are both hot spots for environmental hazards, have limited access to socioeconomic resources and may experience the worst outcomes with respect to loss of life, property or increased morbidity associated with worsening hazards. A conceptualization of such an approach is shown in Figure 5 below and is currently under development for both historical and projected future scenarios by UNDP.

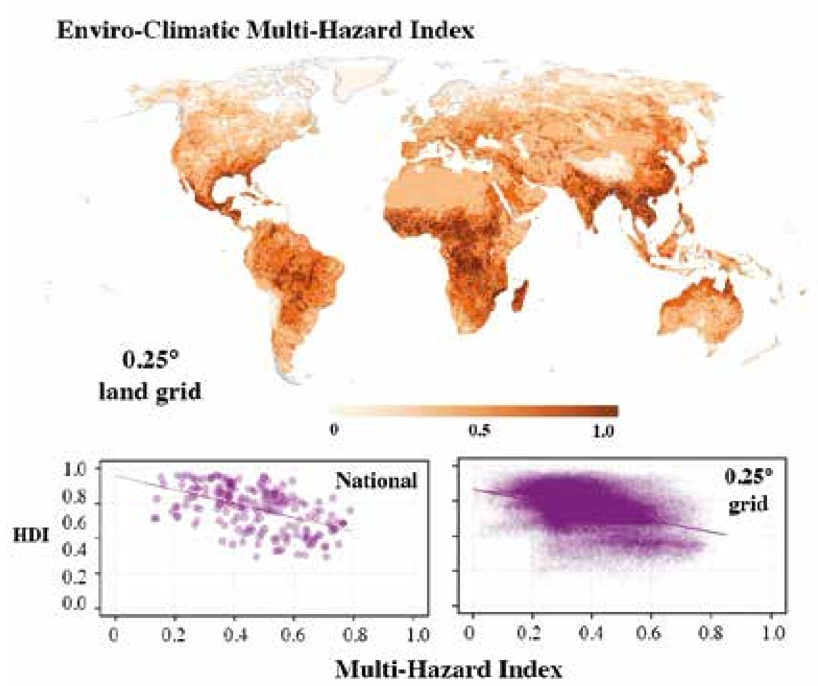

Figure 5. (top) a conceptual representation of six enviro-climatic hazards (heat, drought, tropical storms, outdoor air pollution, flooding, fires) and combined into one normalized 0 to 1 multi-hazard index at a 0.25° spatial resolution. (bottom-left) These multi-hazard index values average at the national scale and compared to national HDI values. (bottom-right) The multi-hazard index values compared to gridded predictions of HDI produced using MOSAIKS. Source: UNDP (in progress).

Identifying the causal impacts between environmental shocks and outcomes relevant to human development is a complex but rapidly growing field of research. Considering the HDI as an effective proxy for human development conditions more broadly, we can assess the evidence linking causal impacts of enviro-climatic hazards to each of its components, focusing discussion here primarily on its 'long and healthy life' indicator.

Long and Healthy Life stressed by environmental conditions

There is an increasingly robust literature quantifying the impacts of climate change and environmental extremes to public health outcomes, such as mortality, morbidity and net impacts to average life expectancies of afflicted regions. For example, when estimating human mortality impacts from changing mean temperature and precipitation across the globe, the Climate Impact Lab (CIL) approximated that the number of (human-caused) deaths related to changes in long-term average temperature and precipitation changes are likely to increase by 9 and 53 deaths per 100,000 people on a globally-averaged basis under moderate and high future emissions scenarios, respectively, by 2100. In some countries these estimates are much higher, as in Niger where these values range from 88 (moderate) to 295 (high emissions) additional deaths per 100,000[16]. This finding highlights not only the magnitude of the danger from rising heat to public health but also the large benefits we can achieve – in the form of averted danger and costs – by limiting warming to low levels.

Similar estimates have been made for different climate extremes. One recent study found that the indirect mortality of exposure to tropical cyclones are much higher than previously understood, estimating that in the United States, an average-strength tropical cyclone (using all events between 1930-2015) causes 7,000 to 11,000 excess deaths. This value stands in stark contrast to the relatively low estimate of 24 deaths-per-event when solely considering direct storm fatalities[17]. The World Weather Attribution initiative estimates that each of the ten deadliest extreme weather events between 2004-2024, which inflicted over 570,000 deaths, were exacerbated significantly by human-caused climate change[18].

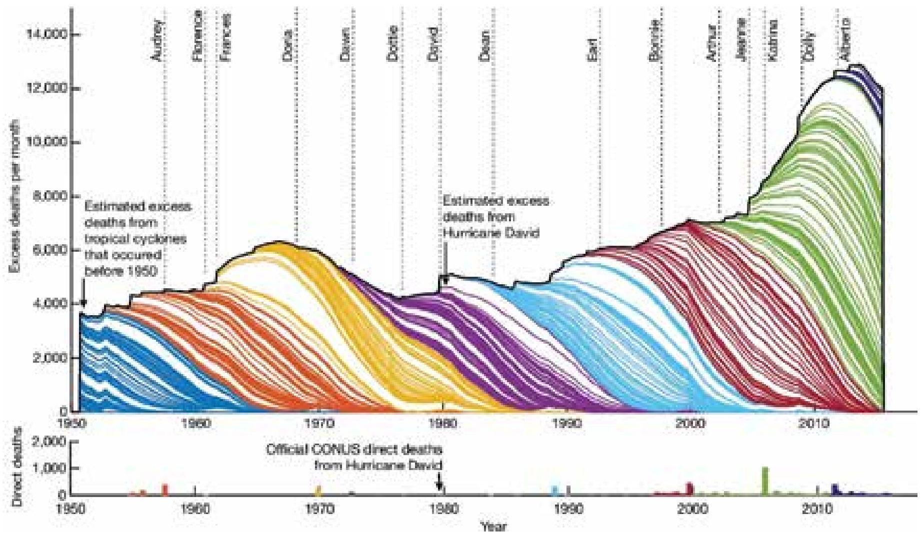

Figure 6. (Adapted from Young & Hsiang 2024) (top) Stacked overlapping excess mortality from each storm for all of the contiguous United States. (bottom) Official deaths directly resulting from TCs for each month according to official government estimates.

Globally extensive, regional climate impacts such as these are also represented on the Human Climate Horizons platform, currently including projected changes to mortality, labor productivity, flood-exposed population and energy consumption for moderate and high-emissions scenarios averaged for near, medium and long-term (end-of-century) time horizons (Figure 7).

