Swiss Re Institute

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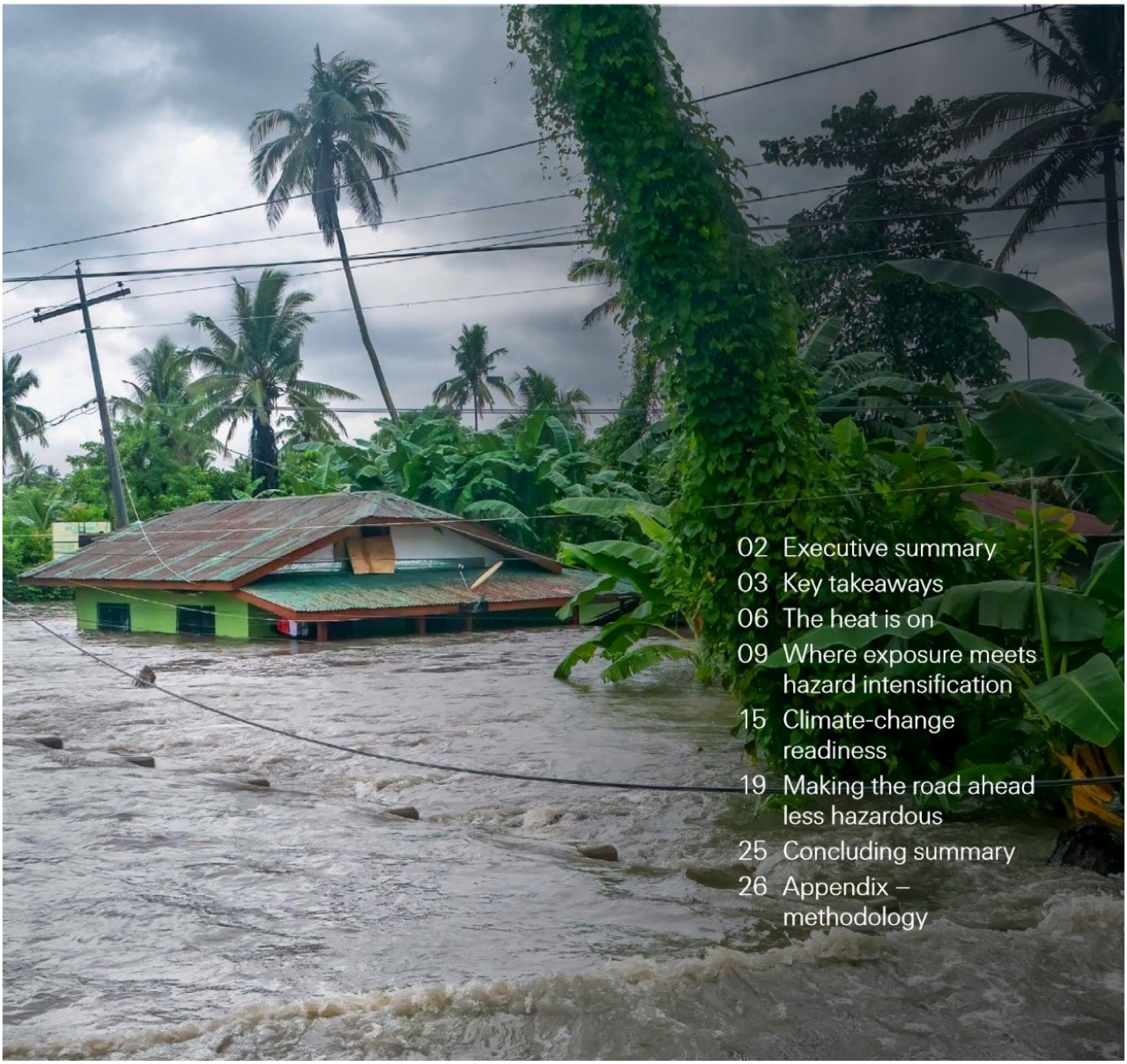
Changing climates: the heat is (still) on

Hazard intensification set to compound economic losses



Executive summary

The world is getting warmer and natural hazards are becoming more intense, likely bringing higher economic losses in the future.

Understanding how natural perils shape the risk landscape is critical to advancing our preparedness for climate change. Warming temperatures bring physical repercussions including more intense hazards, which, in turn, can compound loss outcomes. In this study, we combine our insurance knowledge of property damage resulting from natural disasters with new scientific evidence from the IPCC on the probability (low, medium, high) of more severe weather conditions. To date, the main drivers of rising losses have been economic growth and urbanisation. Climate change plays a relatively small role today, but we expect associated losses to accumulate and contribute more in the future.

Today, four major weather perils result in expected economic losses of USD 200 billion annually. With more severe weather coming, economic losses are set to rise.

Our analysis covers 36 countries and focuses on four major weather perils: floods, tropical cyclones, winter storms in Europe and severe convective storms. These are the main loss-inducing perils for the insurance industry today and account for the largest share of economic losses from natural disasters globally. As of today, in terms of property impact, these perils cause expected economic losses of USD 200 billion annually. This is just the lower bound of all potential losses, as not all weather perils (eg, heatwaves) are covered, and only property losses are accounted for. As changing climates fuel weather-event intensity, loss potential will likely rise. As our 2021 report *The economics of climate change: no action not an option* demonstrates, if global warming stays on the current trajectory, the world could lose up to 7–10% of GDP by mid-century.

Our analysis finds the Philippines to be most exposed to rising losses as hazards intensify, followed by the US. China and India, key economies for global growth, are among the least prepared.

In terms of property damage, the greatest vulnerability to potential for rising losses in the future lies in countries where hazard intensification coincides with high levels of economic exposure. This is the case for the Philippines, where annual economic losses (as a percentage of GDP) from weather events today are much higher than all other countries (around 8x more than the US, the second highest), and it is also exposed to a high probability of hazard intensification. The US presents a combination of the highest economic losses from weather events in the world, in absolute terms, and medium probability of more intense hazards. The losses inflicted by severe weather bring financial repercussions too. Drawing on our research on insurance resilience (the share of physical assets insured against weather perils), from this perspective we find that low insurance penetration renders important global growth engines like China and India as among the least ready to face the rising losses from peril intensification.

Actions needed: adaptation, insurance and mitigation. The economic dividends of adapation can outweigh asscoiated costs by up to 11 times.

The first step to cutting losses is to reduce the loss potential in the first place, through adaptation measures. Insurance can compensate for residual losses. Examples of adaptation actions include enforcing building codes, increasing flood protection and discouraging settlement in areas prone to natural perils. The economic dividends of adaptation steps can outweigh their costs by multiples ranging from 2:1 to 11:1. Even so, adaptation and insurance can only go so far. Climate change mitigation (ie, reducing emissions) is fundamental to counter the overall effects of global warming. It is not just GDP at stake. As recognised by central banks, price and financial stability are threatened too, which could add to the economic cost of inaction.

Private-sector capital should be part of the financing solution.

With debt sustainability a heightened concern for countries at present, greater emphasis is on mobilising private-sector financing for mitigation and adaption projects. In 2022, we estimated a cumulative global investment gap of more than USD 270 trillion must be filled to deliver net zero emissions by 2050. There is scope to channel more private capital into this area. For instance, at a total USD 5.6 trillion, the sustainable debt market is still small (less than 5% of global bond markets), and of *new* global debt issuance, only around 5% is ESG-labelled. Currently less than 2% of adaptation finance comes from private sources, and here the insurance industry can also support. As long-term investors, insurers can contribute to the financing of mitigation efforts and adaptation infrastructure. They can also underwrite climate-positive projects, share risk knowledge and incentivise loss mitigation behaviour.

Key takeaways

Property insurance risks from weather-related perils, as of today

The table below shows which of the four major weather perils considered in our study cause the most property-related losses in each of the sample countries, as of today. The Philippines suffers the largest economic losses as a percent of GDP from the said perils, primarily from flooding and tropical cyclones. Its losses are about 8x those of the US, which ranks second in terms of percent of GDP economic losses, with losses driven by severe convective storms, tropical cyclones and flooding. Ireland, Turkey and Israel suffer the lowest economic losses from the four major weather perils.

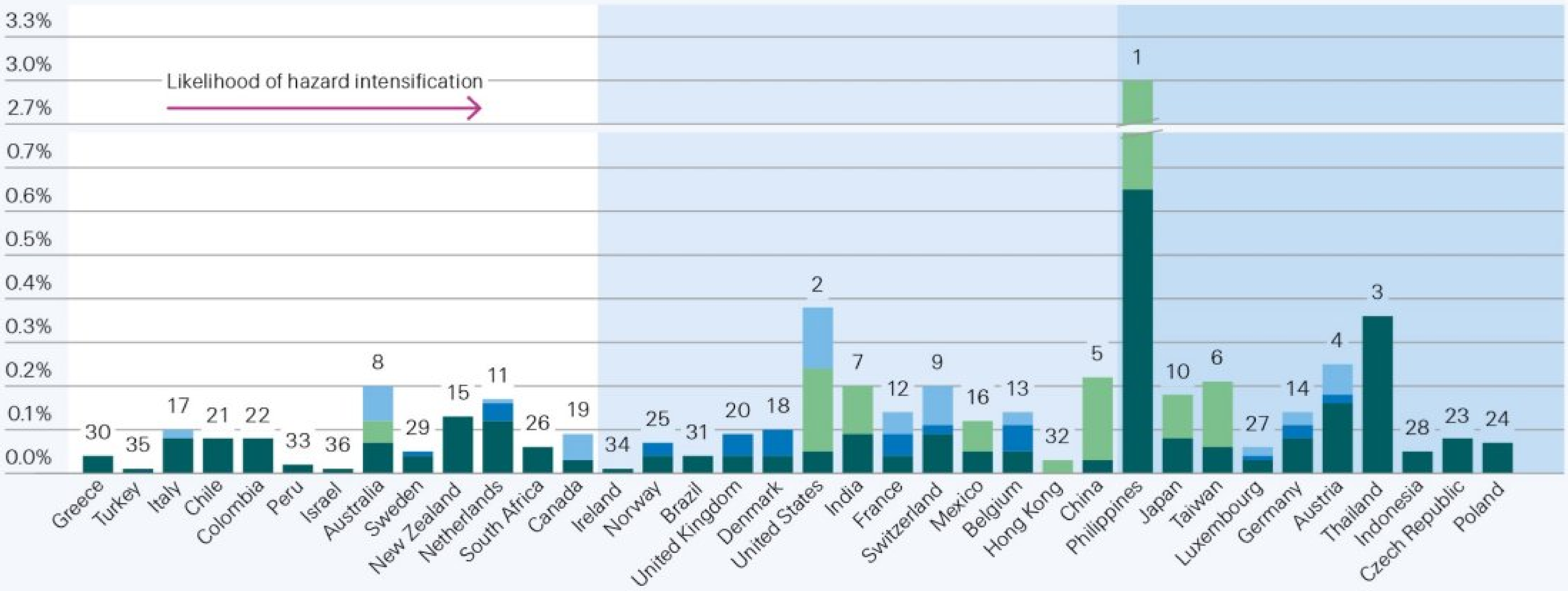
Countries	All weather perils		Floods		Severe convective storms		Winter storms		Tropical cyclones	
	Rank	Eco loss as % of GDP	Rank	Eco loss as % of GDP	Rank	Eco loss as % of GDP	Rank	Eco loss as % of GDP	Rank	Eco loss as % of GDP
Philippines	1	3.00%	1	0.65%					1	2.34%
US	2	0.38%	20	0.05%	1	0.14%			2	0.19%
Thailand	3	0.36%	2	0.36%						
Austria	4	0.25%	3	0.16%	4	0.07%	8	0.02%		
China	5	0.22%	31	0.03%					3	0.19%
Taiwan	6	0.21%	16	0.06%					4	0.15%
India	7	0.20%	6	0.09%					5	0.11%
Australia	8	0.19%	15	0.07%	3	0.08%			8	0.05%
Switzerland	9	0.19%	7	0.09%	2	0.09%	9	0.02%		
Japan	10	0.18%	13	0.08%	12	0.01%			6	0.10%
Netherlands	11	0.17%	5	0.12%	11	0.01%	5	0.04%		
France	12	0.14%	22	0.04%	6	0.05%	3	0.05%		
Belgium	13	0.14%	19	0.05%	8	0.03%	2	0.06%		
Germany	14	0.14%	11	0.08%	7	0.03%	6	0.03%		
New Zealand	15	0.13%	4	0.13%						
Mexico	16	0.12%	18	0.05%					7	0.07%
Italy	17	0.11%	10	0.08%	9	0.02%				
Denmark	18	0.10%	24	0.04%			1	0.06%		
Canada	19	0.09%	30	0.03%	5	0.06%				
UK	20	0.08%	26	0.04%			4	0.05%		
Chile	21	0.08%	8	0.08%						
Colombia	22	0.08%	9	0.08%						
Czech Republic	23	0.08%	12	0.08%						
Poland	24	0.07%	14	0.07%						
Norway	25	0.06%	28	0.04%			7	0.03%		
South Africa	26	0.06%	17	0.06%						
Luxembourg	27	0.06%	29	0.03%	10	0.02%	10	0.01%		
Indonesia	28	0.05%	21	0.05%						
Sweden	29	0.05%	23	0.04%			11	0.01%		
Greece	30	0.04%	25	0.04%						
Brazil	31	0.04%	27	0.04%						
Hong Kong	32	0.03%							9	0.03%
Peru	33	0.02%	32	0.02%						
Ireland	34	0.01%	34	0.01%			12	0.01%		
Turkey	35	0.01%	33	0.01%						
Israel	36	0.01%	35	0.01%						

Source: Swiss Re Institute

Where exposures and hazard intensification collide

Economic growth, urbanisation and accumulation of asset values are the main drivers of rising economic (and insurance) losses resulting from natural catastrophes. Over the longer term, we expect climate change effects will add to weather-event related losses. Countries that already today experience large economic losses, specifically from flooding, tropical cyclones, winter storms and severe convective storms, and where, according to the IPCC, hazard intensification is to be expected, appear more exposed to rising losses in the future as weather events become more severe. This is the case of the Philippines where annual economic losses as a share of GDP from weather events today show to be much higher than in all other sample countries and where there is high probability of hazard intensification. The US, meanwhile, shows as second-most exposed, presenting a combination of, in absolute terms, the highest economic losses from weather events in the world, and medium probability of hazard intensification.

