

The Physical Climate Risks of Swiss Pension Funds

From Exposure to Resilience

Rosa Sangiorgio · Nadir Franca



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PUBLISHED	7 October 2026, Zurich
PARTNERS	RSg Impact Investing · Swiss Platform for Impact Investing (SPII) · CLIMADA Technologies · MSCI
PLEASE CITE AS	Sangiorgio, R. and Franca, N. (2026). <i>The Physical Climate Risks of Swiss Pension Funds: From Exposure to Resilience</i> . Zurich: RSg Impact Investing. https://doi.org/10.5281/zenodo.23167517
DOI	10.5281/zenodo.23167517
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Acknowledgements

This study benefited greatly from the time and expertise of colleagues who reviewed earlier drafts. We are grateful to Kyra Gibhardt, Maha J. Cziesielski, Jascha Lehmann, Sebastian Glink and Lukas Bodenmann for their careful reading, critical questions and constructive suggestions.

We thank MSCI for providing the physical climate risk data used for listed equities, corporate bonds, private equity and infrastructure, and CLIMADA Technologies for the property-level modelling of the Swiss and international real estate samples. We also thank the Swiss Platform for Impact Investing for its support of this work.

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Executive Summary

Swiss pension funds manage approximately CHF 1.2 trillion of assets and invest over horizons extending several decades. Yet physical climate risk remains less systematically incorporated into investment analysis than transition risk. This matters because the financial exposure of a pension fund ultimately depends on the physical assets, economic activities and locations underlying the securities it holds, rather than simply on asset class, sector or issuer domicile.

This study examines physical climate risk from the bottom up across a reference Swiss pension fund investment universe. It looks through financial instruments to three underlying economic exposures: companies and their operations, sovereign economies and public finances, and real assets. Where data permit, the analysis connects these exposures to specific locations and hazards, estimates expected physical and economic losses, and then considers how those effects can transmit into equity value, credit risk, sovereign yields and real asset returns. Because the resulting metrics measure different economic quantities and sit at different stages of the financial transmission process, they are not combined into a single portfolio loss estimate.

The analysis produces five principal findings:

Physical climate risk is already measurable and generally increases over the investment horizon. Across the listed company and covered corporate bond universes, current Total Average Annual Loss ranges from approximately **0.7% to 1.4% of the modelled economic base**. Under SSP5 8.5, expected physical economic loss increases towards 2050 across all major company universes analysed.

Business Interruption matters more than direct physical damage for companies. Business Interruption accounts for more than 90% of current Total AAL across the major listed equity and covered corporate bond universes. Physical climate risk therefore extends well beyond damage to buildings and machinery and includes effects on productivity, access to water and energy, logistics, infrastructure and business continuity. Supply chains add a further loss channel, equal under current conditions to roughly one third of the direct physical loss modelled for companies' own operations across the three equity universes.

The geography of physical risk can differ sharply from the financial geography of the portfolio. Most of the modelled AAL associated with Swiss equities arises outside Switzerland, reflecting the international operations of Swiss listed companies. Developed Markets companies also carry

material physical exposure outside their home markets. Issuer domicile and currency therefore provide only a partial indication of where physical climate risk sits.

Portfolio averages can conceal substantial concentration and tail risk. In the Swiss Real Estate sample, four properties account for approximately half of modelled AAL while representing less than 6% of portfolio value. Average expected losses are relatively small as a share of property value, but individual property losses can become materially larger under severe events. Asset level analysis therefore provides information that aggregate portfolio averages may obscure.

Physical loss and investment loss are different stages of the analysis. The same underlying physical effect can influence equity value through earnings and cash flows, corporate debt through credit quality and spreads, sovereign bonds through economic and fiscal conditions, and Real Estate through income, capital expenditure and asset value. Insurance, leverage, diversification, adaptation and market repricing affect how much of the underlying economic loss ultimately reaches the investor. A credible portfolio level financial estimate therefore requires translating heterogeneous physical risk measures into comparable investment value or return effects before aggregation.

The analysis also highlights important limitations. Near complete coverage of securities does not imply complete coverage of the underlying economic footprint. Mapped locations represent only part of company activity, particularly for financial institutions and asset light businesses, while supply chains, critical infrastructure and other third party dependencies remain only partially captured. Hazard coverage and loss denominators also differ across models. Physical climate risk metrics should therefore be interpreted within the economic exposure and model perimeter they represent rather than treated as directly comparable portfolio statistics.

For pension funds, the value of this analysis lies in the decisions it can improve. Physical risk can be incorporated into portfolio construction, fundamental investment analysis, due diligence, manager selection and active ownership. For directly held Real Estate and infrastructure, it can also inform insurance, capital expenditure and adaptation decisions. Where an asset remains economically attractive, investment in resilience may reduce expected losses and protect long term value. Pension funds can also allocate capital to companies, infrastructure and financing instruments that provide adaptation and resilience solutions.

The central implication is that physical climate risk should increasingly become part of mainstream investment analysis. For Swiss pension funds, the relevant questions are practical: **Where is the underlying economic exposure? Which hazards and dependencies matter? What could the resulting physical and economic effects mean financially? How resilient is the asset, company or economy? What action could improve the investment outcome?**

CHAPTER 1

Introduction

Pension funds are among the world's most important long-term investors. Assets in pension plans managed by pension providers reached USD 63.1 trillion across OECD countries at the end of 2024, almost equivalent to the combined GDP of OECD economies¹. In Switzerland, the country's occupational pension funds reported a combined balance sheet of approximately CHF 1.2 trillion at the end of 2024, equivalent to around 143% of GDP. Their investment decisions therefore matter both for the security of retirement benefits and for the allocation of capital across the economy².

Pension funds invest today to meet liabilities extending over several decades. Over the same period, rising temperatures and changing climate hazards will affect physical assets, economic activity and the conditions under which companies operate. Climate-related risks can therefore become financial risks over horizons directly relevant to pension funds.

Climate-related financial risk is commonly divided into two broad categories: **transition risk**, arising from changes in policy, technology, markets and behaviour as economies move towards lower-carbon models; and **physical risk**, arising from the consequences of climate and weather-related hazards. Both can affect the value and income generating capacity of assets, but they have not received equal attention within investment practice.

Transition risk is increasingly incorporated into portfolio analysis. In Switzerland, the Federal Office for the Environment has conducted coordinated PACTA climate tests since 2017³. In the 2024 exercise, 146 financial institutions participated, including 71 pension funds.⁴

Physical climate risk remains less systematically incorporated into investment analysis. A review conducted for this study of disclosures by major Swiss pension funds found widespread use of carbon and transition-related metrics, while fewer than 10% disclosed physical risk

¹ OECD, *Pensions at a Glance 2025: OECD and G20 Indicators*, Chapter 9, "Assets earmarked for retirement," 2025.

² The OECD global pension figure and the Swiss FSO occupational-pension figure use different statistical scopes. Numbers are shown for scale rather than as directly comparable universes. Source: Federal Statistical Office (FSO), *Pension Fund Statistics 2024: final results and key figures*, 2025.

³ Federal Office for the Environment (FOEN), *PACTA Climate Test Switzerland 2024: Walking the Walk?*, 2024.

⁴ More than 60% of participating institutions reported a 2050 net-zero target in their internal strategy, while fewer than 20% of pension funds made public commitments.

metrics or asset-level geolocation.⁵ This suggests a material gap in how physical climate exposure is identified within investment portfolios, despite its relevance over the long horizons of pension liabilities. For pension fund trustees, this creates a governance question: how to identify financially material physical risks, including geographic concentrations that may remain hidden within conventional portfolio classifications, and incorporate them into existing investment and risk management processes.

Physical risk also requires a different analytical lens. Its financial relevance depends on where the economic activities and physical assets underlying an investment are located, which hazards affect them, how vulnerable they are and how the resulting physical and economic effects transmit to investment value. Conventional classifications such as asset class, issuer domicile or sector may therefore provide only a partial indication of where physical climate risk sits within a portfolio.

This is particularly relevant for Swiss pension funds. Their portfolios combine domestic and international equities, bonds, real estate and private market investments, creating exposure to companies, economic activity and physical assets located around the world. Geographic concentrations of physical risk may consequently remain largely invisible within conventional portfolio classifications, while pension funds must manage assets against liabilities extending over several decades.

Existing research and scenario analysis have established that climate change can have financially relevant consequences for institutional investors. The NGFS scenarios estimate macroeconomic effects through variables including GDP and productivity, while investment consultants and financial institutions have developed top-down methodologies that translate climate scenarios into asset class and portfolio effects.⁶ These approaches provide valuable estimates of overall financial exposure, but provide less visibility on where physical risk originates within the economic activities and assets underlying a diversified portfolio.

This study takes a complementary **bottom-up approach**. Starting from the principal exposures in a reference Swiss pension fund investment universe, it looks through the financial instruments held to three underlying economic exposures: companies and their operations, sovereign economies and public finances, and real assets. Wherever the available data permit, the analysis examines location, climate hazards, vulnerability and expected physical and economic losses, before considering how those effects can transmit into the financial instruments held by the pension fund.

Because the resulting physical risk measures refer to different economic exposures and financial transmission mechanisms, the study does not aggregate them into a single portfolio loss estimate. Instead, it uses portfolio weights to establish the relative importance of the principal exposures and examines what the available physical risk measures reveal within each of them.

The research addresses four questions:

⁵ In our internal review (February 2026) we evaluated the 2024 climate disclosures of 11 major Swiss occupational pension funds, including PUBLICA, BVK, Compenswiss, and CPEG. The analysis screened for the quantification of physical climate risks and asset-level geolocation data. Results showed that while over 70% disclose carbon and transition metrics, none publicly report quantified exposure to acute physical risks, and only 1 fund references asset-level geolocation data.

⁶ Network for Greening the Financial System (NGFS), *NGFS Climate Scenarios for Central Banks and Supervisors: Phase V*, 2024.

1. What physical and economic losses are embedded in the exposures underlying a reference Swiss pension fund investment universe?
2. Where are the principal concentrations of physical climate risk?
3. How can those physical and economic effects transmit into the value and return of different financial instruments?
4. What actions can pension funds take to understand, manage and reduce those risks?

Chapter 2 explains how climate hazards can become economic and financial risks. Chapter 3 sets out the bottom-up measurement approach and the construction of the reference investment universe. Chapter 4 presents the results across companies, sovereigns and real assets. Chapter 5 examines how physical and economic losses can transmit into investment value, and Chapter 6 considers how pension funds can use this information in investment governance and decision making.

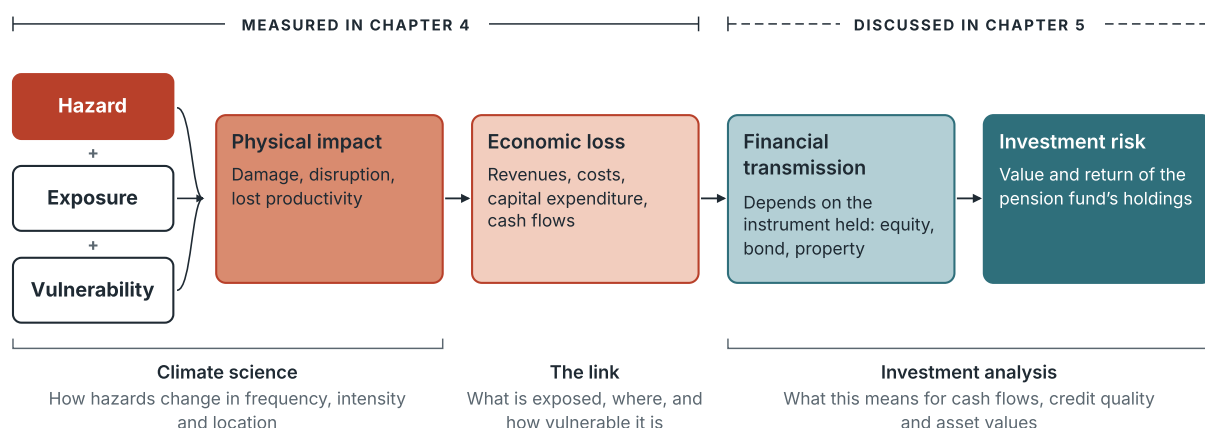
CHAPTER 2

From Climate Hazard to Financial Risk

Understanding the financial implications of physical climate risk requires connecting climate science with investment analysis.

- Climate science describes how hazards vary across locations and may change over time.
- Investment analysis needs to understand what those hazards mean for economic activity and, ultimately, for revenues, costs, cash flows, credit quality and asset values (Figure 2.1).

FIGURE 2.1 *From hazard to investment risk*



2.1 From hazards to physical impacts

Physical climate risk arises through the interaction of three elements: hazard, exposure and vulnerability.

- Hazard describes the physical event or climatic condition and its intensity or probability.
- Exposure identifies the people, buildings, infrastructure, productive assets or economic activities located where the hazard can occur.
- Vulnerability determines how severely those exposed assets or activities are affected.

Hazards include both acute events, such as floods, tropical cyclones, severe storms, wildfires and extreme heat events, and chronic changes, such as rising average temperatures, changing precipitation patterns, sea level rise and persistent changes in water availability. The distinction is useful but not absolute: chronic climatic changes can alter the frequency or severity of acute events.

The interaction between hazard, exposure and vulnerability is fundamental for investment analysis. Two otherwise similar assets can face very different physical risk because they are located in different hazard environments, while two assets at the same location can experience different losses because their vulnerability differs. Natural catastrophe modelling commonly reflects this interaction. The NGFS, for example, describes acute physical risk modelling through the characteristics of the event, the spatial distribution of exposed assets and a vulnerability function estimating the resulting degree of damage.⁷

2.2 Physical risk today and under future climate scenarios

Physical climate risk already exists under current climatic conditions. Switzerland has already warmed by approximately 2.9°C relative to the 1871 to 1900 average, according to MeteoSwiss.^{8 9} According to Swiss Re Institute, natural catastrophes generated approximately USD 220 billion of global economic losses in 2025, across 190 events, of which approximately USD 107 billion was insured. Wildfires, severe convective storms and floods accounted for 88% of global insured natural catastrophe losses during the year.¹⁰

The annual figures fluctuate substantially depending on which events occur in a particular year. Swiss Re estimates that insured natural catastrophe losses have nevertheless followed a long-term real growth trend of approximately 5% to 7% per year. Increasing economic exposure is a major driver: population growth, rising asset values, development in hazard-prone areas and higher reconstruction costs all contribute to larger losses when events occur. Changes in hazards and vulnerability can add to this effect for particular perils and regions.

The distinction between economic and insured losses is important because insurance determines how part of the direct financial cost of physical hazards is distributed across the economy. Insurance transfers some losses from households, companies and asset owners to insurers and reinsurers, but coverage remains incomplete. Swiss Re estimates that more than 40% of global natural catastrophe losses are now insured, compared with 23% thirty years ago, while in many emerging markets between 80% and 90% of catastrophe losses remain uninsured. The remaining protection gap leaves a substantial share of physical losses with households, companies, governments and asset owners.

⁷ Network for Greening the Financial System (NGFS), *NGFS Climate Scenarios Technical Documentation: Phase V*, 2024, Physical Risk module.

⁸ MeteoSwiss and ETH Zurich, *Climate CH2025 – Switzerland's Future Climate*, 2025; Federal Office for the Environment (FOEN), *Natural Hazards in Switzerland*.

⁹ Globally, the corresponding increase was around 1.3°C to 1.4°C by 2024. Source: MeteoSwiss and ETH Zurich, "Climate CH2025 – Scientific Report", 2025

¹⁰ Swiss Re Institute, *sigma 1/2026: Natural Catastrophes in 2025: The Persistent Rise of Wildfire and Storm Risk*, 2026.

Insurance conditions can themselves change as physical risk increases. Higher expected losses can translate into higher premiums, larger deductibles, tighter coverage or reduced availability in highly exposed locations.¹¹ Insurance can therefore mitigate the financial consequences of physical hazards without eliminating the underlying exposure, while changes in its cost and availability can become an additional economic consequence of increasing physical risk.

Future analysis asks how this existing risk may change as climatic conditions evolve. Historical observations provide information about past events, while climate scenarios are used to explore possible future conditions under different emissions and warming pathways. Scenarios should be understood as plausible pathways rather than forecasts of a single future.

The time horizon is particularly relevant for pension funds because their liabilities and investment horizons extend over several decades. Changes towards 2050 can therefore fall within the economic life of assets held or financed today. Differences between climate pathways generally become more consequential over longer horizons as alternative emissions trajectories translate into different climatic conditions.

Scenario-based estimates remain subject to methodological uncertainty. Scenario choice, hazard models, vulnerability functions and assumptions used to translate climate variables into economic outcomes can materially affect results. This is one reason the analysis in this paper considers both current physical risk and changes under future scenarios, while treating scenario results as conditional estimates rather than forecasts.

2.3 From physical hazards to economic effects

Once a hazard interacts with an exposed and vulnerable economic activity, losses can arise through several channels. Their relevance differs across companies, sovereigns and real assets.

