TECHNICAL DOCUMENTATION

Sovereign Climate Risk Rating

COVERING AGGREGATED IMPACTS OF PHYSICAL RISKS ON COUNTRY-LEVEL FORWARD-LOOKING TO THE HORIZONS 2035 AND 2050

Scientific Climate Ratings
An EDHEC Venture

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About Scientific Climate Ratings

Scientific Climate Ratings is an independent climate risk ratings agency born from the EDHEC Climate Institute's applied research ecosystem. We deliver forward-looking ratings, data, and analytics that quantify the financial materiality of climate risks for infrastructure, real assets, corporate, and sovereign exposures worldwide. Combining high-resolution geospatial data, proprietary climate risk models, and one of the world’s largest financial datasets, Scientific Climate Ratings evaluates both transition risks (linked to the shift toward a low-carbon economy) and physical risks (arising from climate hazards such as floods, storms, heatwaves, and wildfires).

Our ratings and climate metrics assess climate exposure and financial vulnerability across multiple climate scenarios and time horizons, enabling users to move beyond qualitative climate risk assessments toward fully quantified inputs for financial decision-making. Applications include capital allocation, risk pricing, resilience planning, portfolio construction, scenario analysis, and regulatory disclosures.

Climate ratings are currently available for more than **6,000 infrastructure assets** globally, over **180 sovereigns**, and can be extended to any real asset worldwide through the ClimateMetrics self-assessment platform. Scientific Climate Ratings will expand its coverage in 2026 to **4,000+ listed equities**, delivering consistent, comparable, and forward-looking climate ratings across asset classes.

Scientific Climate Ratings aims to set a new standard in climate risk management, steering capital towards a more resilient future.

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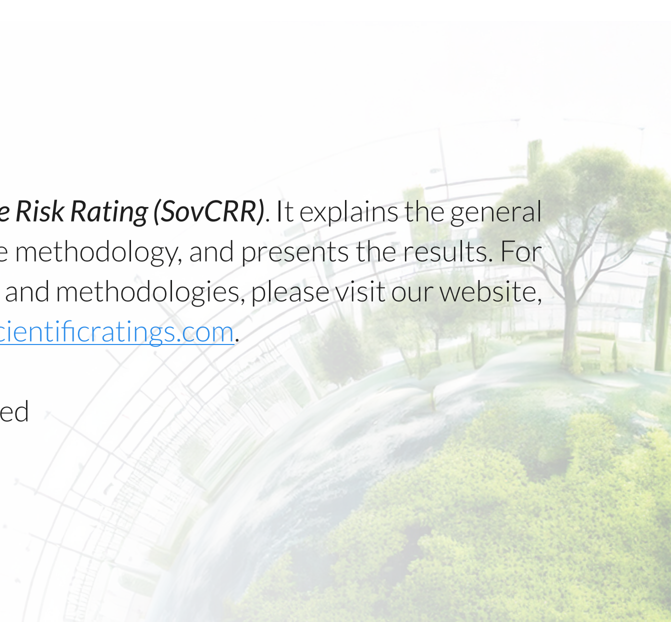

This document summarises the development of ***Sovereign Climate Risk Rating (SovCRR)***. It explains the general approach, outlines the assumptions and calculations, justifies the methodology, and presents the results. For more information on Scientific Climate Ratings and our products and methodologies, please visit our website, where we share a variety of technical documentations: https://scientificratings.com.

Scientific Climate Ratings developed a rating for countries that reflects their sensitivity to present and future climate risks: the **Sovereign Climate Risk Rating** (SovCRR). As a potential measure of climate exposure and vulnerability, we provide SovCRR and related climate risk metrics under various climate scenarios and for two time horizons.

The modelling approach focuses on structural, macroeconomic transmission channels between warming and sovereign financial fundamentals. It captures permanent, compounding damages to economic output that are not yet reflected in sovereign spreads — a known market blind spot. At this stage, SovCRR covers chronic physical risks from temperature-driven productivity shifts.

1. General Approach

The methodology for calculating the SovCRR follows a forward-looking approach, considering exposure and vulnerability to chronic temperature-driven productivity impacts stemming from climate change over two future horizons: 2035 and 2050. The resulting output is not a score in isolation. Instead, the rating sits atop a single, economically interpretable quantity — the **unconditionally expected physical-risk-induced impact on gross domestic product (GDP) per capita**[1], in other words: the projected reduction in economic output relative to a world without further climate change, averaged across all climate scenarios weighted by their probability, at each horizon. Expressing the rating in these terms allows investors to price sovereign climate risk, not merely rank it.

To cover a wide range of future pathways, the SovCRR is calculated within the **Scientific Climate Scenarios** framework, developed by the EDHEC Climate Institute (ECI) to support forward-looking climate risk analysis, valuation, and investment decision-making. Building on existing climate scenarios from the Network for Greening the Financial System (NGFS), the framework enhances their usability for financial institutions and investors through three major innovations: granularisation, extension, and probabilisation of climate scenarios. It includes six original NGFS scenarios, extended with two additional pathways focusing on physical risks, each with assigned probabilities, and considering granular impacts at the sector-country level.

These climate scenarios cover pathways from orderly net-zero transitions to unmitigated warming and the most severe climate breakdown. As the NGFS pathways focus primarily on transition risks, we supplement them with physical risk projections drawn from the Shared Socioeconomic Pathways

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[1] Note that all impact figures underlying the rating are expressed in relative terms — as a percentage deviation from a counterfactual in which the climate remains fixed at its 1980-2010 average — not as absolute monetary amounts. The rating measures the proportional reduction in GDP per capita attributable to chronic physical climate risk; it does not rely on, or constitute, a forecast of absolute future GDP levels.

and Representative Concentration Pathways (SSP-RCP) framework.[2] We map the physical risk projections of two SSP-RCP scenarios (representing a moderate and a worst-case trajectory)[3] to the seven original NGFS (2024) and the two extended ECI climate scenarios. Additionally, we developed a probability-weighted "expected scenario" that estimates the likelihood of each climate scenario and enables us to calculate probability-weighted averages of climate risk metrics. We present all scenarios, their mappings to the SSP-RCP framework, and the corresponding probabilities in Table 1.[4] More details on the calculation of climate scenario probabilities can be found in the respective technical documentation.

2. Data

The SovCRR relies on inputs resolved at the more granular sub-national level. Rather than treating countries as single units, we focus on administrative regions, such as states, provinces, or departments within each country covered.

