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P&I | CUSTOM CONTENT

# Research for Institutional Money Management

## Scientific Climate Ratings
An EDHEC Venture

# Scientific Climate Ratings

An EDHEC Venture

Scientific Climate Ratings is an independent rating agency under EDHEC Ventures. We provide transparent, standardised assessments of climate risk exposure and its financial impact, leveraging our award-winning research expertise in climate finance and quantitative analysis.

We focus on two areas:



## Transition Risk

Financial impacts arising from the shift to a low-carbon economy, including policy changes.

## Physical Risk

Damages and disruptions caused by climate hazards.





From Hazard maps to ... → ... Damage Functions

From Carbon Intensity to ... → ... Carbon Cost

From Comparable A to G ratings to ... → ... Comparable Quantified NAV Impact

From Climate Exposure Rating (CER) to ... → ... Climate Risk Ratings (CRR)

**FROM EXPOSURE to...** **FINANCIAL IMPACT**

Find out More

INTRODUCTION

# Introduction to the Research for Institutional Money Management Supplement in *Pensions & Investments*, November 2026

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Climate risk is an investment risk: one that can affect asset values, sovereign creditworthiness, infrastructure resilience and ultimately portfolio performance. This Scientific Climate Ratings special issue of the EDHEC Research for Institutional Money Management supplement to Pensions & Investments brings together our latest research on how these risks can be measured, translated into financial impacts and incorporated into investment decisions.

In our first article, we introduce our Sovereign Climate Risk Ratings, which translate chronic physical climate risk into expected GDP-per-capita impacts. Damages – aligned with Network for Greening the Financial System scenarios and probability-weighted outputs – are estimated at the sub-national level before being aggregated nationally into a probability-weighted country-level expected loss or gain. This feeds into an A–G rating, supported by a transparent and scenario-consistent estimate of the future impact of climate change. These are designed to help investors capture a genuine measure of risk by producing a probability-weighted expected loss, not just stress tests.

Our second piece explores the very different physical climate risks threatening the diverse geographical regions of the United States and how these translate to tremendous variety in the impact likely to be seen on GDP/GRP on a state-by-state basis. It is this granular variation that informs CLIRMAP, part of the bedrock of our Sovereign Climate Risk Ratings.

We next explore how the homogeneous nature of the Netherlands' geography and climate gives it a very country-specific physical climate exposure, bringing unique strengths and vulnerabilities to this nation in the path of a changing climate. Canny investors will want to price these risks before spreads adjust, because the question is not whether climate risk will be priced; the question is who will price it first.

In our penultimate article, we take a look at the twin challenges investors face when gauging the impact of adaptation and decarbonization on assets: infrastructure investors have traditionally treated physical climate risk and decarbonization as separate problems, but two asset-level analyses show that both can be expressed as the same thing: an impact on net asset value. Our key takeaway is that investors need to screen on both axes, rank interventions before funding them, and treat the financing structure as part of the decision.

Finally, we address how the perception of the cloud as a nebulous miasma of data floating round the earth could not be further from the truth. The data we need is very much a terrestrial phenomenon. We analyzed 1,000 data centers across 34 countries and 11 major operators, assessing wind, flood, wildfire and heat exposure. Our central finding is this: physical climate risk is driven far more by where a data center is located than by who operates it. The AI boom is becoming an infrastructure investment cycle as much as a technology cycle.

We hope this collection presents a useful lens through which to view the impact of climate risk in your own portfolios, and that you find the pieces as worthwhile a read as we found them worth bringing together. Our thanks go to P&I for their continued collaboration in bringing this work to their readers.

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# Addressing a Structural Blind Spot in Sovereign Pricing with the Sovereign Climate Risk Rating

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- SovCRR translates chronic physical climate risk into expected GDP-per-capita impacts.
- Damages are estimated at the sub-national level before being aggregated nationally.
- Regional damage estimates are aligned with NGFS scenarios and probability-weighted outputs.
- A US case study is presented, showing greater GDP risks for southern states than for northern peers by 2050.

Sovereign climate-risk measures typically begin with country averages and end in composite scores. The Sovereign Climate Risk Rating (SovCRR) follows the opposite route. It begins with historical temperature and output records observed at the sub-national level, projects the resulting damages across more than 3,400 regions, translates those estimates into nine probabilistic pathways aligned with the Network for Greening the Financial System (NGFS), and only then aggregates them into a probability-weighted country-level expected loss or gain that feeds into an A–G rating. This article explains this stepwise construction. It outlines the underlying scientific methodology, illustrates its application to the United States and highlights SovCRR's distinctive features. The letter grade is an important reporting layer; beneath it lies a transparent, scenario-consistent and probability-weighted estimate of the future impact of chronic physical climate risk on GDP per capita.

## SOVEREIGN CLIMATE RISK FACES AN AGGREGATION PROBLEM

Climate change is a public good problem, but it is also a distribution problem. Why? Our changing climate is affecting all regions globally, leaving no economic region or unit untreated, but its expected economic materiality will be heterogeneous across space. National economies are clusters of regions spanning different climate zones, sectoral structures, population patterns and sensitivities to additional warming. Collapsing these differences into a national average before estimating damages can therefore produce a misleading result because it does not accurately reflect the heterogeneous distribution of economic activity within countries. The problem is especially relevant because the temperature-output relationship has been found to be non-linear by the scientific literature (Burke et al., 2015): a one-degree increase does not have the same marginal effect in a cool region as in an already-hot one, and moderate gains in cooler areas may not offset the substantial losses predicted in warmer ones.

This matters for sovereign portfolios because climate risk enters credit analysis through economic fundamentals. Persistent productivity losses can weaken the potential output path and, over time, the tax base and fiscal capacity on which debt service ultimately depends. Yet the climate information available to investors is commonly either (i) too aggregated for heterogeneous countries or (ii) expressed as a vulnerability index whose economic meaning is difficult to connect to an existing country-risk model. Moreover, because chronic physical climate risks[1] remain insufficiently reflected in market prices, investors need forward-looking, non-market data to identify structural economic vulnerabilities before they materialize in sovereign credit spreads.

SovCRR addresses these limitations through a focused, economically interpretable and geographically granular measure: the projected change (reduction or increase) in GDP per capita attributable to climate-change-driven shifts in average temperature (i.e., the central component of chronic physical risk), relative to a counterfactual without further climate change, at the 2035 and 2050 horizons. This direct link between climate exposure and macroeconomic outcomes distinguishes SovCRR from broader vulnerability indices and makes its results readily ingestible into the models of sovereign credit analysts. The current version of SovCRR deliberately isolates this temperature-economy channel.

In recent decades, the scientific literature estimating the true macroeconomic cost of climate change has treated it primarily as a public good problem. A stable climate is non-excludable and largely non-rival. While greenhouse gas emissions generate global externalities, exposure to and damages from climate-driven shifts in average temperature vary substantially across space. This leaves no productive units and geographic locations untreated per se. As a result, statisticians have typically relied on the local variability of historical climate fields over time to econometrically predict country- or region-level GDP deviations (Burke et al., 2015; Kalkuhl and Wenz, 2020; Linsenmeier, 2023; Berg et al., 2024; Kotz et al., 2024, among others). This approach, backed by a long line of increasingly granular studies, has structured the applied physical-risk modules used by institutions, central banks and scenario providers in financial-risk and stress-testing frameworks. For example, Oxford Economics (2022) uses Burke et al. (2015); earlier NGFS vintages used Kalkuhl and Wenz (2020); and the latest Phase V used Kotz et al. (2024). This 'local' approach[2] has provided a natural foundation for the EDHEC Climate Institute's applied scientific developments, notably the methodology developed in Schneider (2026a), which underpins the first two stages presented below.

## OUTLINE OF THE METHODOLOGY: HOW THE SovCRR IS BUILT

The model is organized as a four-stage pipeline that moves from historical identification to future regional damages, then from climate scenarios to a sovereign-level decision metric. Each stage has a distinct role, which makes the assumptions, degrees of freedom and potential sources of uncertainty easier to identify.

### Stage 1: Estimate how regional growth has responded to climate

The first stage combines roughly four decades of harmonized gross regional product (GRP) per capita data from the MCC-PIK Database of Subnational Economic Output with local temperature and precipitation records from NASA's Global Land Data Assimilation System (Wenz et al., 2023). Gridded climate observations are matched to administrative regions using geographic boundaries and population-density weights. The estimation panel covers more than 1,500 regions in 87 countries and identifies the relationship using variation within regions over time, with region-specific time trends absorbing persistent cross-sectional differences.

The resulting transfer function is non-linear and concave, consistent with the established climate-economy literature. The benchmark response peaks at an annual average temperature threshold: regions below that level may initially experience small gains or limited losses, while regions already above it face increasingly negative marginal effects as temperatures rise. Lagged responses allow temporary growth shocks to cumulate into lasting differences in the level of output per person.

### Stage 2: Project the response across future local climates

The estimated historical relationship is applied to NASA's bias-corrected and downscaled NEX-GDDP-CMIP6 projections (Thrasher et al., 2022). This extends the calculation to more than 3,400 sub-national regions in 191 sovereign economies, representing more than 95% of global economic output. The original climate ensemble contains 29 global climate models. For the production estimate, 14 models are retained after screening out models whose equilibrium climate sensitivity or transient climate response lies outside the ranges assessed as likely in the climate literature (Hausfather et al., 2022).

[1] *https://www.bloomberg.com/news/articles/2026-09-07/blackrock-says-chronic-climate-risks-not-priced-in-by-markets.*
[2] *In contrast to the 'global' approach of Bilal and Känzig (2026), who instead modeled country- and global-level GDP changes as functions of global temperature variability. A dedicated methodological discussion on local versus global identification of climate impacts on GDP is provided in Schneider (2026c).*

For each region, future temperature changes are measured against the 1980–2010 climate baseline and fed into the transfer function. Physical-risk-induced transient productivity growth shocks are cumulatively compounded over time, yielding a permanent gap in the level of GRP per capita relative to a no-additional-warming counterfactual. The underlying research engine spans 2025–2100, although the current rating focuses on 2035 and 2050 because these horizons are more financially relevant.

### Stage 3: Translate SSP-RCP damages into the NGFS architecture

The economic changes predicted in Stage 2 are, by nature, expressed under SSP-RCP pathways and individual global climate models. Banks and institutions, by contrast, commonly rely on the NGFS framework. SovCRR therefore introduces a translation layer rather than assigning each NGFS scenario mechanically to a single SSP-RCP path. For every region, a non-linear aggregate damage function relates projected damage to GRP per capita to the change in global mean temperature emulated by the MAGICC module. In line with NGFS (2024), the initial calibration uses high-emission pathways to span the widest available temperature range, and the function is estimated without an intercept because damages are defined relative to the climate-neutral (no-additional-climate-impact) counterfactual.

This produces more than 3,400 unique region-specific parameter pairs. They are estimated once, but can be applied across NGFS scenarios, the three integrated assessment models (IAMs) used by NGFS, and projection years. The parameters, which are spatially varying but stable across scenarios, preserve the location-specific non-linearity, persistence and climate-model information embedded in stage-2 damage trajectories, while making those trajectories compatible with different scenario architectures.

### Stage 4: Re-project, aggregate and calculate the unconditional expected loss using scenario probabilities

The regional parameters are applied to annual MAGICC temperature paths across nine forward-looking scenarios: the seven NGFS Phase V scenarios and two higher-warming extensions, Climate Destabilization and Climate Breakdown from *Scientific Climate Scenarios*.[3] The result is a complete scenario-by-IAM matrix of annual regional damage paths. Those paths are aggregated from regions to countries using time-invariant population-density weights from the Gridded Population of the World dataset, so that the spatial distribution of economic agents, which tends to coincide with that of productive activity, matters to the sovereign total.

For each scenario, impacts are averaged across the three IAMs. Unequal scenario probabilities are then applied to calculate an unconditional expected impact for each country and horizon (Rebonato et al., 2025). This expected-impact estimate complements rather than replaces stress testing: all nine scenario-specific estimates remain available. But by moving beyond the conventional "what if?" logic of scenario analysis to assess "what is likely or expected?", SovCRR provides a decision-useful measure of the financial materiality of chronic physical risk for sovereign markets. Investors can therefore directly integrate a probability-weighted estimate of climate-related economic damage into their sovereign-risk models. A chart summarizing this stepwise methodology (i.e., identify, project, translate, aggregate) is given in Figure 1.

## FROM A PREDICTED ECONOMIC IMPACT TO AN A–G RISK RATING

The most important design choice is that the rating does not replace the economic metric. For every country, SovCRR first reports the expected cumulative impact on GDP per capita, in percentage terms, at the 2035 and 2050 horizons. Countries are ranked by that impact and placed into seven approximately equal rating bands from A to G, based on percentile scores ranging from 1 to 100. A denotes the least exposed part of the rated universe and G the most exposed. Horizon-specific thresholds for 2035 and 2050 are calibrated on the expected-scenario distribution and applied consistently to scenario-specific results at the same horizon. These thresholds are naturally versioned and will be recalculated whenever the universe or data change.

Each rating is anchored to horizon-specific thresholds for the probability-weighted expected loss across nine scenarios. The E band lies between approximately –4.4% and –4.8% in 2035 and between –10.0% and –10.9% in 2050, reflecting the compounding of climate impacts over time. A graph representing the expected GDP per capita impact thresholds for SovCRR ratings at the 2035 and 2050 horizons is given in Figure 2.

This architecture separates measurement from communication. The percentage impact is the economically interpretable quantity that can enter a macroeconomic forecast, a sovereign-credit overlay or a stress-testing model. The 1–100 score and A–G grade make cross-country screening and governance easier. Users retain access to the underlying scenario results, annual paths and sub-national decomposition, so two countries with the same letter grade need not be treated as economically identical. Comparisons can also be organized by climate zone, market group or geographical region rather than relying only on a global rank.

FIGURE 1

**Illustration of the stepwise methodology underlying the SovCRR**
Source: Our elaboration based on Scientific Climate Ratings (2026). *Sovereign Climate Risk Rating: Technical Documentation.* Available at: https://scientificratings.com/sovereign-ratings/.

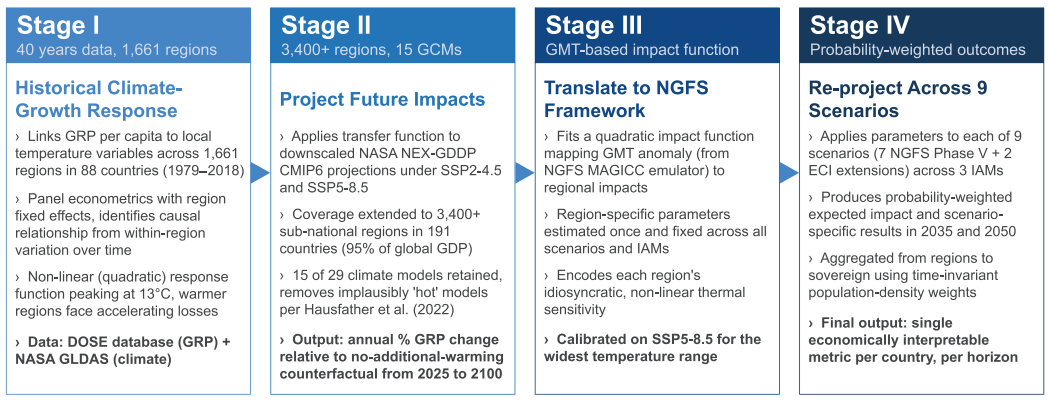
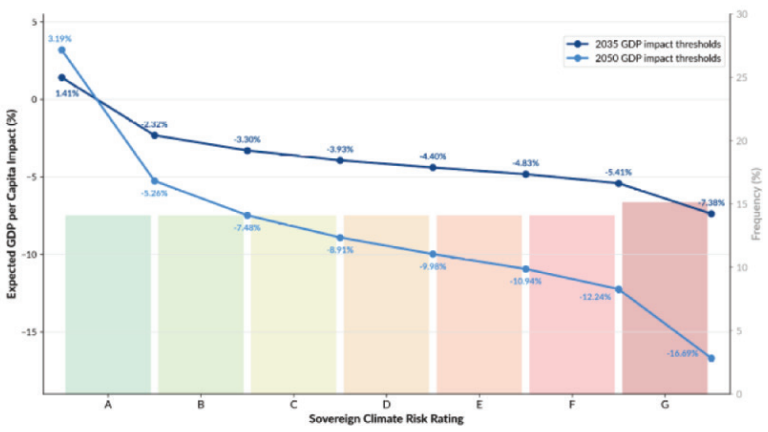



FIGURE 2

**Expected GDP per capita impact thresholds for SovCRR ratings at the 2035 and 2050 horizons**
Source: Scientific Climate Ratings (2026). *Sovereign Climate Risk Rating: Technical Documentation.* Available at: https://scientificratings.com/sovereign-ratings/.