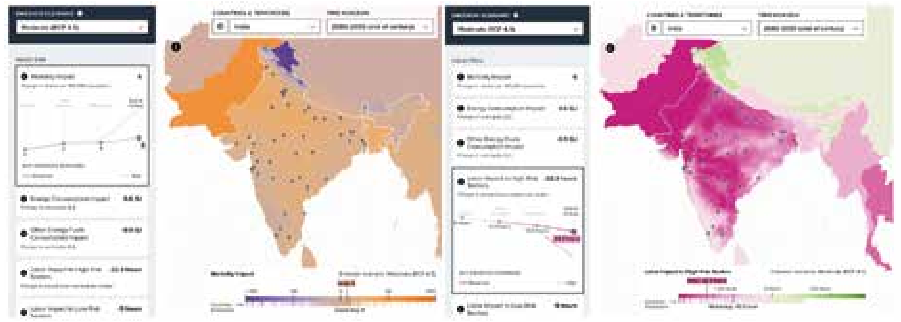

Figure 7. Examples of climate impact maps for India from the Human Climate Horizons Platform. All projections shown are for moderate emissions scenarios at end-of-century (2080-2099). (left) projected change in average annual human mortality rates due to a changing climate (primarily heat stress); (right) projected change in average hours of labor productivity annually.

The above examples represent only a small subset of the research linking enviro-climatic stress to adverse human health outcomes and, crucially focus primarily on mortality although growing instances of different environmentally mediated morbidities are likely to have an increasingly severe impact of worsening hazards. There is a robust and growing literature that links such stressors to the spread of infectious disease, other mortality pathways and morbidity of respiratory, cardiovascular and neurological conditions[19], but much more work is required to better estimate the changing landscape of climate-linked morbidities, including potential effects on mental health and psychosocial wellbeing.

The evolving nature of uncertainty may outpace the ability of existing systems to respond. Traditional mechanisms for managing risks, including private insurance and social protection, were designed for a more stable world. If the baseline of hazards shifts and volatility increases, these instruments may become less effective or increasingly costly, creating a protection gap. New types of data, sector-specific research methods, partnerships and policy innovations will be increasingly needed, as no single actor – whether governments, multilateral organizations, or private sector – can fully assess and manage threats to human development on their own.

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2 PRIVATE INSURANCE IN A NEW PLANETARY REALITY

As the primary role of insurers is to provide protection to individuals, families, and businesses against the risks they encounter in daily life and operations they play a critical role in stabilizing human development and contribute to strengthening societal resilience.

2.1 Modelling the impact of Climate Change on the insurance sector

Life and health insurance portfolios are exposed to rising climate-related risks, due to changes in temperature and geographical spread of infectious diseases.

Generali Group developed a risk model, named Aeolus, to measure how climate change affects its business and hence supporting underwriting and investment strategic decisions.

The measurement is based on a set of climate scenarios containing the projections of physical and energetic variables over long-term horizon from which climate stresses are defined (see Fig. 8).

Figure 8: framework of the Generali Group Climate Risk Model

Collaborating with the United Nations Development Programme (UNDP) has been essential in calibrating such climate stress, as it provided the data foundation, available through the Human Climate Horizon, needed to quantify how long-term shifts in temperature patterns impact human life and health.

Generali Group adopted a comprehensive set of publicly available scenarios, informed by the latest United Nations (UN), Intergovernmental Panel on Climate Change (IPCC) and Network for Greening the Financial System (NGFS).

This analysis in the following sections focus on the scenarios that best capture today's geopolitical and energy realities, namely the 'Delayed Transition' and 'Fragmented World' scenarios, which reflect the (current) slow pace of energy transition progress towards Paris Agreement goals ('Delayed Transition') as well as increasing geopolitical tensions ('Fragmented World').

Non-climate specific assumptions regarding demographic trends were kept constant to present-day conditions.

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2.2 Climate stress on Life and Health

For Life and Health Business, the Aeolus model evaluates the impacts, split by gender and age[20], on mortality and morbidity rates caused by four climate-related factors:

- **Chronic increase of temperature**, representing the yearly increase in average temperature. Hotter temperatures during summer months increases morbidity and mortality rates due to heat exhaustion, heatstroke and hyperthermia, whereas milder winter conditions might reduce mortality due to fewer deaths from hypothermia, frostbite, and respiratory illnesses [21].

- **Air pollution**, representing the contamination of the outdoor environment by any chemical, physical or biological agent that modifies the atmosphere's characteristics[22]. Exposure to air with more pollutants increases morbidity and mortality rates due to cancers and other respiratory diseases such as asthma and more in general respiratory infections[23].

- **Vector-borne diseases**, representing human illnesses caused by parasites, viruses and bacteria that are transmitted by living organisms such as mosquitoes, ticks, and sandflies. Hotter and more humid climate conditions facilitate the development and activity of these vectors. Human exposure to more active vectors for increasingly prolonged periods increases rates of morbidity, mortality and complications from severe infection[24].

- **Heatwaves**, representing a period of abnormally extreme hot temperatures[25], generally defined as a period of abnormally extreme hot temperatures, persisting for at least 3 consecutive days. Exposure to more intense heatwaves and for a prolonged period increases mortality and morbidity rates due to the worsening underlying health conditions of individuals already affected for example by cardiovascular disease, diabetes and asthma[26].

In Aeolus, the effects of climate on mortality rates are assessed across all four factors, whereas only the last two factors are considered for the morbidity rates[27], as summarized in the picture below (Fig. 9).

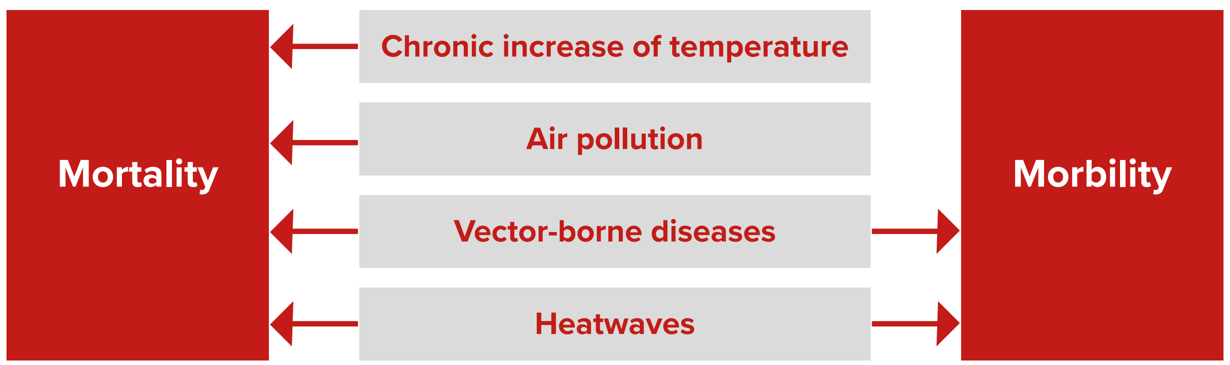

Figure 9: impact of climate change on life and health included in Generali Group Climate Risk Model

By 2050, climate change will worsen health in Europe and Asia as heat, pollution, and disease outweigh fewer cold-related deaths.