2.1. Data Requirements

The rating draws together various datasets, spanning macroeconomic and climate information, which serve four distinct roles:

a. **Economic output data**, including historical gross regional product (GRP) per capita from the MCC-PIK Database of Subnational Economic Output (DOSE; Wenz et al., 2023)

b. **Historical and projected climate data**, including historical temperature and precipitation from NASA's Global Land Data Assimilation System (GLDAS; Rodell et al., 2004) and climate change simulations from NASA's Earth Exchange Global Daily Downscaled Projections (NEX-GDDP CMIP6; Eyring et al, 2016; Thrasher et al, 2022)

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[2] Climate scenario frameworks have evolved significantly over the past two decades. The RCPs were among the first standardised scenarios developed at the request of the IPCC to explore the effects of varying greenhouse gas concentration trajectories on future climate conditions (Van Vuuren et al., 2011). These were subsequently integrated into the broader SSP-RCP framework, which pairs each physical hazard pathway (the RCP component) with an SSP describing the underlying socioeconomic conditions — such as population growth, economic development, and policy ambition — that give rise to those emissions. This combined framework was formally adopted in the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR6; IPCC, 2023) and is now the standard reference in climate risk literature. ECI's extended climate scenarios have been developed in alignment with this evolving framework.

[3] Ideally, we aim to apply more than the two presented SSP-RCP scenarios to distinguish between various physical risk levels (notably, SSP1-2.6, and SSP3-7.0). Due to limitations in the availability and robustness of hazard and impact datasets associated with some SSP-RC P trajectories, the current mapping therefore reflects practical data constraints in addition to conceptual climate scenario alignment.

[4] The Scientific Climate Scenario framework does not include NGFS' Low Demand scenario. For the SovCRR approach, we include the Low Demand pathway by assigning a probability ½ of that of the Net Zero 2050 scenario to preserve the full set of NGFS scenarios.

c. **Climate scenarios and their probabilities**, including global mean temperature anomaly trajectories from NGFS' Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC) emulator across NGFS long-term scenarios and three Integrated Assessment Models (IAMs; NGFS 2024)

d. **Geospatial and population weighting**, including sub-national administrative boundaries from the Database of Global Administrative Areas (GADM)[5] and population density statistics from the Gridded Population of the World (GPW) dataset[6]

We use the data to compute unconditionally expected physical risk–induced projected economic impacts – the main indicator underlying the SovCRR – across more than 3,400 regions that collectively cover 191 countries.

Table 1: NGFS and ECI climate scenarios, their corresponding SSP-RCP scenario, and the respective probabilities

Extended Climate Scenarios	SSP-RCP Scenarios	Description	Probability (%)
Orderly Transition scenarios			
Low Demand	SSP2-4.5	Lower energy demand alongside supply-side decarbonisation aims to limit global warming to below 1.5°C by 2050	0.2
Net Zero 2050	SSP2-4.5	Aims for global net-zero emissions by 2050 to limit global warming to 1.5°C	0.2
Below 2° C	SSP2-4.5	Orderly transition aims to partially meet net-zero targets to limit global warming to below 2°C	1.5
Disorderly Transition scenario			
Delayed Transition	SSP2-4.5	Net-zero transition actions deferred, then abruptly accelerated after 2030	2.4
Too Little, Too Late scenario			
Fragmented World	SSP2-4.5	Heterogeneous and uncoordinated national climate policies, resulting in missed transition goals and elevated physical risks	12.3
Hot House World scenarios			
NDCs	SSP2-4.5	Current pledges and targets to counter climate change, even if countries have not implemented all commitments yet	9.2
Current Policies	SSP2-4.5	Only currently implemented climate policies where global warming continues unabated	30.9
ECI's physical risk-extended scenarios			
Climate Destabilisation	SSP5-8.5	Higher emission trajectories than under the Current Policies pathway, resulting in high physical risks	32.9
Climate Breakdown	SSP5-8.5	Worst-case scenario in which no transition efforts are made, and countries experience the most severe physical risks	10.4

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[5] Available at https://gadm.org/

[6] This dataset provides population distribution using an evenly spaced raster format rather than irregular political or administrative boundaries. Available at https://www.earthdata.nasa.gov/data/projects/gpw

2.2. Sovereign Universe

As part of the 191 sovereign countries, our universe includes 33 non-independent territories incorporated as additional sub-national regions, which we map to their respective sovereign parent countries. Furthermore, we define which geographic units are excluded and why. Together, the SovCRR universe exhaustively covers the full GADM ISO3 country list.

2.2.1. Mapping non-independent territories to their sovereign parent

We incorporate 33 non-independent territories (i.e., dependencies, overseas collectivities, crown dependencies, and autonomous regions) into the risk rating model as additional sub-national regions, each attributed to its respective sovereign parent country. This approach is consistent with sovereign bond investment, in which the sovereign parent is the bond issuer and the constitutional guarantor of the territory's fiscal obligations. Sovereign credit rating agencies (e.g., S&P Global Ratings[7], Fitch Sovereign Ratings[8]) assess sovereign risk across the full constitutional jurisdiction, not the metropolitan perimeter alone. From a climate risk standpoint, the territory's exposure to chronic productivity losses constitutes a real economic liability borne by the sovereign, regardless of the territory's separate administrative or budgetary arrangements.

In practice, each non-independent territory is treated exactly like any other sub-national region of its parent country: Each territory carries its own climate-damage estimate, which is folded into the parent's country-level figure by the same population-weighted aggregation applied everywhere else (see Section 3 for details on the methodology). However, two consequences are worth noting:

a. First, the effect of mapping non-independent territories to parent countries is most material for sovereigns with overseas territories in high-exposure climate zones, for example, France (tropical territories), the United Kingdom (Caribbean and Indian Ocean territories), the United States (Pacific and Caribbean territories), and the Netherlands (Caribbean territories).

b. Second, many of these territories have no gridded population data (i.e., population distribution in a grid-cell raster format) and therefore enter with a weight of zero, so their inclusion is exhaustive in principle but immaterial to the parent's rating in those cases.