For companies, the most direct consequence is **asset damage**. Floods can damage buildings and machinery, storms can damage structures and infrastructure, wildfires can destroy productive assets, and extreme events can interrupt utilities and transport networks. These effects can create immediate repair or replacement costs and reduce the value or productive capacity of the affected asset.

Business interruption is a second channel. A facility can stop operating because it has been damaged, because employees cannot reach it, because electricity or water supplies are interrupted, or because transport infrastructure is unavailable. Productivity effects can arise even without direct damage. Extreme heat can reduce labour productivity and constrain working hours, while water scarcity can restrict industrial production, agriculture and power generation. Economic losses can therefore occur even when physical damage to the company's own assets is relatively limited.

Supply chains create a distinct indirect channel. Damage to a supplier, port, transport corridor or other critical infrastructure can interrupt inputs or distribution far from the location where the physical event occurred. These exposures extend beyond the company's own operations and require information on suppliers, sourcing relationships, logistics and other dependencies.

¹¹ European Insurance and Occupational Pensions Authority (EIOPA), "Climate Insurance Protection Gaps: A Demand-side Challenge", March 2026

Physical climate risk can also increase **operating costs**. Higher cooling and water requirements, repairs and maintenance, and higher insurance costs can affect operating expenditure even where an asset remains operational. Adaptation introduces a further financial dimension. Companies and asset owners may invest in flood protection, cooling systems, water efficiency, building reinforcement, relocation or other resilience measures. Such expenditure increases capital requirements in the short term but can reduce vulnerability, future physical losses and disruption. The financial effect therefore depends on both the cost and the effectiveness of adaptation.

These channels ultimately affect revenues, operating costs, capital expenditure, cash flows, asset values and financing requirements.

For sovereigns, the relevant exposure is the wider economy and public finances. Physical climate effects can influence economic output and productivity, tax revenues, reconstruction expenditure, public debt and financing requirements. The transmission therefore operates through aggregate economic and fiscal conditions rather than only through physical assets owned by government.

For real assets, the connection to physical impacts is more direct. Damage can create repair or replacement costs, while disruption can affect operating income and use of the asset. Insurance costs, adaptation expenditure and changes in the attractiveness or usability of a location can also affect economic value.

Insurance can modify these economic effects by transferring part of the financial cost, while deductibles, exclusions, uninsured losses and changes in premiums or coverage leave part of the impact with the underlying economic actor.

2.4 From economic effect to investment loss

Economic loss does not translate mechanically into investment loss. The financial effect depends on the instrument through which the pension fund holds the underlying exposure.

For companies, the same physical and economic effects can reach equity and debt investors differently. Equity investors are exposed through earnings, future cash flows and valuation. Corporate bond investors are exposed through financial resilience, leverage, debt service capacity, default risk and credit spreads.

For sovereign bonds, effects on economic output, productivity, fiscal revenues, reconstruction expenditure and debt dynamics can influence sovereign creditworthiness, required yields and bond values.

For directly held **real assets**, repair costs, operating income, insurance, adaptation expenditure and residual value can feed more directly into asset valuation and total return.

Portfolio analysis therefore proceeds in two stages. The first identifies and measures physical and economic risk where it originates in the underlying economy. The second translates those effects into the financial variables relevant to the instrument held by the pension fund.

2.5 What asset-level analysis captures, and what it may miss

Asset-level analysis improves visibility on physical climate exposure by connecting economic activities and physical assets with their locations and the hazards affecting them. Issuer domicile alone can be misleading: a company headquartered in Switzerland may operate factories, offices, warehouses and distribution centres across several continents.

The value of this approach nevertheless depends on how much of the underlying economic exposure the model can observe. For asset-intensive activities such as manufacturing, mining, utilities, transportation and real estate, mapped physical assets may be closely connected to the capacity to generate revenues. In other sectors, directly owned assets can represent only part of the relevant exposure.

Financial institutions illustrate the limitation. Mapping a bank's offices, branches and data centres captures the physical exposure of its own facilities, while potentially larger risks can arise through loans, mortgages, securities portfolios and other financed activities. Similar limitations arise for companies that depend materially on outsourced production, data centres, electricity and telecommunications networks, commodities, suppliers or other third-party infrastructure.

This creates a distinction between **direct asset exposure** and **broader economic exposure**. The first asks whether physical assets owned or operated by a company are exposed to climate hazards. The second asks whether the company's revenues, costs, financing or ability to operate depend on assets, counterparties, infrastructure and supply chains that are themselves physically exposed.

This has implications for portfolio analysis. Asset-level geolocation provides a powerful basis for identifying physical climate exposure, but the resulting estimates need to be interpreted in the context of the issuer's business model. Where economic exposure extends materially beyond owned or mapped physical assets, complementary analysis may be required. This can include supply chain exposure, dependence on critical infrastructure, financed emissions and exposures in the case of financial institutions, insurance liabilities, commodity dependencies and other indirect channels.

A low estimate for mapped assets does not necessarily imply low overall physical climate risk if important economic dependencies remain outside the model. The relevant question is both where the assets captured by the model are located and how much of the issuer's broader economic exposure those assets represent.

Chapter 3 develops the measurement approach, Chapter 4 presents the resulting physical and economic risk estimates, and Chapter 5 examines the instrument-specific transmission into investment value.

2.6 Systemic and macroeconomic transmission beyond individual assets

Physical climate effects can also propagate through economic systems in ways that are difficult to attribute to a single company or physical asset. Transport networks, energy systems, water resources, food supply and insurance markets create shared dependencies through which a local

physical shock can affect multiple sectors and regions simultaneously.

Low river levels, for example, can restrict the movement of raw materials and industrial inputs, increasing transport costs and reducing the availability of goods across several value chains.

Water scarcity and extreme heat can constrain electricity generation while increasing demand for cooling, transmitting physical stress into energy prices and industrial production.

Agricultural and water shocks can feed into food prices and broader inflation.

Insurance provides another transmission channel. Rising physical losses can lead to higher premiums, tighter coverage or withdrawal from exposed markets. Where insurance is required for mortgages or financing, reduced insurability can affect collateral values and credit availability. In some jurisdictions, part of the resulting risk may ultimately migrate to public balance sheets through state backed insurance or disaster support.

These effects matter for pension funds because they can influence economic growth, inflation, interest rates, credit conditions and public finances in addition to the direct losses captured at company or asset level. They therefore represent a further layer of physical climate risk that bottom up asset analysis can identify only partially.

CHAPTER 3

Measuring Physical Climate Risk

The methodology follows the economic exposure framework developed in Chapter 2. For each part of the reference investment universe, the analysis identifies the underlying economic exposure, applies the relevant physical climate risk methodology and interprets the resulting metric within its specific economic context. Physical risk is aggregated from individual locations and assets where the available data permit, but heterogeneous measures are not combined into a single pension fund loss estimate.

3.1 Defining a reference Swiss pension fund investment universe

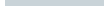
There is no single asset allocation that represents every Swiss pension fund. Allocations vary according to fund size, liability structure, risk capacity, investment beliefs and regulatory constraints. For the purpose of this study, the reference allocation is derived from the 2026 survey of the Swiss Occupational Pension Supervisory Commission (OAK BV), based on pension fund allocations at the end of 2025.¹² The OAK BV data are asset weighted and are therefore used here to represent how Swiss second pillar pension capital is allocated across the principal asset classes.

The portfolio weights provide context for the relative economic importance of each exposure. They are not used to calculate a weighted average physical climate risk measure across the portfolio, since the underlying risk metrics are not directly comparable across companies, sovereigns and real assets.

For the purposes of the analysis, some OAK BV investment categories are aggregated into broader asset classes, as detailed in the note to Table 3.1. The resulting allocation determines the scope and relative importance of the exposures considered in this study.

¹² The survey covers 1,257 pension institutions and is described by OAK BV as the most comprehensive survey of Swiss pension institutions apart from the Federal Statistical Office pension fund census. Source: OBERAUFSICHTSKOMMISSION BERUFLICHE VORSORGE (OAK BV), *Bericht zur finanziellen Lage der Vorsorgeeinrichtungen 2025, 2026*.

TABLE 3.1 *Reference Swiss pension fund investment universe*

ASSET CLASS	APPROX. WEIGHT	ANALYTICAL UNIVERSE	UNDERLYING ECONOMIC EXPOSURE
Swiss bonds	 19.8%	MSCI CH Agg constituents: corporates covered by MSCI physical risk data, sovereign covered by Klusak methodology	 Sovereigns  Companies
International bonds	 12.2%	MSCI Global IG constituents: corporates covered by MSCI physical risk data, sovereign covered by Klusak methodology	 Sovereigns  Companies
Swiss equities	 10.4%	MSCI Switzerland equity universe covered by MSCI physical risk data	 Companies
Developed market equities	 18.7%	MSCI World constituents covered by MSCI physical risk data	 Companies
Emerging market equities	 3.8%	MSCI EM constituents covered by MSCI physical risk data	 Companies
Swiss real estate	 18.8%	SXI Real Estate Fund Broad Index: subset of constituents covered by CLIMADA Technologies physical risk data	 Real assets
International real estate	 3.5%	AFIAA Global Real Estate constituents covered by CLIMADA Technologies physical risk data	 Real assets
Infrastructure	 2.9%	Anecdotal evidence from two infrastructure projects	 Real assets
Private Equity	 2.2%	MSCI All Country Venture-Backed Private Company Top 50 Index constituents covered by MSCI physical risk data	 Companies
Others	 7.7%	Not analysed	—
Total	100.0%		

Source: Swiss occupational pension fund sector allocation; index and portfolio proxies as used in this study.

The analytical representation of those exposures necessarily differs across asset classes because equivalent asset-level datasets are not available across the portfolio. Where broad and sufficiently granular datasets are available, the study uses market index universes as proxies for the relevant exposure. Where they are not, it uses identifiable portfolios or samples of companies or physical assets for which the underlying exposure can be analysed. Fixed income is further separated between sovereign and corporate issuers because their physical climate risk originates in different economic exposures and is measured differently.

The resulting analytical universes should therefore be interpreted according to the type of representation shown in Table 3.1. Listed equities are represented by broad market indices. Private Equity and real estate rely on specific company or asset portfolios and consequently provide narrower representations of their respective asset classes. These analyses are used to investigate how physical climate risk manifests within the relevant exposures rather than to estimate the physical risk of all Swiss pension fund investments in those asset classes.

Infrastructure requires a different treatment. Pension fund infrastructure portfolios vary substantially in their composition, geography and investment structure, and a sufficiently representative portfolio could not be identified for this study. The analysis therefore examines the physical hazard profile of two infrastructure investments as illustrative examples; Section 4.3 explains why a quantitative assessment was not possible

The asset classes grouped under Other in Table 3.1 are not included in the physical climate risk analysis. The study therefore does not claim complete coverage of the reference pension fund allocation.

The purpose of this construction is to provide a transparent representation of the principal exposures in a Swiss pension fund portfolio while preserving the bottom-up nature of the analysis. Portfolio weights indicate the relative importance of each asset class in the reference allocation, but are not used to scale the analytical samples or construct a single portfolio physical loss estimate. Differences in sample construction, coverage, hazard perimeter and loss metrics are considered explicitly when interpreting the results.

Having identified the portfolio in conventional financial terms, the analysis applies the economic exposure lens introduced in Chapter 2.

3.2 Looking through financial instruments to underlying economic exposures

The central methodological challenge is to move from the financial instruments held by the pension fund to the underlying economic exposures through which physical climate risk can generate losses. The appropriate level of analysis differs across companies, sovereigns and real assets.

For companies, the study uses MSCI geolocation and physical climate risk data. MSCI's methodology combines information on company facilities and their locations with hazard and vulnerability modelling to estimate potential physical losses. It distinguishes between direct Asset Damage and Business Interruption, provides physical risk metrics at asset and issuer level, and also considers physical risk transmitted through supply chains.^{13 14 15}

For sovereigns, the study uses the framework developed by Klusak et al., which links climate affected macroeconomic outcomes to sovereign credit ratings and indicative borrowing costs. The sovereign analysis is consequently performed at country level rather than through asset geolocation.¹⁶

For real estate, the study uses CLIMADA Technologies based modelling. CLIMADA Technologies combines the geographical distribution and value of exposed assets, the physical characteristics and probability of hazards, and impact functions representing the vulnerability of those assets to different levels of hazard intensity. The hazard is mapped to each location and the resulting damage ratio is applied to the exposed value, producing physical loss estimates at individual asset level that can subsequently be aggregated.¹⁷ In addition, for the Swiss property sample, the

¹³ MSCI, *Physical Risk Guide for Asset Owners and Asset Managers*, April 2026.

¹⁴ MSCI Supply Chain Intelligence estimates where companies source inputs from Tier 1 suppliers and from Tier 2 suppliers further upstream, combining company information with input output and international trade data. MSCI's physical risk methodology then applies physical loss estimates to those supplier country and sector exposures and estimates the share of supplier costs that can be passed on to the purchasing company. The resulting supply chain AAL therefore represents expected physical risk costs transmitted through the upstream value chain rather than losses affecting the company's own operations. Supply chain AAL is available as an absolute monetary loss and, in MSCI's methodology, relative to company revenue. In the files available for this study, supply chain results are available for current climate conditions only. Equivalent forward looking time series and geographic market breakdowns are not available.

¹⁵ MSCI, *Physical Risk Metrics – Issuer Level Methodology*, September 2026, pp. 5, 14–15;

¹⁶ Patrycja Klusak, Matthew Agarwala, Matt Burke, Moritz Kraemer and Kamiar Mohaddes, “Rising Temperatures, Falling Ratings: The Effect of Climate Change on Sovereign Creditworthiness,” *Management Science* 69, no. 12 (2023): 7468–7491.

¹⁷ Gabriela Aznar-Siguan and David N. Bresch, “CLIMADA v1: A Global Weather and Climate Risk Assessment Platform,” *Geoscientific Model Development* 12 (2019): 3085–3097; CLIMADA documentation.

study draws on MSCI Physical Risk - Infrastructure Assets to capture operational disruption. These business-interruption estimates are used to show how the nature of operational exposure changes, not as an additional loss to be combined with CT AAL.

Infrastructure belongs to the same broad real asset category. Due to the lack of geospatial disclosure in private infrastructure funds, the quantitative analysis relies on two illustrative case-study approach of representative physical assets, assessed using the MSCI Physical Risk - Infrastructure Assets.

The resulting level of analysis therefore differs across the three economic exposures: asset and location level for companies and real assets where data permit, and country level for sovereigns. These differences reflect both the nature of the underlying exposure and the availability of data, and they are important when interpreting and comparing the results.

3.3 Current risk and future climate scenarios

The analysis considers both current physical risk and changes towards 2030 and 2050. The definition of “current” differs across providers. MSCI uses a modelled 2025 climate for the company datasets, while CLIMADA Technologies uses hazard specific historical reference climates for real estate. Property values in the CLIMADA Technologies analysis are held constant, while MSCI projects company revenues and asset values in line with GDP. Absolute AAL levels and percentage changes across the two providers are therefore not treated as directly comparable.¹⁸

Forward looking company and real asset analysis uses SSP pathways, with SSP5-8.5 used as the principal high physical risk stress scenario.¹⁹

The sovereign analysis follows the Klusak framework and therefore uses RCP 2.6 and RCP 8.5. RCP 8.5 and SSP5-8.5 both represent high emissions pathways but are not identical, and their outputs are not compared directly. Scenario results are conditional estimates rather than forecasts.

3.4 Measuring expected and tail losses

Two complementary perspectives are used to assess physical loss: expected annual loss and losses associated with less frequent but more severe events.

¹⁸ The two loss datasets define their starting point differently. In the MSCI data used for listed equities, bonds and private equity, “current” is a modelled climate for 2025, derived from MSCI’s own scenario modelling rather than from an observed historical period. Because MSCI also projects future asset values and revenues in line with GDP, changes over time are measured on relative average annual loss (AAL). In the CLIMADA Technologies real-estate results, the baseline is a historical reference climate specific to each hazard, while property values are held constant. Changes from that baseline therefore isolate the modelled change in hazard, including warming that has already occurred since the reference period. For these reasons, absolute AAL levels are not compared across the two providers, and their percentage changes over time are compared by direction only. Appendix 1 sets out the definitions, sources and remaining uncertainties.

¹⁹ The study uses the Shared Socioeconomic Pathways adopted within the IPCC Sixth Assessment Report and available consistently across the principal datasets used in the study. The main scenarios are: SSP1-2.6, representing a low emissions pathway with strong mitigation; SSP2-4.5, representing an intermediate pathway; SSP5-8.5, representing a very high emissions pathway. The IPCC uses these scenarios to explore a wide range of possible future climatic conditions. SSP1-2.6 is associated with substantially lower long-term warming, while SSP5-8.5 represents a very high emissions future with much greater warming by the end of the century. In this study, SSP5-8.5 is used as a high physical risk stress scenario rather than as a forecast or central expectation of future emissions. Source: Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2021: The Physical Science Basis*, Chapter 1.