Probability of hazard intensification and as-of-today expected (probabilistic) economic losses by peril as % of GDP per country



Floods · Tropical cyclones · Winter storms · Severe convective storms

Overall likelihood of hazard intensification under the scenario of 2–2.4°C warming by 2050 (based on IPCC AR6). Countries are portrayed in terms of probability of hazard intensification, from low (left) to high (right).

Low · Medium · High

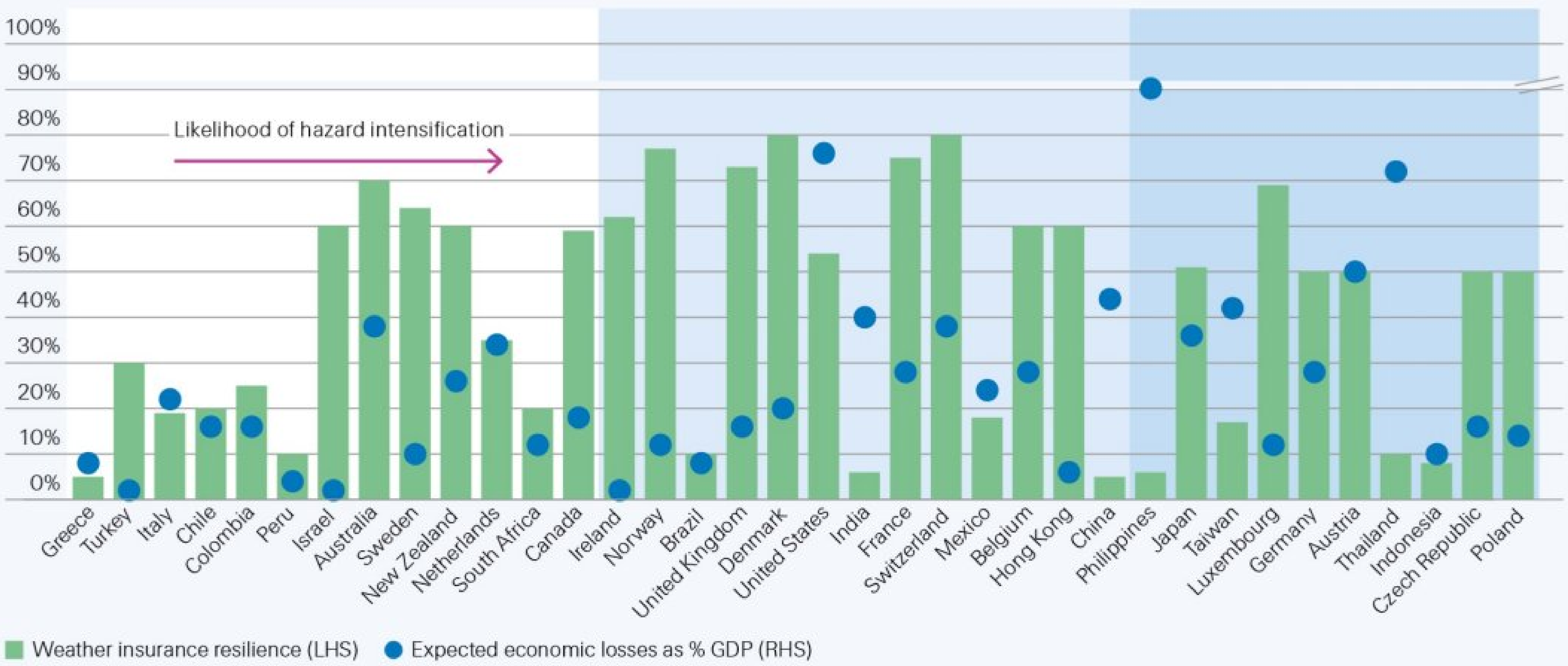
Numbers at top of bars indicate country rankings for economic losses as a % of GDP resulting from the four major weather perils as of today, as in Table 1.

Source: Swiss Re Institute

Financial resilience to hazard intensification

Economic exposure doesn't tell the full story. Countries with sizeable insurance protection gaps are most financially at risk to hazard intensification. The adverse financial effects will be most pronounced where the establishment of loss reduction and prevention measures lag economic growth. Countries similar in terms of exposure to hazard intensification differ in terms of financial preparedness to absorb the losses from weather-event shocks. Our analysis suggests that fast-growing emerging Asian economies, in particular Indonesia, Thailand, China, India and the Philippines, are most vulnerable to financial losses as a result of more severe weather events in the future.

Probability of hazard intensification and weather-related insurance resilience index per country, as of today



Overall likelihood of hazard intensification under the scenario of 2–2.4°C warming by 2050 (based on IPCC AR6). Countries are portrayed in terms of probability of hazard intensification, from low (left) to high (right).

Low Medium High

Source: IPCC, Swiss Re Institute

Private capital can play a central role

Private-sector capital is a key part of the financing solution for the estimated USD 270 trillion investment needed to meet net-zero ambitions by 2050. A large amount of private sector capital is currently under-utilised in the green sector. In 2022, the overall size of global bond markets (publicly traded) totaled more than USD 120 trillion. The overall sustainable debt market reached USD 5.6 trillion in the third quarter of 2023, but that still constitutes less than 5% of the total market. Of new global debt issuance, only around 5% is currently ESG-labelled. Private finance, including long-term investments from insurers, channeled towards adaptation can also be scaled up. Less than 2% of adaptation finance currently comes from private sources.

Sustainable debt as a share of global debt market issuance (%)

Source: Institute for International Finance, Swiss Re Institute

The heat is on

Climate change and rising losses

Large-scale natural catastrophes can inflict large losses. In terms of property damage, today four major weather perils alone result in expected economic losses of USD 200 billion annually.

Understanding how changing hazards induced by climate change will shape risk landscapes in the future is crucial for the insurance industry and society. Already today, extreme weather events like heavy precipitation and severe storms, including tropical cyclones (TC), cause significant economic losses of an estimated USD 200 billion every year. This, however, is at best the lower bound of what severe weather-related losses could be as climate change advances, as the estimate accounts for just four major loss-making weather perils (ie, flooding, TCs, winter storms in Europe and severe convective storm), and includes damage to property only. The losses from other perils such as heatwaves, winter storms in the US and other economic fallout are not included (see *Making the road ahead less hazardous* for more on the broader economic fallout).

The main drivers of losses are socioeconomic, but the contribution of climate change will likely grow in the coming years.

Further, to date, growth in natural catastrophe-related property losses has been mostly driven by rising exposures due to economic growth, accumulation of asset values, urbanisation and rising populations, often in regions susceptible to severe weather events (eg, coastal regions, river fronts and wildland-urban interfaces).[1] In the future, hazard intensification due to climate change is set to add to weather-related losses (see *The path we are on*).

In its most recent assessment, the IPCC provides more evidence of where natural hazard risks are likely to intensify.

While the full extent of the effects of climate change on catastrophe risk and associated losses remains difficult to predict, the volume of scientific data on the impacts of climate change for use in risk assessment at regional level is growing. In this regard the United Nations' Intergovernmental Panel on Climate Change's (IPCC) *Sixth Assessment Report* (AR6) embodies significant advancements. Improved models and analytical methods combined with more observations yield a better understanding of the influence of human activity on various climatic parameters.[2] These climatic parameters are also known as climate impact-drivers (CIDs; eg, river floods, TCs, coastal flooding), and facilitate better overall understanding of hazard intensification.[3]

We draw on the IPCC evidence on hazard intensification likelihood...

Drawing from the IPCC's AR6 report, we analyse where hazard intensification is likely to occur and overlay it with our own estimates of as-of-today expected economic losses resulting from severe weather events (see *Where exposure meets hazard intensification*). This provides a novel view of the possible direct economic implications (in the form of property damage) of the intensification of weather-related natural catastrophes associated with climate change. The IPCC's AR6 report provides future climate projections based on five different emission scenarios (known as the shared socio-economic pathways (SSPs)). It also provides probabilities of direction of change (increase or decrease) of various CIDs in qualitative terms (low, medium and high) for different sub-regions.[4]

...and overlay it with our own estimates of property damage resulting from severe weather events as-of-today as a means to portray possible economic implications of hazard intensification.

We map these CIDs and the respective likelihood of change assigned to each to insurance industry-defined weather-related hazard. In this study, we use the IPCC's "middle of the road" SSP 2-4.5 scenario.[5] This is associated with warming of 2.1-3.5°C by the end of the century and captures an environment where social, economic and technological trends do not shift markedly from historical patterns, and in which progress towards sustainable development goals is slow. The scenario is consistent with the most probable warming path (2.7°C by century-end) identified by the *Climate Action Tracker* given policies currently in place around the world.[6] Our mapping provides a view of future hazard intensification under this scenario, which we then combine with our view of losses today.

[1] See *sigma 2/2020: Natural catastrophes in times of economic accumulation and climate change*, Swiss Re Institute.
[2] Chapter 12 of *IPCC Sixth Assessment Report*, IPCC 2023.
[3] CIDs can be defined as climatic parameters (eg, mean precipitation) that affect a section of society or ecosystems. The CIDs are relevant here because we map them to weather-related hazards as per re/insurance industry definitions to assess the impact of climate change.
[4] As per AR6 of IPCC op. cit., land areas are divided into multiple regions. This is the geographical level of granularity at which the report assesses historical evidence of climate change and provides likelihoods of future projections. For countries with large land area such as the US or Australia, multiple regions constitute one country. For smaller countries like in Europe, multiple countries constitute one IPCC region.
[5] Note, the same likelihoods of change hold true for all higher SSPs.
[6] See *Temperatures*, Climate Action Tracker.

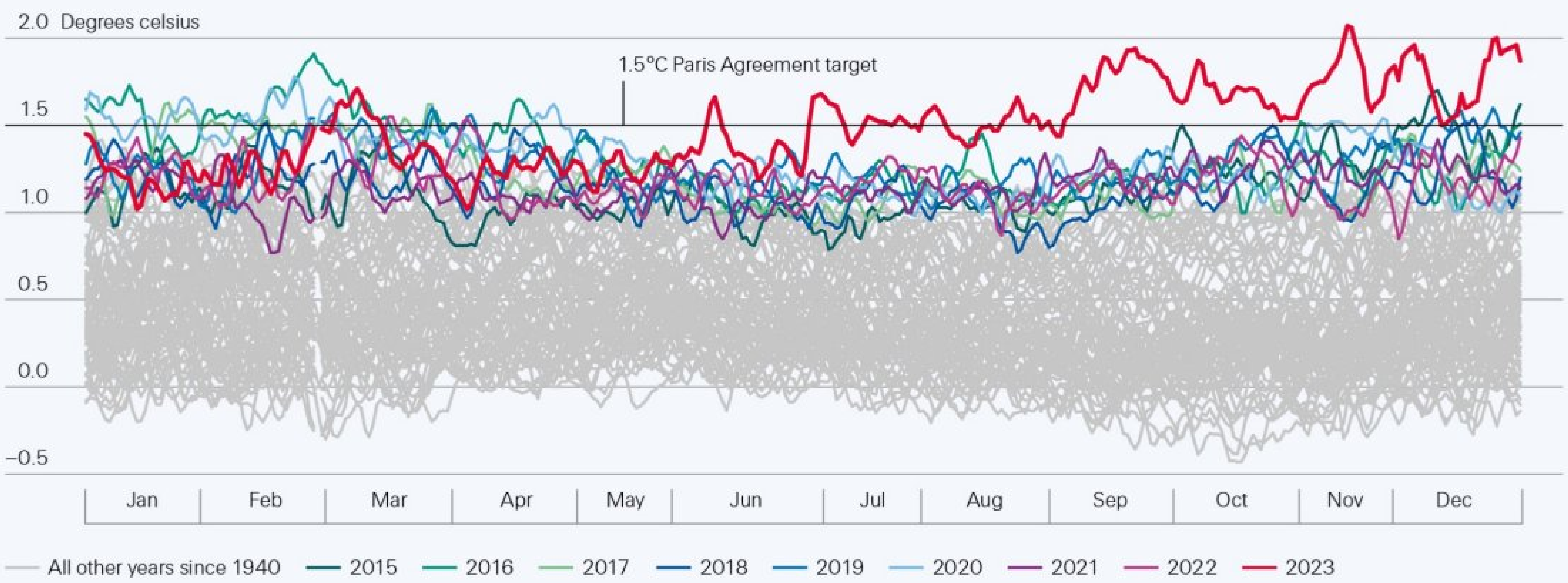
The path we are on

Data and scientific evidence suggest that climate change will continue to have widespread and intensifying impacts.