2.2.2. Excluded territories

We exclude a defined set of units in the GADM ISO3 list from the rated universe, for three reasons:

- **17 insular non-independent territories** are excluded because NEX-GDDP CMIP6 climate data is absent or insufficiently resolved at the required scale. This is primarily the case for small island territories in the Pacific, Caribbean, and Indian Ocean.[9]

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[7] Available at https://www.spglobal.com/ratings/sri/

[8] Available at https://www.fitchratings.com/search?expanded=entity&filter.sector=Sovereigns

[9] This exclusion is a data constraint, not a methodological choice. The physical risk exposure of such territories may be material, and their absence from the SovCRR should not be interpreted as an assessment that their climate risk is negligible.

- **14 territories** are excluded due to **unresolved or contested sovereignty**, where no internationally recognised attribution can be made without taking a contested geopolitical position.
- **Another 8 territories** are excluded because a) no sovereign jurisdiction exists (Antarctica, the Caspian Sea), b) they are micro-states without a sovereign bond market that do not issue sovereign debt (Monaco, Vatican City), or c) the damage-estimation pipeline lacks sufficient historical economic data for robust econometric identification (Antigua and Barbuda, Kiribati, Maldives, Micronesia)[9].

3. Methodology

This chapter sets out how the SovCRR's underlying inputs are produced. First, we introduce a four-stage damage-estimation pipeline that quantifies how climate change, and specifically physical risks, are projected in the future and impact economic output across more than 3,400 sub-national regions. Second, we explain how those granular damage estimates are aggregated and probability-weighted into a single per-country physical-exposure metric.

3.1. Damage Estimation

In order to estimate damage to sovereigns' economic outputs, we develop four stages that move from observed history to forward-looking projections that serve as input to the final rating calculation (see Figure 1):

a. **Stage I — How economies have responded to climate historically**
   Drawing on four decades of historical data (1979–2019), Stage I measures how regional economic growth has responded to year-to-year climate fluctuations. We link each region-year record of harmonised GRP per capita from the DOSE database to local climate variables from NASA's GLDAS, aggregating gridded climate data to the spatial and temporal scale of the economic records using administrative boundaries and population-density weights. Estimated on a representative panel of 1,661 regions across 88 countries spanning diverse climate zones, income groups, and economic structures, the result is a transfer function. This function is a stable, transferable description of the global climate-growth relationship (Bilal & Känzig, 2026; Kalkuhl & Wenz, 2020; Kotz et al., 2024; Linsenmeier, 2023).

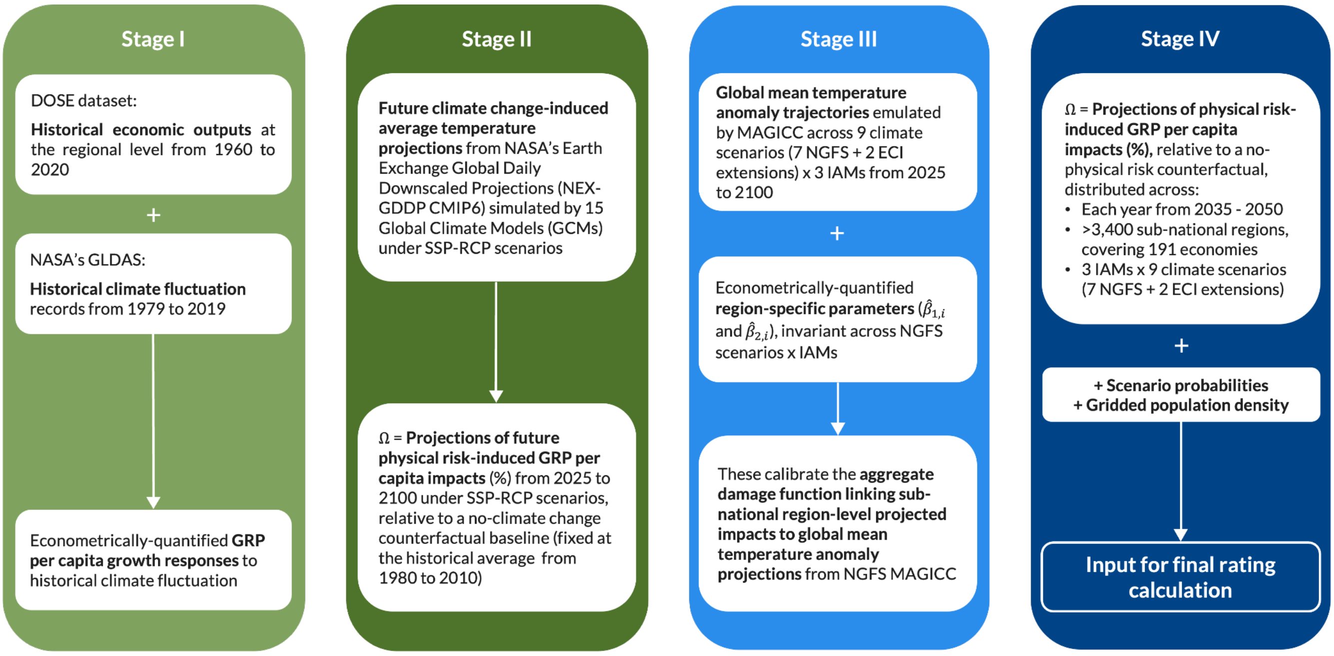

Figure 1: Overview of the methodology generating the input data to the SovCRR

b. Stage II — Projecting future climate damages to economic output

Stage II applies that estimated relationship to downscaled climate projections to obtain future damages under SSP-RCP warming scenarios. Using temperature projections from NASA's bias-corrected NEX-GDDP-CMIP6 ensemble, we recompute the temperature variable for a moderate (SSP2-4.5) and a vigorous (SSP5-8.5) warming scenario and extend coverage to more than 3,400 regions in 191 countries, which represent over 95 percent of global economic output. For each region, we feed the change in average temperature relative to the 1980–2010 baseline into the Stage I model, producing annual productivity shocks that compound over time into permanent damage to the level of GRP per capita, measured against a no-climate-change counterfactual. To avoid overstating warming, we retain 15 of the original 29 climate models, screening out the implausibly "hot" ones (Hausfather et al., 2022). Their distribution defines our 2025–2100 damage estimates.