Average Annual Loss (AAL) represents the expected annual loss when losses from possible events are weighted by their probability of occurrence. It describes an expected annual burden rather than the loss expected in any individual year.

For companies, MSCI separates Asset Damage and Business Interruption. Asset Damage AAL is measured relative to fixed asset value, while Business Interruption AAL is measured relative to annual company output. Total AAL combines the corresponding monetary losses and expresses them relative to the combined economic base of annual output and fixed asset value. The component percentages therefore cannot be added directly.

For real assets, CLIMADA Technologies calculates the closely related Average Annual Impact by combining hazard, exposure and vulnerability at asset level and weighting event impacts by their annual frequency. In this paper the resulting expected annual physical loss is reported as AAL relative to property value.²⁰

AAL is particularly useful because it reduces a probabilistic distribution of possible physical events to a metric that can be compared across locations and scenarios. Actual annual losses can be zero in some years and substantially higher than the average in years when severe events occur.²¹

A second perspective considers **tail risk**.²² Traditionally this is measured through return period losses (RPL). A 100 year RPL represents the loss level associated with an event that has approximately a 1% probability of being exceeded in any given year. A 250 year return period corresponds to an annual exceedance probability of approximately 0.4%.

Terminology can be misleading: a 100 year event does not mean that the event occurs exactly once every hundred years. An RPL establishes a probability threshold. Several such events can occur within a relatively short period, or none may occur during an entire century.

However, because RPL only marks a threshold, it does not capture the magnitude of losses beyond that point. To capture the severity of losses beyond this threshold, the real estate analysis uses Expected Shortfall (ES). ES100 represents the average loss conditional on exceeding the 100 year return period loss, corresponding to the tail beyond the 99th percentile of the annual loss distribution. It therefore captures the average severity of losses once the 100 year loss threshold has been exceeded, rather than the threshold itself.

CLIMADA Technologies supports expected annual impact, RPL and ES metrics, allowing both expected losses and lower probability/higher severity outcomes to be examined together.²³

²⁰ Aznar-Siguan and Bresch, "CLIMADA v1: A Global Weather and Climate Risk Assessment Platform," 2019.

²¹ For companies, the MSCI analysis distinguishes between Asset Damage and Business Interruption. Asset Damage AAL is expressed relative to fixed asset value, while Business Interruption AAL is expressed relative to annual company output. Total AAL combines the corresponding monetary Asset Damage and Business Interruption losses into a single relative measure. Total AAL reconciles to total monetary AAL divided by the combined economic base of annual company output and fixed asset value. Because the component metrics use different denominators, the reported Asset Damage AAL% and Business Interruption AAL% cannot be added directly.

²² In this study tail risk is analysed quantitatively only for real estate using CLIMADA Technologies. Return period information is available for parts of the company datasets, but hazard coverage is incomplete and does not align with the hazards driving company AAL. A company level tail metric based on those fields would therefore describe only a partial risk perimeter and could not be used for cross asset comparison.

²³ CLIMADA documentation; Bressan et al., "Asset Level Assessment of Climate Physical Risk Matters for Adaptation Finance," *Nature Communications*, 2024.

For pension funds, the distinction matters. AAL provides information about the average expected burden of physical hazards, while Expected Shortfall provides information about events that may create substantial losses over shorter periods. A portfolio with a relatively modest AAL may still contain material concentrations of tail risk.

These metrics measure physical or economic loss rather than investment performance. Translating them into changes in equity value, credit risk, bond prices or real asset returns requires an additional instrument specific transmission layer, examined in Chapter 5.

3.5 Comparability across asset classes

Physical climate risk metrics are not necessarily comparable across asset classes.

First, the denominator differs. A physical loss may be expressed relative to property market value, company asset value, company output, revenues or another measure of economic exposure. A 1% loss expressed relative to company output does not represent the same financial quantity as a 1% loss expressed relative to the market value of a property.

Second, hazard coverage differs. Different models and datasets cover different combinations of hazards, so AAL estimates with different hazard perimeters are not equivalent. The results should therefore be interpreted within the hazard coverage of the underlying model.

Third, the financial transmission mechanism differs. Direct property damage has a relatively immediate relationship with the value of a real asset. For a listed company, the same physical loss passes through the company's operating and financial structure before reaching equity or bond investors.

These differences prevent mechanical aggregation across asset classes. Each metric therefore needs to be interpreted within its economic base, hazard perimeter and financial transmission mechanism.

3.6 Limitations

The results of this study should be interpreted in light of several limitations.

Data availability. Asset level geolocation data remain incomplete, particularly for private assets, infrastructure and some fixed income exposures. Where look through information is unavailable, the analysis necessarily relies on less granular information or excludes exposures from parts of the analysis. For private infrastructure specifically, the absence of geospatial disclosure prevented a quantitative assessment of infrastructure (Section 4.3).

Asset representation. The analytical universes differ across asset classes, as summarised in Table 3.1. Results derived from selected company or asset samples have narrower representativeness than those based on broad market indices and should be interpreted accordingly.

Hazard coverage. No single dataset used in this study captures every physical climate hazard relevant to every asset. Results should therefore be interpreted within the hazard perimeter of the model used.

Vulnerability modelling. Translating hazard intensity into physical damage requires assumptions about the vulnerability of assets. Actual vulnerability depends on characteristics such as construction standards, asset type, elevation, protective infrastructure, maintenance and adaptation measures, which are not always observable at scale.

Business interruption and indirect effects. Physical damage can generate losses through production disruption, utilities, transport infrastructure and supply chains. The study includes an MSCI estimate of physical risk costs transmitted through Tier 1 and Tier 2 suppliers, extending the analysis beyond companies' direct operations. The supply chain estimates nevertheless rely materially on modelled sourcing relationships, sector and country input output patterns and cost pass through assumptions, and they are available only for current climate conditions. Some physical climate effects can also propagate through shared infrastructure, energy, water, insurance and logistics systems, generating macroeconomic consequences that cannot be allocated cleanly to individual securities.²⁴

Business model coverage. For financial institutions and other companies whose economic exposure extends materially beyond owned assets, even the combined direct and modelled supply chain perimeter may capture only part of overall physical climate risk. Chapter 2 discusses these indirect channels in more detail.

Insurance. Gross physical loss estimates do not necessarily correspond to losses ultimately retained by the company or asset owner. Insurance coverage, deductibles, exclusions, limits and changes in insurance availability affect the financial consequences of physical events and are not captured consistently across all asset classes.

Financial transmission. Translating physical damage into security prices introduces an additional layer of uncertainty. Market valuations reflect expected future cash flows, financing structures, diversification, insurance, adaptation capacity and investor expectations. The relationship between physical loss and investment value is therefore neither uniform nor mechanical.

Scenario uncertainty. Future physical risk depends on emissions pathways, climate sensitivity and the evolution of exposure and vulnerability. Scenario results describe possible future conditions rather than forecasts.

These limitations do not remove the value of physical climate risk analysis. They define what the resulting numbers can reasonably be used for. At its current stage, bottom-up physical risk analysis is particularly valuable for identifying exposures, concentrations, dominant hazards, changes across scenarios and potential channels of financial transmission. Greater caution is required when heterogeneous physical loss estimates are compressed into a single portfolio level number.

For pension funds, this distinction is important. The usefulness of physical climate risk analytics depends as much on understanding what a metric represents as on the numerical value of the metric itself.

²⁴ MSCI, *Supply Chain Intelligence Methodology*, May 2026, especially model overview and model limitations.

CHAPTER 4

Physical Climate Risk Across the Portfolio

Using the economic exposure framework introduced in Chapter 2 and operationalised in Chapter 3, this chapter presents the physical climate risk results for companies, sovereigns and real assets.

Each result should therefore be read within the economic exposure it describes.

- For companies, the principal measure is Average Annual Loss, or AAL, combining expected Asset Damage and Business Interruption relative to company output and fixed assets.
- For sovereigns, the analysis estimates the effect of climate related macroeconomic changes on credit ratings and indicative borrowing costs.
- For real estate, physical loss is expressed relative to property market value.²⁵

These measures cannot simply be added to derive a pension fund loss, but together they provide a much broader picture of where physical climate risk enters the portfolio (Figure 4.1).

4.1 Companies and their operations

The company exposure spans several financial instruments. Listed equities provide an ownership claim on the company, Private Equity provides a similar claim outside public markets, while corporate bonds expose the pension fund as a creditor.

The underlying physical risk, however, originates in the same place: the assets and operations through which the company generates its economic activity. Indeed, for companies appearing in both equity and bond datasets, the physical loss metric is the same issuer level measure.

Physical economic loss is already measurable today

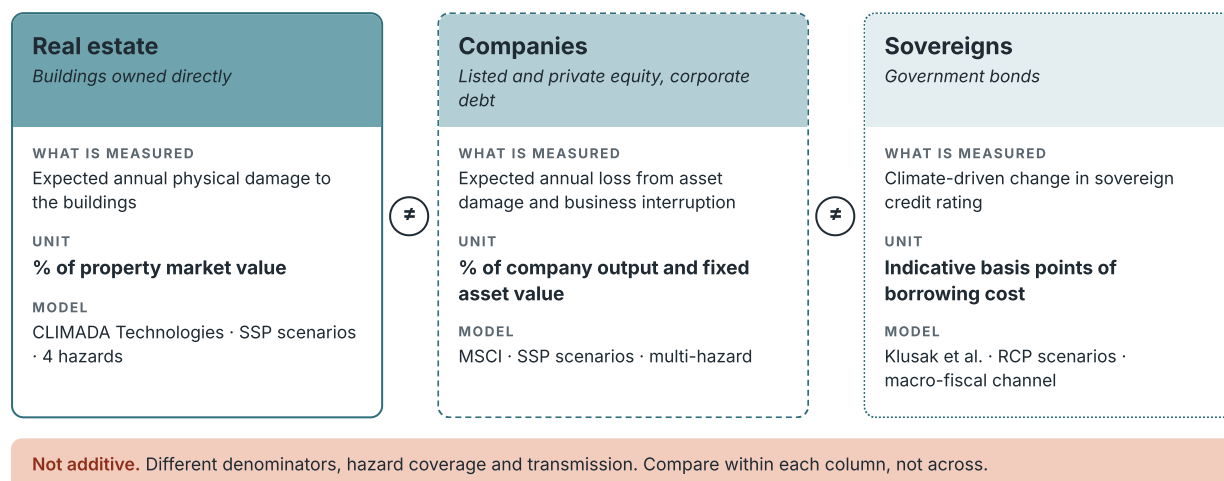
Physical economic loss is already measurable across all company exposures analysed, and increases towards 2050 under the high-emissions scenario (Table 4.1). The results vary across investment universes, but these differences should not be interpreted as a ranking of investment risk. They reflect differences in company composition, geographic footprint, sample

²⁵ For infrastructure, see Section 4.3

construction and model coverage.²⁶²⁷

These AAL estimates measure expected physical economic loss at company level. They do not represent an equivalent reduction in equity value, bond value or Private Equity NAV. The transmission from economic loss to investment performance is examined in Chapter 5.

FIGURE 4.1 Economic exposures and physical risk measures



Infrastructure is not assessed quantitatively; see Section 4.3.

TABLE 4.1 Physical economic loss across company exposures, current and 2050 (SSP5-8.5)

COMPANY EXPOSURE	REPRESENTATION	CURRENT TOTAL AAL	2050 TOTAL AAL	CHANGE TO 2050	BI SHARE, CURRENT	PRINCIPAL CURRENT HAZARD
Swiss equities	MSCI Switzerland IMI	0.73%	0.83%	+14%	95%	Extreme heat
Developed Markets equities	MSCI World	1.01%	1.18%	+17%	96%	Extreme heat
Emerging Markets equities	MSCI Emerging Markets	1.38%	1.66%	+21%	96%	Extreme heat
Swiss corporate-related bonds	MSCI CH Agg (corporate subset)	0.67%	0.76%	+13%	94%	Extreme heat
Global corporate-related bonds	MSCI Global IG (corporate subset)	0.77%	0.88%	+15%	91%	Extreme heat
Private Equity	MSCI AC Venture Backed Private Company Top 50	0.83%	1.04%	+26%	83%	Extreme heat

Total AAL: average annual loss from asset damage (AD) and business interruption (BI), % of company output and fixed assets; 2050 under SSP5-8.5. Bonds cover the corporate issuers mapped by MSCI. Private Equity is valuation-weighted (50 companies). Levels are not directly comparable across rows where coverage or weighting differ.

Source: MSCI physical climate risk data (September 2026 delivery); own calculations. Certain information ©2026 MSCI Solutions LLC. Reproduced by permission.

²⁶ Private Equity requires particular caution. The 50 company sample is not representative of the asset class and contains substantially fewer mapped physical locations than the listed company universes. Results are weighted by each company's last disclosed valuation; equal weighting produces a lower estimate (0.50% current Total AAL, against 0.83%). Valuation weights are highly concentrated: SpaceX alone represents about a third of the total weight, and the four largest companies (SpaceX, OpenAI, Anthropic and ByteDance) almost 80%. Excluding SpaceX, which listed in June 2026, the valuation-weighted AAL is 0.56% currently and 0.71% in 2050 (+28%). Sector codes (NACE) were assigned by the authors. MSCI's model uses them to set each company's fixed-asset base and business-interruption loss functions, so results are also sensitive to this classification. Together, these results illustrate how sensitive portfolio-level estimates are to the way individual company exposures are aggregated.

²⁷ AAL captures losses across the full distribution of possible events, including losses from the most severe risks, weighted by their respective probabilities. However AAL does not represent the total cost of, say, a 1-in-100-year event when that event actually occurs. Instead, it reflects the expected annual contribution of such an event to losses, i.e., 1% of the total cost per year. Tail risk is analysed separately for Real Estate, where more comprehensive asset level data are available.

Physical losses increase over the investment horizon

Within the MSCI model perimeter, the direction of change is consistent across the company exposures. Expected physical loss increases by 2050, with the largest portfolio level increase in Emerging Markets equities. The detailed results are summarised in Table 4.1.

The key finding is that expected physical economic loss is already present and increases across each of the major company exposures over a horizon relevant to pension investors.

The portfolio trend does not apply uniformly to every company. By 2050, Total AAL declines for 18 Swiss, 90 Developed Markets and 19 Emerging Markets issuers. In Developed Markets, 69 of the 90 declining cases are currently dominated by extreme cold. The evolution of physical risk therefore involves a changing balance between hazards, rather than a uniform increase in loss for every company.

Business Interruption dominates corporate physical loss

Across company exposures, the largest modelled economic effect arises from Business Interruption rather than direct damage to physical assets.

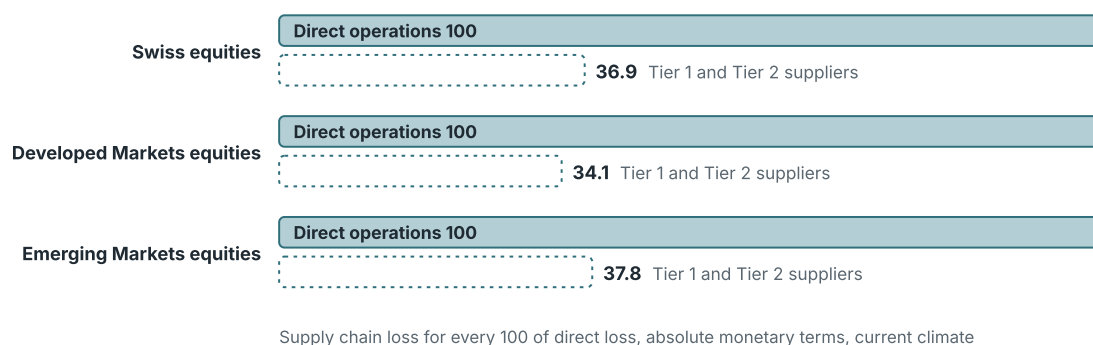
The predominance of Business Interruption partly reflects how physical impacts are modelled. While Asset Damage captures direct damage to fixed assets, Business Interruption captures the effect of physical hazards on economic activity, including disruption to production and reductions in labour productivity. The estimated magnitude therefore depends not only on hazard exposure, but also on assumptions about the duration and severity of operational disruption and on the characteristics of the economic activity affected.

This result broadens the way physical climate risk should be understood. The principal modelled corporate impact does not arise from replacing damaged buildings and machinery alone. Physical hazards affect the ability of companies to operate, with implications for production, labour productivity, access to water and energy, logistics, infrastructure dependencies and business continuity.

Supply chains add a further layer of corporate physical risk

The direct operations analysed above represent only one source of corporate physical climate risk. Companies can also incur losses when physical hazards affect suppliers and the resulting disruption or higher costs are transmitted through the value chain. According to MSCI data, under current climate conditions, aggregate supply chain AAL across the three equity universes represents an additional loss channel equal to roughly 34% to 38% of the direct physical loss modelled for companies' own operations (Figure 4.2). These figures should remain separate from the headline Total AAL percentages as the two metrics have different denominators and cannot be added mechanically.²⁸ The available supply chain data also cover current climate conditions only, so they do not show how this indirect exposure changes towards 2030 or 2050.