## Observations

**Ratings are anchored**
Each grade maps to an expected GDP per capita loss, "A" countries lose less than 5.3% by 2050, "G" countries more than 5.4% by 2035.

**2050 curve steepens sharply**
The gap between A and G nearly doubles from 2035 to 2050, reflecting compounding impact over time.

**G-rated sovereigns face structural impact**
–16.7% GDP per capita loss by 2050 is not a stress scenario, it is the probability-weighted expected outcome across all 9 scenarios.

[3] *https://climateinstitute.edhec.edu/scientific-climate-scenarios.*

## WHY THE APPROACH IS DISTINCTIVE FOR SOVEREIGN INVESTORS

Sovereign pricing tends to respond more strongly to acute climate shocks and transition signals than to gradual, temperature-driven productivity losses. Existing frameworks often provide vulnerability rankings or stress-test results rather than expected economic impacts, while national averages can mask the concentration of activity in exposed regions. SovCRR addresses these limitations in four ways.

- First, it expresses chronic physical risk as an explicit percentage impact on GDP per capita. This metric can be incorporated into macroeconomic forecasts, debt-sustainability analysis and sovereign scorecards, with investors applying their own assumptions to translate output effects into fiscal balances, debt dynamics and spreads.
- Second, SovCRR estimates damages at the sub-national level before aggregating them nationally. This captures the spatial distribution of climate exposure and economic activity and reveals whether a sovereign's risk is broad-based or concentrated in particular regions.
- Third, SovCRR reprojects its own region-specific damage functions across the seven NGFS Phase V scenarios and two higher-warming extensions, rather than using the NGFS physical-damage estimates (NGFS, 2024; Schneider, 2026b). It therefore provides both scenario-specific results for stress testing and a probability-weighted expected impact for portfolio analysis.
- Finally, the methodology remains traceable. The letter grade can be linked back to GDP-per-capita impacts, scenario paths and sub-national drivers, supporting model validation and informed adjustments (Scientific Climate Ratings, 2026).

## A PRACTICAL ILLUSTRATION: THE UNITED STATES

The United States illustrates the importance of modeling climate damages below the national level. A map showing the spatial distribution of probability-weighted projected sub-national economic impacts in 2050 (globally) is presented in Figure 3. Its average temperature lies just below the globally estimated optimum and could therefore make a national damage function appear relatively benign. Yet more than 40% of US economic activity is concentrated in southern states that already exceed the literature threshold, beyond which the response curve becomes markedly steeper. Cooler northern states may initially benefit from warming, but these gains remain smaller than the accelerating losses in warmer states. This domestic asymmetry reflects the broader latitude gradient observed globally, with larger losses generally concentrated in warmer, lower-latitude regions.

The state-level estimates make this contrast explicit. Figure 4 shows the US national rating and selected state-level impacts based on the unconditional expectation. Under this probability-weighted expectation, GRP per capita losses by 2050 reach approximately 13.7% in both Arizona and Texas, compared with 7.5% in New York and 7.7% in Minnesota. California and Florida record losses of 11.0% and 10.1%, respectively. Because economic activity is unevenly distributed and the temperature-productivity relationship is concave, northern and southern states do not provide a natural hedge when aggregated.

At the national level, the methodology estimates a US GDP per capita impact of –4.6% by 2035 and –10.4% by 2050, corresponding to scores of 63/100 and 64/100 and an E rating at both horizons.

The scenario range remains relatively narrow in 2035 but widens substantially by 2050, when the US impact ranges from approximately –4.1% under Low Demand to –14.9% under Climate Breakdown. For investors, the central estimate therefore captures a material structural impact rather than a stress scenario, while the wider distribution shows the additional tail risk. A national average alone would obscure the regional composition underlying both.

## SCOPE, LIMITATIONS AND NEXT DEVELOPMENTS FOR THE PRODUCT

A product is more credible when its boundaries are explicit. SovCRR Version 1 measures exposure to chronic, temperature-driven productivity risk. Acute hazards are not modeled separately, although part of their historical economic signal may be embedded in the estimates. Top-down panel models identify the aggregate relationship between observed temperature variation and GDP, making it difficult to disentangle the effects of gradual warming from those of correlated acute extremes. The estimates may therefore capture elements of both, even though the model does not represent individual hazards explicitly. Tipping points are excluded. Dell et al. (2014) provide a broader review of this empirical literature.

These limitations also define a research and product agenda. First, sector-specific macroeconomic damage functions would reveal which segments in the overall composition of economic activity drive sovereign exposure. A second priority is to separate direct losses from their propagation through supply chains. The financial materiality of physical climate risk extends beyond firms' direct climatic exposure because correlated disruptions can spread through production networks and inter-firm spillovers. Empirical damage estimates based on local temperature variability may capture some of these indirect effects through observed GDP, but the associated 'damage delta' cannot yet be reliably isolated or formally quantified. A third priority is to model future adaptation explicitly; current projections hold adaptation margins fixed at their historically observed levels. Most importantly, calibrating the translation from output losses to sovereign credit ratings and spreads would move the framework closer to valuation.

The existing design and the EDHEC Climate Institute research agenda are intended to allow these extensions to be introduced incrementally.

FIGURE 3

**Probability-weighted projected sub-national economic impacts in 2050 show a pronounced latitude gradient**
Source: Scientific Climate Ratings (2026). *Sovereign Climate Risk Rating: Technical Documentation*. Available at: https://scientificratings.com/sovereign-ratings/.

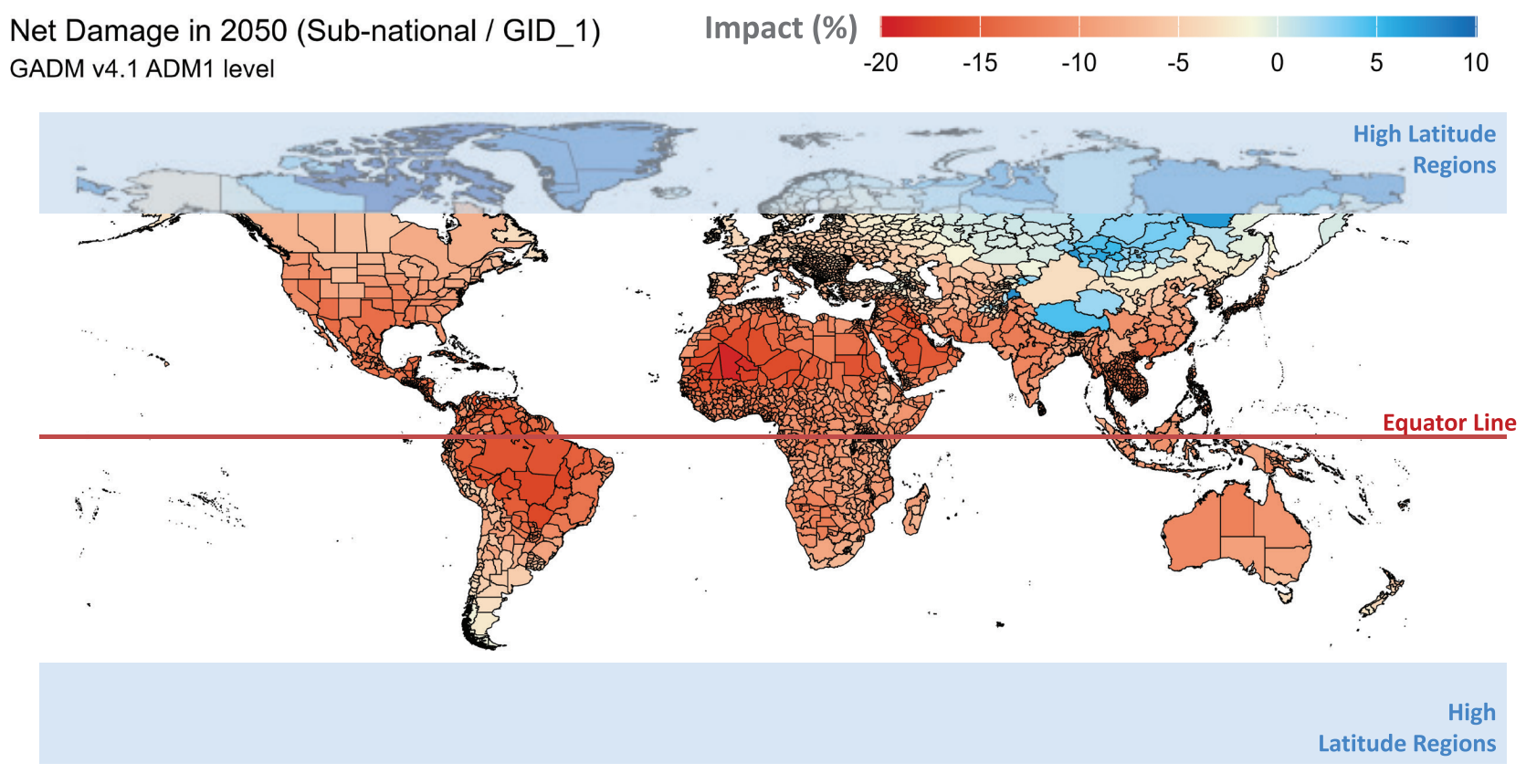


FIGURE 4

**US national rating and selected state-level impacts under the expected scenario**
Source: Scientific Climate Ratings (2026). *Sovereign Climate Risk Rating: Technical Documentation.* Available at: https://scientificratings.com/sovereign-ratings/.

**Sovereign Climate Risk Rating**

**E**

**Scores**
63/100 (2035)
64/100 (2050)

## Expected GDP per capita impact, Expected Scenario

| Horizon | Expected Impact | Score |
|---|---|---|
| 2035 | -4.6% | 63/100 |
| 2050 | -10.4% | 64/100 |

**02** Aggregation Asymmetry

## State-level GRP-per-capita loss snapshot, expected scenario

| State | Avg Temp | Loss 2035 | Loss 2050 |
|---|---|---|---|
| Arizona | ~22°C | -6.0% | -13.7% |
| Texas | ~20°C | -6.1% | -13.7% |
| Florida | ~23°C | -4.5% | -10.1% |
| California | ~15°C | -4.9% | -11.0% |
| New York | ~9°C | -3.3% | -7.5% |
| Minnesota | ~6°C | -3.4% | -7.7% |

## Observations

**The aggregation trap**
**National average (~12°C) places the US near the productivity optimum**, while sub-national disaggregation reveals a different picture.

**Population concentration**
**40%+ of US economic activity is in southern states already above the 13°C threshold**, facing non-linear, accelerating losses.

**Asymmetric curve**
**The impact curve is steeper above 13°C than below**. Cold northern states gain less from warming than hot southern states lose.

## CONCLUSION

SovCRR's principal innovation is a continuous analytical chain from historical climate and economic records to forward-looking, probability-weighted sovereign risk metrics. By estimating damages at the sub-national level before aggregation, translating them consistently across NGFS-aligned scenarios and keeping GDP-per-capita impacts visible beneath the rating, the framework preserves the economic information needed for credit analysis rather than reducing climate exposure to a standalone score.

For investors, this creates a practical bridge between physical climate-risk research and sovereign portfolio decisions. The expected losses can enter macroeconomic forecasts, fiscal analysis and debt-sustainability assessments, while the scenario distribution and regional decomposition reveal the sources and tails of risk. The rating simplifies comparison, but the underlying metric remains traceable. This combination of granularity, scenario consistency and economic interpretability makes SovCRR a distinctive tool for the early identification of the structural vulnerabilities of economies before they are priced into sovereign credit spreads.

SovCRR is designed for several user groups. Institutional investors can use it to quantify climate-related sovereign risk in terms compatible with portfolio and credit models; banks and development-finance institutions can demonstrate climate-risk integration using interpretable economic metrics rather than stand-alone scores; public-sector and supranational institutions can compare climate-vulnerable countries on a consistent, financially grounded basis; and corporate treasuries can assess the climate dimension of their sovereign holdings and geographically concentrated revenues.

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# US Exposure to Physical Climate Risk: Why Every State is Different—EDHEC-CLIRMAP Shows Wide Variation in Temperature-Related GRP Projections Across Climate Zones

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- The United States encompasses highly diverse geographies and climates, which create distinct patterns of physical climate exposure across states.
- These differences can lead to substantial variation in long-term temperature-related economic impacts.
- EDHEC-CLIRMAP produces temperature-based projections of long-term regional GRP effects. It does not model wildfire probability, severity, burned area or wildfire-specific damages. This note uses wildfire evidence to contextualize those projections.
- Tools that translate changes in average temperature into economic impacts are therefore increasingly important.

The sign and magnitude of predicted economic losses are determined by the intersection between space, through local climate zones and baseline temperature conditions, and the non-linear temperature–GDP structural relationship estimated in the underlying EDHEC-CLIRMAP methodology. The location of a given region therefore matters because it determines where that region sits on the response curve, and whether additional warming is projected to generate limited effects, temporary gains, or increasingly negative economic impacts.[4]

EDHEC-CLIRMAP identifies marked differences in projected temperature-related GRP impacts across states. Under the SSP5-RCP8.5 vigorous warming scenario (MPI-ESM1-2-HR model), it projects losses of more than one quarter for Florida and a similar magnitude for California by the end of the century; for Texas, projected losses reach 43% by 2099. These are temperature-based macroeconomic projections and must not be attributed to individual hazards such as storms, wildfires, flooding, drought, heat or sea-level rise.

EDHEC-CLIRMAP (EDHEC-CLimate-Induced Regional MAcroimpacts Projector) is a free online tool developed by the EDHEC Climate Institute (n.d.). Scientists, experts, professional investors, policymakers, and ordinary users can use this free user-friendly platform to discover how climate change–induced shifts in average temperature are projected to affect the GRP of individual regions.

## BACKGROUND

Climate change is happening all around us, sparing no region or industry. Its impact will be determined by the urgency with which nations take action to rein in and slow anthropogenic emission drivers and ultimately adapt to gradually reduce its cost to society.

These risks (and their underlying materiality) are expected to vary significantly across regions (and implicitly, climate zones). The US provides an ideal illustration of this observation, with its wide geography and strong climate extremes – from hot to cold deserts, forests, mountains, flat and cliff-edge coasts, the near equatorial regions of southern states, and the permafrost of Alaska.

This article examines how the physical-climate-risk context varies across US states, using wildfires as a case study of an acute hazard. It uses EDHEC-CLIRMAP to present temperature-based long-term GRP projections for selected states. The tool does not model wildfire hazard or damages; the wildfire discussion is contextual and does not attribute the modeled GRP projections to wildfires.

**We interpret temperature-related GRP projections alongside external evidence on wildfire risk and economic transmission channels. Wildfire drivers and damages are not directly modeled in EDHEC-CLIRMAP.**

## REVIEW OF THE US CLIMATE ZONES

### Geographical extremes in the US

**North and South:**

- **Alaska:** Northern most state, just 2,000 km south of the North Pole.
- **Hawaii:** Southern most state, just 2,100 km north of the Equator.

**High and low:**

- **Mount Denali, Alaska:** highest peak at 6,190 m.
- **Death Valley, California:** lowest point at –86 m.