The level of stress on mortality and morbidity are computed separately for each factor.

The change in mortality rate was modelled by correlating average temperature, country-level $PM_{2.5}$ concentration[28] or heatwave intensity, respectively for chronic increase, air pollution and heatwaves.

For the change in mortality rate under vector-borne disease, the analyses were performed on dengue, zika and chikungunya infections and modeled by assessing the total population that may be infected by vectors[29] and then considering the likelihood that the infected individuals may succumb to the disease.

The change in morbidity rate was derived by adjusting the projected change in mortality rate through a death-to-hospitalization factor for vector-borne disease as well as for heatwaves.

2.3 Key Outcome of the Model

The impacts on mortality and morbidity reported in this section refer only to the 'Fragmented World' scenario, the most severe in terms of projected climate change impacts. The analysis is also limited to the regions where Generali Group has large exposures in the life insurance segment[30], i.e. Europe and Asia.

The results are shown for the projection at year 2050, but the speed at which stress reaches the 2050 level depends on the contributing factor. According to the model's projection, chronic increases in temperature and air pollution will gradually affect mortality rates over time in an almost linear trend, while vector-borne diseases and heatwaves will initially have a gradual and linear impact on both mortality and morbidity rates, with a sudden and sharp acceleration approaching 2050.

In the model, mortality rate increases in response to both extreme cold and hot temperatures, impacting especially elder population. As a result, **chronic increase of temperature** is expected to reduce cold-related deaths in today's cold regions, offering a potential mortality rate benefit, while exacerbating heat-related mortality in currently hot regions, where the adverse impacts are likely to be high. Regions currently dominated by colder climates, such as the Northern and Central parts of Europe, are projected to benefit from a reduction of mortality rate of up to -36 deaths per 100,000 inhabitants. Geographical differences are primarily influenced by the change in the number of frost days[31]. with the model showing a reduction of over 10 days per year in Switzerland, the country with the highest reduction. Places currently dominated by hotter climates, like Spain, Greece, Portugal and Southeast Asia, will experience an exacerbation of heat-related excess mortality. These regions are projected to see an increase in mortality rate up to +27 deaths per 100,000 inhabitants, with geographical differences primarily driven by the change in the number of extreme hot days[32].

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Air pollution is currently the second leading risk factor for mortality worldwide, with children and older adults the most impacted. While the transition to a greener economy is generally expected to drive the widespread adoption of clean technologies, yielding benefits not only through reductions in greenhouse gas emissions but also via improved air quality, this pattern does not hold uniformly across all countries analyzed. European countries are projected to experience a common pattern of attenuation in mortality rate, with reductions of up to -39 deaths per 100,000 inhabitants. Geographical differences are mainly due to the anticipated decrease in air pollution. By 2050, all countries are expected to at least achieve the WHO's recommended $PM_{2.5}$ concentration in the atmosphere of 5 µg/m³. Currently, Northern Europe, Portugal and Spain have lower pollution levels (annual average $PM_{2.5}$ concentration in the atmosphere of 10 µg/m³), so they will experience a smaller decrease in $PM_{2.5}$ concentration and consequently a smaller reduction in mortality rates. Central Eastern European, Italy and Greece, which currently have higher pollution levels (annual average $PM_{2.5}$ concentration in the atmosphere of 16 µg/m³), and will therefore experience a more significant reduction in mortality rate. Asian countries currently have higher pollution levels, with an annual average $PM_{2.5}$ concentration in the atmosphere of 28 µg/m³, which is expected to increase further. This rise in pollution is projected to result in an increase in mortality rates up to +10 deaths per 100,000 inhabitants. This increase is primarily attributed to the projected lower uptake of clean-energy sources and low-emission vehicles compared to other European countries, according to NGFS scenarios, alongside significant rural-to-urban migration trends[33].

Vector-borne disease affects all countries across the globe but is particularly prevalent in tropical and sub-tropical regions. Climate change is expected to expand the habitats and transmission periods of invasive mosquitos, allowing them to spread into previously unaffected areas and infect more people, resulting in higher mortality and morbidity. In Europe, additional deaths could reach up to +10 deaths per 100,000 inhabitants, while in Asia that value rises to as many as +45 deaths per 100,000 inhabitants. This projected rise is attributed to the extended transmission period of vector-borne disease, which is expected to increase in Europe from the current 2 months to up to 5 months, and in Asia from 4 to 11 months. Optimal transmission conditions, average daily temperature above 18°C and annual rainfall exceeding 1,900 mm per year, have historically been rare in Europe but are expected to become increasingly common as the climate continues to warm. In contrast, these conditions are already prevalent in tropical regions of Asia and are being further intensified by climate change. These climatic shifts[34] are expected to also lead to a significant rise in morbidity as more people are exposed to infection risk. In Europe the additional number of people in poor health is expected to increase by up to +3,314 per 100,000 inhabitants, whereas in Asia by up to +15,157 per 100,000 inhabitants. These regional differences are due to varying climate patterns and the disparity in capabilities to face such increase in the morbidity rate, here higher-income economies are already leveraging on vector control strategies[35] while lower-income economies struggle due to weaker health systems[36].

Heatwaves are currently the leading risk factor for climate-related mortality. The number of people exposed to heat stress is projected to grow exponentially as rising temperatures are increasingly accompanied by higher humidity levels, with impacts expected to be more severe on elderly populations. In Europe, additional deaths could increase to +86 deaths per 100,000 inhabitants, with Southern Europe experiencing the most severe impacts. Mortality rates are projected to rise to as many as +43 and +86 deaths per 100,000 inhabitants in Spain and Italy respectively. These two countries are also projected to experience a dramatic rise in the number of annual heatwave days[37], from the current average of 3 days to as many as 50 days by mid-century. In Asia, heat-related mortality is projected to increase up to +17 deaths per 100,000 inhabitants, with the number of annual heatwave days reaching about 60. European and Asian countries are also projected to face a large increase in morbidity rate. In Europe, the number of people in poor health could increase by up to + 988 per 100,000 inhabitants, and in Asia the rise may reach up to +286 per 100,000 inhabitants. The most severe impacts will be experienced in countries with very humid climates, where high humidity significantly increases the perceived temperature and worsens health issues.