²⁸ MSCI defines relative supply chain AAL against company revenue, whereas direct Total AAL combines Asset Damage and Business Interruption relative to company output and fixed assets.

FIGURE 4.2 *Supply chains and physical risk*

Supply chain losses are excluded from the headline direct Total AAL. Relative supply chain and direct Total AAL metrics use different denominators and are not added. Supply chain estimates are available for current climate only.

Source: MSCI physical climate risk data (September 2026 delivery); own calculations. Certain information ©2026 MSCI Solutions LLC. Reproduced by permission.

The hazard mix changes as the climate changes

The composition of physical risk also changes over time (Figure 4.3). Extreme heat is already the principal contributor to modelled AAL across the company universes and becomes more important towards 2050 in several of them (Table 4.2). The rotation is particularly visible in Swiss and Developed Markets equities, while in Emerging Markets and the valuation-weighted Private Equity sample heat already accounts for a large share of current AAL and remains broadly stable as a proportion of total loss.

A stable share does not imply stable loss. Total AAL increases towards 2050 across all company universes, meaning that heat-related economic loss can rise even where heat's share of the total changes little. At the same time, the contribution from extreme cold declines, while some acute hazards gain importance. Physical risk therefore changes in both magnitude and composition.

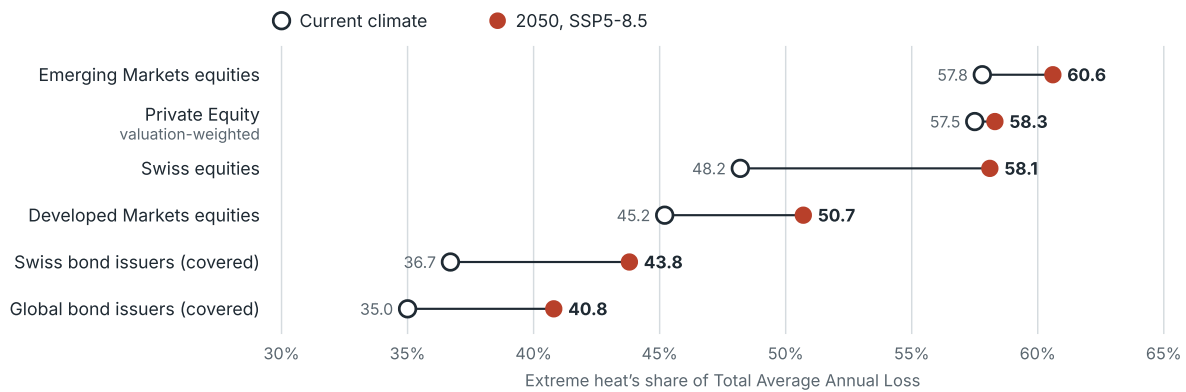
TABLE 4.2 *The hazard mix changes as the climate changes*

COMPANY EXPOSURE	PRINCIPAL CURRENT HAZARD	CURRENT SHARE	2050 SHARE	DIRECTION
Swiss equities	Extreme heat	48%	58%	Increasing
Developed Markets equities	Extreme heat	45%	51%	Increasing
Emerging Markets equities	Extreme heat	58%	61%	Broadly stable at a high level
Swiss bond issuers	Extreme heat	37%	44%	Increasing
Global bond issuers	Extreme heat	35%	41%	Increasing
Private Equity	Extreme heat	58%	58%	Broadly stable at a high level

Share of Total AAL from the principal hazard, current climate and 2050 under SSP5-8.5. Bond rows cover the corporate issuers mapped by MSCI; Private Equity is valuation-weighted.

Source: MSCI physical climate risk data (September 2026 delivery); own calculations. Certain information ©2026 MSCI Solutions LLC. Reproduced by permission.

FIGURE 4.3 Hazard rotation



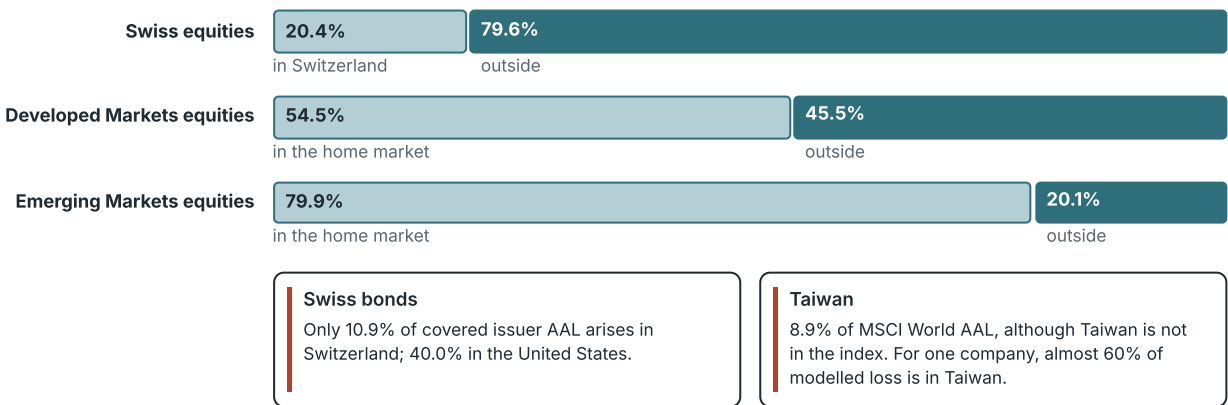
Extreme cold declines over the same period. Private Equity is valuation-weighted (50 companies; four account for about 79% of the weight).
Source: MSCI physical climate risk data (September 2026 delivery); own calculations. Certain information ©2026 MSCI Solutions LLC. Reproduced by permission.

The geography of operations matters more than the domicile of the security

Asset level analysis reveals a substantial disconnect between the financial geography of a portfolio and the location of its underlying physical risk (Figure 4.4). Most of the modelled AAL of Swiss equities and Swiss corporate bond issuers arises outside Switzerland, reflecting the international operations of the companies represented in these portfolios. Developed Markets equities similarly contain significant physical exposure outside issuers' home markets, while Emerging Markets exposures are more domestically concentrated.

Individual companies illustrate how large this disconnect can be. Roche and Novartis alone account for around half of the US physical risk identified within Swiss equities. In Developed Markets, almost 60% of one company modelled physical loss is located in Taiwan, which itself is not part of the MSCI World index. Physical risk therefore follows the geography of economic activity more closely than the domicile or currency of the security.

FIGURE 4.4 Geography and physical risk



Share of current Total Average Annual Loss arising in the issuer's home market and outside it. Shares of total portfolio AAL; 'outside' includes AAL that MSCI reports at region level only (7–13% of the total, depending on the universe).
Source: MSCI physical climate risk data (September 2026 delivery); own calculations. Certain information ©2026 MSCI Solutions LLC. Reproduced by permission.

Sector contribution provides only part of the picture

Sector contribution to portfolio AAL reflects both the weight of a sector in the portfolio and the physical loss intensity of its constituent companies. The sectors generating the largest share of portfolio AAL are therefore not necessarily those with the highest loss intensity (Table 4.3).

TABLE 4.3 *Sector contribution and physical-loss intensity*²⁹

EQUITY UNIVERSE	LARGEST CONTRIBUTOR TO PORTFOLIO AAL	HIGHEST TOTAL AAL INTENSITY	HIGHEST ASSET DAMAGE INTENSITY	MAIN OBSERVATION
Swiss	Health Care	Information Technology	Utilities	High IT intensity largely driven by one company
Developed Markets	Information Technology	Consumer Discretionary	Utilities	Utilities rank high on AD but low on Total AAL
Emerging Markets	Information Technology	Real Estate	Utilities	Real Estate intensity predominantly reflects BI and heat

Current climate. Contribution: sector share of portfolio AAL. Intensity: sector AAL as % of output and fixed assets. AD: asset damage; BI: business interruption.

Source: MSCI physical climate risk data (September 2026 delivery); own calculations. Certain information ©2026 MSCI Solutions LLC. Reproduced by permission.

This distinction is particularly visible in Emerging Markets. Information Technology and Financials together account for around 55% of portfolio AAL, yet both have below average loss intensity. Real Estate, by contrast, has the highest Total AAL intensity despite being a much smaller component of the index. In Developed Markets, Consumer Discretionary also contributes disproportionately to AAL, driven particularly by retail companies.

The metric used also affects which sectors appear most exposed. Utilities have the highest Asset Damage relative to fixed assets across all three equity universes, although they do not rank highly on Total AAL. This distinction reflects the economic base against which losses are measured. For an asset intensive sector, damage to physical infrastructure can be significant relative to its fixed assets while appearing less prominent in a Total AAL measure that combines Asset Damage and Business Interruption against a broader economic base.

Real Estate illustrates a different effect. It has the lowest Total AAL intensity among sectors in Swiss and Developed Markets equities, but the highest in Emerging Markets. The EM result is driven almost entirely by Business Interruption, particularly from extreme heat, while its Asset Damage intensity is similar to Developed Markets Real Estate. The composition of the companies also differs: Swiss and Developed Markets Real Estate are predominantly asset heavy, while the EM universe contains substantially more companies for which economic output represents a large share of the MSCI denominator. Across the Real Estate issuers analysed, Total AAL increases strongly with this output share.

Sector averages can nevertheless conceal company specific effects. The apparent high intensity of Information Technology in Swiss equities, for example, is driven by one company: excluding it, the sector falls below the Swiss equity average. In Developed Markets Consumer Discretionary, by contrast, the result is broader based, with several large retail companies

²⁹ Portfolio contribution measures the share of aggregate portfolio AAL attributable to a sector and is influenced by portfolio weight. Total AAL intensity measures physical economic loss relative to the combined economic base used in MSCI's Total AAL metric. Asset Damage intensity measures expected physical damage relative to fixed assets.

showing above average loss intensity. Sector analysis therefore helps identify where to look, while the underlying companies, business models and operating locations explain much of the variation within sectors.

Asset level analysis does not capture the entire company

Mapped locations represent approximately 46% of company output in Swiss equities, 43% in Developed Markets and only 31% in Emerging Markets, with similar coverage of fixed assets. Near-complete coverage of the securities in an index therefore does not mean that the companies' full economic activity is captured. The results describe risk within the modelled footprint and hazard perimeter and, for financial institutions and asset-light businesses in particular, should be read as a lower bound (see Section 2.5).

4.2 Sovereigns and public finances

Sovereign exposure requires a different analytical approach. A government cannot be assessed through the productive assets and Business Interruption framework used for companies. Physical climate change affects a sovereign through the broader economy, including GDP, productivity, tax revenues, reconstruction expenditure, public debt and financing conditions.

Our sovereign analysis therefore draws on Klusak et al., who estimate how climate affected GDP paths can influence sovereign credit ratings. The climate adjusted rating is then translated into indicative pressure on borrowing costs using the yield sensitivities applied in the literature. The resulting measure represents one potential credit transmission channel from physical climate change to a government borrower.

Swiss sovereign exposure

The sovereign channel is particularly relevant within the Swiss bond allocation: the Swiss Confederation represents 54% of the MSCI CH Agg proxy. The modelled effect on this material exposure depends strongly on both the emissions pathway and temperature volatility (Table 4.4). Under the high emissions pathway, the effect increases materially between 2030 and 2050 and is amplified when higher temperature volatility is assumed. Under RCP 2.6, the 2050 effect is substantially smaller.

A cross-country comparison adds an important perspective. Switzerland remains among the stronger sovereigns in the model, but its relative position deteriorates under the high-emissions scenario: from second among 109 sovereigns under RCP 2.6 in 2030 to tenth under RCP 8.5 in 2050. The difference between the two pathways is also larger for Switzerland than for several current AAA peers.

TABLE 4.4 *Indicative sovereign borrowing cost pressure under RCP 8.5*

SOVEREIGN EXPOSURE	TEMPERATURE VOLATILITY	2030	2050
Swiss Confederation	Baseline	5–7 bp	17–26 bp
	Higher	14–22 bp	21–31 bp
Global sovereign sleeve	Baseline	6–10 bp	16–24 bp
	Higher	11–16 bp	27–41 bp

Indicative, model-implied pressure on sovereign borrowing costs under RCP 8.5, derived from the climate-adjusted ratings of Klusak et al. (2023). Not a forecast of rating-agency actions or market yields.

Source: Klusak et al. (2023); MSCI bond index weights; own calculations. Certain information ©2026 MSCI Solutions LLC. Reproduced by permission.

Global sovereign exposure

Sovereigns represent approximately 69% of the MSCI Global IG proxy. A defensible historical reference rating could be established for nine countries, covering approximately 87% of the sovereign sleeve: the United States, China, Japan, France, the United Kingdom, Italy, Germany, Canada and Switzerland.

At aggregate level, the global sovereign results show the same sensitivity to scenario and temperature volatility as Switzerland (Table 4.4). The portfolio effect is, however, highly concentrated. Under the 2050 RCP 8.5 baseline-volatility case, the United States, China and Japan together account for almost 90% of the weighted deterioration, with the United States alone contributing more than half.

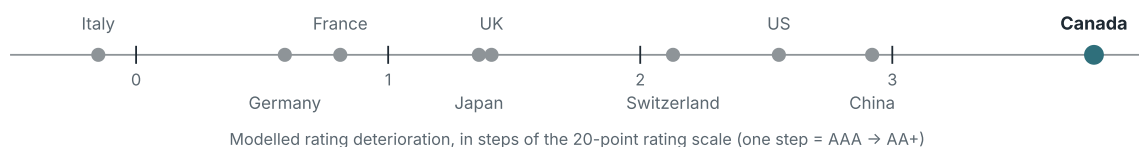
Severity at country level and importance to the portfolio are different. Canada shows the largest individual modelled deterioration among the covered countries, but its smaller portfolio weight limits its contribution to the aggregate result. Japan illustrates the reverse: a more moderate individual deterioration becomes significant because of its larger weight. A sovereign's relevance to the pension fund therefore depends on both the modelled climate effect and the size of the exposure (Figure 4.5).

FIGURE 4.5 *Sovereigns and physical climate risk***Share of the weighted rating deterioration**

RCP 8.5, 2050, baseline temperature volatility · nine covered sovereigns



For comparison, share of covered weight: US 44% · China 15% · Japan 15% · other six 25%

Country-level modelled deterioration**Canada**

Largest individual modelled deterioration among covered sovereigns, but limited portfolio contribution (4%) because of its smaller weight (2%).

Severity at country level and contribution to portfolio risk are different: the United States, China and Japan account for 88% of the effect.

Model-implied outputs of the Klusak et al. (2023) framework, not forecasts of rating-agency actions. Climate-adjusted ratings from Tables E.1–E.2 (random-forest model; 20 = AAA). Covers the nine sovereigns with a defensible reference rating (86.8% of the global sovereign sleeve); deterioration = reference – climate-adjusted rating. RCP scenarios are not directly comparable with the SSP results for companies and real estate.

Source: Klusak et al. (2023); MSCI Global IG Select bond weights; own calculations. Certain information ©2026 MSCI Solutions LLC. Reproduced by permission.

What the sovereign measure does and does not tell us

The Klusak framework provides a route from climate related macroeconomic effects to creditworthiness and indicative financing costs.

Several limitations remain. The model uses RCP 8.5 and RCP 2.6 rather than the SSP scenarios used in the company and real estate analyses. RCP 8.5 and SSP5-8.5 both represent high emissions futures, but they are not identical and the numerical results should not be treated as directly comparable. The sovereign rating results are continuous model outputs on a rating scale and are reported without confidence intervals. They should not be interpreted as forecasts of discrete future rating actions by credit rating agencies. Reference ratings have to be reconstructed because they are not provided directly by Klusak, and the available evidence supports only a subset of countries.³⁰

Most importantly for the pension fund, the indicative yield pressure is not a mark-to-market bond loss. Translating a change in required sovereign yield into the value of the bonds is discussed in Chapter 5.

The result nevertheless demonstrates that sovereign bonds cannot be assumed to sit outside physical climate risk simply because their exposure cannot be represented through asset level AAL. The relevant transmission operates through the economy and the public balance sheet.

³⁰ The magnitude of the sovereign rating changes should therefore be interpreted as an output of the Klusak modelling framework rather than as a market forecast or consensus estimate of future sovereign ratings.

4.3 Real assets

Real assets provide the most direct connection between physical climate hazards and individual physical assets. The reference pension fund portfolio contains both Swiss and international real estate and an allocation to infrastructure. While real estate physical risk is assessed through detailed property-level modelling, the infrastructure allocation is evaluated through targeted, illustrative case studies of key physical assets to address the geospatial data gap inherent in private markets.

Real estate

The Real Estate analysis provides the clearest link between physical hazards and investment assets because both exposure and loss can be assessed at individual-property level. The analysis covers 100 Swiss properties with a combined market value of approximately CHF 10.3 billion and an illustrative international sample of 23 commercial properties.