**Hot and cold:**

- **Great Basin desert:** coldest desert in the US due to elevation (mostly above 1,200 m with peak at 3,000 m) drops as low as –7.3°C in winter.
- **Chihuahuan desert:** largest desert in North America at ~360,000 km² (though mostly in Mexico).
- **Sonoran:** lushest desert, with more plant species than any desert in the world.
- **Mojave:** hottest desert, home to Death Valley, the hottest place ever recorded (56.7°C in 1913).
- **Utqiaġvik, Alaska:** the coldest inhabited place in the US, with winter temperatures that average –24°C. All-time record low of –62°C was recorded at Prospect Creek Camp in 1971.

**Wet and dry:**

- **Hawaii:** wettest state with a mean average of 161.8 cm of rain a year. Its volcanic mountains wring moisture out of trade winds.
- **Nevada:** driest state by far with just 24.1 cm a year. Mountain ranges block Pacific moisture from the desert or high-altitude region of the interior West.

The climate of the US varies hugely, not just from North to South, but within individual states, many of which contain multiple climate zones (see Table 1). The standard classification system for Climate Zones is the Köppen-Geiger framework, which breaks zones into five major groups, each subdivided by temperature and rainfall seasonality:

**A: Tropical:** All months above 18°C. High annual rainfall (1.5+ meters). No true winter. Found in South Florida, Hawaii, and US territories. Subdivides into rainforest (Af), monsoon (Am), and savanna (Aw).

**B: Dry (Arid & Semi-Arid):** Evaporation consistently exceeds precipitation. Hot deserts (BWh) in the SW; cold deserts (BWk) at elevation. Semi-arid steppes (BS) cover the Great Plains and Great Basin. Covers roughly a third of the contiguous US.

**C: Temperate:** Coldest month between –3°C and 18°C. Includes humid subtropical (Cfa) across the Southeast, Mediterranean (Csa/Csb) along the California coast, and oceanic (Cfb) in the Pacific Northwest.

**D: Continental:** At least one month below –3°C; no dry season (f) or dry summer (s). Warm summers (a), cool summers (b), or subarctic (c/d). Dominates the Midwest, Great Lakes, and much of Alaska's interior.

**E: Polar:** No month reaches 10°C. Tundra (ET) has at least one month above freezing; ice cap (EF) does not. Found across Arctic Alaska and at high alpine summits.

**H: Highland:** This is a useful supplementary classification for mountainous terrain (such as the Rockies, Sierra Nevada, Cascades and Alaska Range) where rapid changes in elevation create highly localized climates that don't neatly fit into the core groups.

[4] *The full version of this paper is available here: https://climateinstitute.edhec.edu/news/us-exposure-physical-climate-risk-why-every-state-different.*

TABLE 1

**Some states with multiple climate zones**

| State | Climate Zones |
|---|---|
| Alaska | Maritime Oceanic, Subarctic Continental, Transitional (Southcentral), Maritime-Continental (West), Arctic/Polar (North Slope) |
| California | Mediterranean Coast, Hot-Summer Mediterranean (Central Valley), Marine West Coast (NW), Hot Arid Desert (SE), Cold Desert/Steppe, Alpine/Highland |
| Texas | Humid Subtropical (East), Semi-Arid Steppe (North & Central), Arid Desert (West), Highland/Mountain (Trans-Pecos) |
| Florida | Humid Subtropical (North & Central), Tropical Savanna (South), Tropical Maritime (Keys) |

## HAWAII: A SPECIAL MENTION

### Up to 10 Köppen subtypes on a single island

Hawaii's Big Island is the most climatically diverse place in the US – and arguably on Earth relative to its size (10,430 km²), encompassing four of the five major Köppen climate groups and 10 of the 14 subtypes (Luo et al., 2024). You can drive from a lush tropical rainforest (Hilo, windward east) to a scorching hot desert (Kona coast, leeward west) in under two hours – and ascend Mauna Kea (4,205 m) for polar tundra conditions with occasional snow. The only major Köppen group absent is the continental (D) group; there are no cold winters at sea level and no landmass big enough to generate continental air masses.

## PHYSICAL CLIMATE RISKS

While the risks brought by climate change are numerous and interconnected, NOAA (National Oceanic and Atmospheric Administration) considers the following to be the 10 most major (NOAA, n.d.b), based on its monitoring of "billion-dollar disasters" and climate impacts:

1. Increased Frequency of Severe Storms
2. More Intense and Wetter Hurricanes
3. Destructive Coastal Flooding and Storm Surge
4. Prolonged and Intense Drought
5. **Intensified Wildfire Seasons**
6. Extreme Heatwaves
7. Inland Flooding from Heavy Rainfall
8. Ocean Acidification
9. Shrinking Sea Ice and Glaciers
10. Significant Ecosystem and Biodiversity Disruption

Within this array, it's also useful to understand the difference between **acute and chronic climate risks**.

- **Acute risks** are event-driven, such as sudden, discrete weather events of short duration but high intensity. Examples include hurricanes, floods, wildfires, heatwaves, and extreme precipitation. They tend to cause concentrated, visible damage in a short timeframe.
- **Chronic climate risks** are gradual, longer-term shifts in climate patterns that progressively alter conditions over years or decades. Examples include rising sea levels, increasing average temperatures, changing rainfall patterns, and permafrost melt. The damage is cumulative rather than sudden (TCFD, 2017).

It's also worth noting that the two interact; the frequency and severity of each type of risk may vary considerably and become increasingly difficult to predict, and the drivers may appear with a significant time lag (BCBS, 2021).

## US STATES THROUGH THE EDHEC-CLIRMAP LENS

Throughout the rest of this article, we use EDHEC-CLIRMAP to present results for specific US-state cases. These are temperature-based, long-run GRP projections; they are not estimates of wildfire likelihood or wildfire damages. We examine wildfire evidence separately as external context and do not attribute the model results to that hazard.

EDHEC-CLIRMAP is a top-down macroeconomic methodology that focuses on the relationship between annual average temperature and regional economic growth. Acute climatic events, including wildfires, may be correlated with changes in average temperature and may therefore contribute to the historical GDP responses from which the relationship is estimated. However, they are not directly observed, modeled or separately identified in the framework.

### What is the underlying methodology to these losses?

EDHEC-CLIRMAP estimates how regional output per capita has historically responded to changes in local average temperature, using roughly four decades of data for more than 1,500 regions in 87 countries. It then applies that relationship to downscaled climate projections for more than 3,400 sub-national regions, compounding annual growth shocks into a permanent gap in GRP per capita relative to a no-additional-warming counterfactual (see Figure 1 and Table 2). Because the relationship is non-linear, additional warming weighs far more heavily on already-hot regions than on cooler ones. The full methodology is set out in "Addressing a structural blind spot in sovereign pricing" in this supplement.

## WILDFIRE CONTEXT

- **California, most fires:** the 2025 Palisades Fire was one of the most devastating wildfires in the state's history and destroyed over 6,800 structures (CAL FIRE, 2025).
- **Oregon, most acres:** More wildfires occur in the East and central states, but western fires are far larger (NIFC, n.d.).
- **Alaska, high for both:** the Arctic is warming 3–4 times faster than the rest of the globe and Alaska has vast tracts of highly flammable black spruce forests (NOAA, n.d.a).

### Alaska through the EDHEC-CLIRMAP lens

Alaska is warming rapidly and is experiencing increasing wildfire risk as forest conditions become drier and warmer. But warming is not without upsides for the region, potentially bringing longer growing seasons, lower winter heating costs and longer ice-free shipping seasons along its Arctic coast.

FIGURE 1

**Alaska – projected temperature-related GRP loss by 2099, not a wildfire-loss estimate**
Note: This forecast uses the MPI-ESM1-2-HR model under the SSP5-RCP8.5 vigorous warming scenario.

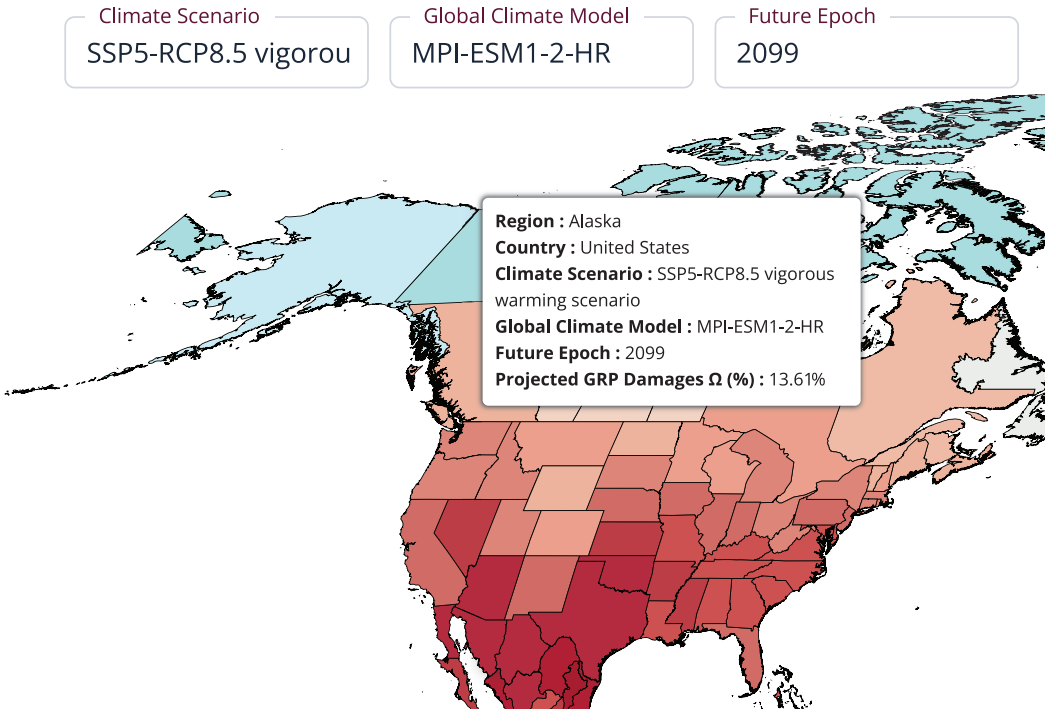


TABLE 2

**Alaska – projected temperature-related GRP loss under the stated scenario**
Note: This forecast uses the MPI-ESM1-2-HR model under the SSP5-RCP8.5 vigorous warming scenario.

| Future Epoch | Projected GRP Loss |
|---|---|
| 2021–2040 | +1.81% |
| 2051–2070 | +9.06% |
| 2099 | +13.61% |

TABLE 3

**California – projected temperature-related GRP loss under the stated scenario**
Note: This forecast uses the MPI-ESM1-2-HR model under the SSP5-RCP8.5 vigorous warming scenario.

| Future Epoch | Projected GRP Loss |
|---|---|
| 2021–2040 | –3.76% |
| 2051–2070 | –10.53% |
| 2099 | –27.3% |

## Wildfire damage

Wildfire damage falls into three broad categories: economic, health, and environmental. The indirect costs dwarf the direct ones.

**Direct structural damage** is the most visible. Between 2015 and 2024, wildfires destroyed more than 8,000 structures annually on average.

**Health costs** are enormous and geographically dispersed. Wildfires now cause approximately 25% of Americans' total exposure to harmful fine particulate matter. Wildfire smoke can lead to lost productivity far from the fire's location and cause premature deaths.

**Economic disruption** beyond structures includes: power shut-offs, business closures, travel cancellations, supply chain disruptions, and steep drops in overall employment and surges in unemployment claims in affected regions (JEC, 2023).

**Agricultural and timber losses** are substantial: damaged watersheds reduce agricultural productivity, while timber losses represent an economic injury that can take decades, and in some cases up to a century, to reverse (Bousfield et al., 2023).

## California through the EDHEC-CLIRMAP lens

Wildfire risk is material in California. Separately, under the stated scenario, EDHEC-CLIRMAP projects a 27.3% reduction in GRP per capita by 2099 relative to a no-additional-warming counterfactual (see Figure 2 and Table 3). This is a temperature-related macroeconomic projection, not an estimate of wildfire damage.

## How climate change is evolving wildfire damage

Warmer, drier conditions are dramatically extending fire seasons and increasing fire intensity. While the annual number of fire ignitions declined approximately 10% between 1990 and 2024, the annual area burned increased substantially, meaning fewer but far larger and more destructive fires (NOAA, n.d.c). The insurance system has been hard hit, with some regions now facing uninsurability challenges (Swiss Re Institute, 2026). Of the nearly $150 billion in damages caused by California's 2018 wildfires, approximately 60% were indirect economic losses from disruption to economic activity (JEC, 2023). Under a middle-of-the-road climate scenario, federal fire suppression costs alone are projected to rise 42% by 2050, and that is before accounting for the cascading economic damage that follows each fire (C2ES, 2026).

## Potential economic transmission channels of wildfire losses

The following pathways explain how wildfire events can affect economic activity. They are based on external evidence and are not variables or outputs of EDHEC-CLIRMAP; they should not be used to attribute the modeled GRP projections to wildfires. Wildfires damage regional economies through a set of transmission channels that are unusually broad and deeply interconnected. The immediate destruction of physical capital (homes, businesses, energy infrastructure, and timber) removes productive assets from the economy, while forced evacuations halt economic activity across entire regions even in areas that escape direct burning. The damage then ripples outward: smoke travels thousands of miles, suppressing labor productivity and driving health costs far beyond the fire perimeter. Real estate values fall in affected areas, eroding household wealth, the local tax base, and access to credit simultaneously. Watersheds are contaminated, raising water treatment costs and threatening agricultural productivity for years after the flames are extinguished. Insurance markets come under structural strain as claims surge and insurers withdraw from fire-prone markets entirely, compounding costs for those who remain.

### *Acute risks*

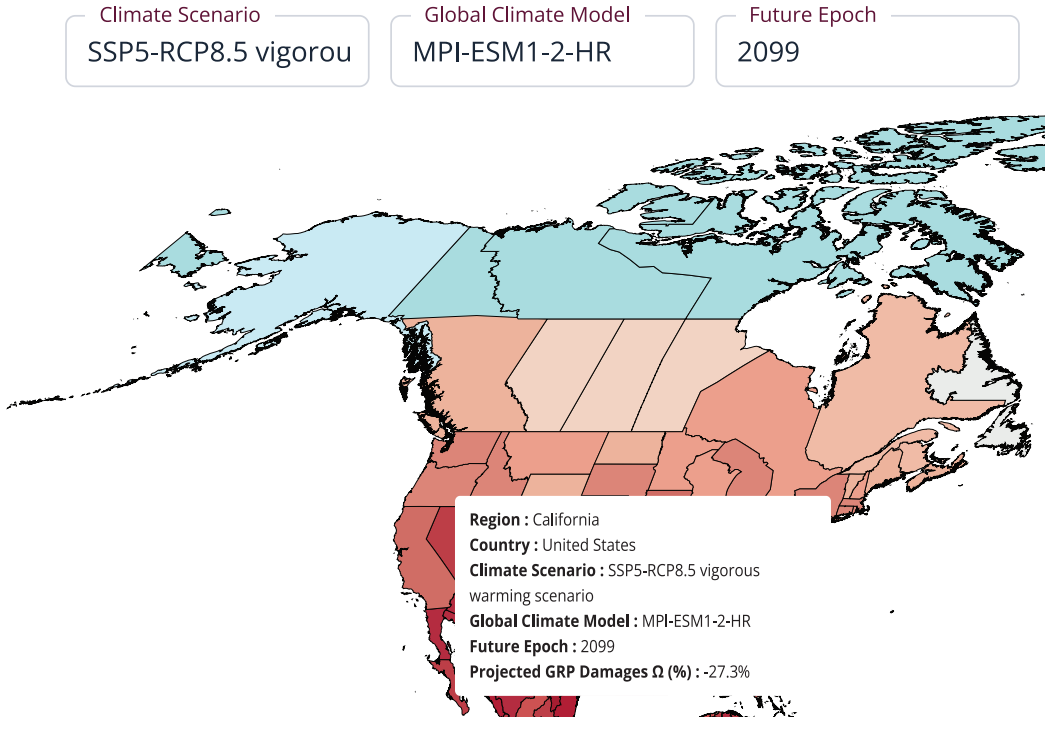
- **Direct asset destruction** to property, timber, and infrastructure costs the US $394 billion–$893 billion annually, equivalent to 2–4% of US GDP (JEC, 2023).
- **Labor market disruption** is amplified by smoke, which extends far beyond the fire zone. It slashes labor market earnings by an estimated $93 billion per year across the entire US (Bayham et al., 2022).
- **Supply chain disruption** dominates the total cost. In California's 2018 wildfires, indirect supply chain losses accounted for 59% of total damages, dwarfing direct capital losses of 19% (Wang et al., 2021).
- **Sectoral impacts** fall hardest on real estate, insurance, forestry, and tourism (Luo, 2023).