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Table 1:

Current mortality rate (deaths per 100,000 inhabitants) and additional mortality rate due to chronic increase of temperature, air pollution, vector-borne disease and heatwaves in Fragmented scenario 2050, Projected by the Generali Model

Region	Country	Current mortality[38]	Chronic increase of T	Air pollution	Vector-borne disease	Heatwaves
Europe	Italy	1,217	-4	-33	+10	+86
	France	1,002	-10	-18	+3	+16
	Germany	1,185	-20	-23	+2	+11
	Austria	986	-33	-21	+3	+13
	Switzerland	815	-36	-10	+3	+6
	Poland	1,083	-12	-38	+1	+4
	Spain	901	+4	-16	+5	+43
	Czech Republic	1,327	-28	-36	+1	+17
	United Kingdom	977	-7	-18	+0	+4
	Croatia	1,405	-19	-16	+8	+38
	Greece	1,165	+7	-31	+6	+20
	Hungary	1,443	-11	-39	+2	+20
	Slovenia	989	-6	-28	+5	+19
	Portugal	1,116	+3	-12	+4	+39
Asia	Viet Nam	658	+0	+4	+37	+1
	Hong Kong	736	+27	-1	+28	+13
	India	661	+5	+10	+23	+11
	Malaysia	516	-1	+2	+38	+1
	Philippines	624	+2	+3	+45	+1
	Thailand	889	+2	+8	+45	+17
	China	787	-2	+3	+30	+14

*The data presented in this paper derives from the Generali risk model and do not necessarily represent official estimates by UNDP

Table 2:

Current morbidity rate (disease cases per 100,000 inhabitants) and additional morbidity rate due to vector-borne disease and heatwaves in Fragmented scenario 2050, projected by the Generali climate risk model

Region	Country	Current morbidity[39]	Vector-borne disease	Heatwaves
Europe	Italy	14,619	3,314	988
	France	14,869	1,155	225
	Germany	14,675	562	126
	Austria	14,042	902	177
	Switzerland	15,047	1,076	102
	Poland	13,046	443	47
	Spain	14,512	2,037	661
	Czech Republic	13,681	289	169
	United Kingdom	14,893	70	53
	Croatia	12,590	2,359	327
	Greece	14,398	2,351	234
	Hungary	12,458	667	168
	Slovenia	14,032	1,906	255
	Portugal	14,572	1,943	630
Asia	Viet Nam	11,860	11,572	22
	Hong Kong	12,203	8,885	214
	India	13,578	7,864	210
	Malaysia	13,488	14,113	25
	Philippines	11,859	12,392	27
	Thailand	15,268	15,157	286
	China	12,203	8,885	214

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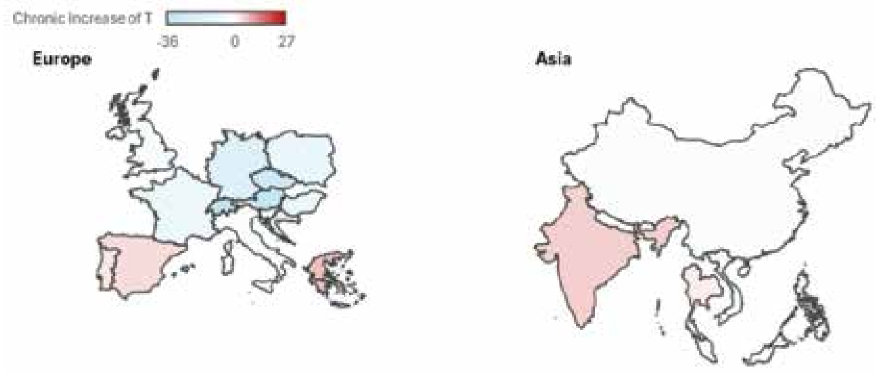


Figure 10: change in mortality rate (deaths per 100,000 inhabitants) due to chronic increase of temperature in Fragmented scenario 2050, projected by the Generali climate risk model

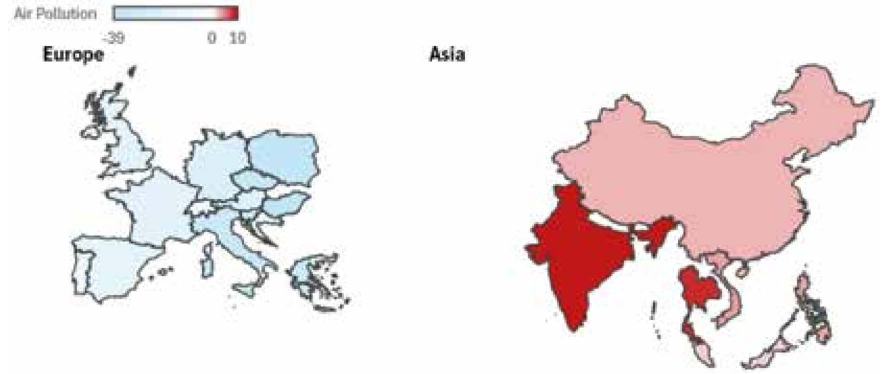


Figure 11: change in mortality rate (deaths per 100,000 inhabitants) due to air pollution in Fragmented scenario 2050, projected by the Generali climate risk model

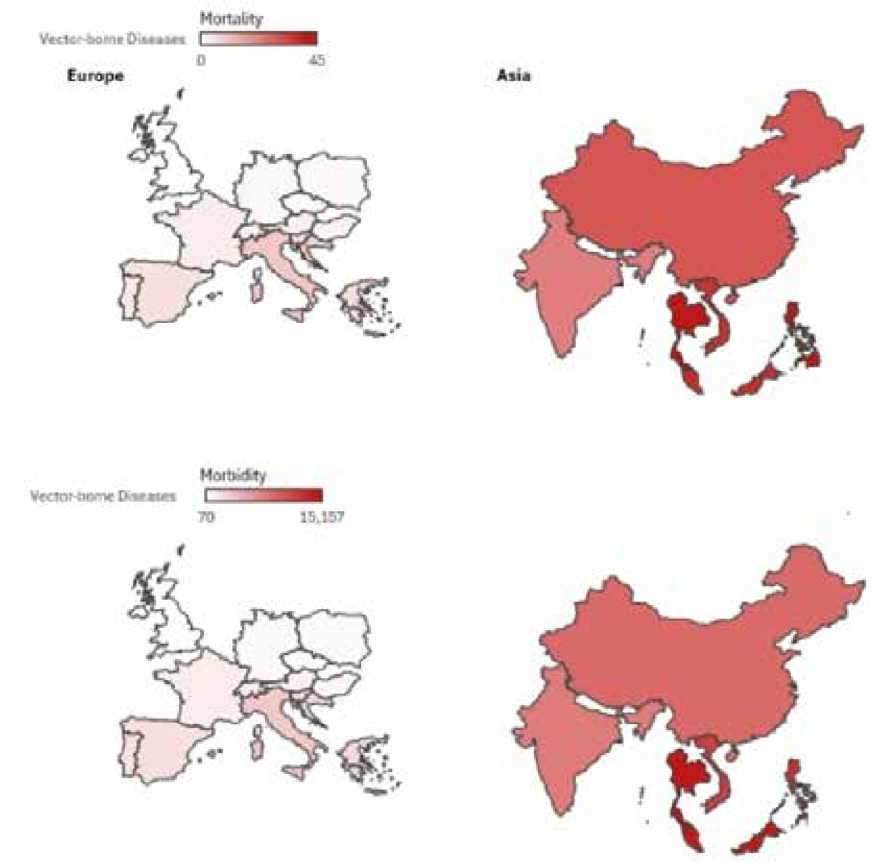


Figure 12: change in mortality (deaths per 100,000 inhabitants) and morbidity (disease cases per 100,000 inhabitants) rate due to vector-borne disease in Fragmented scenario 2050, projected by the Generali climate risk model