Expected annual physical damage is relatively small as a percentage of property value, but increases towards 2050 in both samples (Table 4.5). The Swiss portfolio shows the stronger increase. These AAL figures are measured against property market value and are therefore not directly comparable with the company AAL metrics presented in Section 4.1.

TABLE 4.5 *Physical climate risk in the Real Estate samples*³¹³²

	SWISS REAL ESTATE	INTERNATIONAL REAL ESTATE
Properties	100	23
Approximate market value	CHF 10.3bn	CHF 1.4bn
Current AAL	0.05%	0.04%
2050 AAL	0.07%	0.05%
Change to 2050	+46%	+11%
Principal hazard	Pluvial flooding	Tropical cyclones
Principal hazard share of current AAL	69%	91%
Property-level ES100	3.0% current / 3.3% 2030	3.9% current / 3.8% 2030

AAL as % of market value, market-value weighted; 2030 and 2050 under SSP5-8.5. Property-level ES100 is the value-weighted average of each property's expected loss beyond the 1-in-100-year loss; it is not a portfolio tail measure. The international sample (23 offices) is small and not representative.

Source: CLIMADA Technologies property-level impact analysis; own calculations.

Portfolio averages conceal substantial asset-level concentration. In the Swiss sample, four properties account for approximately half of modelled AAL while representing less than 6% of portfolio value. The five largest contributors account for close to 60% of AAL on less than 7% of value, and 15 properties account for 80% of total AAL (Figure 4.6).

³¹ ES100 figures are value-weighted averages of property-level metrics and do not represent the ES100 of the aggregate property portfolio. The international sample is illustrative; several market values are estimated and its geographic composition is not representative of a global Real Estate allocation.

³² CLIMADA Technologies provides no tail metric for hail, the fastest-rising hazard in the international sample.

This concentration is more decision-relevant than the portfolio average alone. Asset-level analysis identifies a relatively small number of buildings where further engineering assessment, insurance review or adaptation analysis can be focused. The concentration should be interpreted as a characteristic of this particular property portfolio rather than extrapolated to Swiss Real Estate generally.

Concentration also has a geographic dimension. Three towns, Lucerne, Dübendorf and Dietikon, account for over half of portfolio AAL (52%) on 8% of market value. By contrast, Zurich represents a fifth of portfolio value but less than 10% of AAL. The distribution of capital across locations therefore provides little indication of where physical loss is concentrated.

Flooding dominates the structural damage modelled by CLIMADA Technologies for the Swiss sample, with pluvial flooding becoming increasingly important towards 2050. The complementary MSCI analysis points to a different operational channel: Business Interruption associated with extreme heat increases towards 2050 while cold-related disruption declines.

The two measures capture different dimensions of property exposure and are based on different modelling frameworks. The relatively small aggregate MSCI Business Interruption estimate is therefore used here primarily to identify the changing nature of operational exposure rather than as an additional loss estimate to be combined with CLIMADA Technologies AAL.

These modelled losses are gross of insurance, and Switzerland has an unusual insurance structure. In 19 cantons, building insurance is provided by a public cantonal insurer, usually as a compulsory monopoly covering fire and natural hazards, including floods, storms and hail. In the remaining seven, known as the GUSTAVO cantons (Geneva, Uri, Schwyz, Ticino, Appenzell Innerrhoden, Valais and Obwalden), cover is provided by private insurers. Natural-hazard cover is included in fire policies at uniform rates. All four hazards modelled by CT are therefore largely insurable perils for Swiss buildings, and a substantial share of the modelled damage is likely to be transferred away from the property owner. What remains with the investor is the uninsured part: deductibles, loss of rental income during repair (depending on the policy), disruption to tenants, future premium adjustments and any effect on valuation. For a Swiss pension fund, the decision-relevant question is therefore less the gross loss than how much of it the insurance system absorbs and how that may change as physical risk increases.^{33 34 35}

The international sample shows a different risk profile. Tropical cyclones dominate modelled AAL, and the large majority of loss is concentrated in US properties despite the United States representing only a minority of sample value. The result illustrates how geographic and hazard concentration can dominate a property portfolio's physical risk profile.

The 23-property sample is too small and geographically concentrated to represent international Real Estate as an asset class. It is therefore used as an illustration of how asset-level risk can differ across locations rather than as an estimate of the physical risk of a representative international property portfolio.

³³ Alain Marti, "Kantonale Gebäudeversicherungen: Mehr als eine Versicherung," *Die Volkswirtschaft*, 14 July 2026.

³⁴ Eduard Held, "Die Elementarschadenversicherung vereint Solidarität und Wettbewerb," *Die Volkswirtschaft*, 14 July 2026.

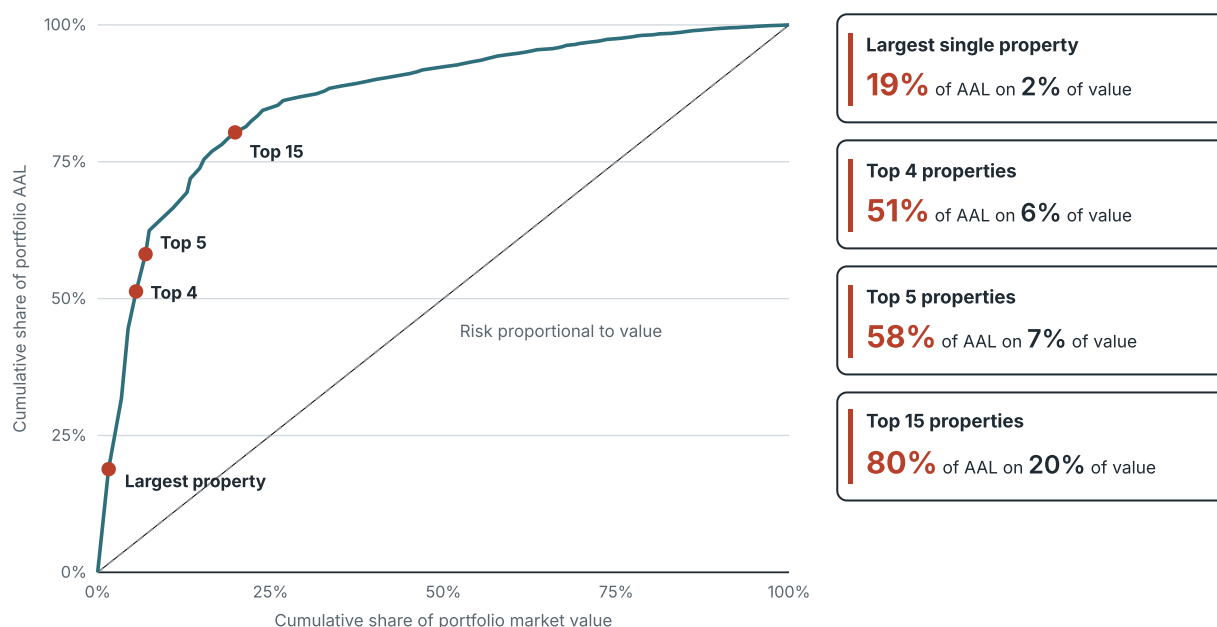
³⁵ Swiss Financial Market Supervisory Authority (FINMA), "Insurance against Natural Hazards"; Insurance Supervision Act (SR 961.01), art. 33.

Tail risk is particularly relevant for real estate

AAL is a very good measure for the expected annualized cost resulting from all possible risks, including tail risks, but is not a good measure for tail risks. In the Swiss sample, the value-weighted average property-level ES100 is around 3% of property value, compared with an AAL of around 0.05%. The international sample shows a similar order of tail exposure (Table 4.5). Individual properties can be considerably more exposed (Figure 4.7).

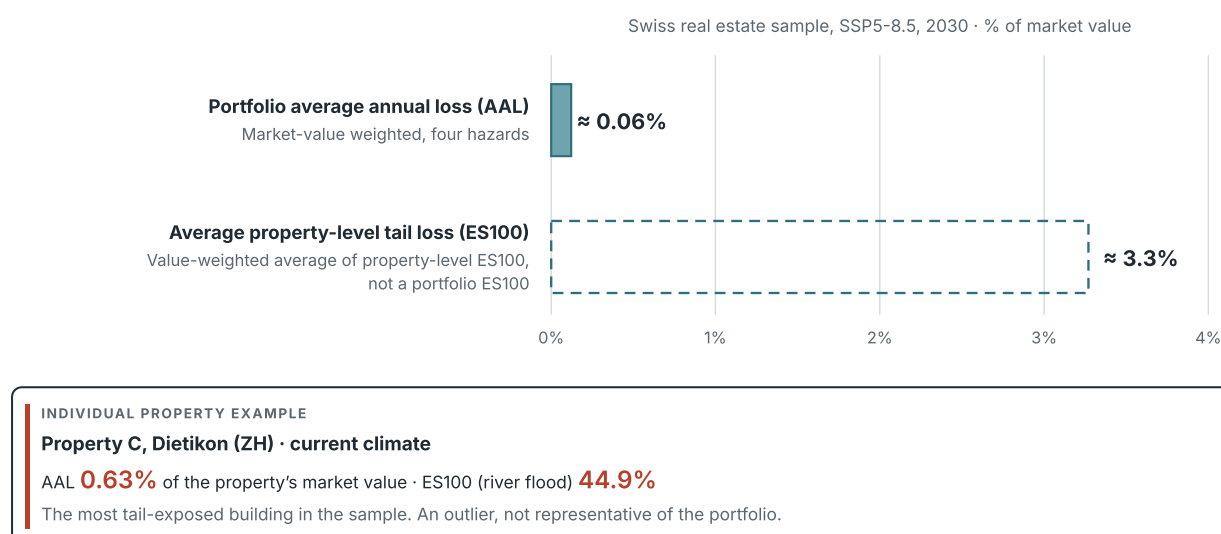
These metrics describe tail exposure at individual-property level rather than the probability distribution of aggregate portfolio loss. A portfolio tail measure would require modelling the dependence between events affecting different properties. The results nevertheless show why a small portfolio-average AAL does not imply that severe physical losses at individual assets are immaterial.

FIGURE 4.6 Swiss real estate: concentration



100 properties from ten SXI real estate funds, CHF 10.3 bn market value, current climate. Properties ranked by contribution to portfolio average annual loss (AAL); AAL is market-value weighted across four hazards (pluvial and fluvial flood, hail, wind).

Source: CLIMADA Technologies property-level impact analysis (SXI Real Estate Fund Broad sample); own calculations.

FIGURE 4.7 *Swiss real estate: tail risk*

ES100: expected loss in events beyond the 1-in-100-year loss, computed per property (summed over pluvial flood, fluvial flood and wind; no ES100 is delivered for hail) and then market-value weighted. It does not account for dependence between properties and is therefore not a portfolio tail measure.

Source: CLIMADA Technologies property-level impact analysis (SXI Real Estate Fund Broad sample); own calculations.

Infrastructure

Infrastructure represents 2.9% of the reference portfolio but could not be assessed on the same basis as the other asset classes, for three reasons.

- First, private infrastructure funds rarely disclose the location and characteristics of their underlying assets, so no representative portfolio could be constructed.
- Second, infrastructure assets are physically heterogeneous. A bridge, a data-transmission node and a solar plant are damaged and fail in different ways, and they require asset-specific damage and outage functions rather than those used for buildings.
- Third, translating physical damage and outage time into financial impact depends on operational and contractual data, such as traffic and revenues, availability payments, concession terms and insurance. These are rarely accessible to an outside investor.

Asset-level hazard data were obtained from MSCI for two assets drawn from Swiss pension fund holdings: a motorway concession in Ireland that includes an estuarine river crossing, and a utility-scale solar portfolio in Spain. Without asset values or operating data, these data describe the physical hazards at each asset rather than financial loss, and are not comparable with the AAL figures in this chapter. They nevertheless show where the hazard sits within each asset, which hazards matter, and how they change under SSP5-8.5.³⁶

³⁶ Asset-level hazard data delivered by MSCI. The data provide flood depth and wind speed by return period, heat, cold and drought indicators, and, for flood, estimated repair time. Monetary outputs require asset values and operating income, which were not available. Time steps are offsets from the provider's current year; the 5- and 25-year steps are reported as "around 2030" and "around 2050", without interpolation. Changes are measured from the current value under the same scenario.

Case study: a motorway concession and estuarine crossing, Ireland

The N25 Waterford Bypass is a tolled motorway in south-east Ireland, opened in 2009 and operated under a public-private partnership. Its principal structure is the Thomas Francis Meagher Bridge, a cable-stayed crossing of the River Suir with a 230-metre main span. The analysis covers about 3.7 km of the route around the crossing, assessed at 38 points roughly 100 metres apart.

Flood exposure is concentrated in two short stretches:

- A low-lying section about 1.6 km north-east of the bridge is already exposed to a 1-in-100 flood, with modelled depths at ground level of up to 65 cm. These rise to about 71 cm by around 2050.
- At the southern end of the river crossing, two points that remain dry in a 1-in-100 flood today become exposed by around 2030, reaching about 20–23 cm by 2050.

The remaining 32 points stay dry even in a 1-in-500 event. Estimated repair time after a severe flood at the most exposed point rises from 16 to 22 days. Extreme heat is negligible at this location, and modelled 1-in-100 wind gusts change little.

The data leave out what may matter most for a long-span bridge. Ground-level flood depth does not measure water levels against the bridge structure, scour around foundations, or closures in high winds. Transport Infrastructure Ireland lists this bridge among three structures to be assessed for retrofitting wind shielding. A newer cable-stayed bridge on the same route has closed to traffic several times in high winds since opening in 2020.³⁷

For an investor, the effect of a closure or repair runs through the concession agreement. Lost toll revenue, repair costs and any compensation depend on how the contract allocates extreme-weather events and on the insurance in place, neither of which is covered by the data.

Case study: utility-scale solar, Spain

The second case is a portfolio of 60 solar photovoltaic plants in Spain with a combined capacity of 91 MW, acquired in 2026 by a Swiss investment foundation for pension funds.³⁸ The data cover one site of about 3.4 km² in the province of Seville, assessed at points along its perimeter.

Here the dominant hazards are chronic, and they are the fastest-changing in either case:

- Under SSP5-8.5, the number of days with a heat index of at least 40°C roughly doubles by around 2050, from 15 to 31 a year.
- Days with a heat index above 35°C rise from 52 to 74.
- The longest drought episode expected once in a century lengthens from 87 to 105 weeks.

Acute hazards are limited. Wildfire probability is modelled as zero, wind gusts are moderate, and flooding affects about one in ten points on the site perimeter, with no material change over time.

³⁷ Caroline O'Doherty, "The Irish Roads and Bridges Most at Risk from Intensifying Extreme Weather," *The Irish Times*, 28 February 2026.

³⁸ Iberian Lawyer, "Bestinver Sells Solar Business to IST for €330M: Advisors," 12 February 2026.

For a solar plant, heat matters less as a source of physical damage than of lost output: photovoltaic module output typically falls by around 0.4% for every degree Celsius above its reference temperature.³⁹ The data do not translate the rising heat into lost generation. They also do not show where inverters and substations sit relative to the flood-exposed parts of the site, or how drier conditions affect dust and cleaning needs.

The investor's exposure is again shaped by the revenue model. Most of the portfolio's income comes from Spain's regulated remuneration regime, which combines a payment per megawatt of installed capacity with a payment per megawatt-hour produced and market sales. Remuneration is reduced only if output falls below a minimum number of operating hours.⁴⁰ A moderate loss of output from heat would therefore affect market and operating revenue first, rather than the regulated return on investment.

TABLE 4.6 *Infrastructure case studies: hazard profile and what the data capture*

	MOTORWAY CONCESSION, IRELAND	SOLAR PV PORTFOLIO, SPAIN
Asset analysed	3.7 km of tolled motorway, including a 465 m cable-stayed estuarine crossing	One site (≈3.4 km ²) of a 60-plant, 91 MW portfolio
Revenue model	Toll concession (PPP)	Regulated remuneration plus market sales
Dominant hazard in the data	Flooding, at a few locations	Extreme heat and drought
Change to around 2050 (SSP5-8.5)	Depth at most exposed point rises from 65 to 71 cm; southern end of crossing becomes exposed to a 1-in-100 flood	Days with heat index ≥ 40°C double (15 → 31); longest 1-in-100 drought +21%
Concentration	3 of 38 points exposed to a 1-in-100 flood today, 5 from around 2030; 32 dry even at 1-in-500	About 1 in 10 perimeter points exposed to a 1-in-100 flood
Not captured	Financial loss; scour; water level at the structure; wind closures; network effects	Financial loss; output lost to heat; soiling; location of electrical equipment

Physical hazard indicators, not losses. "Around 2030" and "around 2050" are the provider's 5- and 25-year steps from its current year.

Source: MSCI asset-level hazard data; public information on the assets. Certain information ©2026 MSCI Solutions LLC. Reproduced by permission.

Three observations follow from the two cases.