Any future impact of climate change depends on the extent of warming that materialises. Ongoing experience indicates that global temperatures continue to rise. 2023 was the warmest year ever, by a substantial margin, with El Niño also having an impact.[7] The year reaffirmed four observations that indicate climate change is set to continue, and that the physical impact will be widespread and become more intense:

1. **Breaching targets:** The overarching goal of the Paris Agreement is to hold the increase in average global temperature this century to well below 2°C above pre-industrial (1850–1900) levels, with the gain ideally limited to 1.5°C.[8] Already today, reaching that target looks improbable. The world is already around 1.2°C warmer than pre-industrial levels and the *daily* global average temperature has breached the 1.5°C threshold more than 400 times since 2015 (see Figure 1). In 2023, the daily average global temperature was above this threshold on almost half of all days. While the Paris target is a long-term limit (over 20–30 years) and a single breach not necessarily significant, the frequency of breaches speak to the rapid advance towards the long-term threshold.[9] The IPCC already expects the global average temperature to reach or exceed the 1.5°C Paris Agreement target over the next 20 years.[10]

Figure 1
Daily average global temperature increase from 1940 to 2023 relative to pre-industrial levels



Source: Copernicus, Swiss Re Institute

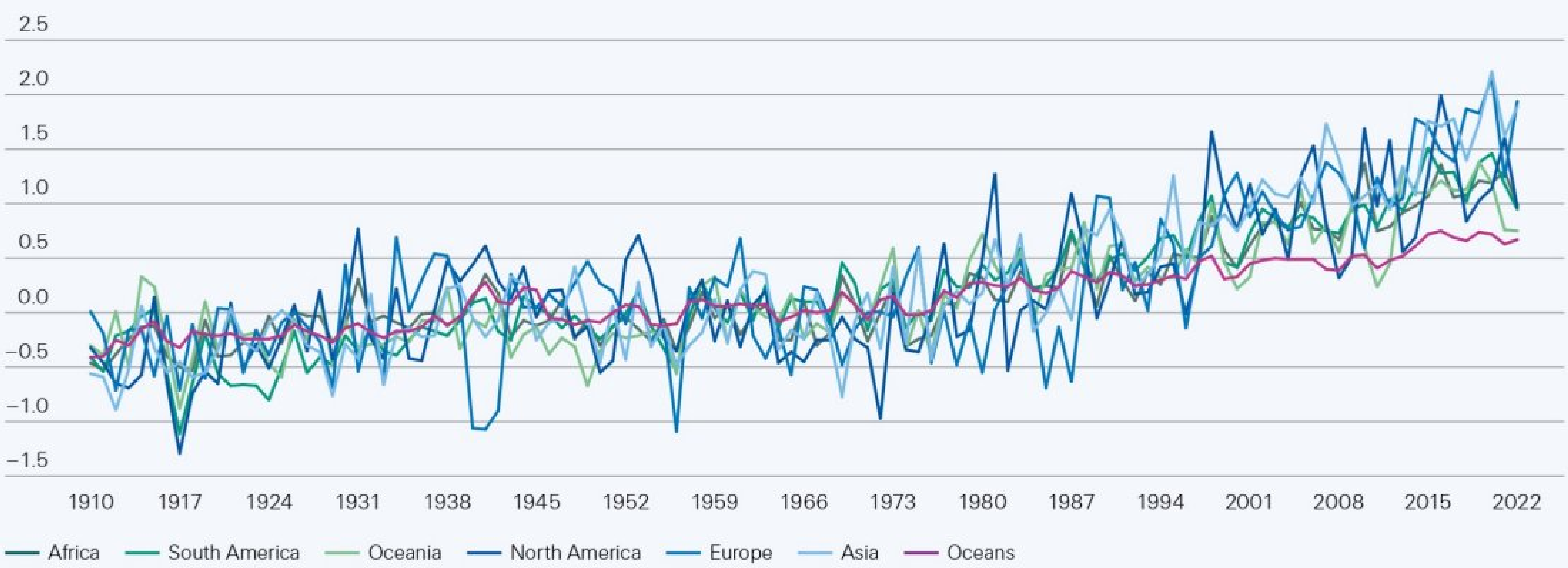
2. **Mitigation shortfall:** Adhering to the Paris Agreement target requires a reduction in greenhouse gas (GHG) emissions but the reality is that these continue to rise. GHG emissions, notably of carbon dioxide, methane, nitrous oxide and F-gases are the main driver of rising temperatures.[11] To reach the Paris Agreement target, GHG emissions would need to peak by 2025 and drop by 43% by 2030 from 2019 levels.[12] Already-actioned mitigation measures, however, fall short of what is necessary to bring about such a reduction. Given existing policies in different countries, it is estimated that emissions will continue to rise through 2030, putting the world on a path to 2.7°C warming by 2100.[13]

[7] *Copernicus: 2023 is the hottest year on record, with global temperatures close to the 1.5°C limit*, Copernicus Climate Change Service, 9 January 2024.
[8] *The Paris Agreement*, United Nations Framework Convention on Climate Change, 2022.
[9] *Tracking breaches of the 1.5ºC global warming threshold*, Copernicus Climate Change Service, 15 June 2023.
[10] *Climate change widespread, rapid, and intensifying*, IPCC, August 2021.
[11] The activities responsible for these emissions include the production, transport (through pipelines), and consumption (in transport, buildings, industry, and agriculture) of energy; industrial processes; agriculture, forestry, and land use (AFOLU); and waste. See *IPCC Sixth Assessment Report*, op. cit.
[12] *2023 NDC Synthesis Report*, UNFCCC.
[13] Climate Action Tracker, op. cit..

3. **Intensifying extremes:** There is mounting scientific evidence that observed changes in historical weather and climate extremes can be attributed to GHG emissions, mainly caused by humans. In particular, evidence points to a strengthening of the link between a changing climate and extreme precipitation, droughts, TCs and compound extremes (including dry/hot events such as heatwaves or fires).[14] Rapid and widespread changes in atmospheric and ocean conditions, and also in the cryosphere (areas of frozen water, such as glaciers or ice sheets) and biosphere (where life exists) have already occurred. In some instances, the changes are irreversible.[15]

4. **Widespread effects:** The impacts of rising temperatures are being felt across the world, with approximately 3.3 to 3.6 billion people living in areas highly vulnerable to climate change.[16] Temperatures are increasing in each continent (see Figure 2). In some regions, this has been alongside extreme weather and more frequent rainfall, while other regions are experiencing more intense heat waves and droughts. This increases risks to the global energy system, which was built for a cooler world with less weather extremes.[17] Polar ice sheets are also melting and sea levels rising. All of the above affect food and water security, ultimately an existential threat to humanity.

Figure 2
Continents' average annual temperatures relative to 1910–2020 average



Source: NOAA National Centers for Environmental Information, Swiss Re Institute

[14] *IPCC Sixth Assessment Report*, op. cit.
[15] Ibid.
[16] Ibid.
[17] *World Energy Outlook 2023*, International Energy Agency, October 2023.

Where exposure meets hazard intensification

In this report we show which countries are at higher risk of hazard intensification, and those in most need of loss prevention and reduction measures.

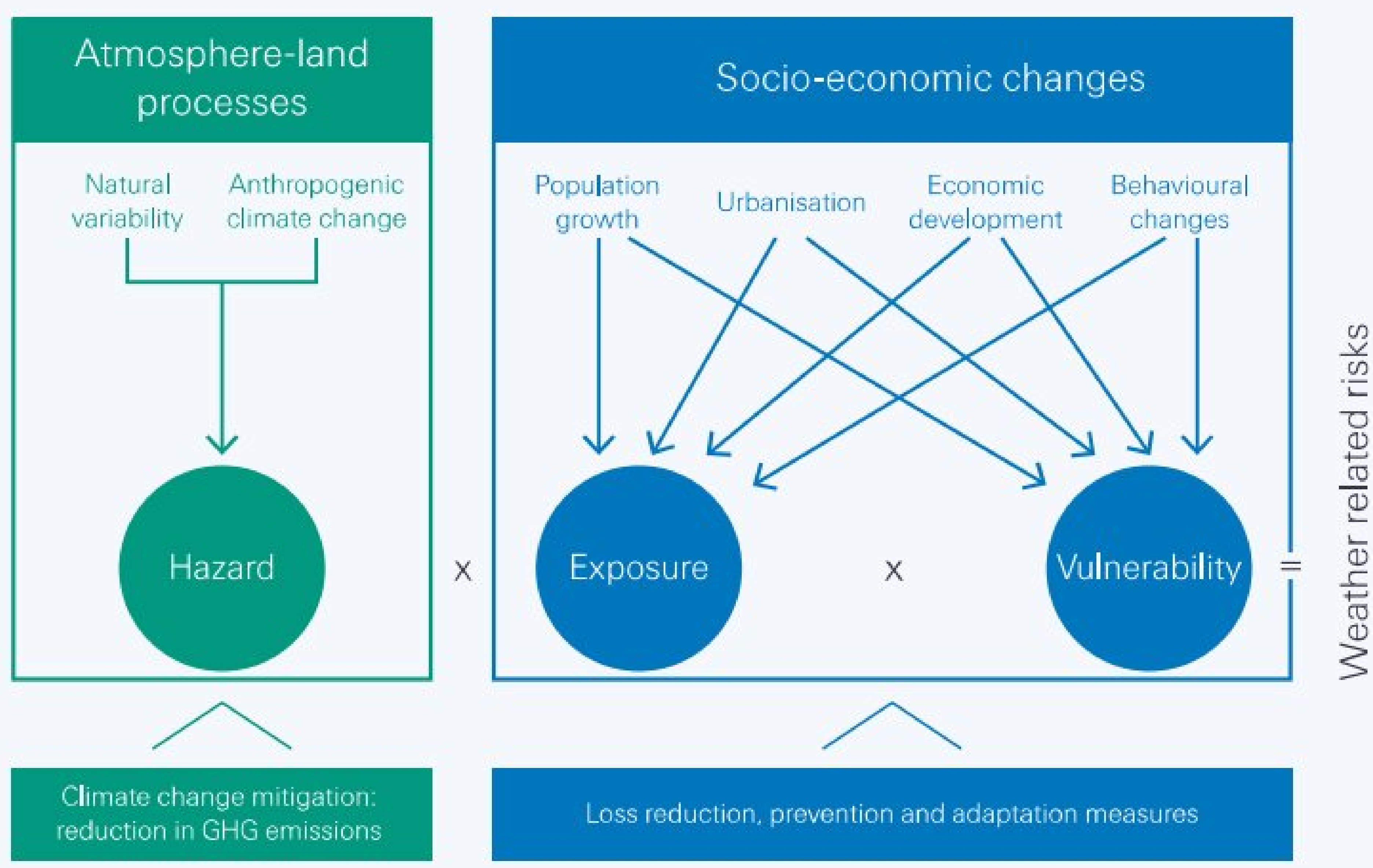
Climate change is a global phenomenon that manifests differently in different regions. A changing climate is already altering the likelihood of extreme weather event occurrence and will likely continue to do so as the world warms further. More frequent and/or intense severe weather events would increase the burden on local communities and governments, both in terms of macroeconomic risks and in terms of fiscal spending to cover losses. Based on the IPCC's regional climate models, in this report we portray those countries at higher risk of hazard intensification. Our analysis also gives indication of those countries where loss prevention, reduction and adaptation measures lower potential for rising losses from a changing climate, should be a priority.

Hazards, exposures, vulnerabilities…

The loss impact of an extreme weather event is dependent on hazard type, levels of exposure and vulnerability.

Three main components determine weather-related risks: *hazard* or type of peril (hurricane, flood etc); *exposure*, which refers to the populations and assets that lie in the path of weather-related hazards; and *vulnerability* (the susceptibility of the exposed elements to the hazards).[18] Figure 3 represents the interplay between the physical and socio-economic components of the weather-related risk equation. Weather-event occurrence and impact is dependent on climate conditions, changes that are largely due to natural variability, though anthropogenic (ie, human induced) change is set to play a growing role. The loss impact of a weather event is also influenced by the existing adaptation and mitigation measures in the area of event occurrence, this is in turn shaped by a country's economic status and policies. Ultimately, how many people and assets are in harm's way determines if an extreme weather event becomes "a disaster".

Figure 3
The three components of weather-related risk, and their associated drivers



Source: Swiss Re Institute

[18] See *sigma* 2/2019: Natural catastrophes in time of economic accumulation and climate change, Swiss Re Institute, for more on the three main components of weather-related risks.

Hazard intensification is seen as a likely outcome of changing climates...

The main drivers of future increases in economic losses due to severe weather will continue to be socioeconomic in nature. According to the IPCC, the impact of still-rising GHG emissions on physical climate conditions will increase, and hence so too will the contribution of climate change to making weather events more intense. In the short term, hazard intensification increases at a slow but steady rate, at times attenuated by natural variability effects.[19] Longer term, the compounding effects of GHG emissions are expected to make hazard events much more intense.