c. Stage III — Translating damage into the NGFS temperature framework

Because the NGFS scenarios are organised around global mean temperature (GMT) rather than the SSP-RCP emissions pathways used to generate the Stage II damages, Stage III re-expresses those damages as a function of GMT to make them compatible with the NGFS framework. Following Schneider (2026b), we fit a quadratic damage function that maps GMT anomaly (emulated by NGFS's MAGICC module) to each region's projected damage over 2025-2100. We calibrate these anomalies on the high-emission SSP5-8.5 path for the widest temperature range and estimate them without an intercept, so damages are read as deviations from a no-climate-change baseline. Letting the relationship vary by region yields a set of region-specific parameters for each of the over 3,400 regions. Crucially, these parameters are estimated once per region and remain fixed across all NGFS scenarios, IAMs, and projection years, thereby encoding each region's idiosyncratic, non-linear sensitivity to warming. The aggregate damage function, once calibrated with these parameters, allows damages to be re-projected under the NGFS framework (Stage IV).

d. **Stage IV — Re-projecting damages across the extended NGFS scenarios**
Finally, Stage IV re-projects the damages across the nine NGFS-based scenarios (seven original NGFS scenarios plus two extended ECI scenarios) and the three IAMs used throughout this methodology. Applying the fixed Stage III parameters to each scenario-IAM combination's annual GMT trajectory, we compute damages for every region in post-processing. The output is a complete grid of physical-risk-induced GRP-per-capita damages (in %), projected annually from 2025 to 2100 for each of the more than 3,400 sub-national regions across all scenarios and IAMs.

3.2. From Damage Estimates to Physical Risk Exposure

This section describes how the sub-national damage estimates from Section 3.1 are turned into the input for the SovCRR. The procedure moves from Stage IV's granular damage trajectories to a single country-level physical-risk exposure metric, which Section 4 then converts into a percentile-based score and a rescaled rating from A to G.

For each country, the physical-risk exposure metric is the unconditionally expected physical risk-induced impact on GDP per capita, expressed as a percentage relative to the no-climate-change counterfactual. It is built in four steps:

- **Step 1: Aggregate from regions to countries**
  Stage IV produces annual GRP-per-capita damage trajectories for each of the more than 3,400 sub-national regions under each of the nine scenarios and three IAMs. We aggregate these to the country level using time-invariant, region-specific population-density weights from the GPW dataset.[10] Because heavily populated regions carry more weight, this step also shifts the metric from regional output (GRP) to national output per person (GDP per capita), providing country-level annual damage trajectories for every scenario and IAM combination.

- **Step 2: Compound to the chosen horizon**
  The figures from Step 1 are annual, point-in-time deviations. To express exposure across our two time horizons, we compound these annual damages year-on-year through 2035 and 2050. The result is the net cumulative impact on GDP per capita that has accumulated by each horizon,

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[10] For some territories, especially those made up of small, remote islands, gridded population data are unreliable or unavailable. When the GPW dataset is missing for some regions within a country, those regions receive a weight of zero in the aggregation. When data is missing across all regions within a country, we aggregate, assuming equal population weights across that country's regions.

representing the total permanent shortfall in output per person relative to the no-climate-change counterfactual, rather than the impact in that single year alone.

- Step 3: Average across the IAMs
  For each scenario, we take the average of the compounded impacts across the three IAMs, yielding a single value per country, scenario, and time horizon.

- Step 4: Weight across scenarios
  Finally, using the scenario probabilities, we take the probability-weighted average across the nine climate scenarios. This yields the unconditionally expected metric: a single number per country and time horizon that serves as input to the scoring and rating procedure.

The physical-risk exposure metric therefore inherits the key properties of the underlying damage estimates: It is (1) economically interpretable (a % impact on GDP per capita), (2) scenario-consistent (derived from NGFS-compatible GMT trajectories), (3) probability-weighted across the full scenario set, and (4) grounded in causal econometric identification from within-region historical variation.

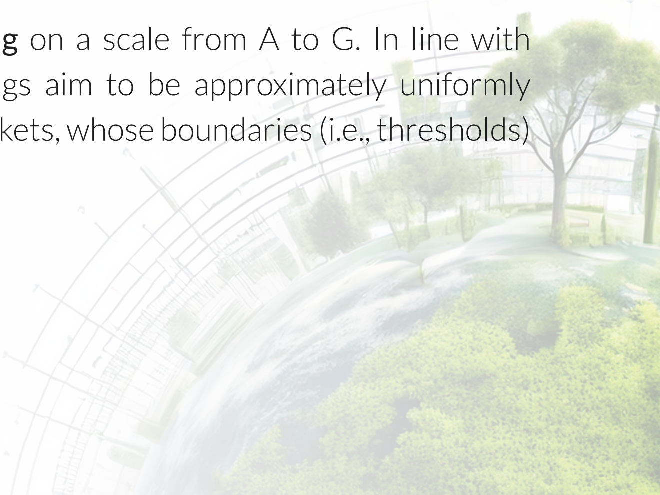
4. Scoring and Rescaling into Ratings

Based on this physical-risk exposure metric – the unconditionally expected GDP-per-capita impact from physical climate risk, expressed as a percentage relative to a no-climate-change counterfactual – we assign each country an **exposure score** from 1 to 100, followed by a letter rating from A to G.

We calculate the score in two steps:

a. For all countries in our universe, we rank them by their net cumulative compounded GDP-per-capita impact at each time horizon (2035 and 2050). This order defines a distribution of country-level GDP impacts.
b. Based on this distribution, we calculate percentiles and translate them into scores from 1 to 100. For example, if a country's metric falls below the 1st percentile, we assign a score of 1; if a country's impact falls above the 99th percentile, we assign a score of 100.

Finally, we transform the risk exposure score into a **rating** on a scale from A to G. In line with standard practices in financial risk ratings, our final ratings aim to be approximately uniformly distributed. For this, we split the scores into equal-sized buckets, whose boundaries (i.e., thresholds) separate one rating grade from the next.



Scores and ratings are calculated across multiple climate scenarios and at two time horizons. To be able to compare results across these conditions, we need a **common scale**, that is, a single fixed set of thresholds. Accordingly, we use the scores under the probability-weighted expected scenario to identify the thresholds, which provides the most relevant risk-management perspective. We define one such scale for each time horizon that is then applied for ratings across all climate scenarios:

- Ratings for any scenario at the 2035 time horizon are read against the expected-scenario thresholds for 2035.
- Ratings for any scenario at the 2050 time horizon are read against the expected-scenario thresholds for 2050.