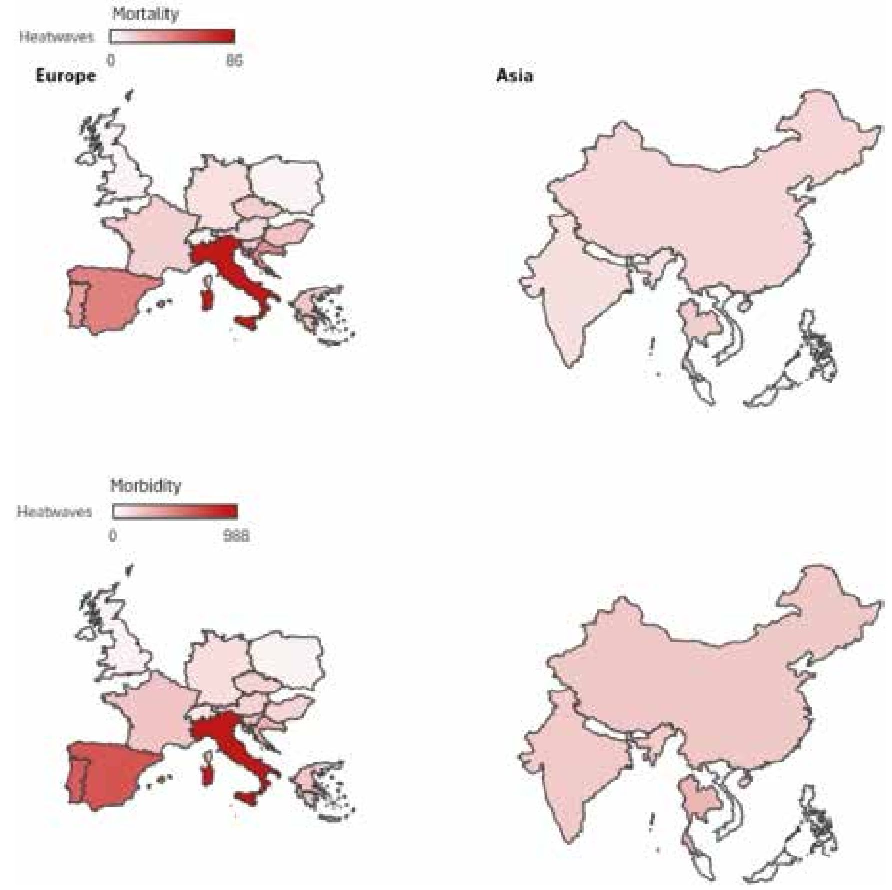
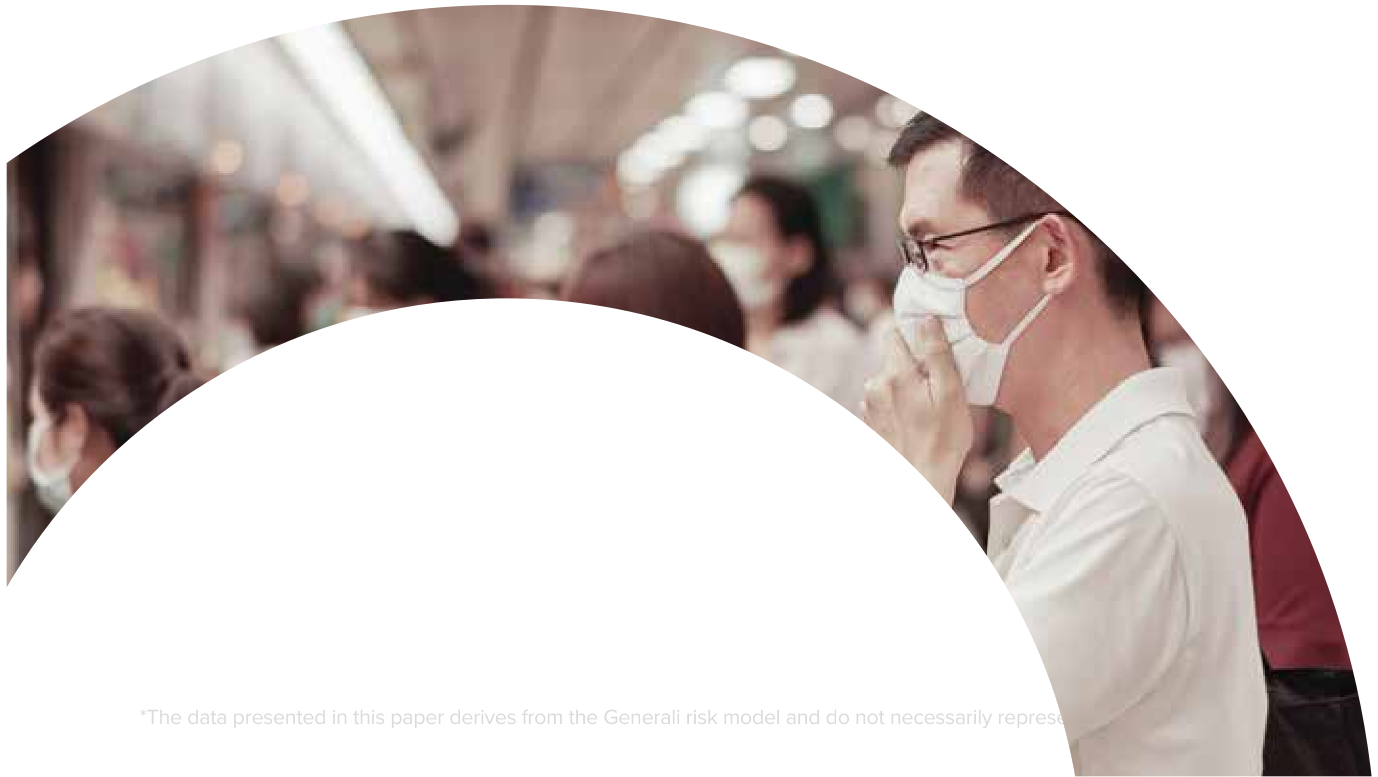


Figure 13: change in mortality (deaths per 100,000 inhabitants) and morbidity (disease cases per 100,000 inhabitants) rate due to heatwaves in Fragmented scenario 2050, projected by the Generali climate risk model



3 WARMING TEMPERATURES ADD PRESSURE TO ALREADY STRAINED HEALTHCARE SYSTEMS

The data presented above stems from the projections by Generali and illustrates the projected impacts of climate change on global health, revealing stark regional disparities.