...and potential loss implications

...and will likely lead to rising losses from natural catastrophe events in the future.

We define hazard intensification as changes in natural perils in ways that adversely impact human society, manifesting in rising property losses resulting from occurrence of severe-weather and other catastrophe events. To investigate which regions and countries will likely experience most hazard intensification on account of climate change, this report focuses specifically on floods, TCs, winter storms in Europe and severe convective storms (SCS). These are the main loss-inducing perils for the insurance industry today and account for the largest share of economic losses globally. This is not to say, however, that other perils, including "dry" weather events like heatwaves and drought, do not also cause significant losses.

Floods, tropical cyclones and winter storms in Europe are expected to intensify the most. SCS hazards will intensify the least.

We map a combination of different CIDs to the four perils they shape to assess the changes to hazards resulting from warming temperatures (see Appendix for more on methodology). Based on the likelihood of changes in CIDs as reported by the IPCC, our mapping exercise indicates that of the four, on aggregate global flooding will intensify the most, followed by TCs, winter storms in Europe, and last SCS.

Property insurance risks, as of today

The first building block of our analysis is to rank countries in terms of economic losses as of percent of GDP caused by the four weather perils as of today.

Table 1 presents the as-of-today expected economic losses (percentage of GDP) resulting from the different four weather perils in our sample list of countries (Swiss Re Institute estimates). It shows which peril causes the most property damage losses in each of the countries, and ranks the countries accordingly for each peril. Empty cells indicate where the listed hazard is not relevant for a country.

The Philippines stands out as experiencing the largest said losses, followed by the US.

Today, the Philippines suffers the largest economic losses as a percent of GDP from the major weather perils. The main drivers are flooding and TCs. Winter storms and SCS are not relevant for the Philippines. The losses in the Philippines are around 8x the losses experienced in the US, which as of today ranks second in terms of percent of GDP economic losses from the four weather perils. In the case of the US, the main loss drivers are SCS and TCs, and to a lesser extent flooding. At the other end of the spectrum, today the four perils cause very low economic losses in Ireland, Turkey and Israel.

[19] *Climate Change 2023 Synthesis Report Summary for Policymakers*, IPCC, 2023.

Table 1
As of-today probabilistic economic losses as a percentage of GDP from the four major weather-peril events, by country

Countries	All weather perils		Floods		Severe convective storms		Winter storms		Tropical cyclones	
	Rank	Eco loss as % of GDP	Rank	Eco loss as % of GDP	Rank	Eco loss as % of GDP	Rank	Eco loss as % of GDP	Rank	Eco loss as % of GDP
Philippines	1	3.00%	1	0.65%					1	2.34%
US	2	0.38%	20	0.05%	1	0.14%			2	0.19%
Thailand	3	0.36%	2	0.36%						
Austria	4	0.25%	3	0.16%	4	0.07%	8	0.02%		
China	5	0.22%	31	0.03%					3	0.19%
Taiwan	6	0.21%	16	0.06%					4	0.15%
India	7	0.20%	6	0.09%					5	0.11%
Australia	8	0.19%	15	0.07%	3	0.08%			8	0.05%
Switzerland	9	0.19%	7	0.09%	2	0.09%	9	0.02%		
Japan	10	0.18%	13	0.08%	12	0.01%			6	0.10%
Netherlands	11	0.17%	5	0.12%	11	0.01%	5	0.04%		
France	12	0.14%	22	0.04%	6	0.05%	3	0.05%		
Belgium	13	0.14%	19	0.05%	8	0.03%	2	0.06%		
Germany	14	0.14%	11	0.08%	7	0.03%	6	0.03%		
New Zealand	15	0.13%	4	0.13%						
Mexico	16	0.12%	18	0.05%					7	0.07%
Italy	17	0.11%	10	0.08%	9	0.02%				
Denmark	18	0.10%	24	0.04%			1	0.06%		
Canada	19	0.09%	30	0.03%	5	0.06%				
UK	20	0.08%	26	0.04%			4	0.05%		
Chile	21	0.08%	8	0.08%						
Colombia	22	0.08%	9	0.08%						
Czech Republic	23	0.08%	12	0.08%						
Poland	24	0.07%	14	0.07%						
Norway	25	0.06%	28	0.04%			7	0.03%		
South Africa	26	0.06%	17	0.06%						
Luxembourg	27	0.06%	29	0.03%	10	0.02%	10	0.01%		
Indonesia	28	0.05%	21	0.05%						
Sweden	29	0.05%	23	0.04%			11	0.01%		
Greece	30	0.04%	25	0.04%						
Brazil	31	0.04%	27	0.04%						
Hong Kong	32	0.03%							9	0.03%
Peru	33	0.02%	32	0.02%						
Ireland	34	0.01%	34	0.01%			12	0.01%		
Turkey	35	0.01%	33	0.01%						
Israel	36	0.01%	35	0.01%						

Source: Swiss Re Institute

Where major weather perils will intensify most...

In west central Europe, floods account for around half of annual weather-related economic losses today. The intensity of flood hazard is expected to increase.

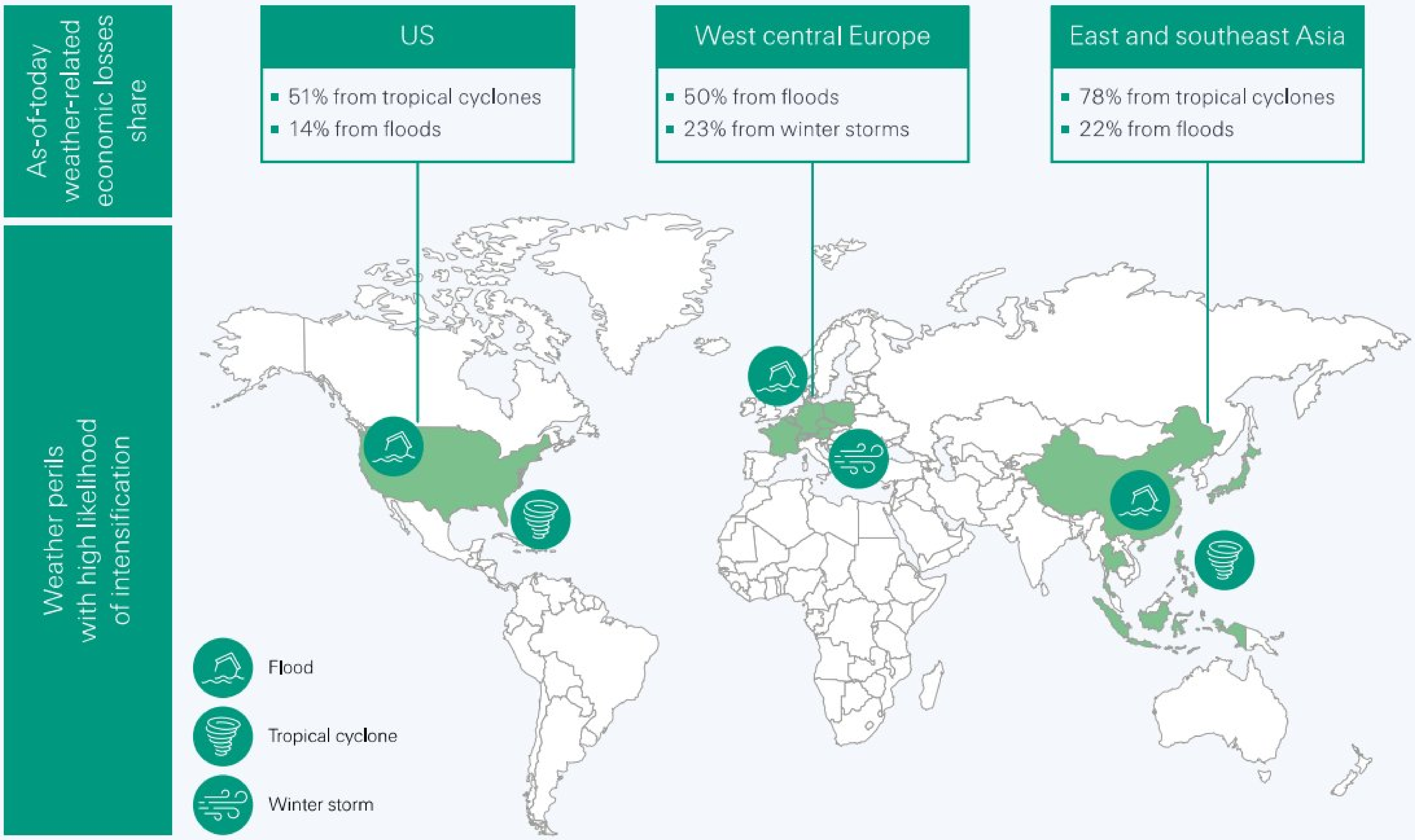
Table 1 is the first building block of our analysis. From here, we map the likelihood of hazard intensification as per the IPCC to develop a sense of the potential loss exposures of different countries in the future as weather events become more severe. Figure 4 shows that by region, the US, west central Europe, and east and southeast Asia are where floods, TCs and winter storms will intensify the most, as according to the IPCC. These also happen to be the regions where already today these perils cause the biggest losses. Almost all major economies of the world fall within these regions, a total of 16 countries accounting for around 60% of global GDP.[20]

[20] Estimate based on data from Swiss Re Institute's *sigma* data base.

Already today, flood risk accounts for 50% of annual weather-related economic (ie, property) losses in west central Europe.

Flood risk affects all of the aforementioned regions, and currently accounts for 50% of annual weather-related economic losses in west central Europe. More intense flood events could have significant impact on associated economic losses in the future. Flood hazard is expected to intensify due to changes in both pluvial floods from high intensity rainfall events, and fluvial (river) floods.

Figure 4
Regions with highest probability of hazard intensification and major as-of-today probabilistic losses from major weather perils



Source: IPCC, Swiss Re Institute

Tropical cyclones are the main drivers of weather-related economic losses in the US and parts of Asia.

While flood risk is projected to intensify most globally, Figure 4 also shows that in the US and east and southeast Asia, TCs are currently the main driver of major weather-related economic losses. Today, hurricanes pose substantial risk to the eastern and Gulf Coast states of the US. According to *sigma* data, about 50% of annual global economic losses from weather-related perils originate in the US, and about 50% of those are the result of TCs. East and southeast Asia also currently often suffer large losses from TCs, including those resulting from coastal flooding due to TC-related storm surges.

More rainfall and sea storm surges due to more intense TCs will exacerbate coastal flood risk in many regions.

Globally, the IPCC expects TCs to become more extreme, with increases in both the proportion of the most intense storms (category 3–5) and peak wind speeds. Confidence is also high that TCs will bring more intense rainfall. This, coupled with increase in coastal flooding due to rising sea levels, will exacerbate flood risk for coastal areas.

...and associated property damage risk, by country

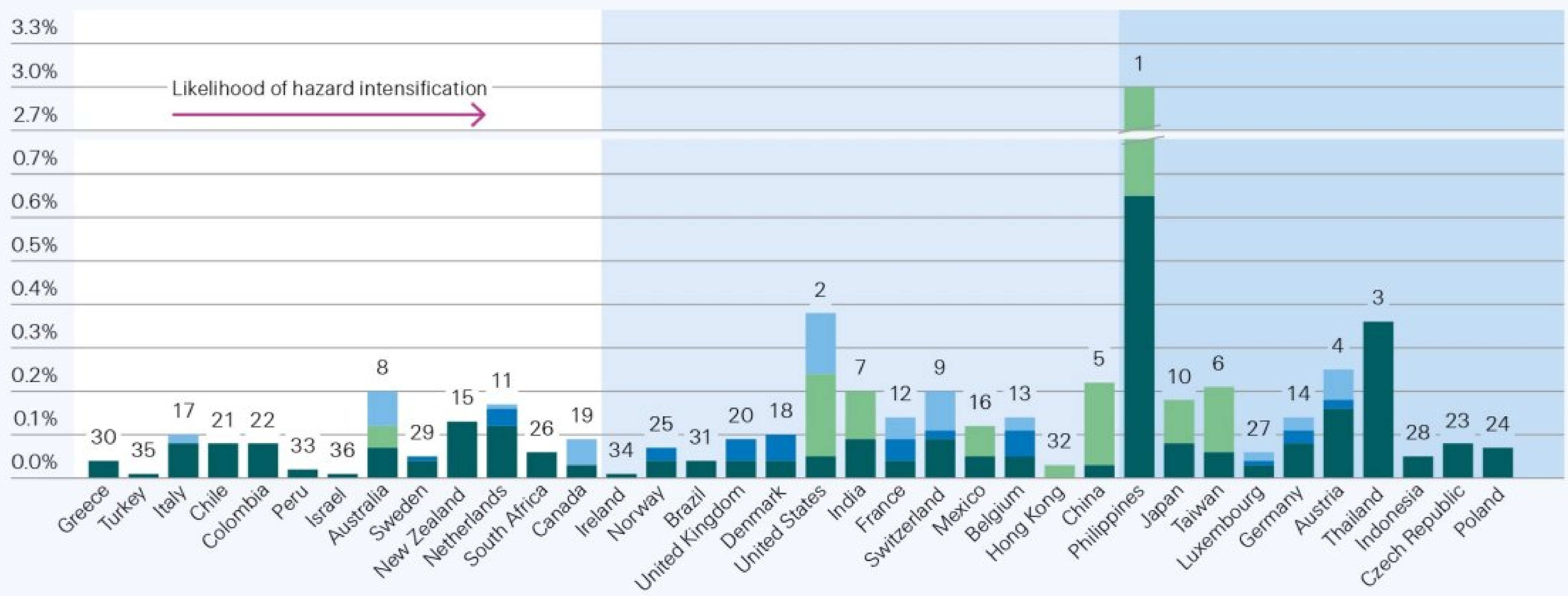
Countries that today suffer large losses from weather perils and where the probability of hazard intensification is high, appear more exposed to rising losses in the future.