We recalculate thresholds once per release cycle. When new countries enter the rated universe, or data is revised, the thresholds are updated at the next cycle, and ratings assigned under earlier thresholds are clearly versioned. Figure 2 shows the resulting SovCRR rating distribution and the expected GDP-per-capita impact values underpinning each grade for the 2035 (dark blue) and 2050 (light blue) horizons. The impact thresholds represent the values that separate each rating bucket (A to B, B to C, etc.) and the minimum and maximum values across the sovereign universe.

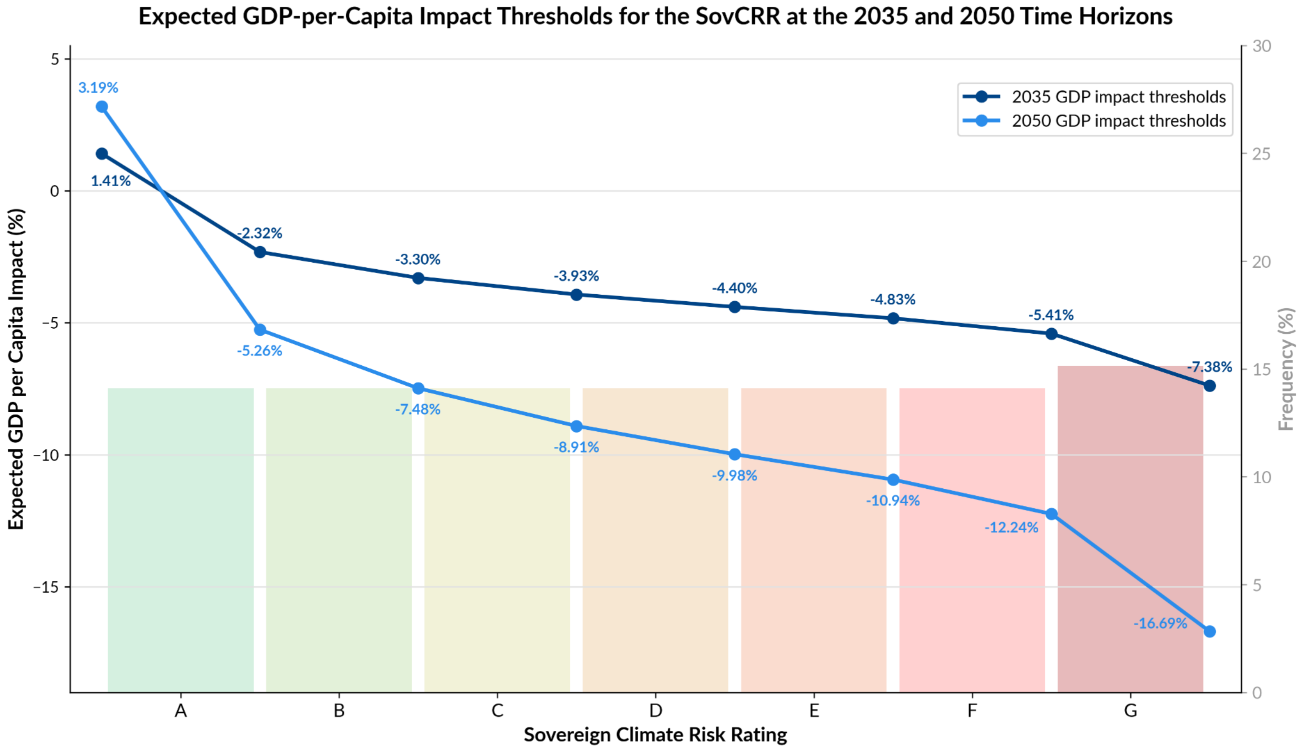


Figure 2: The SovCRR across our universe and related GDP impact values under the expected scenario at the 2035 and 2050 time horizons

In addition to the SovCRR, we produce the following outputs for each country:

- Scenario-specific ratings for each of the nine climate scenarios and at both time horizons (2035 and 2050), computed using the three-IAM average

- The underlying physical-risk exposure scores (1–100)
- The expected GDP-per-capita impact (in %) at the country level
- Sub-national damage decompositions in GRP per capita, enabling region-by-region attribution
- The climate zone at the regional and country levels, enabling clear between-country comparisons within the same climate zone (see Section 4.1 for details on climate zones)

4.1. Comparability Between Countries

Beyond the headline rating, the SovCRR is built to support between-country comparisons. We provide three complementary lenses: climate zone, market group, and geographical area.

Comparability between climate zones

Countries sharing similar agro-climate characteristics, as defined by the Köppen-Geiger climate classification, tend to face structurally similar temperature-driven productivity dynamics. The Köppen-Geiger climate classification categorises the world into five primary climate zones, based on temperature and precipitation (Beck et al., 2018):

- **Tropical:** regions with temperatures above 18 degrees Celsius throughout the year and significant precipitation
- **Arid:** regions with low precipitation that do not fit the polar criteria
- **Temperate:** regions with a moderate climate with distinct seasons
- **Cold/continental:** regions with at least one month averaging below 0 degrees Celsius and at least one month averaging above 10 degrees Celsius
- **Polar:** regions with monthly average temperatures below 10 degrees Celsius throughout the year

Tropical and arid economies are generally more exposed to chronic warming damages, because they already operate near or above the temperature thresholds identified in the empirical damage functions. As climate zones isolate the role of economic structure and adaptive capacity from base-level thermal exposure, comparisons between countries in the same climate zone are therefore especially meaningful.

The aggregated climate zone metric is calculated as follows:

- **At the region level:** We use the zone occupying the largest area (i.e., the highest number of 1-by-1 km pixel resolutions) within the region
- **At the country level:** We aggregate the within-country population share in each climate zone and select the dominant zone (i.e., the one with the largest population). This population-weighted choice mirrors the macroeconomic perspective of the product and the population-weighting step in the methodology (Section 3.1).

Comparability between market groups

Countries may also be compared within groups defined by international organisations (OECD, G7, etc.) and by market structure (e.g., emerging markets, advanced economies, etc.). The market-specific nomenclature follows common practice among major index and rating providers (MSCI, S&P, Moody's, etc.). We focus on the following regional markets:

- OCED
- EMEA (Europe, Middle East, and Africa)
- Developed Markets
- APAC (Asia-Pacific)
- G7
- Europe Zone
- Core Emerging Markets
- GCC (Gulf Cooperation Council)

Comparability between geographical areas

Countries may also be compared across geographical areas, following the seven regions of the United Nations (UN) M49 Continental Regions classification (Northern America, Latin America, Europe, Africa, Asia, Oceania, Antarctica; UN, n.d.). The naming signals that assignments follow a defined statistical convention rather than pure physical geography. This is the most defensible standard for a financial product with global sovereign coverage, as it is used by the UN, World Bank, International Monetary Fund, and most major data providers, ensuring interoperability and avoiding geopolitical sensitivity.