These figures underscore that while the effects of climate change on life expectancy through increased mortality are significant, the broader effects on overall population health through increased morbidities are even more profound. The deterioration of health conditions can exacerbate existing strains on healthcare systems, widening the mismatch between healthcare demand and capacity.

The demand for healthcare is largely driven by the volume of people in poor health and the type and duration of care they require. Though the specifics differ across countries, structural drivers of this rising demand are consistent and include population aging, shifts in lifestyles shaped by social, economic and environmental factors, and shortfalls in preventive approaches.

As populations age, the prevalence of chronic diseases, particularly cardiovascular and respiratory conditions, increases. Longer life expectancy, especially in high-income countries, also may extend the duration of required healthcare services[40].

Concurrently, Non-Communicable Diseases (NCDs) such as diabetes, obesity and mental health conditions are rising, often linked to unhealthy diet, insufficient physical activity social isolation and other factors[41]. These trends were sharply visible during the COVID-19 pandemic, where isolation, coupled with uncertainty on future, triggered a global surge in psychological disorders across both developed and developing regions[42].

Despite being widely acknowledged as cost-effective, preventive care remains underutilized. The reasons are manifold: high upfront costs, delayed visibility of benefits, and persistent gaps in public health education and engagement.

On the supply side, healthcare systems rely on a complex ecosystem: hospitals, clinics, facilities, skilled professionals, equipment, and pharmaceuticals. Yet the capacity and structure of these systems differ markedly across countries, shaped by policy choices, health system design, and public-private investment levels[43].

In many countries, fiscal constraints significantly limit the ability to expand or modernize healthcare delivery. This often manifests as shortages of hospital beds and staff, outdated diagnostic tools, and limited access to advanced treatments, including personalized therapies. Furthermore, many health systems fail to fully leverage medical technology due to high initial costs and delayed returns[44].

Against this backdrop, climate change is expected to drive a sharp increase in morbidity, with our modeling predicting worsening cardiovascular conditions, diabetes, other respiratory diseases and even mental illness[45]. As more individuals require medical attention, particularly for chronic conditions, the demand for hospital beds will surge both in volume and duration of use. At the same time, the shortage of healthcare workers is likely to become one of the most critical constraints for effective healthcare delivery. Together, these pressures pose serious challenges to human well-being and societal resilience[46].

Considering only the additional mortality due to vector-borne disease reported in Table 2, patients requiring medical care for such diseases may occupy up to 10% of hospitalization capacity in Europe and more than 50% in Asia[47]. For context, at its peak, COVID-19 pandemic patients occupied as much as 70% of hospitalization capacity in some Asian countries. Today, average bed occupancy ranges from 60% to 80% of hospitalization capacity across countries in Europe and Asia. In Europe, occupancy averages close to 80%, nearing the emergency preparedness threshold of 85% identified in the scientific literature[48]. In Asia, average occupancy is lower, though some countries such as China report much higher levels. With a maximum projected increase of people in poor health of 3,314 and 15,157 per 100,000 in Europe and Asia (see Table 2) respectively, many countries will breach the 85% occupancy threshold, especially in Asia, with Thailand, Malaysia, and China, potentially exceeding 100%.

As hospital bed occupancy approaches or exceeds the emergency preparedness threshold, the workload per healthcare worker increases significantly. Staffing adequacy is commonly measured as the ratio of beds per healthcare worker. The scientific literature considers a minimum safe threshold to be 1.5 workers per bed[49]. Current levels are generally safe, ranging from 3 to 6 in Europe and from 2 to 5 in Asia. In Europe, this ratio is projected to approach the minimum threshold, stretching staff to the brink. In Asia, the situation is more severe: many countries are expected to fall below the 1.5 threshold, with a projected shortfall of over 10 million healthcare workers needed just to return to the minimum safety standard.

Beyond medical needs, climate change is also expected to influence behavioral patterns. As illness becomes more prevalent, people are expected to spend more time at home, leading to increased social isolation, loneliness, poorer nutrition and sedentary behavior, factors closely linked to mental health disorders and obesity. By weighing the country-level additional morbidity rates reported in Table 2 by each country's current population, the average projected increase in morbidity rates is estimated at +1,551 in Europe and +9,033 in Asia per 100,000 inhabitants. This will result in an increase in time spent at home by 1% in Europe and 8% in Asia beyond the current average of 10 hours/day. This raises the odds of being obese by 8% in Europe and 44% in Asia, and the probability of experiencing mental illness by 1% and 3% respectively.

All the above estimations do not account for the effects of population aging. Most of the projected increase in people in poor health will occur among the group of age above 65 years, which accounts for 20% of the population in Europe and 8% in Asia. According to UN projections[50], these shares will rise to 30% and 17% respectively. This demographic shift will further amplify the pressure on healthcare systems, exacerbating the already critical challenges outlined above.

Lastly, indirect climate impacts can also erode the healthcare system's ability to respond. Extreme weather events can disrupt essential infrastructure, such as electricity supply, compromising access to medical equipment and degrading working conditions for healthcare staff[51]. These cascading effects may widen the healthcare protection gap, especially in regions already operating at, or beyond capacity. These issues are expected to be more pronounced in developing countries and among vulnerable populations, where climate shocks can accelerate health deteriorations and widen inequalities.

The insurance industry in its role as a social stabilizer, as above described, face dual pressures: risks cause higher pricing, while anti-selection reduce mutualization further inflating costs, and potentially leading to affordability or even insurability issues.