Figure 5 presents current exposure to specific weather hazards per country, proxied by annual economic losses as percentage of GDP and the ranked by the probability of hazard intensification (the four major weather perils only), as according to the IPCC. With respect to hazard intensification, some countries are more prone to certain perils. Those that already today experience large weather-related economic losses as share of GDP (the Table 1 country rankings for aggregate losses from major weather perils today show in numbers above the bars) and where risk of hazard intensification is high, will likely be more exposed to potential for rising losses from increasing weather event severity in the future. The Philippines and Thailand, where the IPCC says the probability of hazard intensification is high, show to be among those countries that could fare worst in this regard. In the Philippines, TCs and flooding are the main hazards; Thailand is highly exposed to flood risk in particular.

The Philippines, the US and Thailand appear to be most exposed.

The US, which presents a combination of high economic exposure and medium likelihood of hazard intensification, also shows as amongst those countries more exposed to potential for rising losses in the future. Today, in absolute terms, economic and insured losses from weather events in the US are the highest in the world, mostly driven by TCs (hurricanes). Severe convective storms also account for a large share of the economic losses as a percentage of US GDP.

Figure 5
Probability of hazard intensification and as-of-today probabilistic annual economic losses by peril as % of GDP per country, as of today



■ Floods ■ Tropical cyclones ■ Winter storms ■ Severe convective storms

Overall likelihood of hazard intensification under the scenario of 2–2.4°C warming by 2050 (based on IPCC AR6). Countries are portrayed in terms of probability of hazard intensification, from low (left) to high (right).

Low Medium High

Numbers at top of bars indicate country rankings for economic losses as a % of GDP resulting from the four major weather perils as of today, as in Table 1.

Source: IPCC, Swiss Re Institute

Country-specific peril characteristics shape the risk landscape and potential loss outcomes.

Poland and Czech Republic rank highest for probability of hazard intensification. This is due to their specific exposures to pluvial and river flood risk. To date, however, economic losses from weather events account for just a small share of GDP in both countries. At the opposite end of the spectrum, the IPCC sees Italy as among those countries with lower probability of experiencing more intense hazards in the future in the context of the major weather perils covered here. As per the IPCC, there is medium probability of an *increase* in pluvial flooding in Italy and medium probability of a *decrease* in river flooding. Based on the likelihood of changes in CIDs as reported by the IPCC and our mapping exercise, of the four perils SCS are expected to intensify the least. Yet in 2023, Italy suffered record losses from SCS. This apparent discrepancy is a question of timing, of knowledge accumulation. To date, there are still many uncertainties with respect to the impact of climate change on SCS activity due to lack of evidence and incomplete understanding of the physical processes involved.[21] And our mapping exercise uses 2022 for countries' respective economic losses as a percent of GDP. Scientific evidence is growing that climate change may also play a role in influencing SCS, including observation of more SCS hazard activity in Italy specifically. This, alongside growing exposures, are likely to result in rising losses from SCS events in Italy in the future.

[21] For more on the evidence of climate change effects on different weather-related perils, see *sigma* 1/2023: Natural catastrophes and inflation in 2022: a perfect storm, Swiss Re Institute.

Hence countries exposed to similar economic loss potential today may experience different loss outcomes in the future due hazard intensification.

The same level of as-of-today economic loss potential translates differently by country depending on the likelihood of hazard intensification. For example, China and India today both already experience significant weather-related losses (more than 0.2% of GDP). However, the probability of hazard intensification in China is more than in India. The inference is that in the future, China may be exposed to potentially higher weather-related losses as a percent of GDP than India. In China, TCs are the main loss driver; in India, both flooding and TCs are the main risks.

In all countries, however, levels of exposure will remain the main driver of economic losses as climates change.

Economic exposure will remain the biggest driver of losses: a country with higher exposure has higher loss potential. In Europe, in absolute terms the potential losses resulting from severe weather events is highest in Germany on account of it having the largest economy and thus highest exposures. When expressed as a percentage of GDP, however, today Germany suffers lower losses than Austria, which has a much smaller economy and thus less exposure, even though the two countries have similar profiles with respect to probability of hazard intensification. Even though losses (in absolute terms) as result of hazard intensification will likely rise in both countries, the losses as a share of GDP of each country will ultimately depend on future adaptation, loss reduction and prevention actions taken.

Climate-change readiness

Are you climate-change ready?

Analysing where hazard intensification is likely to occur and whether affected countries have the capacity to respond to protect populations and assets is critical to understanding readiness for climate change. Insurance is a key tool to lower individual household and broader macroeconomic losses following extreme weather-related events. It enables accelerated economic recovery by promptly providing funds for reconstruction and thereby limiting periods of lower output.[22] Catastrophe insurance can increase resilience by improving the understanding and assessment of climate change risks and the associated possible risk reduction measures. It can also provide incentives for loss reduction behaviour.[23]

At the limit of loss prevention, risk transfer comes into play.

All told, insurance is *not* a substitute for adaptation: the two are complementary. Loss prevention fosters insurability through risk reduction and preventing losses from occurring in the first place. Inevitable residual risk (ie, where vulnerability and exposure have already been lowered) is best dealt with by insurance.

Are you ready?

Countries with similar exposure to hazard intensification may differ in terms of financial preparedness to absorb losses from more severe weather events.

Countries similar in terms of exposure to hazard intensification differ in terms of financial preparedness to absorb the losses resulting from weather-event shocks. Figure 6 ranks countries according to the probability of hazard intensification occurrence. This time the vertical axis shows countries' weather-related resilience. This reflects the share of physical assets insured against the four weather perils, drawing on our recent work on resilience indices.[24] A higher index score implies that a larger share of losses are covered by insurance and hence greater financial preparedness (resilience) to manage more severe weather events in the future. In other words, climate-change readiness.

This is a function of countries' existing level of resilience to weather shocks.

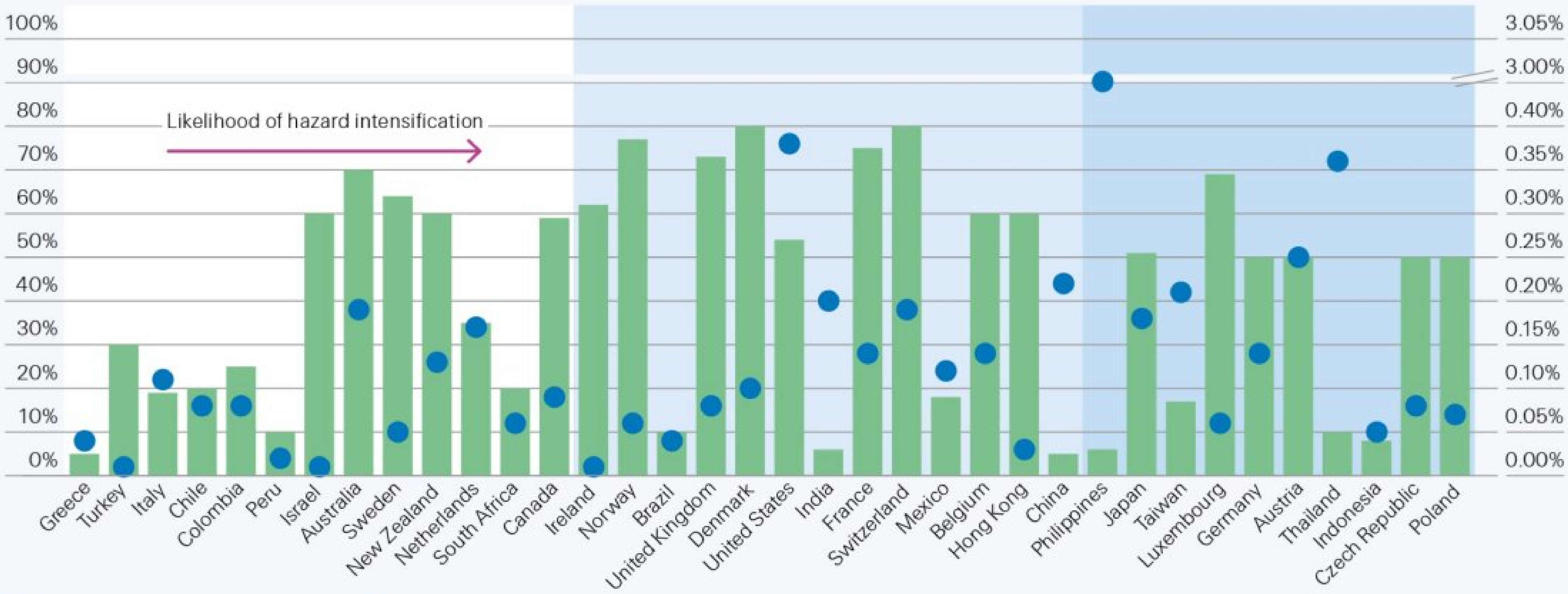
Countries in east and southeast Asia, and in west and central Europe, that display similar exposure to potential for rising economic losses demonstrate different levels of financial preparedness for hazard intensification. For an extreme example, in Figure 6 the probability of hazard intensification in India and Switzerland is medium in both, and as a share of GDP, the two countries suffer similar losses from weather events, in spite of very different economic profiles. However, the countries are at opposite ends of the resilience spectrum. With a large insurance protection gap, India is significantly less climate-change ready than Switzerland.

The potential for financial distress as a result of hazard intensification is more severe in countries where insurance penetration is low.

Severe weather events pose a major threat to societies but many countries still lack protection against the cost of damage to businesses and property. Economic losses from storm and flood catastrophes will increase as a consequence of climate change, everywhere. The adverse financial effects of climate change-driven hazard intensification will be most pronounced in countries where the establishment of loss reduction measures lags economic growth. This reflects an absence of more robust disaster protection infrastructure/measures, and also well-established insurance markets, helping businesses and homeowners to manage the financial fallout from natural catastrophes.

[22] *Policy options to reduce the climate insurance protection gap*, European Central Bank and European Insurance and Occupational Pensions Authority, April 2023.
[23] *Policy measures to reduce climate-related insurance protection gaps*, EIOPA, 13 September 2023.
[24] *sigma* 2/2023 – Restoring resilience: the need to reload shock-absorbing capacity, Swiss Re Institute. We define the SRI Natural Catastrophe Insurance Resilience Index as the ratio between protection available from private insurance and protection needed, based on modelled annual expected natural catastrophe losses. In other words, it measures the aggregate amount of insurance against major natural hazards in a country or region.

Figure 6
Probability of hazard intensification and weather-related insurance resilience index per country, as of today



Weather insurance resilience (LHS) Expected economic losses as % GDP (RHS)

Overall likelihood of hazard intensification under the scenario of 2–2.4°C warming by 2050 (based on IPCC AR6). Countries are portrayed in terms of probability of hazard intensification, from low (left) to high (right).

Low Medium High

Source: IPCC, Swiss Re Institute

Fast-growing emerging markets, many in Asia, are most vulnerable in this regard.

In emerging Asian markets like China, India, Indonesia, Thailand and the Philippines, meanwhile, high exposures as-of-today as proxied by weather-related economic losses as a share of GDP, coincide with low levels of resilience. Such fast-growing emerging markets with also large insurance protection gaps are likely under-prepared to manage the financial fallout of more intense weather shocks in the future.

Adaptation: it's imperative

Without adaptation, losses will continue to rise.

Countries are not helpless to the rising loss potential associated with climate change: there are means to reduce the amount of losses occurring in the first place. Adaptation to natural catastrophe risks (ie, adjustments to avoid, limit, or better weather the impacts and moderate potential damages) is a powerful means to structurally reduce vulnerabilities and/or exposure to hazards and, by extension, also the potential economic and financial impacts. Adaptation is critical for today's climate conditions, let alone the climate of tomorrow. Without it, property damage losses and the overall costs of inaction, will likely continue to rise.

Adaptation strategies exist and are available, today...

Much is being done but a lot more needs to be done. A host of adaptation, loss reduction and prevention strategies available today help decrease the vulnerability of people or assets exposed to hazards, and can also improve management of water resources and land use, and strengthen emergency response processes. For example, behavioural changes (where people choose to live), zoning, adopting building codes, and increasing flood protection infrastructure are all examples of adaptation measures that can significantly reduce risk of property damage. Taking the example of building codes, in the US it has been shown that adopting the latest model codes (the 2018 I-Codes, versus standards from the 1990s) in new-build real estate can save USD 6 on average for every USD 1 spent against riverine flooding specifically.[25] Similarly, USD 10 is saved for every USD 1 invested on average to reduce damage from hurricane winds. In terms of existing buildings, *retrofit* measures for residential, private-sector real estate to reduce flooding and damage from hurricane winds bring benefits that exceed costs six-fold.