5. Results

This section presents the rating's principal outputs, beginning with the global picture — the aggregate trajectory of climate damages over the century and their geographic distribution across countries and regions — before turning to the United States as a worked example that traces the full methodology, from sub-national damage estimation through to the headline sovereign rating.

5.1. Global Results and Narrative

Across all 191 countries and more than 3,400 sub-national regions, the model produces a clear and economically intuitive global pattern, both in the aggregate trajectory of damages over time and in their geographic distribution.

At the global level, aggregated net damages to Gross World Product (GWP) per capita rise steadily over the century (see Figure 3). Under the Current Policies scenario, projected GWP impacts reach roughly -10 percent by mid-century (2050) and -23 percent by the end of the century (2099). These

results align with those reported independently by NGFS (2024), which use the NiGEM model on a sample of 49 economies, providing external validation of our pipeline.

A feature central to the sovereign risk assessment is the timing of scenario divergence. Projected damages remain within a narrow band through 2035 and out to around 2050, then fan out sharply thereafter. In practical terms, a country's near-term (2035) exposure is driven largely by its physical and economic structure and is relatively insensitive to which climate pathway unfolds, whereas its 2050 exposure depends materially on the scenario realised — which is why the reference horizons for the rating sit within this window.

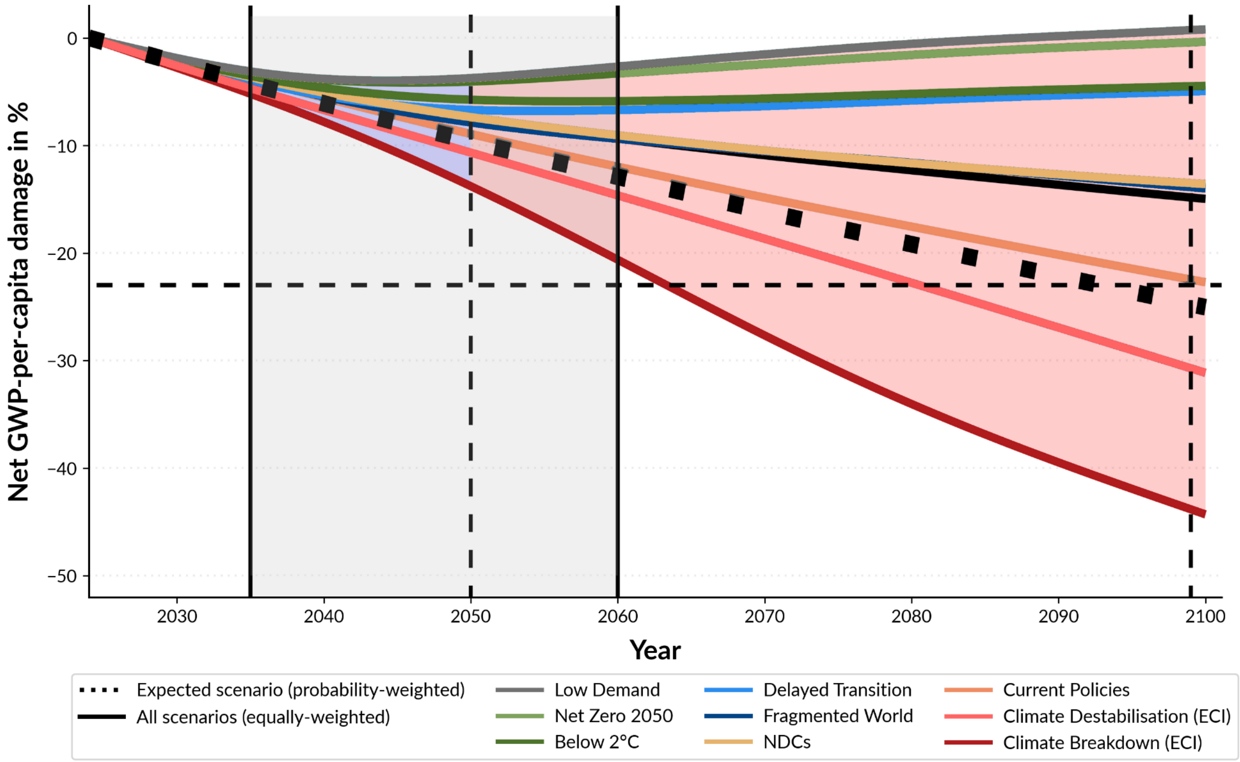


Figure 3: Globally aggregated net projected damages (in %) to GWP per capita across nine climate scenarios

Note: The projected net GWP-per-capita damages from 2025 to 2100 are built up from sub-national GRP-per-capita impacts across the seven original NGFS scenarios and two more extreme ECI extensions, averaged over the three IAMs and aggregated to 191 countries and to the global level, using region- and country-specific, time-invariant population-density weights.

Geographically, expected GRP-per-capita impacts by 2050 follow a pronounced latitude gradient: High-latitude regions see limited losses or modest net gains, while losses deepen toward the tropics, with country rankings broadly tracking inverse distance to the equator (see Figure 4). Again, these results are consistent with the established climate-economics literature (Burke et al., 2015; Kotz et al., 2024). High-latitude economies such as Canada and Russia are ambiguous cases, in which the national result reflects the balance between regions that are damaged and those that benefit from early warming, ultimately determined by where population and economic activity are concentrated.