- 1. Exposure is concentrated within the asset.** A few hundred metres of a motorway, or a minority of a solar site, carry the flood exposure. This shows where engineering assessment and adaptation should focus, much as a small number of properties drive the real estate results.
- 2. The relevant hazard follows the asset type and location.** It is acute flooding, and potentially wind, for a transport crossing in a maritime climate. It is chronic heat and drought for a solar plant in southern Spain, and there it is changing faster.
- 3. The hazard does not map one-to-one onto investment loss.** Concession terms, regulated remuneration and insurance determine how much of a physical effect reaches the investor.

A quantitative assessment of infrastructure therefore requires dedicated resources: asset-level location and engineering data from managers; asset-specific damage and outage functions; operational, contractual and insurance information; modelling of dependencies on power, transport, water and communications networks.

³⁹ U.S. Department of Energy, *Understanding Solar Photovoltaic System Performance: An Assessment of 75 Federal Photovoltaic Systems*, 2021. The report provides the illustrative temperature coefficient of 0.004/°C used in the text.

⁴⁰ Spain, *Real Decreto 413/2014, de 6 de junio*, on the specific remuneration regime for renewable electricity generation.

Damage to a critical node can disrupt activity well beyond the asset itself, a systemic channel that current asset-level data only partially describe. Closing these gaps is a priority for further work.

4.4 What the portfolio analysis reveals

Looking across companies, sovereigns and real assets provides a more complete picture of physical climate risk than any single metric or conventional asset class classification.

First, physical climate risk is **already measurable** across substantial parts of the economic exposures underlying the pension fund portfolio. Company analysis identifies expected losses associated with direct asset damage and business interruption and, through a separate current climate screen, costs transmitted through Tier 1 and Tier 2 suppliers. Property analysis connects physical hazards directly with individual buildings. Sovereign modelling identifies a macroeconomic and fiscal transmission channel through which climate change can influence creditworthiness and borrowing costs.

Second, the **direction of change** is broadly consistent over the investment horizon. Expected economic losses increase by 2050 across the major company universes examined. Private Equity follows the same broad pattern. Swiss real estate shows a particularly strong increase under the high warming scenario. Sovereign ratings also deteriorate materially by 2050 under RCP 8.5. The units differ, but each analysis indicates greater physical climate pressure over a horizon directly relevant to pension liabilities and long lived assets.

Third, conventional portfolio classifications provide an incomplete picture of **where physical risk sits**. A Swiss company or Swiss franc bond can represent predominantly international physical exposure. Developed Market companies can carry material operating risk in countries outside the index itself. In sovereign portfolios, the country is explicit, yet a small number of large issuers can dominate the result. For direct real estate, aggregate allocation weights can conceal the importance of a handful of highly exposed properties.

Fourth, **the drivers of loss** differ materially across the underlying economy. Business Interruption accounts for the large majority of expected corporate loss, with extreme heat becoming increasingly important. Real estate risk can instead be dominated by a specific local hazard such as surface water flooding. Sovereign effects arise through macroeconomic performance, fiscal conditions and the sensitivity of creditworthiness to alternative climate pathways. The same term, physical climate risk, therefore encompasses very different economic mechanisms.

Fifth, **averages capture only part of the risk**. AAL is particularly useful for identifying the recurring expected burden of climate hazards and for comparing changes within a consistent model. It provides little information about the severity of infrequent events. The corporate datasets currently offer very limited tail information, while the real estate analysis shows how much larger individual property losses can become at longer return periods. Concentration, severe event exposure and the potential correlation of losses therefore remain essential complements to expected annual loss.

Finally, **measurement remains incomplete**. Near-complete coverage of listed securities can coexist with much lower coverage of the underlying economic footprint, private-market geolocation is thinner, and infrastructure could not be assessed quantitatively. The limitations set out in Section 3.6 affect the precision of individual estimates, but not the broader finding that physical climate risk can increasingly be identified at the economic source from which it enters the portfolio.

For a pension fund, this is the principal value of moving below conventional asset class labels. The analysis identifies which companies, countries and physical assets carry the exposure, where they are located, which hazards or economic channels drive the risk, how that risk may develop over time and where significant analytical gaps remain.

It still does not answer the pension fund's ultimate financial question: **how much could these physical and economic effects reduce the value or return of the investments held?** Answering that question requires a further step. A loss to company operations needs to be translated into equity value or credit risk. A change in sovereign borrowing costs needs to be translated into bond valuation. Property damage needs to be considered together with insurance, rental income, adaptation expenditure and market repricing.

Chapter 5 therefore turns from the measurement of physical and economic loss to the mechanisms through which those effects can become investment loss.

CHAPTER 5

From Physical Loss to Investment Risk

Chapter 4 measures physical climate risk at the level of the underlying economic exposure. This chapter examines the next step: how those effects can reach the financial performance of the securities and assets held by a pension fund.

The transmission differs by investment instrument. For companies, physical loss can affect earnings, cash flows and valuation. For corporate debt, the same operating effects matter through credit quality and spreads. For sovereign bonds, climate-related macroeconomic effects can influence borrowing costs and bond values. For directly owned Real Estate and infrastructure, physical damage and disruption can affect income, expenditure and asset value.

Existing methodologies illustrate this two-stage approach. MSCI's Physical Climate Value at Risk, for example, translates projected company physical costs into a present-value measure relative to enterprise value⁴¹, while the Bank of England applies financial valuation and credit models to climate-scenario economic outputs.⁴² Both illustrate the need for a financial transmission layer between physical loss and investment performance.

The timing of the financial effect also matters. Physical losses may affect realised cash flows gradually as hazards occur, while severe events can produce sudden losses. Financial markets may also reprice an asset before physical damage occurs if investors revise their expectations of future costs or risks. Future physical effects can therefore be reflected in current valuations rather than appearing only as losses when the underlying hazards materialise.

5.1 Companies: from physical loss to equity value

For companies, the physical effects measured in Chapter 4 reach equity value primarily through operating performance. Asset Damage can require repair or replacement expenditure and reduce productive capacity. Business Interruption, heat-related productivity losses, water constraints and supply-chain disruption can reduce output or revenues and increase operating costs.

⁴¹ MSCI, *Physical Risk Guide for Asset Owners and Asset Managers*, April 2026.

⁴² Lewis Holden, Jordan King, Harriet Richards, Caspar Siegert and Lukasz Krebel, "Measuring Climate-related Financial Risks Using Scenario Analysis," *Bank of England Quarterly Bulletin*, 17 April 2024.

For an equity investor, these operating effects ultimately matter through the value of the company. Lower expected revenues, higher operating costs, additional capital expenditure and greater working capital requirements reduce the future cash flows available to investors. These effects can be incorporated into a discounted cash flow or comparable valuation framework.

Physical climate risk can also affect valuation through the discount rate. Greater uncertainty around future cash flows, exposure to severe events or a climate-related risk premium can increase the return required by investors and reduce the present value of the company.

Physical risk can therefore reach equity value through both expected cash flows and the rate at which those cash flows are valued.

Empirical research supports the first part of this transmission. Pankratz, Bauer and Derwall find that greater extreme-heat exposure reduces company revenues and operating income⁴³, while Pankratz and Schiller show that heat and flood exposure at supplier locations can affect both suppliers and their customers.⁴⁴ Barrot and Sauvagnat similarly find that shocks to difficult-to-substitute suppliers can generate output and market-value losses for customer firms.⁴⁵

The same physical loss can therefore have different valuation effects across companies. Profitability, production diversification, insurance, leverage and the ability to adapt determine how much of the underlying economic loss reaches future cash flows and valuation. The same logic applies to Private Equity, although valuation is observed through periodic company valuations rather than continuously traded market prices.

5.2 Corporate debt: from operating loss to credit risk

Corporate bond investors are exposed to the same underlying company losses as equity investors, but through a contractual claim. Physical damage, Business Interruption and supply-chain disruption can reduce cash generation, while repair and adaptation expenditure can increase financing needs. The resulting deterioration in leverage, interest coverage and debt-service capacity can affect credit quality, probability of default, recovery expectations, credit spreads and refinancing costs.

Empirical studies provide evidence of this transmission. Research on Chinese corporate bonds finds that greater physical climate risk is associated with wider credit spreads, particularly through lower internal cash flows and tighter financing constraints.⁴⁶ Other studies using MSCI physical-risk measures and US corporate data similarly find evidence that physical exposure can be reflected in credit conditions and bond pricing.^{47 48}

⁴³ Nora Pankratz, Rob Bauer and Jeroen Derwall, "Climate Change, Firm Performance, and Investor Surprises," *Management Science* 69, no. 12 (2023): 7352–7398.

⁴⁴ Nora M. C. Pankratz and Christoph M. Schiller, "Climate Change and Adaptation in Global Supply-Chain Networks," *The Review of Financial Studies* 37, no. 6 (2024): 1729–1777.

⁴⁵ Jean-Noël Barrot and Julien Sauvagnat, "Input Specificity and the Propagation of Idiosyncratic Shocks in Production Networks," *The Quarterly Journal of Economics* 131, no. 3 (2016): 1543–1592.

⁴⁶ Feng He, Xingzi Ren, Yueren Wang and Xingfan Lei, "Climate Risk and Corporate Bond Credit Spreads," *Journal of International Money and Finance* 154 (2025): 103297.

⁴⁷ Xinxin Wang and Nisarga Reddappa, "Physical Climate Risk and Corporate Bonds: Evidence from Hurricanes," MSCI Research & Insights, 23 June 2026.

⁴⁸ Hasibul Chowdhury, Ihtisham Malik, Hui Sun and Searat Ali, "Natural Disasters and Corporate Default Risk," *International Review of Economics & Finance* 106 (2026): 104949.

Translating the AAL measured in Chapter 4 into a bond-price effect would therefore require a few steps. The first step would be to incorporate the physical loss into the issuer's financial position. The second would be to estimate how the resulting change in cash flow, leverage and asset value affects probability of default or the credit spread demanded by investors. The final step would translate that spread or default shock into the market value of the particular bond, taking account of its maturity, duration, seniority and recovery assumptions.⁴⁹

Bond maturity also affects the transmission. A change in yield has a larger price effect on longer-duration securities, while expected future climate deterioration can be priced before the physical loss occurs. The timing of market repricing therefore matters alongside the timing of the underlying physical effect.

5.3 Sovereign debt: from economic damage to bond value

For sovereign bonds, the transmission operates through the economy and public finances rather than through individual physical assets. The Chapter 4 analysis already moves one step along this chain by translating climate-related macroeconomic effects into indicative changes in sovereign borrowing costs.⁵⁰

For investors, changes in sovereign yields affect the market value of outstanding bonds, with the price effect depending primarily on the magnitude of the yield change and the bond's duration. Longer-maturity securities are therefore more sensitive to a given climate-related yield shock.

The timing of repricing remains important. A physical or macroeconomic effect projected for 2050 does not imply that bond prices adjust only in 2050. If investors anticipate the deterioration, part of the effect may be reflected in yields earlier. The Bank of England's scenario methodology provides one example of incorporating this forward-looking repricing into sovereign bond valuation.⁵¹

Applying this final valuation step to the sovereign results in Chapter 4 would require assumptions about when the modelled borrowing-cost effect enters the yield curve and the duration of the pension fund's individual bond holdings.

5.4 Real assets: from physical damage to investment return

For Real Estate, physical climate risk reaches investment performance through the two components of property return: **income and capital value**. Income can be affected by business interruption, vacancy, operating and insurance costs, while capital expenditure may be required for repair or adaptation. Capital value reflects these expected future cash flows as well as changes in insurability and the yield required by future buyers.

Empirical property-market research provides evidence that physical risk can be capitalised into asset prices. Studies of flood exposure, for example, find effects on property values, although their magnitude varies with geography, insurance arrangements and the information available

⁴⁹ MSCI provides an example of this approach through its Climate Adjusted Probability of Default. See MSCI, *Physical Risk Guide for Asset Owners and Asset Managers*, April 2026.

⁵⁰ Klusak et al. (2023).

⁵¹ Holden et al. (2024).

to market participants.⁵²

Tail risk adds a further dimension. As Chapter 4 shows, relatively small expected annual losses can coexist with much larger losses at individual properties under severe events. Such losses may create discrete impairments and additional capital requirements rather than a smooth annual reduction in return.

Investment frameworks increasingly bring these channels together. IIGCC's Physical Climate Risk Appraisal Methodology, for example, integrates climate science, engineering assessment and financial materiality, including insurance and the value of resilience measures.⁵³

Infrastructure follows the same broad valuation logic, although the specific cash flow mechanism depends heavily on the asset. Physical damage can interrupt availability, reduce usage or revenues, increase operating expenditure and require additional capital expenditure. For regulated or concession based assets, contractual arrangements can determine whether costs remain with the owner, are transferred to users or are absorbed by public counterparties. Physical risk can also influence debt service capacity and the cost of financing. Assessing these channels requires operational and contractual data at asset level, which were not available for this study.

5.5 From security level impacts to portfolio return

A portfolio-level financial effect can be estimated only after the physical and economic exposures have been translated into investment metrics appropriate to each instrument. Equity effects would need to be expressed in changes in company value, corporate and sovereign bond effects in security-level price or credit measures, and Real Estate effects in property value and income.

Once expressed in comparable financial terms over a common scenario and horizon, these security-level effects can in principle be aggregated using the pension fund's portfolio weights.

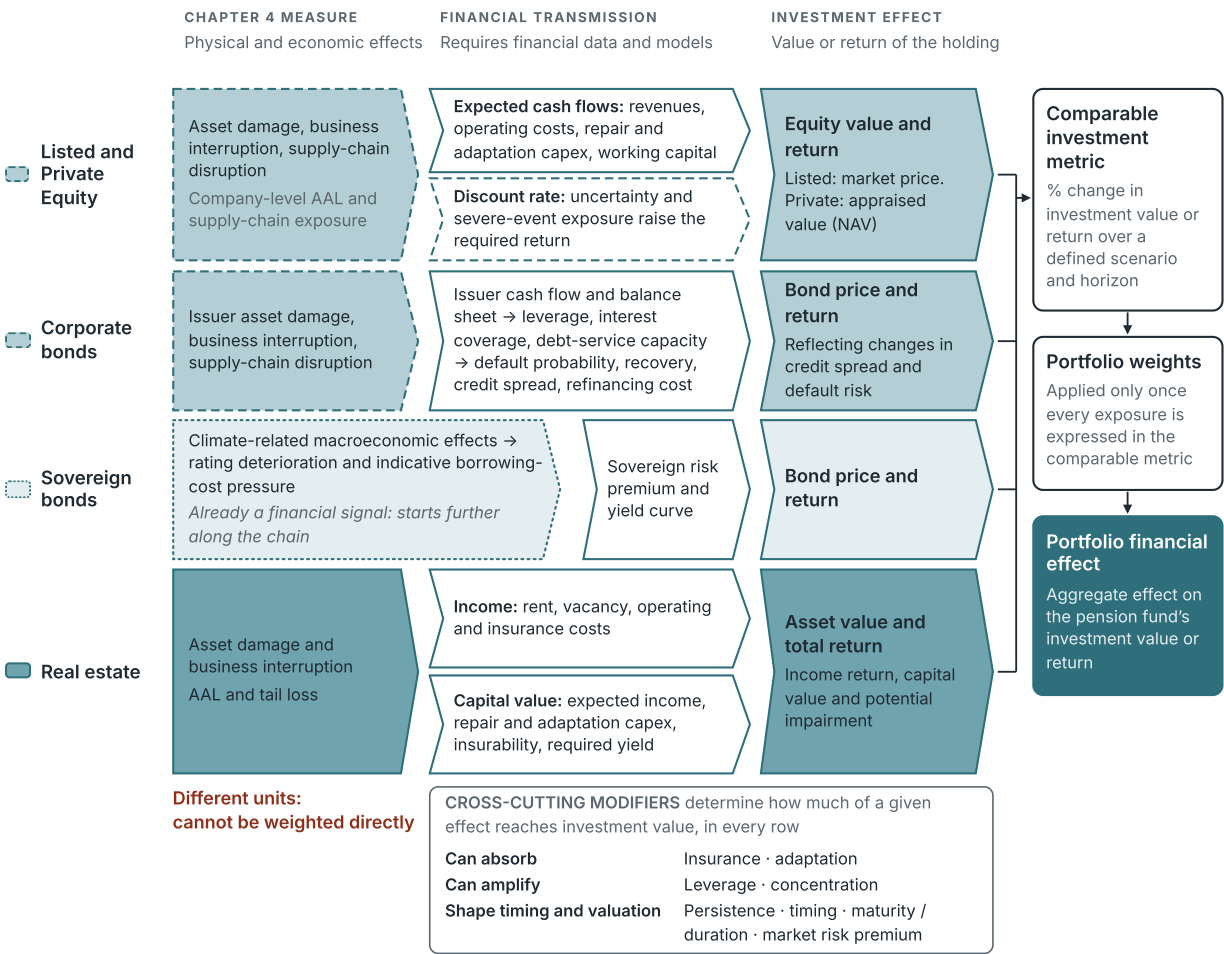
The analysis in this paper stops before that final step. The Chapter 4 results sit at different stages of the transmission process and use different economic bases. Applying a uniform conversion factor across them would therefore introduce an additional level of assumptions.