[25] *Natural Hazard Mitigation Saves: 2019 Report*, National Institute of Building Sciences, December 2019.

...but the extent and effectiveness differ across countries.

Effective adaptation, however, requires careful consideration of the detailed area-specific risk equation at play. What are the *hazard(s)*? What are the sources of *exposure* and *vulnerability*? Which of these factors are driving losses? And how might tomorrow differ from the past? To date, the extent and effectiveness of such strategies and/or infrastructure, and the resources available to build and deploy risk prevention and reduction and adaption measures, have varied greatly from country to country. Adaptation projects often come with significant lead times, which adds to the urgency for action today.

More than wind, water and climate at play

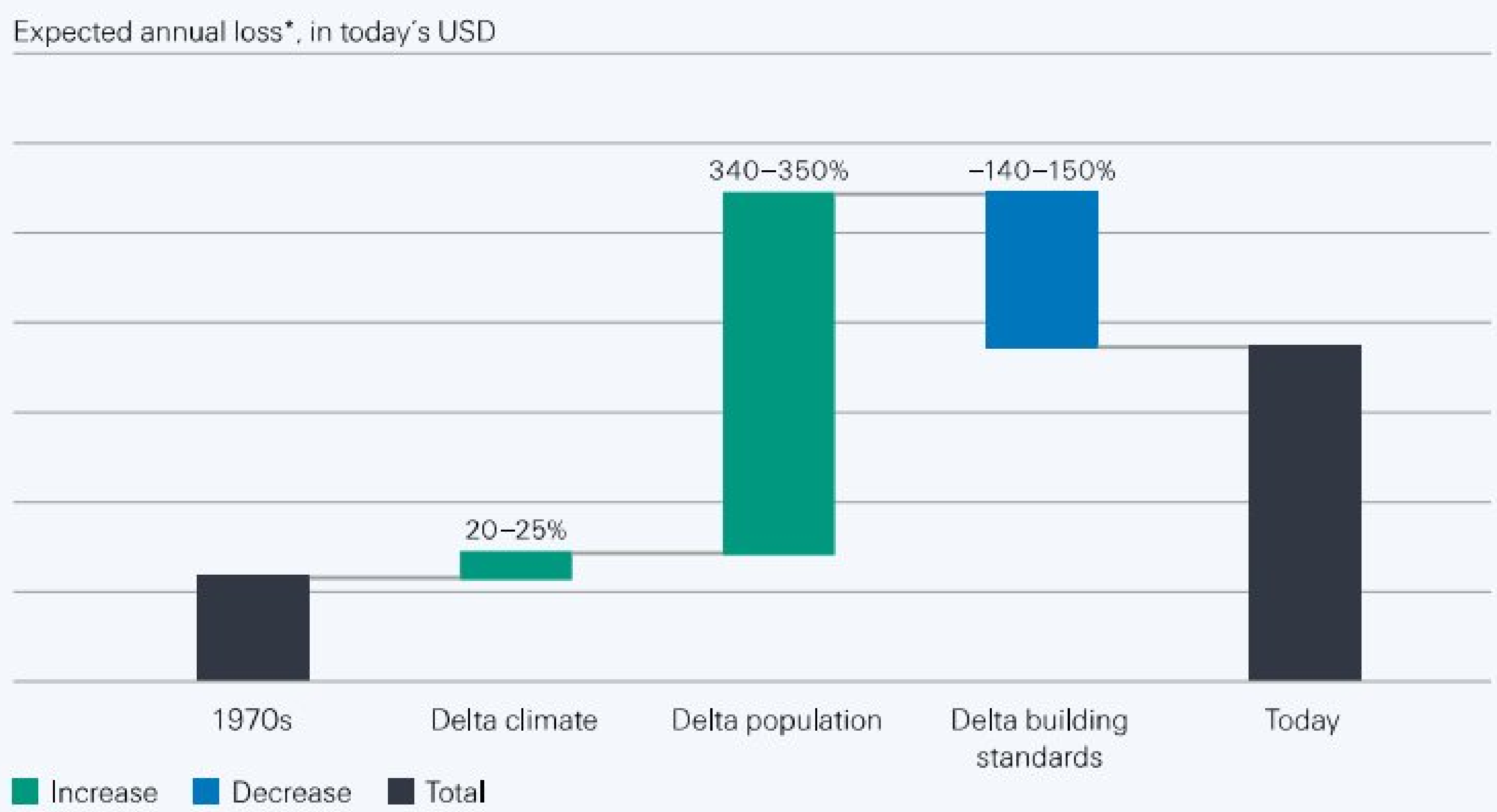
Hurricane Ian in 2022 is a prime example of exposure growth in exposed regions.

In 2022, Hurricane Ian, the second most costly hurricane ever for the insurance industry, demonstrated the loss potential of a single major hurricane hitting a densely populated coastline, and the potential risks involved when people settle in regions prone to experience extreme weather events. Since 1970, the population where the storm made landfall, the Cape Coral-Fort Meyers metro area, has increased by 620%, exceeding both the population increase in the state of Florida (+217%) and the entire US (+65%).[26]

A concentration of valuable assets in regions that are hazard prone...

Figure 7 shows that such population growth is the most significant driver of increases in hurricane losses, to the tune of a 350% increase today compared to 1970 (for wind risks and for residential exposure only). Reducing vulnerability by strengthening building codes, a key element of adaptation, has lowered the loss potential but is insufficient to compensate for expected losses from value accumulation. This calls for an acceleration of adaptation efforts, both in high-growth areas and also in areas where growth has been more modest. Most of all, vulnerability-reduction measures such as erecting more resilient buildings should be accompanied by integrated urban planning and land-use restrictions. For example, people should be discouraged from moving to high hazard areas like floodplains, or else rising pressure on weather-related property losses will continue unabated and even intensify as climates change. Land issues, already central to the challenges of today's urban population growth, are at the core of urban climate challenges.

Figure 7
Changes in expected insured losses in Hurricane Ian's landfall area, by driver



*Residential exposure and wind only. Delta represents changes between today and the 1970s.
Source: Swiss Re[27]

...and lagging adaptation can drive weather-event related losses higher.

This is even more of an issue in developing countries where unplanned development creates higher levels of disaster risk. The extreme flood in Thailand in 2011 is a case in point. Rapid, mostly unplanned urban sprawl in high-risk areas, meant replacement of natural water retention areas and thus loss of natural drainage systems, a key contributor to the flood's catastrophic losses. The Chao Phraya River basin had become home to more than 40% of Thailand's population at the time of the flood occurrence. It is also home to most of Thailand's manufacturing industry, which had grown rapidly during years of strong

[26] *sigma* 1/2023 op. cit.
[27] *Ian revisited: Disentangling the drivers of US hurricane losses*, Swiss Re, September 2023.

economic growth, with many foreign companies setting up operations there.[28] Rising exposure in a context of insufficient water management efforts and poor land planning led to catastrophic losses amounting to 12.6% of Thailand's GDP in 2011.[29]

Thailand is exposed to high and medium probability of intensification of flash and river floods, respectively.

The growth rate of built-up surfaces in Thailand over the past 20 years is 43%, with more than half (55%) in areas exposed to inland flooding.[30] The economic exposure to weather hazards in Thailand today stands at an already-elevated 0.36% of the country's GDP (as in Table 1), primarily owing to flood risk. In addition, our analysis (as in Figure 5) finds Thailand as among those countries most susceptible to climate change risk. There is a high and medium probability of intensification of flash floods and river floods, respectively. The downstream area of the Chao Phraya River basin is particularly prone to both river and flash floods.

Since the devastating floods of 2011, Thailand has undertaken various measures to reduce flood risk. But there is more to do.

Since the 2011 floods, Thailand has undertaken various measures to reduce risk of water inundation. The immediate response was to strengthen and raise flood walls along the lower reaches of Chao Phraya and dikes in the north-eastern part of Bangkok. Further, Thailand has a 20-Year National Strategy (2018–2037) and formulated the 20-Year Master Plan on Water Resources Management (2018–2037), and the National Adaptation Programme (NAP)[31] has flood as a key focus area. There are also international collaborations, for example the Thai-German Climate Programme (TGCP) – that focuses on Integrated Water Resources Management (IWRM) and Ecosystem-based Adaptation (EbA).[32] Currently the NAP appears to be in the exploratory phase. Many recommendations of the Post Disaster Needs Assessment of the 2011 floods have not yet been addressed. The institutional and legal reform process started in 2017 but is not yet complete.[33]

Urban sprawl in high-hazard areas also drives flood loss risks higher.

There is an urgent need to mitigate the flood risk in Thailand and other countries in Asia including Indonesia, India and China. Dense urban conurbations around large river systems, often in unplanned settlements, strongly increase flood risks. According to Swiss Re, in China built-up areas have expanded by 68% over the last 20 years, half of which (50%) are areas exposed to inland flooding. The same respective rates for India are 71% and 38%.[34] The larger urban populations are, the higher the need for loss prevention and adaptation measures. In addition, many of Asia's mega-cities are located in low-lying coastal regions. In cities like Jakarta, Bangkok, Mumbai, Guangzhou, and Shanghai, the combined effects of urban sprawl into high-hazard areas land subsidence and sea level rise have accentuated the loss potential from coastal flooding events.[35]

[28] *The world's costliest flood: the 2011 Thailand flood, 10 years on*, Swiss Re Institute, 30 September 2021.
[29] *Thailand Economic Monitor: Coping with Floods and Drought*, World Bank, June 2023.
[30] Data from *Global Human Settlement Layer*, European Commission's Joint Research Centre, 9 December 2021, with elaboration from Swiss Re.
[31] "Do governments track the implementation of national climate change adaptation plans? An evidence-based global stock take of monitoring and evaluation systems", *Environmental Science & Policy*, 2021.
[32] See *IWRM Action Hub* and *Ecosystem-based Adaptation*, The International Union for Conservation of Nature.
[33] *Thailand Economic Monitor: Coping with Floods and Droughts*, The World Bank, June 2023
[34] Data from European Commission's Joint Research Centre, op. cit.
[35] *Cities at risk: Asia's coastal cities in an age of climate change*, East-West Center, 2010.

Making the road ahead less hazardous

Rising temperatures = rising losses and costs to economic activity

There is no way around the need for climate change mitigation.

In the face of climate change, adaptation and insurance can ultimately only go so far. No matter how advanced adaptation measures are or how developed an insurance market is, neither can fully prevent the accumulation of risk potential and associated losses as hazards continue to intensify. Climate change mitigation (ie, reducing GHG emissions, the root cause of global warming) is essential to counter the build-up of physical risks (hazard intensification) and lessen the likelihood of the most catastrophic of climate change effects materialising.

Already today, the economic impact of severe weather extends beyond property damage.

Already today the full economic impact of severe weather goes well beyond property damage. It can affect GDP entirely unrelated to or even in the absence of direct property damage. Trade disruptions, the effects of increased morbidity or mortality on lives and livelihoods, or lower agricultural or labour productivity are just some of the additional physical risks posed by extreme weather events.

Evidence from the 2018 drought in Europe illustrates the complex web of impacts.

Drought is a case in point, demonstrating also that hazards other than the four major weather perils covered in this report need to be considered. For example, the drought in central Europe in 2018 induced a complex web of impacts spanning many sectors. It caused water levels in most rivers, including the Rhine, to fall to critical levels. This mostly did not lead to physical damage to property, but the resulting disruptions to transportation and power supply, business interruption, extensive crop failure, and livestock and forestry impacts had significant economic repercussions. Many ships could only carry 40% of their usual cargo on the Rhine, squeezing European supplies of important industrial commodities.[36] On parts of the Elbe, there was no ship traffic at all. The German section of the Elbe River basin saw a 20–40% drop in production of staple crops.[37] Impaired water supply led to partial shut-downs of nuclear power plants.[38] In Germany, industrial output fell 1.5%, and GDP was down 0.4%.[39] In the Netherlands, the estimated economic impact was EUR 0.45 – 2.08 billion, or about 0.3% of GDP.[40] More recently, since 2023 the worst drought in the 143-year history of the Panama Canal has affected up to 25% of maritime trade flows of several countries in Latin America, with disruptions felt as far as Asia.[41]

Climate change will be a main driver of future economic risks.

As climate change contributes to the intensification of severe weather events, so too are the associated economic repercussions set to intensify, with the overall fallout amplified by the interconnectedness of the global economy. In our view, beyond the natural catastrophe losses driven by economic growth and urbanisation, in the longer term, climate change will be a main driver of economic risks (including GDP growth loss, volatile inflation and financial market stability). It will also drive economic accumulation risk, that is the potential for adverse impacts of one event to spread to various parts of the economy.[42]

Both acute and chronic physical risks pose a threat to economic activity.