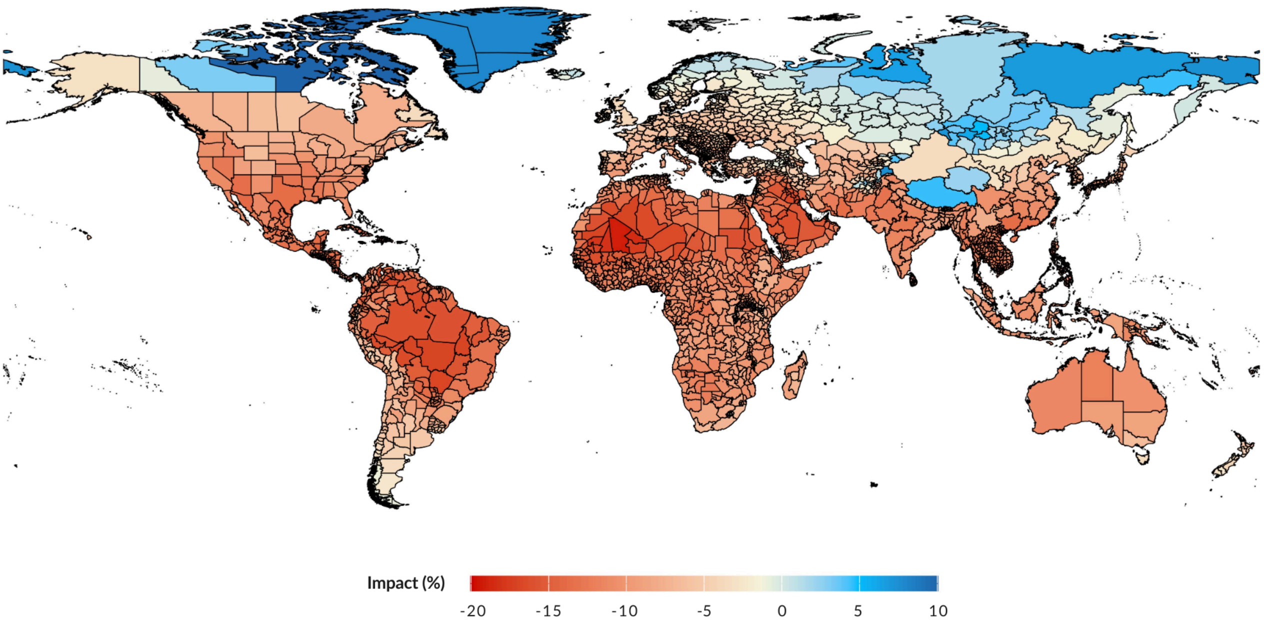


Figure 4: Region-level GRP-per-capita impacts (in %) under the expected scenario in 2050

Note: Unconditional expected net GRP-per-capita impact (in %) at the 2050 horizon for more than 3,400 productive regions across 191 national economies, computed as the probability-weighted average across the nine scenarios and three IAMs.

5.2. Worked Example - United States of America

To illustrate the end-to-end rating process from sub-national damage estimation through to the SovCRR, we use the United States (USA) as a worked example. The USA is a uniquely instructive case for three reasons:

- Internal heterogeneity
  The USA spans a vast range of climate zones, from the hot semi-arid south-west to the temperate north-east, the humid subtropical south-east, and the continental mid-west. A single national rating therefore conceals sharp regional divergence that the sub-national step is designed to capture.
- Positioning on the damage-function curve
  The empirically estimated temperature–output response function (the curve linking a region's average temperature to its economic productivity) peaks at 13°C (Schneider, 2026a). USA regions range from well below to well above this threshold, placing them on opposite sides of the inverted U-curve and so generating heterogeneous damage trajectories.
- The southern USA as a high-damage zone
  Schneider (2026a) identifies the south-western USA as one of the areas of particularly high projected zonal (i.e., localised, sub-national) impacts, alongside southern Europe, West Africa, and tropical Asia. This makes the USA an especially meaningful case for testing how sub-national granularity prevents concentrated regional risks from being diluted in the national aggregate.

The example follows the four-stage methodology described in Section 3.1, progressing from state-level historical climate exposure, through NGFS re-projection, to population-weighted aggregation and the final rating.

5.2.1. Physical-risk exposure metric

This section explains the rating process for the USA through the three steps that produce its physical-risk exposure metric: (1) estimating sub-national damage trajectories, (2) aggregating them to the country level, and (3) compounding them over the rating horizon.

Regional damages – Stages I to IV

The pipeline starts at the sub-national level: For the USA, that means the 50 states plus the District of Columbia, each carrying its own historical temperature record, its own estimated sensitivity to warming, and therefore its own GRP per capita damage trajectory. State temperature baselines differ markedly across the USA, and each state's position relative to the 13°C productivity optimum sets the sign and curvature of its damage path, for example:

- **Arizona, Texas, Florida (~20–25°C):** well above the optimum, on the declining, accelerating-loss side of the concave temperature-output curve. Further warming pushes them deeper into negative productivity territory, with a non-linear rate of decline.
- **California (~15°C):** internally heterogeneous, coastal zones near the optimum, the Central Valley and southern desert regions (~22-24°C) above it. Population-weighted aggregation to the state level conceals high intra-state dispersion.
- **New York, Pennsylvania, Illinois (~9–12°C):** slightly below the optimum. Early-period warming narrows the gap to the peak before turning negative at higher cumulative temperatures.
- **Minnesota, Montana, North Dakota (~4–8°C):** significantly below the optimum, so initial warming has the smallest near-term negative effect. Under vigorous scenarios, however, significant end-of-century temperature anomalies push even these northern states beyond the optimum.

Re-projecting each state across the likely climate-model ensemble (GCMs) layers state- and year-specific differences between future temperature projections and the historical baseline, providing the additional warming relative to the no-climate-change counterfactual. This warming is itself uneven across the country. End-of-century figures under the high-emissions pathway (SSP5-8.5) project the following compared to the 1980-2010 baseline:

- Southern states (Texas, Arizona, Florida): +3.0-4.5°C
- North-eastern states: +3.2-4.0°C, with higher model-to-model variability
- Northern Great Plains (Minnesota, Montana): +4.0-5.5°C, reflecting the well-documented amplification of warming at higher latitudes.

Compounding these annual effects over time produces a persistent loss in each state's GRP per capita, relative to the no-climate-change counterfactual. For illustration, Table 2 shows state-level results, representing the median of the 15 likely models under the expected scenario.