### *Chronic risks*

- **Permanent natural capital erosion** as rising fire frequency depresses the long-run value of western forestry, recreation, and watershed services (Wang and Lewis, 2024).
- **Persistent air quality drag** as smoke seasons lengthen, reducing earnings across manufacturing, healthcare, real estate, and transport (Borgschulte et al., 2022).
- **Insurance market retreat** renders high-risk areas effectively uninsurable, depressing property values and undermining local tax bases over the long term (Tavor, 2024).

FIGURE 2

**California – projected temperature-related GRP loss by 2099, not a wildfire-loss estimate**
Note: This forecast uses the MPI-ESM1-2-HR model under the SSP5-RCP8.5 vigorous warming scenario.




### A REAL-WORLD EXAMPLE OF THE FINANCIAL IMPACT OF ACUTE WILDFIRE DAMAGE: LOS ANGELES FIRES, JANUARY 2025

Driven by exceptional Santa Ana winds and prolonged drought conditions, the Palisades and Eaton fires tore through Los Angeles County in January 2025, destroying more than 16,000 structures. Insured losses alone amounted to $40 billion, making them the costliest wildfires on record globally (Swiss Re Institute, 2026), and total economic loss to $250 billion–$275 billion (AccuWeather, 2025). Property and capital losses of $76 billion–$131 billion helped fuel a 0.48% decline in county-level GDP for 2025, equivalent to approximately $4.6 billion (Li and Yu, 2025).

### CONCLUSION: DISCUSSING THE TRUE DAMAGE FIGURE DOES NOT NEGATE THE THREAT

EDHEC-CLIRMAP supports analysis of the spatial distribution of temperature-related macroeconomic impacts. This article combines those projections

with external evidence on wildfire risk and economic transmission channels. It does not estimate wildfire occurrence, severity or wildfire-specific economic loss.

These estimates should nevertheless be interpreted as partial measures of risk. Current damage functions and integrated assessment models often do not fully capture cascading failures, threshold effects, compound shocks or climate tipping points. In particular, many models assume that damages increase smoothly with temperature, while some physical and economic impacts may become non-linear beyond certain warming levels.

This limitation is especially relevant for compound events. A wildfire following a drought and heatwave, or a storm affecting a coastal city already exposed to sea-level rise, can generate larger and more persistent losses than the same hazard considered in isolation. Future research therefore needs to better account for interacting hazards, tipping points and propagation channels across regions and sectors.

The implication is that the damage estimates discussed in this article, while already material, may remain conservative (Dietz et al., 2021; Carbon Tracker Initiative and University of Exeter, 2026).

## From regional projections to sovereign ratings

EDHEC-CLIRMAP shows how temperature-related impacts vary within a single country. The Sovereign Climate Risk Rating builds on the same sub-national foundation: it translates regional damages across nine NGFS-aligned scenarios, weights them by probability and aggregates them into a country-level expected impact on GDP per capita, which feeds an A–G rating. Like CLIRMAP, it measures chronic, temperature-driven risk rather than hazard-specific exposure such as wildfire.

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# The Netherlands' Climate Paradox: The Cloned Bananas of Europe—How to Assess Structural Risk in a Climatically Uniform Nation

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- The Netherlands' physical consistency makes it uniquely vulnerable to the challenges of climate change.
- Scientific Climate Ratings' ratings cast a light on the weaknesses – and strengths – that this uniformity creates.
- Canny investors will want to price these risks before spreads adjust.
- The question is not whether climate risk will be priced; the question is who will price it first.

The homogeneous geography and climate of the Netherlands make it uniquely vulnerable to the challenges of climate change (Dutch Climate Risk Assessment, 2026; World Bank, 2021). In this note, we use our Sovereign Climate Risk Rating for the nation, and our Climate Exposure Ratings on some of its key infrastructure assets, to cast a light on the weaknesses – and strengths – that this uniformity creates.

## THE GEOGRAPHY OF IMPOSSIBILITY

The Netherlands is perhaps Europe's most climatically uniform nation: a single, consistently temperate maritime zone draped over relentlessly flat terrain, where a 322-meter-high point represents the extreme (World Bank, 2021). The country experiences the same rainfall and temperature gradient across its entire 42,000 km$^2$ landmass. As a consequence, when climate change brings compound stress, an entire nation of 18 million shares identical vulnerability.

A quarter of the Netherlands lies below sea level (Dutch Climate Risk Assessment, 2026), with vast swathes reclaimed from the sea and protected by dikes – engineered into existence across a climate zone that has remained stable for centuries. Thousands of kilometers of engineered polders represent humanity's defiance of physics. That uniformity has been a Dutch triumph: perfect optimization for predictability. But climate change has moved the goalposts and stolen that predictability away.

Climate change is accelerating the rise of sea levels and salting groundwater; for a nation where agriculture represents 100 billion euros annually in exports and bulb-growing, market gardening, and drinking water supply are climate-sensitive, this is an existential threat (Netherlands Environmental Assessment Agency, 2023). At the same time, it is intensifying both droughts and rainfall (Climate Change Post, 2024). And when the nation's rivers flood, they flood simultaneously; the entire nation faces identical shock (Climate Change Post, 2024). Like cloned bananas – which dominated global markets until a single fungal disease wiped out the entire Gros Michel variety in the 1950s because genetic uniformity meant zero resistance – the engineered efficiency of the Netherlands is now its greatest fragility in the face of climate change (Agronomy Science, 2022). When the baseline conditions shift, it has zero internal diversity baked into the mix to absorb the blow.

By 2050, sea levels could rise 19–39 cm; by 2100, up to 2 m in high-emissions scenarios (Dutch Climate Risk Assessment, 2026; World Economic Forum, 2023). The country's challenge is to implement adaptations that can outrun the structural vulnerabilities hardwired into the nation's very existence. Its 17,691 km of flood defenses (Asterra, 2024) face surging flood risks from both land and sea perimeters, as well as new challenges such as drought-related cracking and peat oxidation (Alliance4Water, 2024).

These evolving threats present investors with valuation challenges. Assessments of sovereign spreads, infrastructure bonds, or regional development projects can no longer rely on historical precedents; they need forward-looking frameworks that price structural exposure. The Netherlands' very uniformity – an absence of geographic or climatic refugia – means that climate risk is not diffuse or regional; it is nationwide.

Every dike reinforcement, every water-management project, every infrastructure adaptation to the warmer weather hinges on accurate pricing of long-term macroeconomic exposure. This is where Scientific Climate Ratings, with applied research born of the EDHEC Climate Institute, is filling the gap: by quantifying the expected GDP impact of chronic physical climate risk at subregional granularity (and translating predicted economic losses into an A–G risk rating) (Scientific Climate Ratings, 2026a), Scientific Climate Ratings and its SovCRR product identify how an evolving climate is likely to impact economic productivity curves under warming scenarios. And by providing in depth analysis of the risks to its infrastructure network, asset by asset, we build a bottom-up assessment of the nation's vulnerability to climate change.

For the Netherlands, a nation where adaptation is not optional but existential, early identification of climate risk translates directly into capital allocation decisions and competitive advantage for those who understand it first.

The objective of this article is to show how Scientific Climate Ratings' sovereign and infrastructure climate-risk analytics can translate the Netherlands' distinctive physical exposure into financially material signals for investors (see Schneider (2026a, 2026b)). Using the Netherlands as a case study, the paper highlights how the country's particular geography and climatic uniformity creates systemic vulnerability to chronic physical risks, while also examining how Scientific Climate Ratings' approach, born out of research from the EDHEC Climate Institute, can quantify these risks through (i) sovereign ratings, (ii) asset-level exposure metrics, and (iii) scenario-consistent estimates of long-term economic and credit impacts.

### THE POLDER PARADOX: WHEN THE CLIMATE SHIFTS THE 2,000 YEAR-OLD GOALPOSTS

The low-lying tracts created when dikes reclaim land from a body of water are termed **polders**. However, reclamation is not a one-and-done process. The land typically requires continuous pumping and dike vigilance to avoid waterlogging and floods. The Dutch have been doing this for millennia (the oldest dike in the country is a post-and-wickerwork structure uncovered at Vlaardingen, near Rotterdam, dating to the 2nd century BC) perfecting a system of monitoring and maintenance that is an engineering and administrative masterpiece.[5] However, a changing climate means every aspect of this tried-and-tested methodology is being challenged – and for the first time in many centuries, Dutch engineers need to reinvent the wheel.

## TRANSLATING VULNERABILITY INTO FINANCIAL RISK: THE EDHEC CLIMATE INSTITUTE'S FOUNDATION

The Sovereign Climate Risk Rating, described in full earlier in this supplement, estimates how shifts in average temperature are likely to affect GDP per capita across more than 3,400 sub-national regions, weights the results across nine NGFS-aligned scenarios and aggregates them into a country-level expected impact. That percentage impact stays visible beneath the A–G rating, so investors can feed it directly into their own sovereign credit models.

### Why the approach is distinctive for sovereign investors

Our ratings provide a transparent, scenario-based alternative to traditional ratings, incorporating forward-looking physical risk expressed as an expected

[5] *https://www.vestigia.nl/en/possibly-the-oldest-dike-in-the-netherlands-discovered-in-vlaardingen/.*

GDP per capita impact (Scientific Climate Ratings, 2026a). Correlated physical shocks across multiple regions create systemic fiscal stress that cannot be diversified away (Dutch Climate Risk Assessment, 2026). The SovCRR provides information in the language that institutional investors speak: climate-conditioned sovereign credit scores, overlaying unconditionally expected loss from physical climate risk.

## APPLYING SCIENTIFIC CLIMATE RATINGS TO THE NETHERLANDS

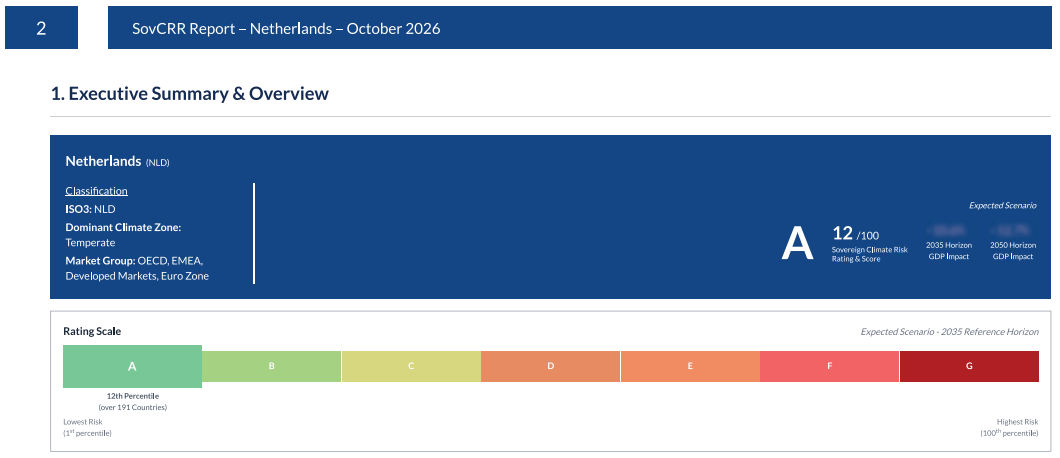
We rate 191 sovereigns on an A–G scale ratings anchored to expected GDP per capita damage under the most probable warming pathway by 2035 and 2050 (Scientific Climate Ratings, 2026a).

The Netherlands, as a temperate-zone country, sits in a peer group of 47 nations sharing similar dominant climate characteristics (Scientific Climate Ratings, 2026a). Within that peer group, it ranks in the top tier on climate risk – comparable to Denmark (A rating), the UK, and Ireland. And while the nation has proven adaptive capacity in the past – integrated water management, engineered flood defenses, systematic land reclamation, and policy coherence across sectors (World Bank, 2021) – past performance does not guarantee future outcomes when the climate regime itself is shifting.

Our ratings reveal the true exposure. Figures 1 and 2 show a snapshot of our Sovereign ratings report for the country.

FIGURE 1

**A snapshot of our Sovereign ratings report for the Netherlands**




## INFRASTRUCTURE RISK: WHERE UNIFORM VULNERABILITY BECOMES VISIBLE

Scientific Climate Ratings' Climate Exposure Rating (CER) assesses infrastructure assets' exposure to future climate risks under a continuity scenario – the most likely pathway based on today's global policies (Scientific Climate Ratings, 2026b). The rating integrates both physical risks (floods, storms, heat, wildfire) and transition risks (demand shifts as the economy decarbonizes, carbon pricing, policy restrictions).

Four Dutch infrastructure assets illustrate the nation's exposure profile:

### TMA Logistics (Port, G/98) – worst-case physical risk

TMA Logistics, a major port facility, carries the worst climate exposure rating in its peer group: G, with a score of 98/100 (Scientific Climate Ratings, 2026b). Its location holds the key: storm exposure accounts for 95% of the impact. The facility faces a probable maximum loss (PML) of –30.4% of asset value in a single worst-case storm year, and a cumulative discounted loss of –18.2% of asset value by 2035 – the most severe impact among the four assets surveyed. This is pure cloned banana risk: a port in the Rhine delta, built on flat terrain, with nowhere to relocate and no geographic refuge (see Figures 3–6 for the top level snapshot of Scientific Climate Ratings' assessment of this asset).

### Maastricht Aachen Airport (G/87) – storm vulnerability in transition

Maastricht Aachen Airport, serving the Dutch-German border region, rates G/87, with 95% of exposure driven by storm risk (Scientific Climate Ratings, 2026b). Storm PML is –17.5%, and cumulative asset value impact is –10.4% by 2035. The airport ranks in the top 35% of airport peers on exposure, meaning two-thirds of the world's airports face worse climate risk – but for temperate-zone airports, this is a poor ranking.

### The Data Center Group (F/79) – critical infrastructure under pressure

The Data Center Group, a major Dutch digital infrastructure operator, rates F/79 (Scientific Climate Ratings, 2026b), bridging the gap between worst-case airport/port exposure and better-performing assets. Physical exposure dominates (95% weight), driven by storm (91%) and flood (5%) risk. Probable maximum loss is –11.9% in a single worst year, with cumulative asset value impact of –6.6% by 2035.

Data centers are critical infrastructure, without which the likes of financial systems, e-commerce, cloud services and even traffic control cannot function. Yet this facility, like most Dutch infrastructure, sits in the path of compound flooding risk (Climate Change Post, 2024). A single event combining heavy rainfall and the resulting river floods along with a coastal surge could simultaneously damage this asset whilst increasing the costs for its reconstruction.

### Enecogen power station (F/81) – the stranding paradox

The most instructive case is Enecogen, a gas-fired power station (Scientific Climate Ratings, 2026b). Its overall rating is F/81, but the composition tells the true story:

- Physical Risk Rating: A/11 (top 4% of gas-fired plants globally – nearly immune to direct climate damage)
- Transition Risk Rating: G/99 (among the most exposed to market demand shifts)

Storm and flood PML are negligible, rounding down to zero combined; the facility will not be destroyed by climate hazards. But it faces existential economic risk as the global economy decarbonizes. By 2035, shifts in market demand account for 92% of Enecogen's climate exposure rating. This is not physical vulnerability; it is stranding risk.

The paradox is revealing for investors. Traditional climate risk frameworks focus on physical damage – floods, heat stress, supply chain disruption. But Enecogen illustrates a subtler risk: an asset perfectly adapted to its physical climate but at risk of becoming economically obsolete in a decarbonized world. Bond investors holding Enecogen debt do not need to fear physical asset damage, but collateral that generates no revenue because the market for its output has vanished.