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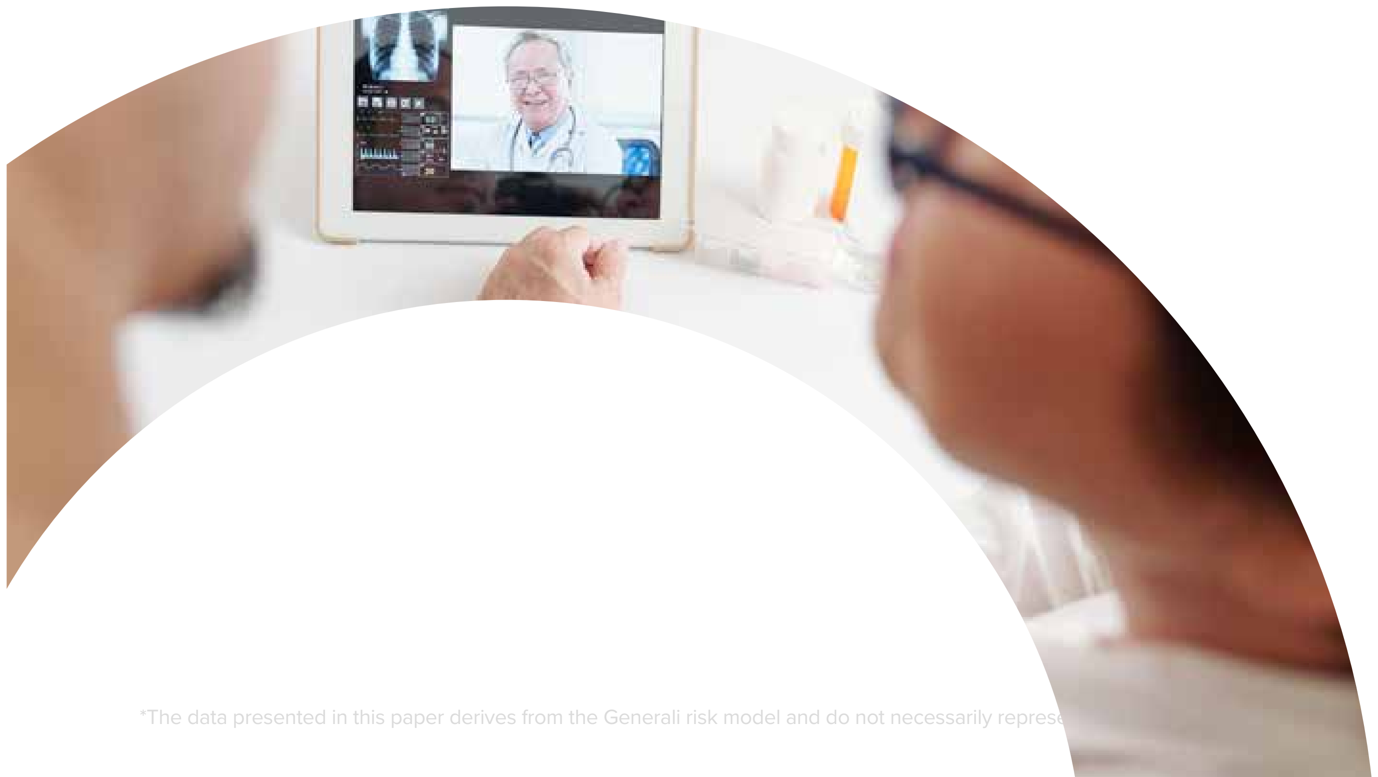
4 PATHWAYS FORWARD

Given the current and growing impacts of climate change on health, the implementation of both mitigation and adaptation measures is crucial to address the growing healthcare protection gap.

Mitigation measures address the long-term trajectory of our planet, shaping the structural conditions for ecosystems worldwide. Without decisive mitigation efforts, the pace and magnitude of climate change will eventually outstrip the effectiveness of adaptation, rendering these measures increasingly insufficient.

However, even with successful mitigation, climate change is already unfolding in diverse ways across the globe, requiring context-specific adaptation responses. Given that mitigation measures are extensively covered in climate literature and can be followed through the framework of the Paris Agreement[52], the sections below concentrate on adaptation measures. These are not thought to be an exhaustive list, but examples of actionable policy options in the face of enhanced climate change-related health risks.



Adaptation Measures to face Climate-Change related Health Risks

Healthcare systems – even in high income countries – are not well prepared to tackle the emerging challenges of climate change[53]. There are, however, tangible adaptation measures that could significantly improve the preparedness of healthcare systems. Depending on current healthcare system adequacy and climate evolution, they encompass strategies to enhance healthcare service delivery, support the adoption of more climate-resilient individual behaviors, and improve the understanding of climate dynamics.

Enhancement of infrastructure and urban planning play a pivotal role in improving living conditions and increasing health resilience to climate change, particularly in view of the increasing frequency and intensity of heatwaves. Integrating green infrastructure, such as parks or green roofs, helps mitigate the urban heat island and improve air quality while providing social and health co-benefits.

In terms of healthcare delivery, hospitals should remain focused on complex and acute treatments that demand advanced technologies and highly specialized personnel. In contrast, less complex interventions, such as routine check-up or chronic disease management, should be decentralized through a dense network of local clinics.

To further improve outreach, home-based nursing and telemedicine services must be scaled up to facilitate the continuity of care, becoming even more critical with the aging of the population.

An effective healthcare system requires a high level of interoperability, aligning operations and exchanging clinical information, to access and update patient records securely. To this extent, digital health technologies should be embedded across the entire service chain and the use of digital platforms and wearables devices expanded.

In parallel, strategic investment in medical technologies and innovation is necessary to meet the increasing demand for care, especially for diseases aggravated by climate conditions. Funding should be directed toward expanding access at lower costs to early diagnostic tools, such as AI-assisted imaging and portable screening kits. In fact, while advanced diagnostic tools might entail higher upfront costs, they often prove more cost-effective over time by reducing clinical uncertainty, allowing diseases to be detected and treated in earlier stages.

Moreover, the long-term sustainability and effectiveness of the healthcare system fundamentally depend on the strength, adaptability, and distribution of its workforce. Climate change introduces not only new patterns of disease but also logistical and operational challenges.

Adapting healthcare to climate change requires resilient infrastructure, digital care, skilled staff, public awareness, and strong partnerships

Equally important is the retention of healthcare personnel. Structured career development pathways, including access to mentoring, leadership programs, and research opportunities, can significantly improve retention and professional satisfaction.

Upskilling and reskilling programs must become a permanent feature of healthcare workforce management, covering cross-cutting competencies such as data science, digital health, climate-specific epidemiology, and crisis response protocols, including climate-adaptive care.

Another key set of adaptation measures encompasses the strengthening of public awareness and education that is a foundational element of climate adaptation, particularly in the health domain, like integrating climate-related education into formal schooling to prepare future generations for the increasing health risks associated with climate change.

Beyond schools, targeted training campaigns should be developed for workers and local communities to promote awareness and encourage the adoption of preventive behaviors and risk mitigation practice.

Finally, effective communication strategies for vulnerable people should ensure timely and accessible information during acute climate events, such as early warning systems or real-time alert protocols, that inform the public about imminent risks and recommend protective actions.

Building New Partnerships for Adaptation of Healthcare Systems

The implementation of an ambitious set of adaptation measures necessitates a systematic approach that integrates private actors with public sector.

Public authorities are the first actors to finance or subsidize the upgrade of critical public health infrastructure, particularly in climate-vulnerable regions, invest in public education and workforce development programs, and enforce urban planning standards and environmental health regulations that incorporate resilience criteria, conduct health and climate vulnerability assessments to inform policy priorities and resource allocation.

However, fiscal spaces in many geographies are already under pressure due to welfare spending augmenting with ageing populations and increasingly unsustainable post-pandemic debt levels. Bureaucratic inertia, and fragmented institutional mandates can also slow the implementation of forward-looking reforms, especially when the benefits are perceived as long-term or diffuse.