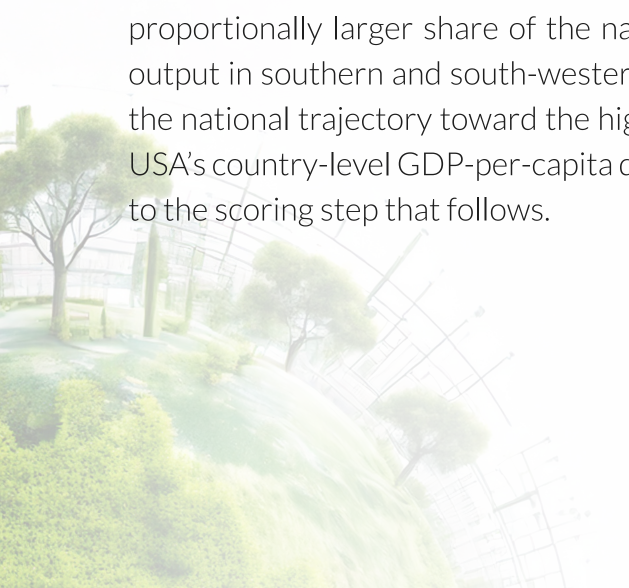
Table 2: Illustrative state-level historical temperature (population-weighted) and GRP-per-capita loss under the expected scenario

State	Climate zone	Historical temperature (mean °C)	GRP loss by 2035 (in %)	GRP loss by 2050 (in %)
Arizona	Arid	~22	-6.0	-13.7
Texas	Temperate	~20	-6.1	-13.7
Florida	Temperate	~23	-4.5	-10.1
Louisiana	Temperate	~19	-5.7	-12.9
California	Temperate	~15	-4.9	-11.0
New York	Cold	~9	-3.3	-7.5
Illinois	Cold	~10	-4.2	-9.6
Minnesota	Cold	~6	-3.4	-7.7
Montana	Arid	~6	-3.2	-7.2
United States (population-weighted)			**-4.6**	**-10.4**

These results illustrate the fundamental spatial heterogeneity in the USA. States such as Arizona, Florida, and Texas — all above the 13°C productivity optimum — face larger, non-linearly accelerating damage trajectories. States well below the optimum see near-zero losses by 2035 under moderate warming, but larger losses by 2050 as cumulative temperature deltas grow. This directly expresses the empirically estimated quadratic response function: Productivity is a concave, non-linear function of temperature, peaking at 13°C, with losses accelerating the further a region moves above the optimum.

Aggregation to country level

The state-level GRP-per-capita damage trajectories are aggregated into a single country-level GDP-per-capita trajectory using population-density weights, so that heavily populated states carry a proportionally larger share of the national figure. Because the USA concentrates population and output in southern and south-western states sitting above the 13°C optimum, this weighting pulls the national trajectory toward the high-damage end rather than averaging it out. The output is the USA's country-level GDP-per-capita damage trajectory under each of the nine scenarios — the input to the scoring step that follows.



Compounding over the time horizon

For each scenario, the USA's national trajectory is then compounded over the 2025–2035 and 2025–2050 windows, giving its GDP-per-capita damage metric at the 2035 and 2050 horizons under each of the nine scenarios. Table 3 reports these national estimates.

Table 3: *National GDP-per-capita damage estimates for the USA across all nine climate scenarios and two time horizons, including GMT anomaly estimates at the 2050 time horizon*

Extended Climate Scenarios	GMT anomaly 2050 (in °C)	GDP-per-capita loss in 2035 (in %)	GDP-per-capita loss in 2050 (in %)
Low Demand	~1.5	-3.4	-4.1
Net Zero 2050	~1.5	-3.4	-4.4
Below 2° C	~1.6	-3.8	-6.3
Delayed Transition	~1.9	-4.3	-7.3
Fragmented World	~2.0	-4.2	-8.5
NDCs	~1.8	-4.0	-8.0
Current Policies	~2.1	-4.2	-9.7
Climate Destabilisation	~2.4	-5.1	-11.6
Climate Breakdown	~2.7	-5.6	-14.9

The notable feature of these results is the relative convergence of scenarios at the 2035 horizon, meaning how similar climate projections across different scenarios are in 2035 compared to 2050. As Schneider (2026b) documents, GMT trajectories across the NGFS scenarios remain relatively narrow through roughly 2050, then diverge sharply in the second half of the century. Accordingly, scenario divergence becomes materially more consequential at the 2050 time horizon, particularly under the most extreme scenarios.

5.2.2. Score and rating assignment

With the USA's national GDP per capita damage trajectories for each of the nine climate scenarios, the final step reduces those scenarios into a single expected figure. Based on the scenario probabilities, we calculate a probability-weighted average to derive the USA's unconditionally expected physical-risk exposure at each time horizon.

The expected impact is then converted to a score and rescaled to the A–G scale by mapping it onto the common scale shared by all rated sovereigns in the universe, as described in Section 4. This determines the final USA's SovCRR at the 2035 and 2050 horizons:

- For both the 2035 and 2050 time horizons, the USA records scores of **63/100** and **64/100**, respectively, and an identical rating of **E**.
- The scores and rating are based on the USA's unconditionally expected GDP-per-capita impact of **-4.6 percent by 2035** and **-10.4 percent by 2050**, reflecting the state-level exposure structure and sensitivity parameters.

5.2.3. Interpretation

The USA example illustrates three properties of the SovCRR that are general but particularly visible for a large, internally heterogeneous economy.

The aggregation problem makes the USA a harder case than it seems

A naive country-level assessment using the national average temperature (~12–13°C) would place the USA near the productivity optimum and yield a relatively benign damage estimate. Sub-national disaggregation reveals a structurally different picture: A significant share of the USA population (and hence economic activity) is concentrated in states already well above the optimum, particularly in the south and south-west, facing accelerating, non-linear losses. The national aggregate rating is therefore pulled toward the high-damage end relative to what a country-level model would predict. This is the aggregation problem that Schneider (2026a) demonstrates empirically.

Regional states heterogeneity is not diversification

While it could be expected that the USA's internal climate diversity (cold northern states alongside hot southern ones) would provide natural hedging at the sovereign level, the damage function does not support this. The response curve is concave, meaning gains from warming in cold states (moving toward the optimum) are smaller in absolute value than losses from equivalent warming in hot states (moving away from the optimum), because the curve is steeper to the right of the 13°C peak than to the left. Therefore, population-weighted aggregation does not cancel regional extremes, but rather absorbs them, with heavily populated southern and south-western states dominating the national aggregate.

Scenarios remain close until 2035, then diverge by 2050

As Table 3 shows, the USA physical-risk exposure metric varies only modestly across scenarios at the 2035 horizon but more materially at the 2050 horizon. Accordingly, scenario choice has limited implications for the near-term rating but becomes increasingly consequential at mid-century, especially under the most extreme scenarios, where the GMT trajectory varies sharply, and the non-linear quadratic damage term amplifies divergent regional outcomes.

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