FIGURE 2

**A snapshot of our Sovereign ratings peer ranking for the Netherlands**

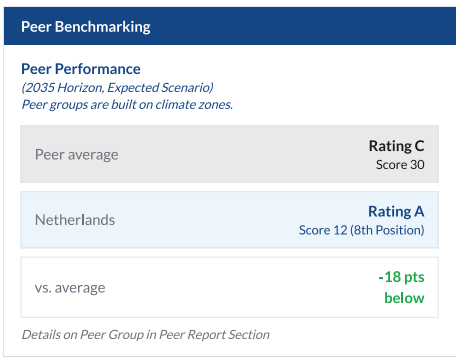



FIGURE 3

**Live maps pinpoint global location**




## FROM SCENARIOS TO SPREADS: THE MISPRICING WINDOW

Sovereign spreads for the Netherlands reflect traditional credit analysis: low debt-to-GDP, strong institutions, OECD membership, and precious AAA-equivalent credit quality. They do not yet reflect the potential structural, permanent GDP losses threatened by chronic climate warming (and implied debt implications) under warming scenarios.

SCR's ratings address questions that traditional analysis does not: what are the long-term productivity trajectories under a 2°C warming scenario? How does permanent regional productivity loss erode tax capacity? At what point do debt sustainability ratios become concerning (Dutch Climate Risk Assessment, 2026)?

Similarly, when infrastructure investors assess TMA Logistics or Maastricht Aachen bonds, they can see the –18.2% and –10.4% cumulative asset value impacts by 2035 (Scientific Climate Ratings, 2026b). These are measurable, scenario-consistent damage projections. Traditional ESG scores offer rankings; Scientific Climate Ratings offers financial quantification.

FIGURE 4

**Key climate exposure metrics, grade and peer rankings**

## TMA Logistics

IC603040 - Other Port

**Peer Group:** Other Port
**Asset ID:** NLD_00125
**Country:** NLD
**Rating Updated:** 2026-08
**Scenario:** Expected

| CLIMATE EXPOSURE RATING (2035 Horizon) | PHYSICAL EXPOSURE (2035 Horizon) 95% CER Weight | TRANSITION EXPOSURE (2035 Horizon) 5% CER Weight |
|---|---|---|
| G 98 /100 | G 97 /100 | D 57 /100 |
| Peer Ranking: **Top 76%** | Peer Ranking: **Top 76%** | Peer Ranking: **Top 6%** |
| Peer Median: **G Rating** | Peer Median: **G Rating** | Peer Median: **F Rating** |

FIGURE 5

**A summary of climate risk exposures**

**Top 3 Climate Drivers,** Expected Scenario

| Rank | Driver | Category | CER Contribution |
|---|---|---|---|
| 1 | Storm | Physical | 95% |
| 2 | Market Demand Shifts | Transition | 3% |
| 3 | Flood | Physical | 2% |

**Climate Exposure Evolution,** Expected Scenario

| | 2035 | 2050 |
|---|---|---|
| Score | 98/100 | 98/100 ↑ |
| Peer Ranking | Top 76% | Top 73% ↓ |

FIGURE 6

**A snapshot of risks and opportunities**

**Climate Risk & Opportunity Snapshot**

Probable Maximum Loss (PML)

Open Physical Section

**How bad could the worst single year look?** Asset's highest hazard impact highlighted with others listed for reference, not added to it.

**30.4%** Storm PML | **0.7%** Flood PML | **0.1%** Heat PML | **0.0%** Wildfire PML

Cost of Inaction - Cumulative climate impact to selected horizon, assuming no new measures

Open Strategy Section

**PHYSICAL**

**-18.2%** of asset value

Discounted cumulative impact to 2035 horizon
**Unadjusted** (no resilience measures reported)

**TRANSITION**

**0.0%** of revenue

Discounted cumulative impact to 2035 horizon
**Unadjusted** (no decarbonisation measures reported)

For investors who price these risks before spreads adjust, the window is narrow but valuable. With access to climate-adjusted credit analytics, they can:

- Identify which sovereigns' spreads are lagging their climate fundamentals;
- Reweight sovereign bond portfolios to reflect unpriced climate damages;
- Stress-test infrastructure portfolios against NGFS-aligned scenarios; and
- Price bond duration differently based on climate-adjusted long-term growth expectations.

### POLICY RESPONSE: FROM CRISIS TO OPPORTUNITY

The Netherlands is not passive in the face of this exposure. The government has launched multiple initiatives, from the Room for the River program (Utrecht Law Review, 2021) (which strategically floods designated areas to manage water) to ambitious heat transition targets (gas-free new buildings since 2018, retrofitting upward of a million homes by 2030) (Netherlands Environmental Assessment Agency, 2023). One initiative that exemplifies the integration of climate adaptation into civic culture is the nation's Tegelwippen ('Tile Flipping') competition (see Box 1).

### WHY THIS MATTERS: THE STRANDING ARGUMENT REVISITED

The Netherlands is absorbing real economic costs now – retrofitting buildings, upgrading dikes, investing in green infrastructure. And in a decarbonized economy (2040+), these costs are sunk, and the competitive advantage is locked in. Meanwhile, nations delaying transition will transition anyway, but later, at higher cost, with weaker positioning (Climate Change Post, 2024).

### BOX 1: GREEN CITIES FROM THE GROUND UP – NETHERLANDS TEGELWIPPEN COMPETITION

Since 2021, the annual 'Tile Flipping' competition has mobilized Dutch municipalities to remove paving slabs from gardens, streets, and public spaces, replacing them with trees, grass, and green infrastructure. In 2025 alone, 328 municipalities participated, with 5.9 million tiles removed – the largest result in the competition's history (Alliance4Water, 2024).

The initiative addresses three climate vulnerabilities simultaneously:

- First, concrete and paved surfaces absorb and retain heat, exacerbating urban heat islands (Global Commission on Adaptation, 2019); green spaces cool cities naturally.
- Second, paved surfaces prevent rainwater infiltration, overloading drainage systems and increasing flood risk during heavy rainfall (Global Commission on Adaptation, 2019); soil and plants absorb precipitation naturally.
- Third, gardens support biodiversity and ecosystem services.

Many participating towns run a free 'tile taxi,' collecting removed paving from residents' homes, removing barriers to participation. The competition's success shows that when local organizations make climate adaptation easy and celebratory – rather than punitive – behavior follows.

The program is now spreading: Flanders has adapted the model, and from 2026, two environmental organizations will oversee expanded efforts. For policymakers, it demonstrates that climate adaptation can be simultaneously beautiful, measurable, and community-driven.

Consider infrastructure investors with exposure to both Enecogen (stranded gas plant) and Dutch renewable energy projects. Our ratings reveal the divergence (Scientific Climate Ratings, 2026b): transition risk makes fossil fuel assets economically obsolete, whilst climate-resilient renewable and adaptation infrastructure holds value. Awareness of this dichotomy can inform investment decisions.

For sovereigns, the dynamic is similar. The Netherlands already spends around €11 billion a year – roughly 1% of GDP – on flood defenses, fresh water and climate-proofing, and the Delta Commissioner has warned that this needs to at least double, to 2% of GDP. Yes, this is expensive; failure would be far more so. A nation that absorbs these costs early can potentially emerge from the transition with proven adaptive capacity, climate-hardened infrastructure, and intellectual property (vertical farming technology, water management expertise, cycling infrastructure) that is now globally exportable (World Bank, 2021). These structural issues will feed into bond spreads; knowing this will differentiate savvy investors from those late movers who only recognize the shift after Dutch bonds reprice and asset values have already adjusted.

### ONE DIRECTION: HOW RISING TEMPERATURES TRANSLATED TO LOST GDP IN SUMMER 2026

- **Rivers run dry.** The Rhine, the main way fresh water enters the country, hit an all-time low at Lobith in July.
- **Rain stops.** July delivered just 13 mm of rain versus a historical norm of about 78 mm, triggering an official water shortage.
- **Freight stalls.** Locks closed on the Nieuwe Maas and Twente Canal, costing businesses hundreds of thousands of euros a day.
- **Barges sail half-empty.** Low water forced cargo to be split across extra vessels, driving up costs across the Rhine corridor.
- **Bridges jam.** Steel expands in the heat, and Rijkswaterstaat flags moveable bridges as especially vulnerable.
- **Runways soften.** In heatwaves Schiphol now has to hose down its tarmac in the summer so that heavy aircraft don't damage the softened asphalt.
- **Rivers become warm baths.** The Rhine and Meuse reached about 25°C, bringing algal blooms and fish deaths, and threatening cooling water for power and industry.
- **Landscapes become tinder.** Dry forests, heaths and dunes raise wildfire risk, and one Brabant marsh dried out for the first time in 700 years.
- **Nights stop cooling.** Towns stayed near 20°C overnight, putting care homes, prisons and asylum centres under strain.
- **Cities lose their footing.** Drought lowers groundwater, the land subsides, and centuries-old wooden piles rot once exposed to air (Klimaateffectatlas, n.d.).
- **…and then it pours.** Every 1°C of warming lets air hold about 7% more moisture. Dutch records show hourly cloudbursts intensifying at twice that rate (Lenderink and van Meijgaard, 2008), so water sheets off baked-hard ground and floods inland areas.

### WHY SCIENTIFIC CLIMATE RATINGS IS VITAL

Traditional sovereign credit ratings and financial analysis cannot capture what SCR reveals (Scientific Climate Ratings, 2026a):

- **Granularity:** Scientific Climate Ratings disaggregates climate risk to 3,400+ sub-national regions, identifying which parts of which countries face the steepest economic damage curves. The Netherlands' temperate zone ranking masks intra-country variation: coastal regions face different risks than inland regions; Rotterdam faces different risks than the eastern provinces.
- **Transparency:** Scientific Climate Ratings publishes its methodology and provides full access to underlying regional-level damage projections. Users can see exactly what assumptions drive each rating. Traditional ESG scores are opaque; Scientific Climate Ratings is auditable.
- **Scenario Consistency:** Our ratings are anchored to nine NGFS-aligned climate pathways (EDHEC Climate Institute, 2026), enabling investors to build climate scenarios into their own risk models, stress tests, and long-term asset allocation decisions. This is not a single opinion; it is a probability-weighted range of outcomes.
- **Financial Materiality:** Unlike climate vulnerability scores (which rank exposure without quantifying economic impact), Scientific Climate Ratings translates climate risk into expected GDP loss and asset-level collateral deterioration. This is the language investors actually use.
- **Forward-Looking:** Historical default probabilities and credit spreads are poor predictors of future risk when the climate regime is shifting. Scientific Climate Ratings projects damage under different warming pathways, allowing investors to price risks before credit markets fully reprice them (Dutch Climate Risk Assessment, 2026).

### CONCLUSION: THE COMPETITIVE EDGE OF FORESIGHT

The Netherlands is not simply a climate-vulnerable nation hoping to survive. It is a nation optimizing for a decarbonized, climate-adapted future, absorbing costs today to capture competitive advantage tomorrow (Netherlands Environmental Assessment Agency, 2023). That said, its uniform climate zones and vulnerability to rising sea levels and the twin challenge of heavier periodical rainfall alongside hotter, drier periods mean it is overhung by unique challenges. Investors can use climate-adjusted credit analytics to assess these dynamics.

The cloned banana metaphor is not necessarily pessimistic. It is a call to action. The Netherlands has centuries of experience adapting to water (Climate Central, N.D.). How it adapts to a 2-meter sea level rise remains to be seen (World Economic Forum, 2023).

What is certain is this: investors and policymakers need to price that uncertainty, and recognize the structural climate risk now overhanging assets with historically stable spreads (Dutch Climate Risk Assessment, 2026). Scientific Climate Ratings exists precisely to translate climate science into financial precision at the moment when markets still have a window to reprice.

For the Netherlands, and for any nation facing similar compounded climate exposure, that window is closing. The question is not whether climate risk will be priced; the key question is who will price it first.

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# Adaptation and Decarbonization: Two Halves of One Valuation Problem

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- Infrastructure investors usually treat physical climate risk and decarbonization as separate problems, but we show that both can be expressed as the same thing: an impact on net asset value.
- We use the example of a Brazilian transmission line facing severe physical risk and a Norwegian waste-to-power plant facing substantial transition risk.
- Both face material losses in value, yet each would have looked safe if it had been screened for only one of the two risks.
- Hence investors need to screen on both axes, rank interventions before funding them, and treat the financing structure as part of the decision.

*Infrastructure investors have learned to treat physical climate risk and decarbonization as separate disciplines, run by separate teams on separate timetables. Two recent asset-level analyses, one on a Brazilian transmission line and one on a Norwegian waste-to-power plant, suggest that is a mistake. Both resolve into the same number (see Figure 1).*

## THE PROBLEM IS A VALUATION PROBLEM

Infrastructure is the asset class where climate risk bites earliest and hardest. Assets are immobile, long-lived, capital-intensive and often contractually bound to deliver a service for decades. They cannot be repositioned away from a hazard, and many of them sit in sectors where the cost of emitting is set by policy rather than by the market.

The aggregate numbers are now large enough to be a portfolio consideration rather than a disclosure exercise. A report published this year by the World Bank Group's International Finance Corporation (IFC, AXA Climate and Scientific Climate Ratings, 2026) puts average annual loss from extreme weather events affecting infrastructure and buildings at more than USD 700 billion, and estimates that low- and middle-income countries alone absorb around USD 390 billion a year in financial and economic losses, equivalent to 1–2% of GDP. On an unmitigated path, it projects that climate impacts could cost 43 million jobs across 49 countries by 2050, and that targeted measures could cut those losses by more than half.

What those figures do not tell an investment committee is what to do on a Tuesday morning about a specific asset. That requires the risk to be expressed in the same units as everything else on the investment case: cash flow, net asset value, internal rate of return. Two recent pieces of asset-level work do exactly that, from opposite directions.

## PHYSICAL RISK: WHAT A TRANSMISSION LINE IN MATO GROSSO REVEALS

That report, Low Cost, High Yield: The Adaptation and Resilience Investment Opportunity for Infrastructure, was published in June 2026 and co-produced with AXA Climate and Scientific Climate Ratings, which led the quantitative business case analysis. It examined three existing Brazilian assets across power transmission and distribution, water and sanitation, and roads.

The transmission case is the clearest illustration. The asset is a 500 kV double-circuit overhead line of more than 1,000 km running through three consecutive segments in Mato Grosso, operating under a concession that runs to 2042. As of 2024 it supplied electricity to roughly 8.8 million people in a state that is one of Brazil's largest producers of soy, corn, cotton and cattle.

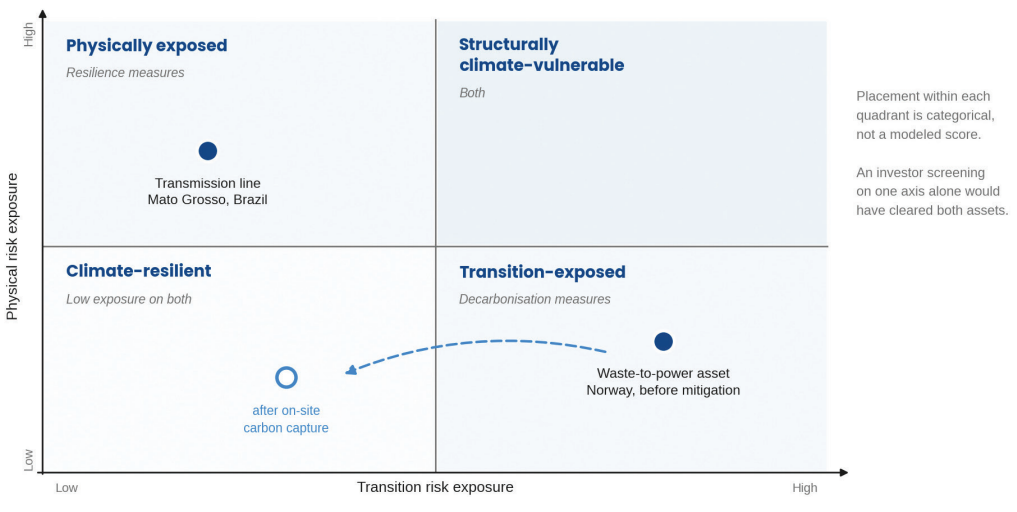
Modeled without any adaptation, the three material hazards erode around **30% of net asset value** over the 2026 to 2042 concession period. Two findings matter more to investors than the headline.