The results nevertheless provide the inputs needed for that next modelling layer: the location and magnitude of physical economic exposure, its evolution under climate scenarios, and the channels through which it can reach investment performance (Figure 5.1).

⁵² Laura Bakkensen and Hannah K. Friedrich, "Flooding, Housing Prices, and Insurance: Evidence from the United States," *Annual Review of Resource Economics* 18 (2026), in press.

⁵³ Institutional Investors Group on Climate Change (IIGCC), *The Physical Climate Risk Appraisal Methodology 2.0*, November 2025.

FIGURE 5.1 From physical risk measures to a portfolio financial effect



Chapter 6 turns to how investors can use this information in practice, through governance, investment decisions, engagement and adaptation.

CHAPTER 6

From Measuring Risk to Managing It

Measuring physical climate risk has limited value if the resulting information remains confined to climate reporting. For pension funds, the objective is to translate better information about hazards, exposure and potential financial losses into investment decisions that protect the long term interests of beneficiaries.

The emerging practice among institutional investors suggests that physical climate risk can be incorporated at several levels: governance and risk management, portfolio construction and investment decisions, acquisition due diligence, active ownership and manager oversight, and investment in adaptation and resilience. The appropriate response will depend on the asset class, the materiality of the exposure and the investor's ability to influence the underlying asset.

Importantly, **identifying high physical risk does not automatically imply divestment**. An asset located in a highly exposed geography may remain attractive if the risk is appropriately valued, insurance is available, effective adaptation measures are in place and the asset or company has sufficient financial and operational resilience. Conversely, an apparently moderate hazard exposure may represent a greater investment risk if vulnerability is high and the capacity to adapt is limited.

The investment question therefore moves beyond identifying where hazards are located. It becomes one of understanding **exposure, vulnerability, financial materiality and capacity to adapt**.

6.1 Make physical climate risk part of investment governance

The first step is to establish where responsibility for physical climate risk sits within the investment organisation.

This matters because physical climate risk crosses conventional organisational boundaries. Sustainability teams may understand climate scenarios, risk teams may own portfolio analytics, investment teams make security and manager decisions, and real asset teams may have direct access to information on individual properties and infrastructure assets. A physical risk assessment becomes useful when these perspectives are connected.

For a pension fund, this could mean establishing a regular physical climate risk assessment covering the portfolio, identifying material exposures and concentrations, and defining how those findings enter existing investment and risk processes. Physical climate risk does not necessarily require a parallel governance architecture. It can increasingly become part of the processes already used to assess investment risk.

This approach is consistent with emerging investor frameworks from MSCI and IIGCC, which emphasise clear accountability and the integration of physical climate risk into existing investment, risk management and stewardship processes.^{54 55}

A practical starting point for pension funds is therefore to define a small number of questions that can be revisited regularly:

- Where are the largest physical climate exposures in the portfolio?
- Which hazards and locations drive those exposures?
- Which exposures could have a financially material effect?
- How are the most important risks expected to evolve?
- What is being done to reduce vulnerability?
- Who within the investment organisation is responsible for acting on this information?

The final question is particularly important. Better physical climate data will have little effect if responsibility for responding to it remains unclear.

6.2 Integrate physical risk into investment decisions

Once material exposures have been identified, physical climate risk can inform investment decisions at two levels: portfolio construction and individual investment analysis. The information required, and the decisions it can support, differ across investment types.

At portfolio level, scenario analysis can help pension funds understand concentrations across economic exposures, operating locations and hazards under different climate pathways. This information can complement traditional risk factors used in strategic asset allocation and asset-liability management. As Chapter 4 shows, these concentrations may not be visible from conventional portfolio classifications alone.

At individual investment level, physical risk can become part of investment analysis, valuation and due diligence. The relevant information depends on the nature of the exposure.

For companies, investors can consider the location of critical facilities, exposure to relevant hazards, potential Business Interruption, supply chain and infrastructure dependencies, insurance and expected adaptation expenditure alongside conventional financial information.

⁵⁴ MSCI's 2026 *Physical Risk Guide for Asset Owners and Asset Managers* makes a similar point. It argues that translating physical risk analysis into portfolio decisions requires clear accountability and consistent execution across investment, risk, sustainability and reporting functions. Its proposed workflow moves from measuring exposure to identifying material risks and then integrating the findings into investment strategy, risk management and oversight. MSCI, *Physical Risk Guide for Asset Owners and Asset Managers*, April 2026.

⁵⁵ The Institutional Investors Group on Climate Change takes a similar approach in its *Climate Resilience Investment Framework*, which supports investors in developing climate resilience goals and implementation strategies across internal structures and policies, asset level risk management and broader investor stewardship. Source: IIGCC, *Climate Resilience Investment Framework*, 2025.

For sovereign debt, analysis can consider how physical climate effects may influence economic resilience, public finances and creditworthiness.

For Real Estate and infrastructure, the analysis can reach the underlying physical asset itself. Physical risk can be assessed during acquisition due diligence, reflected in valuation and insurance assumptions, and used to prioritise capital expenditure and adaptation measures during the holding period. Asset level analysis can also identify where further investigation is most valuable. In the Swiss Real Estate sample analysed in Chapter 4, for example, four properties account for approximately half of modelled AAL while representing less than 6% of portfolio value.

Swiss market practice is beginning to reflect this approach. Swiss Prime Anlagestiftung, for example, integrates climate related risks into its investment and risk management processes and assesses ESG risks during acquisition due diligence, with identified risks and potential optimisation measures considered from the start of an investment. Climate related risks are also incorporated across the investment process and reported to the Foundation Board.⁵⁶

The PRI's 2025 technical guidance for private markets explicitly identifies these uses. It recommends that investors use physical risk assessments to inform portfolio strategy, individual investment valuations, insurance requirements and adaptation measures. For asset owners investing through external managers, the same framework can be used to evaluate how managers identify and manage physical risk.⁵⁷

This has direct implications for Swiss pension funds, where a substantial proportion of assets are managed externally. Physical climate risk can increasingly become part of manager selection, investment mandates and reporting requirements.

Questions for an external manager could include whether physical risk is assessed at asset or issuer level, which hazards are covered, how geolocation is incorporated, which scenarios and time horizons are used, how adaptation measures affect the assessment, and how identified risks influence investment decisions.

The objective should be to understand the investment decision that follows from the metric and whether the identified risk is already reflected in valuation. A sophisticated physical risk score has little investment value if neither the asset owner nor the manager can explain what would cause the score to influence valuation, portfolio construction, engagement or capital expenditure.

Case study: From analysis to investment decisions at NBIM⁵⁸

Norges Bank Investment Management provides an example of how physical risk is beginning to move into mainstream portfolio management.

Its 2030 Climate Action Plan commits the fund to stress test its equity portfolio against extreme climate scenarios, further develop its internal climate scenario analysis, monitor physical climate risk across the portfolio and provide climate risk analytics to investment portfolios. For unlisted Real Estate and infrastructure, it plans to analyse both direct physical impacts and

⁵⁶ Swiss Prime Anlagestiftung, *Jahresbericht 2025*, TCFD-Bericht, p. 102.

⁵⁷ Principles for Responsible Investment (PRI), *Assessing Physical Climate Risk in Private Markets: A Technical Guide*, 2025.

⁵⁸ Norges Bank Investment Management (NBIM), *2030 Climate Action Plan*.

effects on surrounding infrastructure and integrate the findings into investment decisions and asset management. It also plans specific analysis of physical climate risk in government and government related fixed income portfolios.

At company level, NBIM intends to expand its climate engagement focus to include companies with heightened vulnerability to physical climate and nature risks.

The example illustrates how physical climate risk can move through the organisation: from portfolio analytics, to individual asset classes, investment decisions and company engagement.

6.3 Use active ownership to understand resilience

For portfolio companies (listed and private), pension funds generally cannot decide how an individual factory, warehouse or office should adapt to a changing climate. They can, however, use their position as owners to understand whether those companies are identifying and managing their material physical exposures.

This requires engagement to become more operational.

Traditional climate engagement has often concentrated on greenhouse gas emissions, transition plans and net zero targets. Physical climate risk raises a different set of questions:

- Where are the company's most critical physical assets and suppliers?
- Which climate hazards could materially affect them?
- How does the company assess vulnerability at those locations?
- What proportion of expected losses arises from physical damage and what proportion from operational disruption?
- Which adaptation measures have been identified?
- How are these measures prioritised and incorporated into capital expenditure?
- What residual risk remains after adaptation?
- How is insurance coverage changing in terms of availability, exclusions, deductibles and cost?
- What contingency plans exist if a critical facility, supplier or transport connection becomes unavailable?
- How does management assess the resilience of the business under different climate scenarios?

These questions are increasingly reflected in emerging investor practice. IIGCC's 2026 work on adaptation and resilience engagement proposes first identifying portfolio companies with heightened physical vulnerability, then developing sector specific engagement priorities and using existing investor engagement programmes to address adaptation and resilience. IIGCC also highlights an important difference from emissions based engagement: physical climate risk cannot be reduced to a single common metric, because vulnerability and appropriate adaptation responses depend heavily on location, sector and operational context.⁵⁹

⁵⁹ Institutional Investors Group on Climate Change (IIGCC), "Supporting Investor Action on Physical Climate Risk: Adaptation and Resilience Priorities for 2026," 2026.

Corporate disclosure is also evolving in this direction. IFRS S2 requires companies to disclose information enabling investors to understand the resilience of their strategy and business model to climate related changes and to use climate scenario analysis to inform that assessment. The standard explicitly covers physical climate risks and asks companies to consider how climate related risks could affect cash flows, access to finance and cost of capital over the short, medium and long term.⁶⁰

This creates an opportunity for asset owners to use corporate reporting as an input while also using engagement to address information that remains unavailable or insufficiently granular.

The need for this additional information is evident in current corporate practice. MSCI and First Street find significant gaps between companies' physical climate exposure, their awareness of that exposure and reported adaptation measures.⁶¹

For asset owners, broad acknowledgement of physical climate risk is therefore a starting point rather than evidence that the underlying vulnerability is understood or being reduced.

6.4 Adapt rather than simply exit

Identifying material physical risk does not automatically imply that an investment should be sold. Where an asset remains economically attractive, investing to reduce its vulnerability can preserve income, reduce expected losses and protect long term value.

For a physical asset, this might involve flood defences, improved drainage, heat resistant materials, cooling systems, water efficiency, fire protection, redundancy in power or transport connections, or relocation of particularly vulnerable equipment. For companies, adaptation may include diversifying suppliers, increasing inventories of critical inputs, redesigning production processes or relocating activities over time.

The investment question is whether the expected financial benefits of greater resilience justify its cost. These benefits can include lower physical damage and Business Interruption, reduced tail risk, improved insurability and protection of operating income and residual asset value.

Recent modelling by MSCI and First Street illustrates the potential economics of this approach. Across companies assessed as having higher physical exposure and lower preparedness, the majority of modelled asset hardening measures generated positive savings on investment. These

⁶⁰ IFRS Foundation, *IFRS S2 Climate-related Disclosures; Climate Resilience and Climate-related Scenario Analysis Requirements in IFRS S2*, March 2026.

⁶¹ Across annual reporting from 25,346 global companies between 2023 and 2025, 81% mentioned physical climate risk, while only 27% provided detailed disclosure identifying how specific physical hazards could affect the business. The same research found approximately 900 MSCI ACWI constituents, or 37% of the assessed universe, in a higher exposure, lower preparedness group: companies with potentially material modelled acute physical risk for which no disclosed evidence of relevant asset hardening measures was found. Source: MSCI and First Street, *The Price of Not Knowing: Connecting physical climate risk awareness, exposure and adaptation*, 2026, pp. 4, 5 and 13.

estimates represent modelled avoided losses rather than realised investment returns.⁶²

This approach is increasingly reflected in investor frameworks. IIGCC's Physical Climate Risk Appraisal Methodology 2.0, published in 2025, integrates climate science, engineering and financial appraisal for real estate and infrastructure. The methodology explicitly considers adaptation options, their costs and benefits, asset value enhancement, insurability and nature based solutions.⁶³

Physical risk analytics can therefore provide an input into decisions about where resilience investment creates economic value.

Case study: Swiss Life Investment Foundation

A concrete Swiss example comes from the Swiss Life Investment Foundation, which invests occupational pension assets. At Albisstrasse 152 in Zurich, the conversion of a former office building into residential use incorporated a wrap-around balcony designed to shade large window openings and provide natural heat protection. The renovation also included broader building upgrades under Minergie standards. The example illustrates how heat protection can be incorporated into capital expenditure on an existing Real Estate asset held for Swiss pension investors.⁶⁴

6.5 Invest in adaptation and resilience

Beyond increasing the resilience of assets already held, pension funds can allocate capital to investments whose products, services or infrastructure support adaptation and resilience. The scale of the financing need is considerable.

UNEP's 2025 *Adaptation Gap Report* estimates that developing countries will require more than USD 310 billion per year in adaptation finance by 2035 based on modelled costs. The estimate rises to approximately USD 365 billion when based on needs identified in national climate plans. International public adaptation finance flows were approximately USD 26 billion in 2023, leaving an estimated annual financing gap of USD 284 billion to USD 339 billion.⁶⁵

Not all of this gap represents an investable opportunity for pension funds. Many adaptation needs concern public goods, vulnerable communities or projects without commercial revenue streams and will continue to require public or concessional finance. UNEP's 2025 report

⁶² Among approximately 900 MSCI ACWI companies classified as higher exposure and lower preparedness, 94% had at least one modelled asset hardening measure with positive savings on investment under present day risk conditions. Among companies with a positive opportunity, the median benefit cost ratio was approximately 5 times. Across the group, approximately USD 5.6 billion of modelled adaptation investment was associated with USD 58.2 billion of avoided physical damage and operational downtime. The estimates should be interpreted as modelled adaptation economics rather than realised investment returns. The analysis focuses on asset hardening for acute hazards, including flooding, severe storm winds and wildfire, and assumes no additional adaptation measures at the assessed assets. Over a 30 year horizon under SSP2-4.5, the same study finds that the median modelled benefit cost ratio rises to approximately 37 times, illustrating how the economics can strengthen as avoided losses accumulate and physical risk increases. Source: MSCI and First Street, *The Price of Not Knowing: Connecting physical climate risk awareness, exposure and adaptation*, 2026, pp. 15 to 17.

⁶³ Institutional Investors Group on Climate Change (IIGCC), *The Physical Climate Risk Appraisal Methodology 2.0*, 2025.

⁶⁴ Swiss Life Investment Foundation, *ESG Product Report: Commercial Real Estate Switzerland*, as at 30 September 2021, p. 28, "Sustainable renovation project at Albisstrasse 152 in Zurich."

⁶⁵ United Nations Environment Programme, *Adaptation Gap Report 2025: Running on Empty*.

estimates that private finance could potentially contribute around USD 50 billion per year to adaptation with appropriate enabling policies and blended finance support. Public finance and risk sharing mechanisms may still be required to make some of these opportunities investable.

For institutional investors, adaptation and resilience opportunities can appear through several channels.

They can appear through **companies providing adaptation solutions**, including water management, cooling technologies, resilient construction materials, climate analytics, early warning systems, agricultural technologies and technologies that strengthen energy and communications infrastructure.

They can be financed through **infrastructure and private market investments**, particularly where resilience improvements generate identifiable revenues or protect long lived productive assets.

They can also be financed through **debt instruments**, including corporate, sovereign and labelled bonds where proceeds are directed towards eligible adaptation and resilience activities.

The market remains less mature than climate mitigation investment. One reason is definitional: identifying what qualifies as an adaptation investment and measuring the resulting resilience benefit remain difficult. UNEP FI's 2026 Adaptation Finance Taxonomy Playbook was developed specifically to help financial institutions identify and classify adaptation finance opportunities across jurisdictions, while its Adaptation and Resilience Impact Measurement Toolkit provides a framework for assessing and reporting the resilience outcomes generated by financed activities.⁶⁶

Recent market practice also suggests that the investable universe is broadening. GFANZ's 2026 *Investing in Resilience* report draws on 22 case studies involving banks, insurers, asset managers and asset owners financing adaptation and resilience across developed and emerging markets. A recurring feature is the need to combine physical risk analytics with financial structuring and, in some cases, multiple sources of value to create an investable proposition.⁶⁷

This distinction matters for pension funds. Investing in adaptation should not become another thematic label applied to investments with only a loose connection to climate resilience. The investment needs to have a credible mechanism through which it reduces vulnerability, increases adaptive capacity or provides a product or service that enables others to do so. Measuring the resulting resilience benefit is therefore an important part of establishing the investment case.