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For these reasons, the private sector can participate as a co-financer or full partner in design, implementation and delivery of new adaptation measures, like digital and data-driven healthcare solutions, remote monitoring, and climate-health analytics.

Crucially, public authorities can create adequate conditions for the expansion of the policy toolkit to achieve the goal of effective Universal Health Coverage[54]. This could include regulation and blended financing tools to align private incentives with societal goals, such as promoting the voluntary use of private healthcare services as a complement to public provision.

In this space, insurance companies have a unique and pivotal role to play in the adaptation landscape as both institutional investors and risk managers.

Firstly, insurers manage large volumes of capital: in Europe alone, the insurance sector held approximately €12 trillion in assets in 2023. Part of these resources can be directed towards the financing of resilient infrastructure or the development of technologies that support early detection, remote care, and emergency preparedness.

Insurers could channel capital into development of integrated healthcare solutions by establishing agreements with private providers or becoming owner of medical facilities, as Generali is already doing through a strategic partnership with Gruppo San Donato, aimed at creating a national network of smart clinics focused on prevention, quality care, and digital accessibility.
Secondly, the core business of insurance is risk pooling and risk management: by spreading risks across time and populations, insurers make protection accessible and financially sustainable.
Insurers can also offer integrated solutions that go far beyond traditional coverage, for example health protection plans that combine insurance with access to telemedicine platforms, diagnostic tools, or wearable technology.

The key to realize such collaboration is a strong public–private partnership. Policymakers can utilize legal and fiscal measures to incentivize insurance penetration, such as fiscal subsidies. In turn, a more diversified insured base increases the risk mutualization and lowers premiums.

Pricing can also be optimized through incentives for risk mitigation. For instance, when insured individuals adopt proactive health or climate-resilient behaviors, insurers can reward them with financial or service-based incentives.

In addition to providing coverage and capital, the insurance sector plays an educational and anticipatory role. Given its long-standing and continuous relationship with clients, the industry is in a unique position to raise awareness of the direct and indirect consequences of climate change and to encourage protective action.

Finally, the evolution of actuarial models and academic partnerships contributes to a broader understanding of emerging risks, generating new global public goods. Improved health and climate risk modelling, supported by higher data granularity and interdisciplinary research, will lead to better decision-making and more targeted adaptation responses over time.

In this context, the collaboration between Generali Group and UNDP represents a valuable foundation that will be further strengthened in the areas of data development, risk modelling and health impact analysis in relation to climate change.

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Notes

[1] UNDP (United Nations Development Programme), 2022b.

[2] UNDP 2025

[3] Such as warming temperatures

[4] {Grant, 2025 #1655}.

[5] Daalen and others 2022.

[6] IPCC 2023.

[7] UNEP 2024.

[8] Hagen and others 2024.

[9] Risser, North and Wehner 2024.

[10] Clarke and others 2024.

[11] UNDP and CIL.

[12] Kulp and Strauss 2019.

[13] Román and others 2019; Santos-Burgoa and others 2018.

[14] Chancel and others 2022.

[15] Sherman and others 2023.

[16] Carleton and others 2022.

[17] Young and Hsiang 2024.

[18] WWA 2024.

[19] IPCC 2023.

[20] Age buckets considered are: 0-19, 20-64, +65.

[21] Consistent with findings of, for instance, Carleton and others (2022).

[22] Among the main pollutants, the analyses were performed on Particulate Matters 2.5 (PM2.5).

[23] HEI and IHME (2024).

[24] Colón-González and others (2021).

[25] Abnormally is generally defined as temperature higher than 85th percentile of historical temperature distributions.

[26] Xu and others (2024).

[27] The model does not address the impact of chronic increase of temperature and air pollution on morbidity due the absence of data that isolates the pure effect of climate on diseases and the lack of robust modeling approaches.

[28] Country-level $PM_{2.5}$ concentration is estimated based on urbanization degree and CO2 emissions from industry and transportation.

[29] The model estimates the spread of such diseases based on the projected number of suitable months per year with active Aedes mosquitos' proliferation, which depends by the projections of temperature, humidity and precipitation amount. The model incorporates the likelihood that the exposed population may become infected during suitable months.

[30] Italy, France, Germany, Austria, Switzerland, Spain, Portugal, Czech Republic, Hungary, Poland, Slovenia, Croatia, Greece, India, Malaysia, Vietnam, Hong Kong, Philippines, Thailand, China and United Kingdom

[31] Number of annual days with minimum temperature below 0°C.

[32] Number of annual days with maximum temperature above 35°C.

[33] UN Habitat, nd. https://unhabitat.org/asia-and-the-pacific-region#:~:text=Urbanization%20continues%20to%20be%20a,an%20additional%20 1.2%20billion%20people.

[34] In the most affected European countries, Northern Italy and central and southern Croatia, the average daily temperature is expected to increase from 17 °C up to 20°C in 2050. Precipitation is projected to be less frequent but more intense, rising from the current average of 1,500 up to 2,000 mm per year in 2050. In the most affected Asia countries, including Philippines, Thailand and Malaysia, the average daily temperature is expected to rise from 26°C to about 28°C in 2050, while precipitation is projected to increase from the current average of 2,200 up to about 3,000 mm per year in 2050. Other European and Asian countries are likely to experience slightly drier conditions.

[35] Long-lasting insecticidal nets, indoor residual spraying, space sprays, larvicides and environmental management for specific target vectors.

[36] Sharma and others 2025.

[37] It represents the number of annual days under climatological heatwaves conditions.

[38] From Human Mortality Database.

[39] It represents the difference between the life expectancy (source World Bank) and the healthy life expectancy (source WHO).

[40] See discussion about different potential patterns in Kallestrup-Lamb et al (2024).

[41] Ong and others (2023); Sapien Labs (2025).

[42] Schluter and others (2022).

[43] See, for instance, variations in the capabilities of healthcare systems around the world in UNDP (2022a).

[44] Barrios and others (2023).

[45] Mitchell and others (2024).

[46] Clarke and others (2025).

[47] These figures are calculated comparing the number of available hospital beds provided by the World Bank to people requiring hospitalization for vector-borne disease considering that on average 20% of patients with a confirmed vector-borne disease diagnosis were hospitalized.

[48] Bagust and others 1999.

[49] American Medical Association, American College of Clinical Pharmacy, https://www.fathomhq.com/kpi-glossary/staff-to-patient-ratio.

[50] UN, 2001. World Population Ageing: 1950-2050.

[51] Sandstad and others (2020).

[52] See, for instance, https://climateactiontracker.org/

[53] See UNDP 2022, chapter 6.

[54] SDG Target 3.8.

*The data presented in this paper derives from the Generali risk model and do not necessarily represent official estimates by UNDP

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