The economic impact from climate change is not limited to severe weather events (or *acute* physical risks). *Chronic* physical risks arising from the gradual increase in temperature over time, such as sea level rise and more prevalence of infectious diseases, also impact economic activity. In our 2021 report *The Economics of Climate Change: no action not an option*, we estimate the GDP impact of chronic physical risks: compared to a no-warming scenario, the world could lose up to 7–10% of GDP by mid-century if warming stays on the current trajectory, and the Paris Agreement target is not met.[43]

[36] *The great drought of 2018: Germany's endless summer* Energy Transition, 26 December 2018.
[37] *Cross-sectoral impacts of the 2018–2019 Central European drought and climate resilience in the German part of the Elbe River basin*, Regional Environmental Change, 1 February 2023.
[38] "Lessons from the 2018–2019 European droughts: a collective need for unifying drought risk management," *Natural Hazards and Earth System Sciences*, 2022.
[39] "Extreme Weather Events and Economic Activity: The Case of Low Water Levels on the Rhine River", *German Economic Review*, March 2023.
[40] *Economische schade van droogte in 2018*, Ecorys, 2019.
[41] *Climate Change is Disrupting Global Trade*, IMF, 15 November 2023.
[42] In insurance, accumulation risk is the potential loss exposure of one event spreading to multiple lines of business in an insurer's portfolio.
[43] *The Economics of Climate Change: no action not an option*, Swiss Re Institute, 2021.

In 2021, we estimated that the world could lose up to 7–10% of GDP by mid-century if global warming stays on the current trajectory.

Recap: *The economics of climate change: no action not an option*
Our 2021 study uses scenario analysis to simulate the possible outcomes in terms of GDP associated with various temperature increases by 2050 based on several chronic physical risk impact channels. The latter includes the effect of rising temperatures on agricultural productivity; on human health (morbidity and mortality); on labour productivity (heat stress); on sea level rise and the increased risk of flooding of areas of economic activity; on tourism flows; and on household demand for energy. The study additionally accounts for uncertainty by 1) approximating the effect of omitted economic impact channels not explicitly modelled (eg, disruptions to supply chains impacts on biodiversity);[44] and 2) applying multiplicative factors to the simulated economic impact to capture the potential for tail risk parameter uncertainty.

The IPCC puts likely global warming at 2°C by mid-century, meaning the Paris Agreement target would not be met.

On the current path, global warming is likely to be at 2°C by mid-century (range of 1.6–2.5°C on average over 2041–2060), and at 2.7°C by the end of the century (2.1–3.5°C from 2081–2100).[45] This corresponds to two of the warming scenarios in our 2021 report, which in turn simulates that warming of 2–2.6°C by mid-century could lead global GDP being 11% to 14% less than if there were no warming. Reaching the Paris Agreement ambition of 1.5°C warming would see GDP contract by around 4 percentage points (ppt) less.

The broader economic costs of inaction

Risks are seen as extending beyond economic activity, including price...

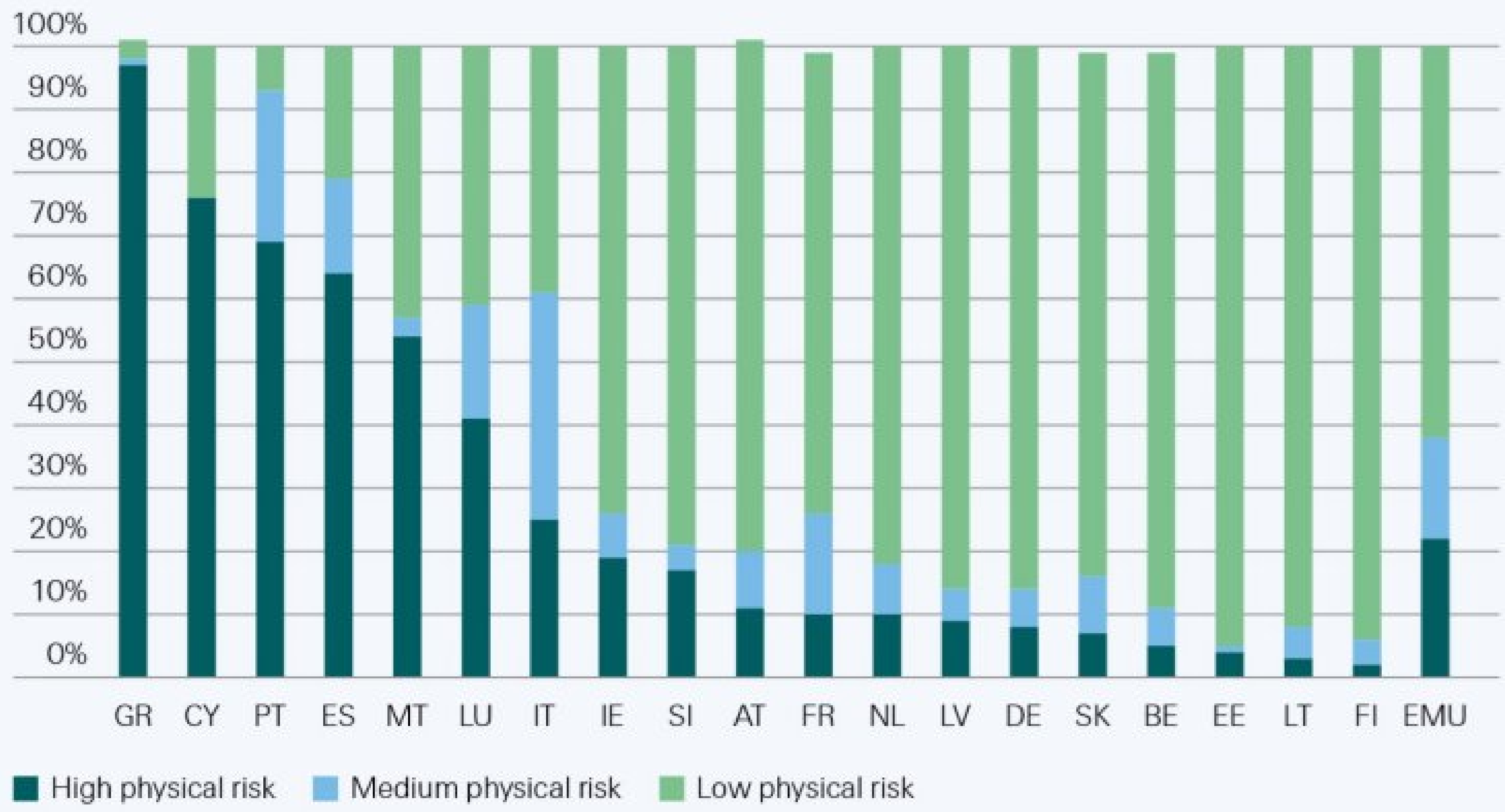
Climate change also poses threats to price and financial stability, as recognised by central banks.[46] Extreme weather events can create inflation volatility by causing near-term fluctuations in output supply (eg, by disrupting production and supply chains) and demand (hoarding).[47] Gradual temperature increases, in turn, push agricultural and other prices higher as productivity and output fall. Even if aggregate inflation stays unchanged, changes in food prices alone can leave households worse off.[48] The share of household spending allocated to food ranges from 20–60% in emerging economies vs 10–20% in advanced markets.[49] Higher food price inflation therefore disproportionately negatively impacts consumers, irrespective of whether aggregate inflation is stable. More indirectly, the transmission of monetary policy (ie, central banks' ability to control inflation) to the economy could be impaired as losses generated by physical risks weigh on financial institutions' balance sheets or bring about sharp and abrupt rises in credit risk premiums, making the cost of borrowing more expensive for households and businesses.[50]

...and financial stability.

Concerns around financial stress have prompted the development of climate stress tests as a tool to integrate climate-related risks into financial stability monitoring. Globally, over 67 climate stress tests have been completed, are ongoing or are planned by supervisory authorities.[51] Most recently, six large US banks participated in a pilot climate scenario exercise in 2023.[52] In Europe, the latest example is the European Central Bank's (ECB) climate stress test conducted in the first half of 2022.[53] The exercise concluded that the materialisation of climate risk can have a sizeable impact on bank profitability, but that banks with strong capital buffers should be able to absorb climate-related losses. Exposure to physical risks, however, is geographically concentrated. For example, in the euro area 22% of banks' loans to non-financial corporates (NFC) are exposed to high physical risks, mostly driven by wildfires and affecting countries in southern Europe (see Figure 8). In Greece, Cyprus, Portugal and Spain, the share is more than 60%.[54]

[44] For more on biodiversity impacts, see *Biodiversity and ecosystems services: a business case for insurance*, Swiss Re Institute, September 2020.
[45] *IPCC Sixth Assessment Report*, op. cit. and Climate Action Tracker op. cit.
[46] See, for example *The climate and the economy*, European Central Bank 2023.
[47] "The Impact of Disasters on Inflation," in *Economics of Disasters and Climate Change*, April 2018.
[48] European Central Bank, 2023, op. cit.
[49] *Policy Responses to High Energy and Food Prices* IMF, 24 March 2023.
[50] *Climate change and monetary policy*, European Central Bank, 31 August 2021.
[51] *Climate scenario analysis by jurisdictions. Initial findings and lessons*, FSB/NGFS, November 2022.
[52] Ibid.
[53] See *2022 Climate Stress Test*, European Central Bank, 2022.
[54] *Climate stress tests: Are banks fit for the green transition?*, Deutsche Bank Research, 12 January 2023 and *ECB economy-wide climate stress test*, ECB Occasional Paper 281, September 2021.

Figure 8
European bank's exposure to physical risk (share of NFC loans, in %)



Source: ECB economy-wide climate stress test, Deutsche Bank Research, Swiss Re Institute

Policymaking challenges and trade-offs could be exacerbated.

Simultaneous strains on economic activity and price and financial stability complicate policymaking, exacerbate trade-offs and risk heightened economic instability. Central banks, for example, could face a more difficult balancing act between supporting growth and tempering inflation. However, in a world with structural commodity, food and natural resource shortages, higher inflation and inflation volatility may need to be tolerated.

Private capital as a financing solution

Mitigation requires financial resources.

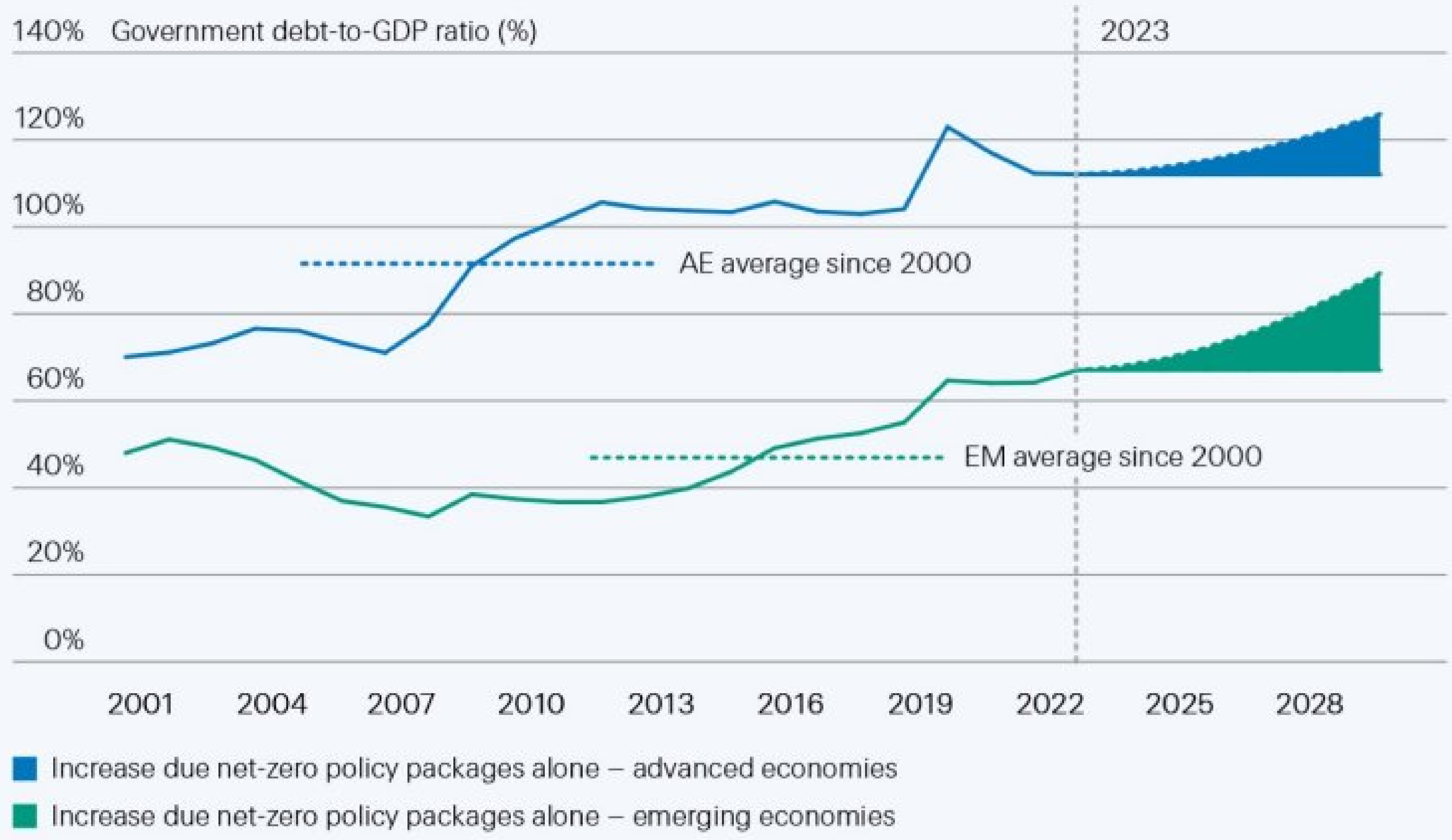
Climate change mitigation requires significant financial resources. In 2022, we estimated a cumulative global investment gap of more than USD 270 trillion (USD 9.4 trillion on average annually) to bring about the economic transformation that would deliver net zero emissions by 2050.[55] According to the IEA, to reach net zero emissions, annual global investment in clean energy alone needs to reach USD 4.2 trillion already by 2030 (from USD 1.7 trillion in 2023; or from 2% of global GDP annually to nearly 4% by 2030).[56]

But public debt sustainability concerns in many countries...