The first is the composition of the loss. Wildfire, not flood or storm, is the dominant driver, and **95% of the projected loss is direct physical damage** rather than revenue lost to service disruption. Storms were modeled as low risk, although the report notes that historical experience suggests greater impact from downbursts, which the hazard modeling does not capture.

The second is that the loss barely moves between scenarios. The figure is approximately 30% under an intermediate-emissions pathway and 30.3% under a high-emissions one. Over a horizon that ends in 2042, the two pathways have not yet diverged far enough to change the answer. Scenario choice is therefore a second-order question for this asset, which removes one of the more common reasons for deferring a decision.

FIGURE 1

**The four climate vulnerability categories, and where each asset sits**
Note: Categories as defined in the Climate Risk Rating framework.
Sources: IFC, AXA Climate and Scientific Climate Ratings, Low Cost, High Yield (June 2026); Scientific Climate Ratings Climate Risk Rating analysis.




## FROM DIAGNOSIS TO A RANKED SET OF DECISIONS

A risk number on its own does not generate an action. What turned this analysis into a capital allocation exercise was costing and ranking seven candidate measures on a common basis. The measures were selected by partner engineering companies, which assessed implementation costs, and their effectiveness was evaluated using the ClimaTech database of adaptation and resilience strategies, which also supplied cost estimates where local data was unavailable.

The ranking is more instructive than any single result (see Figure 2):

- **Firebreaks** cost around 3% of NAV and avoid 25.7%, a benefit-cost ratio of roughly **8:1**. Financed by a ten-year loan, total losses fall from 30.3% of NAV to 7.6% once the cost of the measure is counted: 4.6 points of residual damage plus 3 points of cost.
- **Vegetation management** avoids 18.2% at a cost of 5.1%, a ratio of about 3.5:1. Worth doing, clearly second.
- **Fireproof building materials** avoid 9.1% but cost 55.5% of NAV. The benefit-cost ratio falls below 1. The measure addresses the right hazard and still fails the test.

- **Flood and storm measures** avoid less than 1% of NAV each and did not proceed to financial analysis at all.

That last point deserves emphasis in a market where adaptation is often discussed as an undifferentiated good. On this asset, most of the available measures were not worth financing. The value sat in one cheap intervention against one dominant hazard.

The financing analysis produced a further result that runs against instinct. Comparing an internal cash-flow payment against a ten-year loan, **loan tenor mattered considerably more than interest rate**. Longer maturities spread repayment while avoided-loss benefits compound, and interest rate variation had minimal effect. For investors negotiating resilience capex with lenders or regulators, that reframes what to argue for.

The operational co-benefits reinforce the financial case. Modeled service disruption falls from around 10.8 days a year to 1.6, a reduction of roughly 85%. Across all three Brazilian assets, investing less than 10% of NAV in targeted measures delivered multiples of that cost in protected value: **USD 8.6 per dollar in transmission and distribution, USD 6.3 in water and sanitation, USD 2.2 in roads**.

The report is explicit about its limits. The cases use simplified assumptions and publicly available data rather than operator inputs, exclude measures operators have already implemented, and rest on damage functions that are tailored to sector and geography but not to the specific asset. The internal rates of return reflect only avoided losses and measure costs, not full project economics. The authors describe the output as illustrative, indicating the order of magnitude and the business-case logic rather than an asset-specific risk assessment. Read as a screening output rather than a forecast, that is the appropriate standard of proof for a prioritization decision.

FIGURE 2

**Cost against avoided loss, transmission line, high-emissions scenario**
Note: Four measures are reported in the source as avoiding less than 1% of NAV and are plotted here at a nominal 0.9%.
Source: IFC, AXA Climate and Scientific Climate Ratings, Low Cost, High Yield (June 2026), Table 2.2.

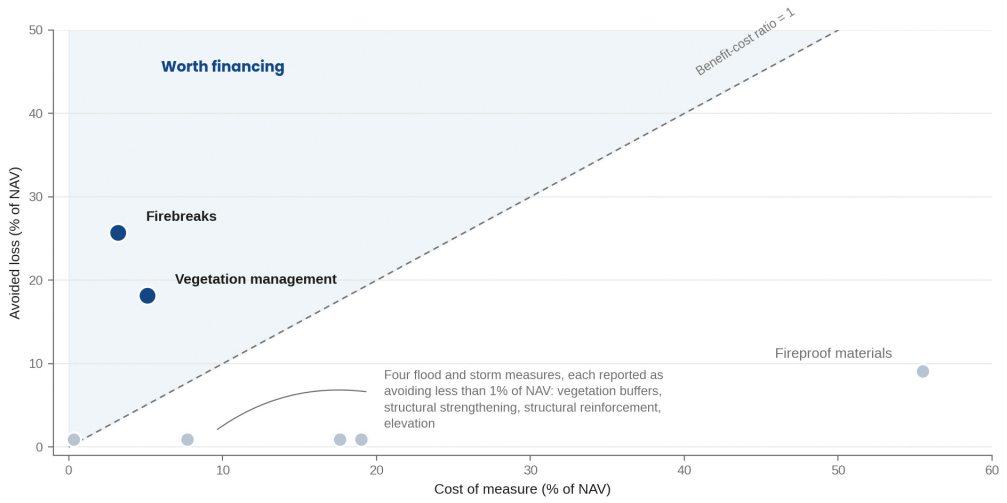



FIGURE 3

**The six steps, with physical and transition risk modeled in parallel and combined at the adjustment stage**
Source: Scientific Climate Ratings, Climate Risk Rating methodology.

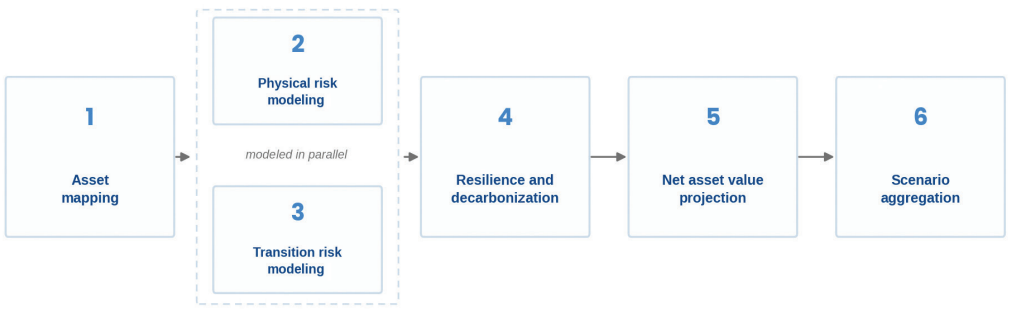
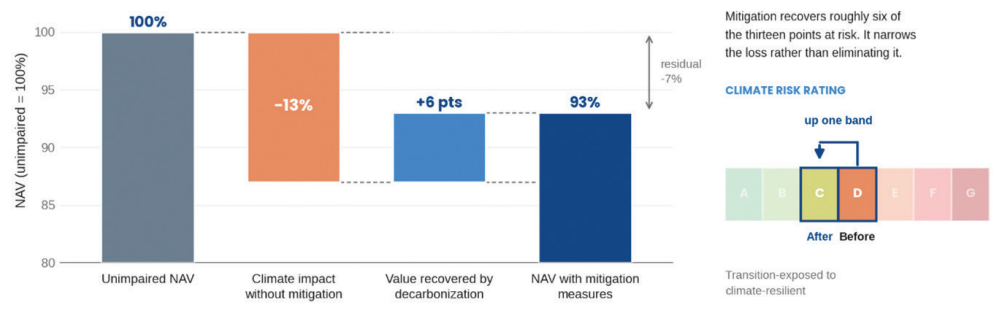



FIGURE 4

**Projected climate-induced net value loss by 2050, before and after the decarbonization investment. Points recovered is the difference between the two stated loss figures. Excludes the capital cost of the facility**
Source: Scientific Climate Ratings Climate Risk Rating case analysis.




## TRANSITION RISK: A WASTE-TO-POWER ASSET IN NORWAY

The second case inverts the exposure. Scientific Climate Ratings assessed an operating waste-to-power and heat generation asset in Norway using the Climate Risk Rating framework. It begins with asset mapping and boundary extraction. Physical and transition risk are then modeled in parallel, on separate data and separate damage logic (see Figure 3), before the two are brought together and adjusted for resilience and decarbonization measures, projected through a discounted cash flow model of net asset value, and aggregated across scenarios into an A to G rating.

The initial physical risk work found the plant to have **low physical exposure**. On the transmission line's terms, it would have screened as a low-priority asset.

The transition picture was entirely different. The asset's Scope 1 and 2 emissions intensity, multiplied by the projected increase in the national carbon price rather than its level, produced a rising and material carbon cost.[6] The distinction matters: the carbon price already in force is reflected in the asset's current economics, so what drives exposure is the additional burden imposed as the price climbs from where it is today. The sector had already absorbed a 200% increase in carbon tax in the two years before the project, with further increases projected. It is that forward trajectory, not the prevailing rate, that the model prices. On a business-as-usual path, the asset was on a trajectory towards becoming stranded: forced to cease operating before the end of its natural life because transition costs had become prohibitive.

The owner is constructing an on-site carbon capture facility, supported by state funding aligned with the country's net zero ambitions. The facility is expected to cut operational emissions by **close to 90%** against business as usual over ten years.

The valuation effect is measured against what the asset stands to lose. Without mitigation, projected climate-induced net value loss by 2050 runs to **13%**. With the capture facility factored in, that narrows to **7%**, recovering roughly six percentage points of value. The rating moves from **D to C**, and in the framework's terms the asset shifts from transition-exposed to climate-resilient (see Figure 4).

[6] *The transition exposure, rating and net asset value impacts for this asset were calculated under the methodology version in force at the time of the analysis. The framework has since been updated, and current direct carbon cost calculations are set out in the published Climate Exposure Rating and Climate Risk Rating technical documentation.*

Two features of that result deserve attention. The mitigation narrows the loss rather than removing it: on these figures the asset still sits below an unimpaired valuation once the work is done, which is the realistic outcome for most assets and a more useful planning assumption than a return to par.

And the figures measure value preserved. They do not net off the capital cost of the facility itself, so the six points recovered are not a return, and the investment case would need that cost set against them.

For an investor, the relevant output is not the letter. It is that a specific engineering decision has been priced, and that the pricing is expressed in a currency that survives an investment committee: value at risk, value recovered, and what remains exposed after the work is done.

## PUTTING BOTH INTO THE INVESTMENT PROCESS

The two cases are complementary rather than parallel. A Brazilian transmission line carries almost no transition risk and severe physical risk. A Norwegian waste-to-power plant carries almost no physical risk and severe transition risk. A screen on either axis alone would have flagged one asset and cleared the other.

The two analyses did not use the same method. The Brazilian business cases were a streamlined screening exercise, run across an intermediate and a high-emissions pathway and built for speed across many assets. The Norwegian asset went through the full rating framework, which weights outcomes across a set of scenarios by assigned probability. What they share is the endpoint. Physical damage, business interruption and carbon cost are all routed through a discounted cash flow model and expressed as an impact on net asset value, which is what makes two very different assets comparable at all. Where probability weighting is applied it adds something a stress test cannot, converting a question about what could happen into an estimate of what is likely, which is what a valuation requires.

Three practical implications follow.

**Screen on both axes, always.** Exposure is unevenly distributed. A first-level exposure assessment across a portfolio costs far less than missing a concentration, and identifies which assets justify deeper financial analysis.

**Rank interventions before funding them.** Neither case supports the proposition that adaptation or decarbonization is uniformly value-accretive. Both show wide dispersion, and in the Brazilian case the majority of candidate measures failed a benefit-cost test. The ranking is the deliverable.

**Treat the financing structure as part of the measure.** The tenor finding is not incidental. An intervention that fails on one financing structure can clear comfortably on another.

## IMPLICATIONS FOR PORTFOLIOS

Neither case requires an investor to take a view on climate policy. The transmission line loses roughly the same share of its value under both modeled scenarios. Both are exercises in pricing conditions that are substantially already in motion.

Both also argue for spending, and for spending decisively. One measure on the Brazilian line returned roughly eight times its cost and cut projected losses from 30% of net asset value to under 8%. Across the three assets, less than a tenth of NAV committed returned multiples of that in protected value. But the returns were concentrated rather than spread. On the same asset, against the same dominant hazard, one intervention cleared at eight times cost while another fell below break-even. A portfolio-level mandate to adapt or to decarbonize averages across exactly the distinction that produced the return.

Asset-level quantification is what makes that distinction visible. Instead of asking whether a portfolio is exposed to climate risk, an investor can ask which assets, exposed to which hazard or which cost, at what magnitude, addressable by which measure, at what ratio, financed how. Those are ordinary investment questions. They happen to need climate science to be comprehensively answered, and such answers belong on the investment case rather than in a separate report.

# The Cloud Has a Physical Address: Climate Exposure in the Infrastructure Behind AI

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- We assessed how physical climate hazards could affect the value and operations of the infrastructure underpinning the AI economy.
- A key finding is that physical climate risk is driven much more by where a data center is located than by who operates it.
- The AI boom is becoming an infrastructure investment cycle as much as a technology cycle.
- We may think of our data as living in the cloud, but the infrastructure that stores and processes it is firmly rooted on the ground.

## SUMMARY

Scientific Climate Ratings analyzed 1,000 data centers across 34 countries and 11 major operators, assessing wind, flood, wildfire and heat exposure to 2035 and 2050 under two emissions scenarios. Our central finding is this: physical climate risk is driven far more by where a data center is located than by who operates it. By 2050, the average discounted cost of inaction ranges from 3.4% of asset value across assets in Sweden to 20.6% in Japan, against a much narrower 4.3–9.6% spread across operators – meaning facilities belonging to the same company can sit at opposite ends of the risk spectrum depending on location.

The broader implication is that the AI boom is becoming an infrastructure investment cycle as much as one of technology. The cloud may be digital, but when it comes to the economics of AI, technology investment is increasingly materialized by physical infrastructure.

## THE CLOUD ISN'T REALLY A CLOUD...

We may think of our data as living in the cloud, but the infrastructure assets that store and process it are firmly rooted on the ground. They are location-bound and unmovable. They depend on vast quantities of reliable energy and water. They must be able to withstand an increasingly volatile range of extreme weather events. As a result, they are exposed to the same physical climate risks as other critical infrastructure assets. This means the next constraint on the digital economy is increasingly physical, not digital.

Most of the attention paid to data centers and climate runs in one direction: what these facilities consume, in power and in water. Far less has been paid to the reverse – what a changing physical environment does to the facilities themselves, and to the capital tied up in them. That is the question this report takes up, asset by asset.

Computing infrastructure has evolved through distinct eras.

- In the initial enterprise server room era, companies operated modest server closets on-site.
- From the early 2000s, colocation providers built shared facilities where multiple companies rented rack space, spreading the cost of power and cooling.
- The cloud era, beginning with AWS in the mid-2000s, let companies rent computing capacity rather than physical racks, hosted inside data centers owned by a small number of providers.
- Since the early 2010s, the largest of those providers have built 'hyperscale' campuses, which are dedicated, self-owned, gigawatt-class sites.
- The launch of consumer generative AI tools from late 2022 triggered a further step-change, and a build-out that is still accelerating.

As demand for AI computing has grown and diversified, so too have the physical demands placed on data centers. Training and inference workloads are substantially more computationally intensive than many previous cloud-era workloads, increasing power consumption and, critically, the amount of heat that must be dissipated. Higher-density computing therefore requires increasingly sophisticated and energy- and water-intensive cooling infrastructure, placing greater demands on the physical systems and resources that underpin each facility (see Figure 1).