Climate change mitigation is a global public good and there are limits to the extent that the gap can be government financed (see Figure 9). Currently about 60% of all low-income countries are either in debt distress or at high risk thereof, exacerbated by higher borrowing costs due to rising interest rates in advanced economies.[57] As higher rates and debt levels push government interest expenses higher, also in advanced markets, domestic debt strains are set to increase. Net-zero policy packages aside, according to IMF forecasts emerging market government debt-to-GDP ratios are already set to be about 25 percentage points (ppt) higher on average between 2023 and 2028 (at 71%) than the long-run average since 2000 (46%). Even among advanced economies, the IMF estimates that government debt will average 114% of GDP between 2023 and 2028, roughly 20 ppt more than the long run average.[58] Additionally, climate ambitions vary greatly across countries as governments do not agree on how to share the burden of responsibility for spending on climate change mitigation.

[55] *Decarbonisation tracker: progress to net zero through the lens of investment*, Swiss Re Institute, October 2022. The investment gap figure excludes investment in fossil fuels that will still be forthcoming over the next years.
[56] *World Energy Outlook 2023* and *World Energy Investment 2023*, International Energy Agency, 2023.
[57] *2023 International Debt Report*, World Bank, 2023.
[58] IMF World Economic Outlook Data.

Figure 9
Historical government debt levels and cumulative future changes associated with net zero policy packages alone, relative to business as usual (% of GDP)



Source: IMF Fiscal Monitor 2023, Swiss Re Institute

...shift the onus to private capital markets.

The private sector is by necessity a key part of the solution, and has capacity to be so. Today the amount of private sector capital in the green sector is negligible. There can be more. In 2022, the total value of global bond markets (publicly traded) was more than USD 120 trillion.[59] The overall sustainable debt market, however, still constitutes less than 5% of the total, standing at USD 5.6 trillion in the third quarter of 2023 (comprising USD 3.9 trillion outstanding sustainable debt securities, and USD 1.7 trillion sustainable loans).[60] And of new global debt issuance, only around 5% is currently ESG-labelled (see Figure 10). Indeed, the IEA's net zero emissions scenario sees private sources contribute more than 70% to clean energy investment by 2030 (implying an over threefold increase from recent levels).[61] In addition, there is scope to mobilise more private funding for adaptation projects: currently less than 2% of adaptation finance globally comes from private sources.[62]

Figure 10
Sustainable debt as a share of global debt market issuance (%)

Source: Institute for International Finance, Swiss Re Institute

[59] Based on Bloomberg data.
[60] Data from the Institute of International Finance
[61] *World Energy Outlook 2022*, IEA, October 2022.
[62] *State and Trends in Climate Adaptation Finance 2023*, Climate Policy Initiative, 2023.

Societal benefits of investing outweigh the costs.

While the size of investment required for mitigation and adaptation is large, so too is the net benefit to society. According to the IMF, the potential benefits from avoiding physical damages from the impacts of climate change greatly offset the climate mitigation policy costs. It sees the net potential GDP benefit from transitioning to net zero by 2050 as close to 8%.[63] Investment in *adaptation* also protects economies' growth capacity, fiscal resources and delivers other economic benefits. Mirroring the example of deployment of latest building codes in the US, other studies have shown that adaptation investments for various hazards can generate economic dividends that outweigh the cost 2:1 to 11:1 (see Table 2). For example, according to the World Bank, every USD 1 invested in sustainable infrastructure can unlock new economic opportunities and jobs, yielding an average USD 4 in economic benefits.[64]

Table 2
Summary of benefit-to-cost ratios of select adaptation investments

Sector	Intervention	Benefit-to-cost ratio	Source
Infrastructure	Retrofitting utilities and transportation infrastructure	4:1	US National Insitute of Building Sciences
	Making new infrastructure more resilient in EMs	4:1	World Bank*
	Making new infrastructure resilient	4:1 (2:1 to 10:1)	Global Commission on Adaptation
Real estate	Retrofitting existing private-sector buildings	4:1	US National Insitute of Building Sciences
	New build meeting 2018 I-Codes**	11:1	US National Insitute of Building Sciences
	New build exceeding select 2015 I-Codes***	4:1	US National Insitute of Building Sciences
	New build adopting Florida building codes****	3:1	Wharton Risk Center*

Note: **Lifelines: The Resilient Infrastructure Opportunity*, World Bank, 2019 and *Building Code Economic Performance under Variable Wind Risk*, Risk Management and Decision Processes Center, The Wharton School, University of Pennsylvania, 2018; **Versus standards from the 1990s. Total against riverine floods, hurricane winds and earthquakes; ***Total against riverine floods, hurricane winds and surge, earthquakes, and wildland-urban interface fire; ****Against wind damage.
Source: Swiss Re Institute

Multiple macro-financial impediments constrain attracting and scaling up private-sector finance.

Yet mobilising the needed investment is not merely a matter of finding sources of financing. For one, the supply of investable projects remains limited. There is a lack of large investment grade projects and liquid markets, resulting in stringent competition for a scarce pipeline of projects and compressed margins.[65] Moreover, though many tools and approaches (eg, definitions, taxonomies, and ratings, verification and certification schemes) to aid in scaling climate investments are being developed, a lack of interoperability and consistency has created a fragmented investment landscape. [66] Additionally, high upfront capital and transaction costs, and risks associated with climate projects (eg, stemming from long time frames or uncertainties about future climate policies or technological costs) may imply insufficient returns in unproven markets.[67]

In addition to the direct climate-related spend, governments play a critical role in incentivizing private sector action.

More fundamentally, the responsibility for investment in mitigation and/or adaption (eg, in the case of real estate or infrastructure) is typically tied to asset ownership. Even where benefit-to-cost analysis yields net benefits to society, there may be no business case for private investment. The policy and regulatory landscape therefore play a key role in shaping private investment opportunities. Governments and the public sector more broadly need to create the economic incentives to turn the public good benefits of green investments into private economic incentives, lower investment barriers, and improve data transparency and standardisation to foster private sector investment. Partnerships between investors and governments can also provide an effective way to share risks, achieve scale and establish a pipeline of investment-grade projects.[68]

[63] *Benefits of Accelerating the Climate Transition Outweigh the Costs*, IMF, 5 December 2023.
[64] For more on the costs, benefits, and barriers to different adaptation measures, see *sigma* 2/2023, op. cit.
[65] *Investment-Grade Climate Change Policy*, UNEPFI, September 2011.
[66] *2021 Synthesis Report*, G20 Sustainable Finance Working Group, 2021.
[67] UNEPFI, op. cit.
[68] *Green Infrastructure in the Decade for Delivery: Assessing Institutional Investment*, OECDiLibrary.

The US Inflation Reduction Act of 2022 is an example of a step in the right direction.

A recent example of a step in the right direction is the *US Inflation Reduction Act of 2022*. Not only is it set to channel USD 369 billion to clean energy developments and climate investments in infrastructure, but it incentivises greater private sector action.[69] Boston Consulting Group expects strong multipliers, with total investment potential north of USD 1 trillion.[70] Moreover, as part of this legislation, the Federal Emergency Management Agency (FEMA) – responsible for helping communities rebuild post-disaster – has announced it will for the first time fund net-zero energy projects, thereby helping communities rebuild by incorporating smart, net-zero energy techniques and technology when rebuilding critical infrastructure like hospitals and fire stations.[71] In the EU, meanwhile, the *Net Zero Industry Act* includes the intention to set in place a predictable and simplified regulatory environment, to promote investment in the production capacity of products key to meeting the region's climate goals.[72]

[69] *Alliance of CEO Climate Leaders: Open letter for world leaders at COP28*, WEF, 24 October 2023.
[70] *US Inflation Reduction Act: Climate & Energy Features and Potential Implications*, BCG, August 2022.
[71] *Biden-Harris Administration Announces New Actions to Help Communities Reduce Greenhouse Gas Emissions, Build Back Stronger, Cleaner and More Resilient Post-Disaster*, FEMA, 30 January 2024.
[72] *The Net-Zero Industry Act: Accelerating the transition to climate neutrality*, European Com., 16 March 2023.

Concluding summary

The following visual presents the key narrative and takeaways of this report.

1 **The warming continues**
Changing climates will continue to have widespread and intensifying impacts on weather conditions and economies.

2 **Countries facing high economic exposure and hazard intensification are most at risk**
Understanding how natural hazards shape risk landscapes is critical to advancing preparedness for climate change.

3 **No alternative to climate adaptation...**
As the planet warms, property losses from extreme weather events will likely continue to rise. Adaptation is key to curb this growth.

4 **...and risk mitigation**
So too is climate change mitigation, to curb underlying risk accumulation potential. This requires significant investments and joint action across all stakeholders.

Measure	Actions	Primary stakeholders			Role of the insurance industry and other or primary stakeholders
		Government/ public sector	Private sector	Insurance industry	
Risk reduction					
Mitigation	Reduce GHG emissions	✓	✓		Governments are in the lead to drive GHG emission reductions at scale, with the entire private sector also involved as every area of the economy needs to decarbonise.
Adaptation	Loss reduction, loss prevention and adaptation	✓	✓	✓	The insurance industry, together with governments, households and businesses, plays an important role in establishing and enforcing risk reduction standards.
Investment in mitigation and adaptation	Public and private	✓	✓	✓	As part of mitigation and adaptation actions, the public and private sectors have a role in direct financing of climate action. Mobilising private sector investment requires government support in the form of policies that create incentives and lower investment barriers. Insurers, meanhwhile, can catalyse investments, either directly as a long-term investor, or indirectly by underwriting climate-positive projects and sharing risk knowledge.
Risk transfer	Private insurance	✓		✓	Where loss potential has been reduced (through mitigation and adaptation actions), the residual risk for both private and public assets can be transferred to the insurance industry. Government can support insurance take-up via tax reduction incentives. Other risk transfer solutions involving both the public and private sectors include microinsurance schemes for low-income, vulnerable households; mandatory insurance programmes; government-backed programmes for risks that are not fully insurable; and public-sector insurance programmes.

Source: Swiss Re Institute

Appendix – methodology

- The IPCC AR6 report provides the likelihood of hazard intensification for regions across the world for a large list of "climatic impact drivers" (CIDs).

- We map these CIDs to our definitions of natural catastrophe loss-inducing perils to derive the likelihood of hazard intensification, specifically for tropical cyclones (TCs), winter storms in Europe, severe convective storms (SCS), and floods. We exclude dry perils (eg, heatwaves, drought).

- Similarly, the CIDs are mapped to a selection of weather-related peril definitions relevant to re/insurance industry. For example, TCs are mapped to two CIDs: wind tropical cyclones and coastal flood.

- Our analysis considers five illustrative scenarios as shared socio-economic pathways (SSPs) that cover the range of possible future development of anthropogenic drivers of climate change. These scenarios are used to drive climate models to project future changes in climate system. These are models that participate in the Coupled Model Intercomparison Project Phase 6 (CMIP6) of the *World Climate Research Programme* and include new and better representations of the physical world compared to climate models considered in previous IPCC assessment reports.[73] These climate models produce projections of not only direct impact in terms of temperature rise but also indirect impacts such as changes in sea levels, rainfall patterns, soil moisture, etc.

- We mapped the IPCC defined regions to individual countries. For large countries in terms of land area, multiple regions make up a single country. For smaller countries, one or more countries are mapped to a single region. For example, the regions north central America, western north America, central north America and eastern North America are mapped to US.

- The hazard intensification has three categories: low confidence, medium confidence and high confidence in direction of change. The change can be either an increase or decrease in hazard intensification. These categories are mapped to a scale of 1 to 10. Then peril-wise estimates are derived by aggregating across mapped CIDs for large countries averaging across different regions.

- The likelihood of intensification for each peril is aggregated for each country using the expected economic loss for the peril as weights, The weight reflects the overall likelihood of hazard intensification for weather-related catastrophes for each country.

- In case of large countries such as the US, Australia, China etc., more than one IPCC regions are mapped to a country. Here the impacts of climate change in different regions are averaged out and then applied to the country level economic loss estimates. This adds another level of uncertainty to our estimates. This is because not all perils are not relevant for all regions and even when relevant, the losses seen are not of similar magnitudes. The ideal scenario would be to have economic losses for each IPCC region, which could have be combined with the climate change intensification likelihood factor and aggregated across regions.

- The model here does not account for compound events (intensification of two or more perils occurring together). For example, TC-induced flooding from storm surge in coastal areas coupled with pluvial flooding caused by extreme rainfall events.

- The paper covers the current trajectory and does not account for climate tipping points.

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