FIGURE 1

**The asset and the network it depends on**
Source: Scientific Climate Ratings – The Cloud Has a Physical Address Report (September 2026).

Each facility is a chain of component systems inside a structural shell, and every link in that chain reaches beyond the fence line for power, water and connectivity.

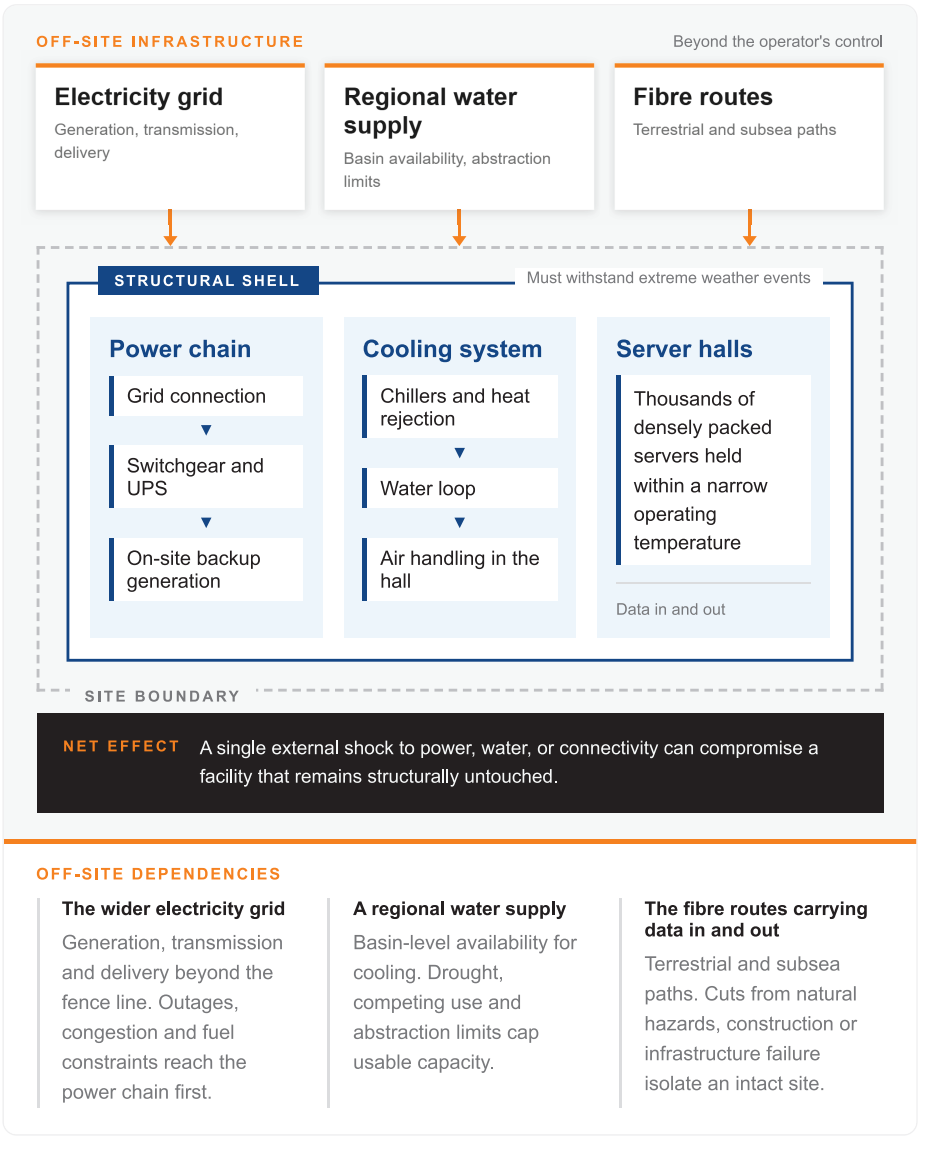


FIGURE 2

**Where the exposure sits**

All 1,000 assets, coloured by Physical Exposure Rating and sized by modelled total value impact. Below, the same assets summarised by country. The United States dominates the sample at 616 assets and spans the full scale from A to G, while Japan, on 22 assets, is the only country where every asset rates F or G.

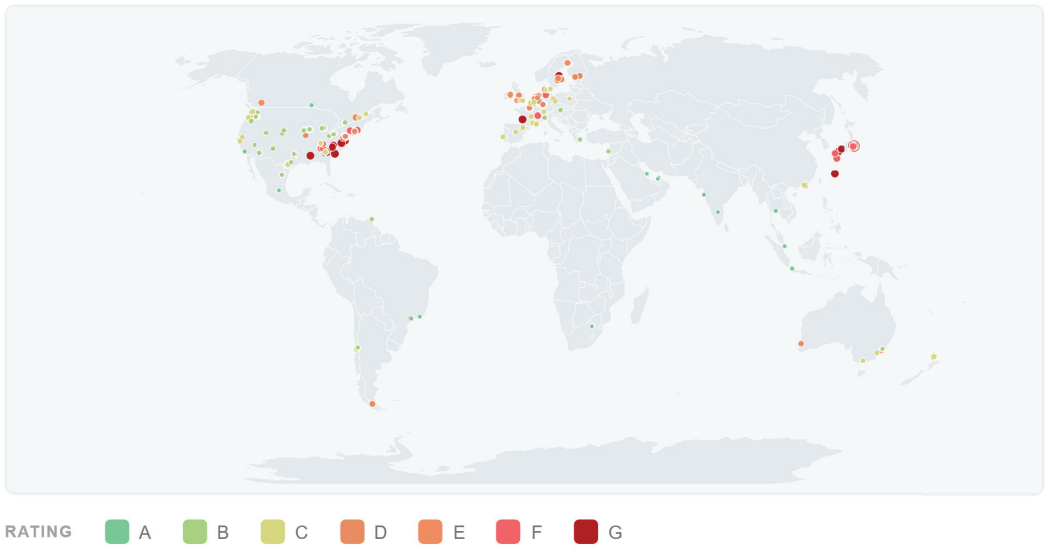



TABLE 1

**The countries holding the most assets**
Source: Scientific Climate Ratings – The Cloud Has a Physical Address Report (September 2026).

| Country | Assets | Average Rating | Range | Rated F or G | Annual Expected Asset Value Impact |
|---|---|---|---|---|---|
| **United States** | 616 | C | A–G | 1% | **0.60%** |
| **Germany** | 63 | D | C–D | 0% | **0.80%** |
| **Ireland** | 51 | E | E–F | 22% | **1.47%** |
| **United Kingdom** | 39 | C | C–D | 0% | **0.81%** |
| **France** | 32 | D | C–F | 6% | **0.86%** |
| **Australia** | 30 | C | B–C | 0% | **0.43%** |
| **Netherlands** | 26 | F | D–G | 69% | **1.85%** |
| **Japan** | 22 | F | F–G | 100% | **2.78%** |
| **Sweden** | 16 | B | B–C | 0% | **0.43%** |
| **Canada** | 14 | B | A–C | 0% | **0.41%** |

While most of the debate about data centers and climate has focused on the associated emissions, far less attention has been paid to a different question, one that matters just as much: what physical risks are assets in a given location exposed to and how can these risks be mitigated?

## DATA CENTERS ARE HIGHLY RESOURCE DEPENDENT AND CLIMATE VULNERABLE

Data centers depend on continuous access to power, cooling, and connectivity, demands that are already putting strain on supply. In Ireland, data centers now account for 23% of the country's metered electricity consumption, up from 5% in 2015 (Central Statistics Office, 2026). Meanwhile in the US, data centers consumed about 17bn gallons of water directly in 2023, projected to reach 38–73bn by 2028 (Shehabi et al., 2024). A warming climate will only intensify resource scarcity.

## SCIENTIFIC CLIMATE RATINGS' ANALYSIS

To establish the extent of the physical climate risks faced by data centers, we assessed 1,000 individual assets spanning 34 countries and 11 operators. We selected these assets on the basis of operator relevance, data quality, and analytical coverage, rather than sampling the market at random.

Table 1 shows the 10 countries holding the most assets, ordered by asset count; the remaining 24 countries are grouped. Average rating is the mean Physical Exposure Rating across the country's assets, expressed on the A–G scale. Range is the span of individual ratings present. Mean impact is the mean total value impact across that country's assets, as a percentage of asset value, SSP5-8.5 at 2050. The US holds 616 of the 1,000 assets, so global averages are heavily US-weighted (see Figure 2).

A country mean near 1% therefore looks modest. But it recurs annually against assets built to run for decades and effectively impossible to relocate. It is the accumulation that matters to an owner or lender, and that is what the cost of inaction below measures.

### Reading the numbers: An annual figure, not a one-off loss

These are annual expected values: the probability-weighted average loss in a typical year, as a share of tangible asset value. Not a single severe event, and not a forecast for one particular year.

Our approach starts at the level of the individual asset; we map each data center's precise location and physical footprint, then assess it against Scientific Climate Ratings' physical hazard models for flood, wind, wildfire, and heat stress. Each model translates climate hazard intensity into an expected damage or disruption metric, using asset-type-specific engineering damage functions and location-specific hazard data. These metrics are then combined into a Physical Exposure score and converted into an A to G Physical Exposure Rating, benchmarked against a reference distribution so that results are comparable across assets, geographies, and time. We ran this analysis across the 2035 and 2050 horizons under the two recognized emissions pathways, SSP2-4.5 and SSP5-8.5.

## SCOPE: WHY THE ANALYSIS COVERS FOUR HAZARDS

Exposure to a broader set of physical hazards can be assessed in the underlying data. The analysis carries flood, wind, wildfire and heat through to financial impact because they combine material climate relevance with damage functions suitable for financial quantification.

1. **Material climate hazards**
   Flood, wind, wildfire and heat are among the major climate-related hazards responsible for substantial physical and economic impacts globally (as identified in UN Office for Disaster Risk Reduction, 2020).
2. **Financially quantifiable**
   For these four hazards, peer-reviewed damage functions are available and sufficiently robust for our methodology, allowing physical exposure to be translated into financial impact.

One further point is worth making upfront: this is an analytical sample, not a full census of the global data center market. The findings below should be read as a rigorous look at a representative set of assets, not as a definitive map of the entire sector's exposure.

## WHAT OUR ANALYSIS REVEALS

The scale of climate exposure faced by data centers is significant, but the distribution of risk across the portfolio is more revealing than any single headline number: physical climate exposure is widespread and far from uniform (see Figures 3 and 4):

- The operator comparison shows a varied distribution of A–G ratings (with A reflecting the lowest risk).
- NTT and Microsoft sit at the higher exposure end amongst the operators, with 9.8% and 9.6% of their data center assets respectively assigned a 'G' (severe) exposure rating.
- At the country level the concentration is far sharper: 54% of assets in the Netherlands and 32% in Japan rate G, while no other country in the sample reaches 1%.

FIGURE 3

**Operator exposure, 2050 horizon**
Source: Scientific Climate Ratings – The Cloud Has a Physical Address Report (September 2026).

Share of each operator's assets by Physical Exposure Rating, from A (lowest risk) to G (severe). Rows are sorted by the share rated G, then by the share rated F.

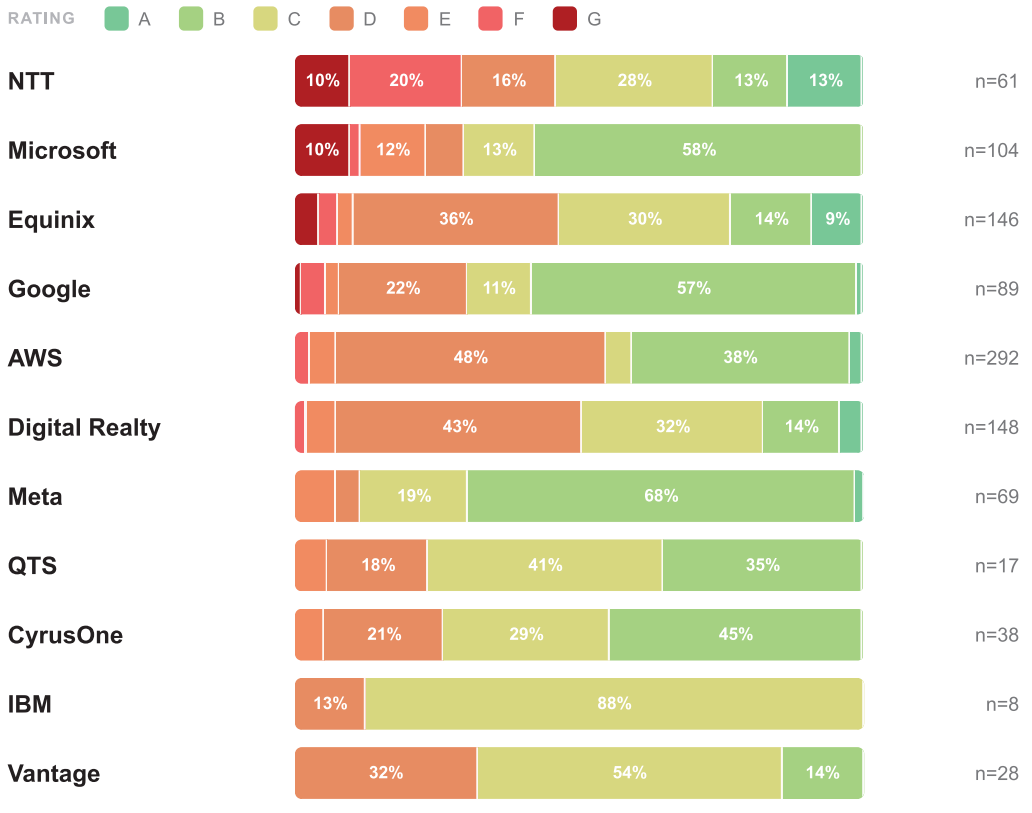
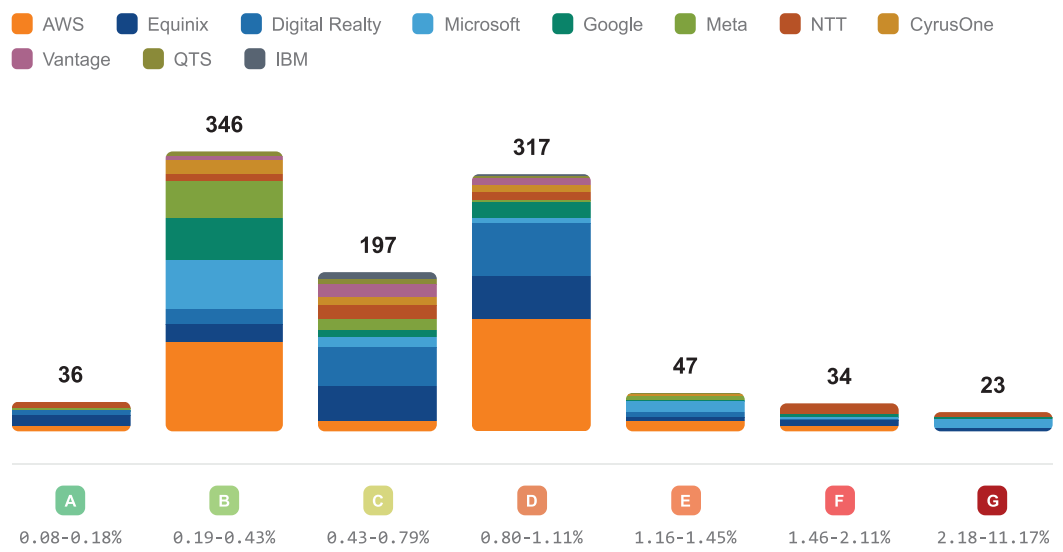



FIGURE 4

**Same rating, different operators**
Source: Scientific Climate Ratings – The Cloud Has a Physical Address Report (September 2026).

The same view read the other way: all 1,000 assets sorted into their 2050 rating bucket and stacked by operator, with the range of modelled total value impact behind each rating letter. Most operators appear in most buckets. B is the largest bucket at 346 assets, and AWS supplies 32% of it; AWS's largest concentration is in D, where it holds 44%.




Column height is the number of assets in the bucket; the figure above each column is that count. Ranges are the minimum and maximum total value impact of assets carrying that rating at the 2050 horizon.

The geographic variation is important because it reinforces a central finding of our analysis: climate exposure is driven more by where a data center is located than by which company operates it.

The figures that follow isolate structural damage, which is one of the two routes by which a hazard reaches the value impact totals above; the other is operational disruption, the revenue effect of lost operating time. Separating the two matters because hazards do not split evenly between them: for the flood-exposed assets, damage accounts for 95% of the value impact, while heat carries no damage mechanism at all and reaches the totals through disruption alone. On damage, wind ranks highest, averaging 0.62% of asset value across all 1,000 assets, and it applies to every one of them (see Figure 5).

Averaging across the full sample this way makes the hazards directly comparable, but it also means flood's low average reflects how few sites are exposed rather than how mild the hazard is where it does apply: among those 185 assets, flood damage averages 0.33%, their mean total value impact (including damage and revenue disruption impacts) is 0.35%, and the worst-placed site reaches 8.9% of damage alone.

Heat requires a different interpretation model again. The model does not assign a structural damage figure to heat: the absence of a value is not a zero, but reflects the fact that heat is treated as an operational hazard rather than a mechanism of direct physical damage to the structure. This distinction is particularly relevant for data centers, where extreme heat can affect cooling efficiency and operating conditions without necessarily producing the kind of direct asset damage captured for wind or flood.[7]

The forward-looking analysis also reflects an important nuance. The 2035 and 2050 measures are look-ahead windows from today rather than sequential snapshots of the same asset's future state. In other words, the comparison should not automatically be read as a trajectory from 2035 to 2050. In fact, 93.5% of assets have an identical physical exposure rating at the two horizons. The implication is that much of the underlying location-specific exposure is already visible today, rather than emerging only in the longer-term scenario.

Carried forward, those annual figures compound into materially larger totals. On the same SSP5-8.5 pathway, discounted to 2050, the mean cost of inaction runs from 3.4% of asset value in Sweden to 20.6% in Japan, a sixfold spread driven almost entirely by location. The operator spread is far narrower, from 4.3% at Meta to 9.6% at NTT, which is the same finding the rating distributions showed: where an asset sits matters more than who runs it. The two charts below (see Figures 6 and 7) set out those totals, first by country and then by operator.

At the country level, however, the forward-looking financial picture shows meaningful differences in both the level and rate of change of exposure. Japan has the highest overall mean total-value impact in the sample at 2.78%, followed by the Netherlands at 1.85% and Ireland at 1.47%. The Netherlands is particularly notable because it has the steepest change between the two horizons, widening by 0.58 percentage points.

The extremes reinforce why averages should be treated carefully. The five highest-exposed assets are two NTT facilities and one Equinix facility at Urayasu on Tokyo Bay, an Equinix site at Union City (US) and a Google facility at The Dalles (US). At the other end of the distribution sit Amazon Web Services facilities in Bahrain and the United Arab Emirates, alongside NTT sites in Johannesburg and Bangalore and Equinix sites in Dubai and Abu Dhabi. The concentration of both high- and low-exposed assets within the same operators again points to location as a critical differentiator.

## THE IMPLICATIONS FOR STAKEHOLDERS

The significance of physical climate exposure is amplified by the characteristics of data-center assets. They are capital-intensive, have long operational lifetimes, and are effectively immovable once constructed.

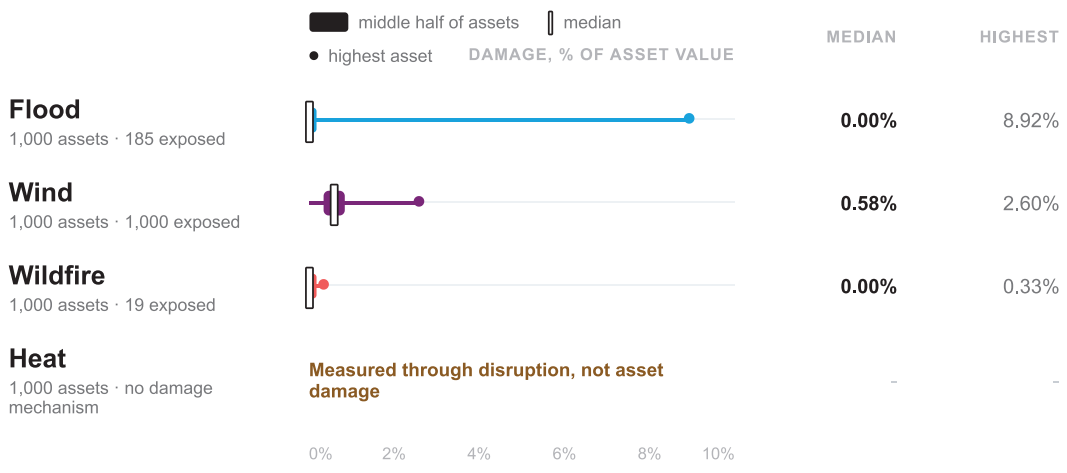
Decisions about location and design therefore have implications over decades rather than over a typical technology investment cycle.

That has practical consequences across four decision points.

[7] *https://scientificratings.com/data-and-analytics/#physical-risk-data.*

FIGURE 5

**Structural damage: most assets sit near zero, a few sit far out**
Source: Scientific Climate Ratings – The Cloud Has a Physical Address Report (September 2026).



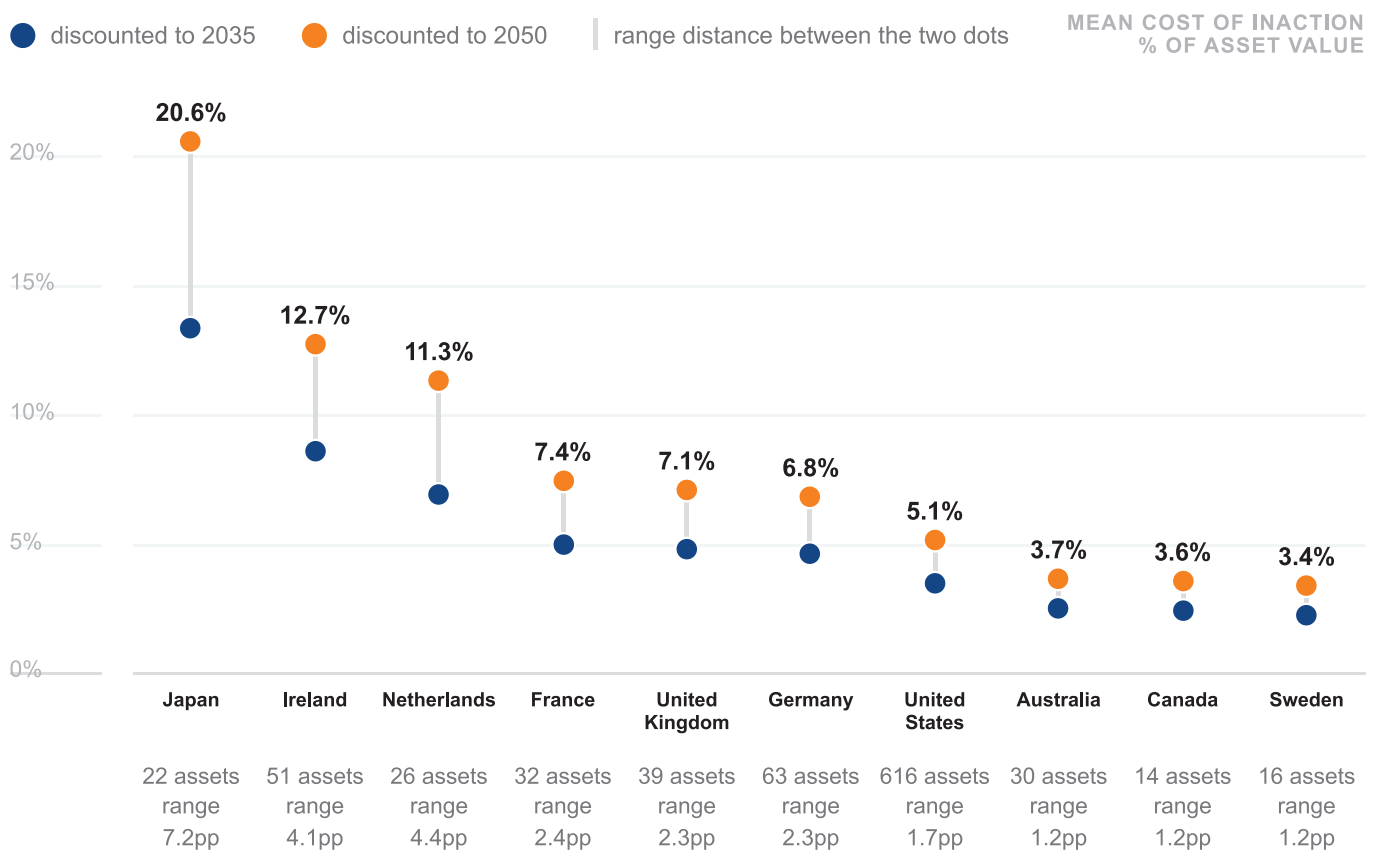

1. **CapEx planning:** An asset's climate exposure should serve as a direct input into resilience spending, such as backup cooling capacity, on-site water storage, and hardened structures. This should be budgeted alongside the build itself rather than treated as a later retrofit.
2. **Insurance terms:** Underwriters are already differentiating pricing and, in some cases, availability by physical exposure. An asset's Physical Exposure Rating gives a forward-looking basis for that conversation rather than relying solely on historical loss data that predates the current pace of warming.
3. **Financing conditions:** Lenders assessing a data center-backed facility can use asset-level exposure, not just operator-level averages, to price risk correctly, particularly given the variation within portfolios.
4. **Site-selection strategy:** For the next wave of build-out, exposure ratings are best used at the stage of choosing a site, when the cost of avoiding a hazard is lowest, rather than after ground has broken.

The AI build-out is therefore creating not only a technology investment cycle, but a major infrastructure

FIGURE 6

**Country cost of inaction: to 2035 vs to 2050**
Source: Scientific Climate Ratings – The Cloud Has a Physical Address Report (September 2026).

One column per country; a blue dot marks the mean cost of inaction discounted to 2035, an orange dot the same figure to 2050. Japan leads on both, reaching 20.6% of asset value by 2050, six times Sweden's 3.4%. Limited to the ten countries with the most assets.

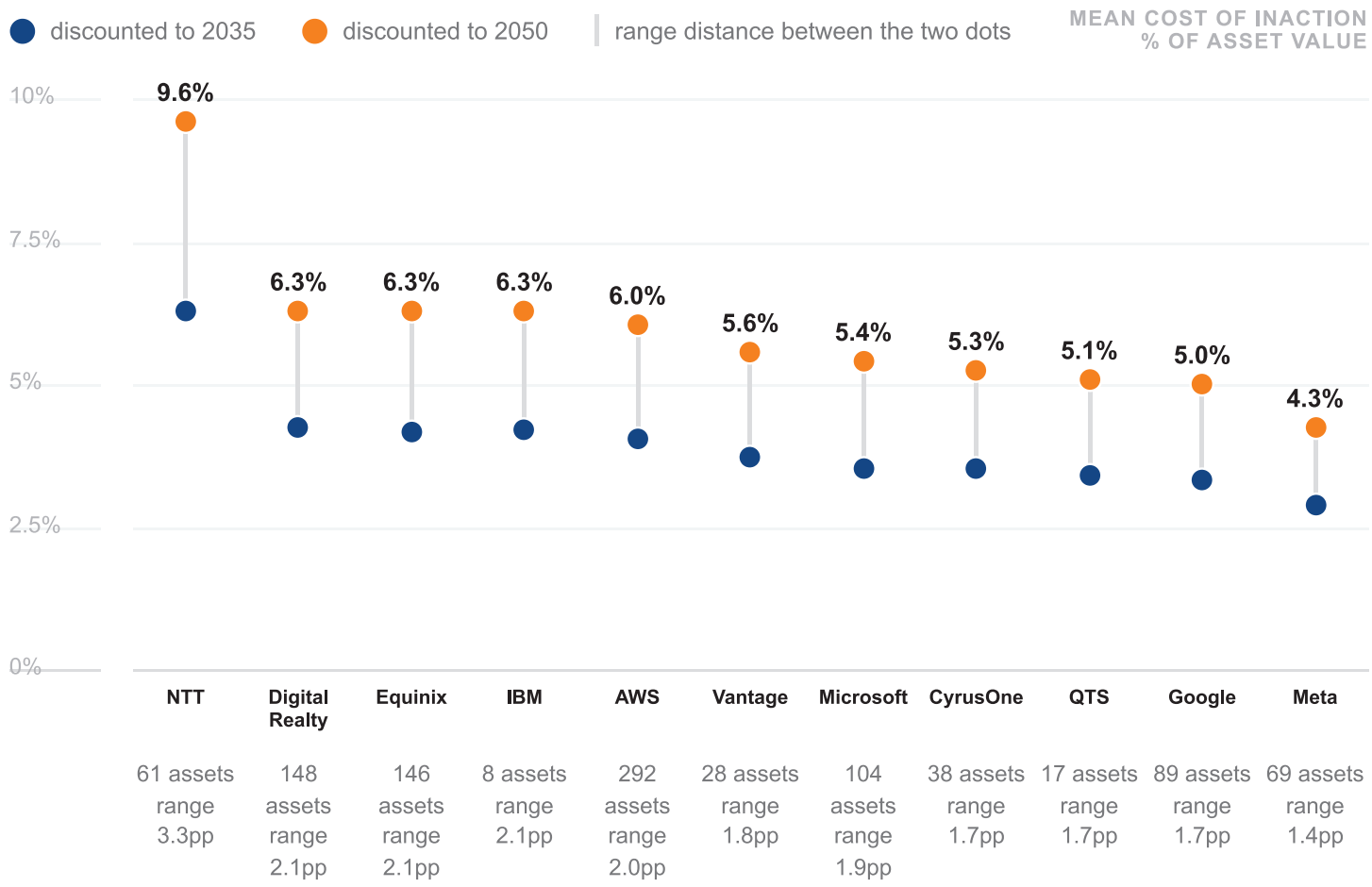



Mean cost of inaction per country, as a percentage of asset value, taken from the modelled cost-of-inaction figures in the underlying data and discounted using the Scientific Climate Ratings and NGFS rates, which sit near 10% and vary by year, sector and country. Columns are sorted by the 2050 figure; under each label is the asset count and the distance between the two dots in percentage points. The longer horizon carries more years of accumulated impact, so the 2050 figure is larger by construction. Figures cover physical risk only and are gross of any further resilience investment beyond the measures already in place.

FIGURE 7

**Operator cost of inaction: to 2035 vs to 2050**
Source: Scientific Climate Ratings – The Cloud Has a Physical Address Report (September 2026).

Same format as the previous figure, by operator. The spread is far narrower than the country view: 4.3% to 9.6% by 2050, against 3.4% to 20.6% across countries. NTT stands clear at the top; the other ten operators sit between 4.3% and 6.3% on very different portfolio sizes.




Identical to the previous figure, grouped by operator, and on the same basis: physical risk only, gross of further resilience investment. Note the vertical scale differs: it runs to 10% here against 22% for countries, so these columns are not directly comparable in height with the chart above.

investment cycle in which physical climate exposure can affect the cost, resilience, and long-term value of the assets being built.

## THE FUTURE OF AI IS ALSO CLIMATE DEPENDENT

The AI build-out is already well underway, developing with unprecedented scale and speed. But this build-out is also running directly into a warming world and changing weather conditions, in ways that are already evident at the level of the individual asset.

The next constraint on the AI economy will not be chips or power alone. The continued operation of data centers will be dependent on climate-resilient design and financing and ensuring that these centers are built in places, and in ways, that can withstand the changing physical world.

Read the full report at: https://scientificratings.com/2026/09/07/the-cloud-has-a-physical-address-climate-exposure-in-the-infrastructure-behind-ai/.

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# Steering Capital Towards a Sustainable Future