Case study: Pension capital financing adaptation solutions

APG, which manages assets for Dutch pension funds, provides an example of adaptation investment through both companies and debt instruments. APG reports investments on behalf of its pension fund clients in Xylem, whose technologies support water transport, treatment, reuse and more efficient water consumption, as well as in green bonds issued by Nederlandse

⁶⁶ United Nations Environment Programme Finance Initiative (UNEP FI), *Adaptation Finance Taxonomy Playbook*, June 2026; UNEP FI, *Adaptation and Resilience Impact Measurement Toolkit: A Practical Framework for Financial Institutions*, December 2025.

⁶⁷ Glasgow Financial Alliance for Net Zero (GFANZ), *Investing in Resilience: Lessons from Private Finance for Unlocking Investment in Adaptation*, 2026.

Waterschapsbank financing water related activities.⁶⁸ The examples illustrate two routes through which pension capital can support adaptation: investment in companies providing resilience solutions and financing infrastructure addressing physical climate needs.

Case study: Financing adaptation infrastructure through blended finance

Norwegian municipal pension fund KLP illustrates how institutional investors can deploy capital into climate adaptation while meeting fiduciary requirements by committing to Climate Investor Two (CI2), a blended finance facility managed by Climate Fund Managers. Focusing on water, sanitation, and coastal infrastructure across emerging markets, CI2 targets projects like bulk water storage, wastewater treatment, desalination, and flood defence to strengthen systemic resilience against physical climate hazards.

To address emerging market risks, CI2 uses a tiered structure where concessional and donor funds absorb initial first-loss risks during early feasibility and ESIA assessments. This de-risking allows investors like KLP to enter at the construction equity stage with risk-adjusted returns. The fund also enforces strict governance through sustainability and audit committees to evaluate adaptation via concrete resilience metrics.

For Swiss pension funds, this demonstrates that capitalizing adaptation solutions does not require direct infrastructure operation, but rather thorough manager due diligence to ensure proper financial de-risking and measurable real-economy outcomes.^{69 70 71}

6.6 Towards a physical climate risk investment process

The emerging frameworks and practices reviewed in this section point towards a relatively simple investment cycle (Figure 6.1).

Measure. Identify the underlying assets and locations, assess relevant hazards and estimate physical and financial exposure.

Prioritise. Focus attention on exposures where potential financial consequences are greatest, while recognising model uncertainty and data gaps.

Investigate. Understand vulnerability, insurance, operational and supply chain dependencies, and existing adaptation measures rather than relying exclusively on hazard scores.

Act. Incorporate the findings into portfolio construction, valuation, manager mandates and stewardship.

Adapt. Where an existing investment remains economically attractive, assess whether investment in resilience can reduce expected losses and protect long term value.

Invest. Allocate capital to companies, assets and projects providing economically viable adaptation and resilience solutions.

⁶⁸ APG, “How does the drought affect investors?”, 18 August 2022.

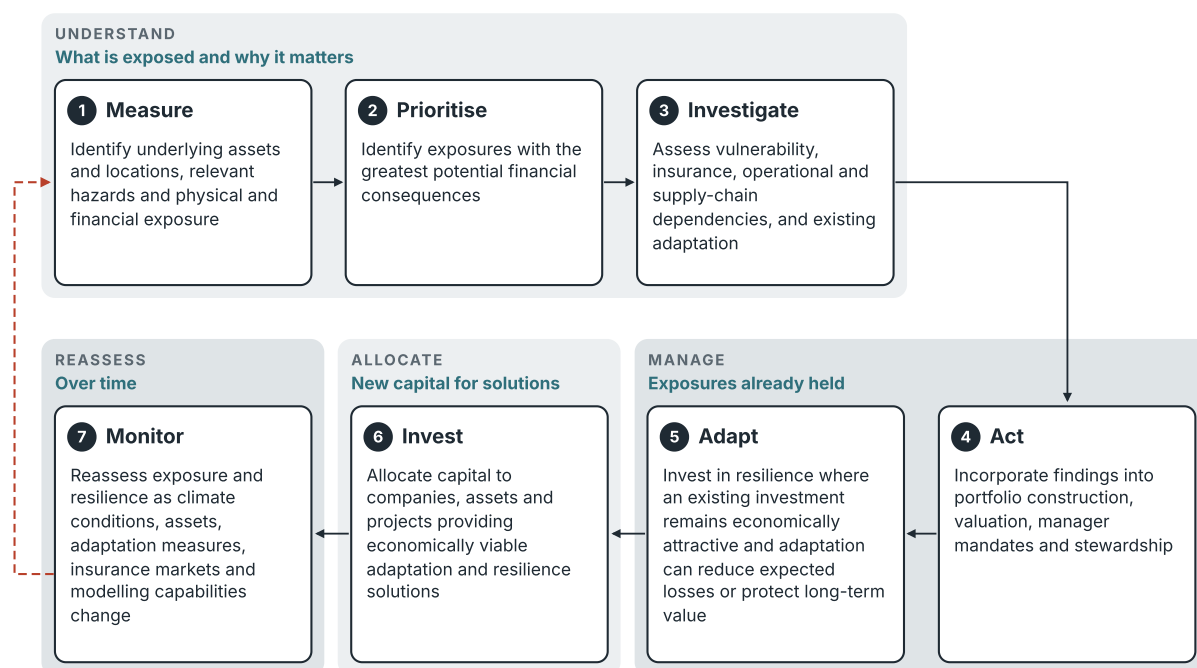
⁶⁹ Climate Fund Managers, *Climate Investor Two: SFDR Website Product Disclosure*, December 2022.

⁷⁰ Climate Fund Managers, *Climate Investor Two*.

⁷¹ Climate Fund Managers, “Climate Fund Managers Announces the First Close of CI2,” 11 November 2021.

Monitor. Reassess exposure and resilience as climate conditions, asset locations, adaptation measures, insurance markets and modelling capabilities evolve.

FIGURE 6.1 *A physical climate risk investment cycle*



Monitoring feeds the next round of measurement: an iterative investment process

For Swiss pension funds, this progression offers a practical way to move from climate risk measurement towards investment management. It also responds directly to one of the findings of this study: physical climate risk cannot be understood through a single portfolio metric. Different assets are exposed to different hazards, through different locations and different financial transmission mechanisms. Management of those risks therefore requires information that remains sufficiently granular to support decisions.

The objective is ultimately to improve resilience at two levels. At portfolio level, pension funds can seek to understand and manage the physical risks affecting the long term value of beneficiaries' assets. At real economy level, their capital and ownership position can support companies and assets in reducing vulnerability and adapting to physical climate change.

Physical climate risk analysis therefore has a role beyond identifying what could be lost. It can help investors determine where resilience is economically valuable, where capital is required, and where investment decisions can contribute to preserving value in a changing climate.

CHAPTER 7

Conclusion

For a Swiss pension fund, physical climate risk begins with a practical problem: conventional portfolio classifications provide only limited information about where the underlying exposure is located. A Swiss security can carry predominantly international physical exposure, companies can depend on operations and suppliers far beyond their country of domicile, and a Real Estate portfolio with a modest average loss can contain substantial risk in a small number of properties.

The bottom up analysis in this study makes these exposures more visible. Across the listed company and covered corporate bond universes, current Total AAL ranges from approximately **0.7% to 1.4% of the modelled economic base**, with Business Interruption accounting for **more than 90% of expected loss**. Around **80% of current Swiss equity AAL arises outside Switzerland**, while in the Swiss Real Estate sample just **four properties account for approximately half of modelled AAL on less than 6% of portfolio value**. These results describe different economic exposures and should not be combined into a single portfolio loss measure.

Identifying where the risk sits is only the first investment question. Investors also need to understand what creates the economic loss and how that loss reaches the financial instrument they hold. For companies, Business Interruption highlights the importance of productivity, infrastructure, water, supply chains and business continuity. For Real Estate, local hazards, concentration and tail risk are particularly relevant. For sovereigns, the transmission operates through economic and fiscal conditions.

The final financial effect consequently depends on the investment. Physical loss can affect company cash flows and equity value, corporate credit quality, sovereign yields, or Real Estate income and capital value. Insurance, leverage, diversification, adaptation and market expectations influence how much of the underlying physical and economic effect reaches the investor. Because current physical risk metrics differ in their economic bases, hazard coverage and position along the financial transmission chain, a credible portfolio level financial estimate requires an additional translation into comparable investment value or return effects.

For pension funds, the value of this analysis lies in the decisions it can improve. It can identify where deeper investigation is required, inform valuation and due diligence, strengthen manager oversight and engagement, and direct resilience expenditure towards assets where it can protect future income and value. It can also help investors identify companies, infrastructure and financing instruments that provide adaptation and resilience solutions.

For Swiss pension funds, the relevant questions are increasingly concrete: **Where is the underlying economic exposure? What drives the potential loss? What could that mean financially? What action could improve the investment outcome?**

Pension funds invest across decades. Over the same period, the physical conditions affecting the assets and economic activities they finance will change. Better visibility on those exposures can improve the quality of decisions made today, both in protecting the long term value of existing investments and in allocating capital to a more resilient economy.

APPENDIX 1

Methodological note

Datasets: MSCI Physical Risk Metrics for listed equities, corporate bonds and private equity, with a supplementary real-estate delivery; CLIMADA Technologies property-level impact analysis for Swiss and international real estate.

1 · Why the definition of “current” matters

A future estimate is only interpretable relative to its starting point. Two questions determine what a change from “current” to 2050 measures:

- **The starting climate:** an observed historical climate, a modelled present-day climate, or something else?
- **What else changes:** do exposure values, asset locations or damage functions change alongside the hazard?

If only the hazard changes, the % change in average annual loss (AAL) isolates the modelled effect of climate change on a fixed portfolio. If exposure also grows, the change mixes climate and economic effects. If the starting climate lies in the past, it also includes warming that has already occurred. The two providers answer these questions differently, so the study reports changes *within* each dataset, not across them.

2 · MSCI Physical Risk Metrics

DEFINITION OF “CURRENT”

A modelled present-day climate derived from the 1.5°C NGFS REMIND Orderly output of the last full historical year. Time step 2025 for the listed-equity, bond and private-equity deliveries; 2024 for the earlier real-estate delivery. It is not an observed climatology such as 1981–2010, and the averaging window is undisclosed; return-period metrics imply it represents the climate state at 2025 warming, not the weather of one year.

Hazards modelled by Swiss Re (observation-based, current only; convective storm and windstorm carry losses) are excluded from all combined loss metrics, so every hazard in the combined AAL follows the NGFS-based definition.

FUTURE TIME STEPS

2030, 2050 and 2100 under eleven scenarios: SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5 (about 2°C, 3.1°C, 4.1°C and 5.4°C of warming by 2100) and seven NGFS REMIND scenarios. The study uses the “average” outcome. Hazard data draw on CMIP6 models and partner catastrophe models.

WHAT CHANGES

- **Hazard:** by scenario.
- **Exposure:** grown with OECD long-term GDP projections, identically in every scenario. The implied company denominator (fixed assets plus output) grows by a median $\times 1.2$ by 2030 and $\times 2.7$ by 2050.
- **Locations and damage functions:** not described as changing. No adaptation is modelled.

CONSEQUENCE FOR THIS STUDY

Absolute USD losses grow mainly because the economy grows: in MSCI World (equal-weighted), absolute AAL rises about 220% from 2025 to 2050 under SSP5-8.5, relative AAL about 15%. All MSCI changes over time therefore use **relative AAL**: the hazard change from a modelled 2025 climate, plus a minor geographic-mix effect as markets grow at different rates.

3 · CLIMADA Technologies property-level results

DEFINITION OF “BASELINE”

Reported alongside SSP1-2.6, SSP2-4.5 and SSP5-8.5 for 2030, 2050 and 2080. The public CLIMADA datasets on which such results are typically built use historical reference periods:

TABLE A1.1 *Reference periods and future approach by hazard in public CLIMADA datasets*

HAZARD	PUBLIC REFERENCE PERIOD	FUTURE APPROACH
River flood	1980–2000 (ISIMIP historical, 20-year window)	Model-driven 20-year windows under RCPs
Tropical cyclone	Observed tracks 1980–2020; scaling vs 1982–2022	Frequency scaling, Knutson et al. (2020) via Jewson (2021)
Windstorm	1980–2010 (CMIP6 historical)	CMIP6 ensembles under SSPs
Hail	2011–2021 (convection-permitting simulations)	A single +3°C warming level
Coastal flood	Aqueduct “historical”	Sea-level-rise scenarios, 2030/2050/2080
Pluvial flood	Not publicly documented	Not publicly documented

The baseline is therefore a **hazard-specific historical reference climate spanning roughly 1980–2021**, not a representation of 2025 conditions.

WHAT CHANGES AND WHAT STAYS CONSTANT

- **Exposure and locations: constant.** Each property carries one market value across all scenarios and years; losses are % of that value.
- **Damage functions: constant.** One function per hazard, with no documented variation over time.

Changes therefore isolate the modelled hazard change for today’s properties at today’s values.

CONSEQUENCE FOR THIS STUDY

Because the baseline lies in the past, changes from it include warming already realised. Under SSP1-2.6, Swiss real-estate AAL is already about 10% above baseline by 2030 (pluvial flood about 17%), while MSCI relative AAL for listed equities rises only 1–3% from 2025 to 2030.

- **Windstorm** moves irregularly across scenarios and horizons (differing climate-model samples) and is not interpreted on its own.
- **Hail** is unavailable for SSP5-8.5 in 2080; results for that year use a three-hazard basis.

4 • Summary

TABLE A1.2 MSCI and CLIMADA Technologies compared

	MSCI PHYSICAL RISK METRICS	CLIMADA TECHNOLOGIES
Meaning of current / baseline	Modelled present-day climate: first time step of MSCI's scenario modelling, from NGFS REMIND 1.5°C output	Historical reference climate, specific to each hazard
Reference period	2025 (2024 in the real-estate delivery); averaging window undisclosed	Labelled 2000 or undated; public datasets span roughly 1980–2021
Scenarios and horizons used	SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5 at 2030, 2050, 2100	SSP1-2.6, SSP2-4.5, SSP5-8.5 at 2030, 2050, 2080
Hazards covered	Both AD and BI: Tropical cyclones, Pluvial (surface-water) flooding, Fluvial (river) flooding, Coastal flooding, Wildfire Only BI: Extreme heat, Extreme cold, Extreme precipitation, Extreme snowfall, Extreme wind, River low flow	Swiss sample: Pluvial flood, River (fluvial) flood, Hail, Windstorm International sample: Tropical cyclone, Coastal flood, River flood, Windstorm, Hail
Hazard change / exposure change	Yes / grows with GDP, identically across scenarios	Yes / held constant
Loss metric used for change	Relative AAL (% of output plus fixed assets)	AAL as % of property market value
A change to 2050 measures	Hazard change from a modelled 2025 climate, plus a minor geographic-mix effect	Hazard change from a historical reference climate, including warming already realised

APPENDIX 2

From findings to investment decisions

TABLE A2.1 *From findings to investment decisions*

FINDING FROM THE ANALYSIS	INVESTMENT QUESTION	POTENTIAL INVESTOR RESPONSE
1 · Operational resilience and the evolving risk profile		
Business Interruption accounts for more than 90% of modelled corporate AAL across the analysed company exposures.	How resilient are the company's operations to physical disruption? Are critical production sites, labour, infrastructure and utilities exposed, and what redundancy exists?	Assess business continuity, operational redundancy and adaptation measures. Incorporate material disruption risks into fundamental analysis and engagement.
Physical losses increase towards 2050 across the analysed company exposures.	Could increasing physical risk affect future revenues, costs, margins, capital expenditure or financing needs over the investment horizon?	Incorporate forward looking physical risk into scenario analysis and longer term valuation assumptions where financially material.
The hazard mix changes over time, with heat becoming increasingly important across corporate exposures.	Are current risk management and adaptation plans designed for the hazards expected to become more material, rather than primarily those that dominate historical losses?	Assess forward looking adaptation plans and capital expenditure against the evolving hazard profile.
2 · Where the risk sits: geography, supply chains and concentration		
A significant share of corporate physical risk arises outside the issuer's country of domicile.	Does country or regional allocation accurately represent the portfolio's underlying geographic exposure to physical hazards?	Use asset level geolocation where available. Look beyond issuer domicile when assessing geographic concentration and diversification.
Supply chains create an additional physical risk channel beyond companies' own operations.	Are critical suppliers or inputs concentrated in climate exposed locations? Can disruption be substituted or passed through to customers?	Extend due diligence and engagement beyond directly owned assets to critical supply chains, sourcing dependencies and supplier diversification.
Physical risk varies materially within sectors and can be concentrated in individual companies or assets.	Is portfolio level or sector level analysis concealing concentrated exposures?	Drill down from portfolio and sector averages to issuers, locations and individual assets where concentrations are material.

Real estate expected losses can be concentrated in a relatively small number of properties.	Which individual properties drive portfolio physical risk, and is the concentration visible in aggregate portfolio metrics?	Prioritise high contribution assets for engineering assessment, adaptation planning and asset specific risk mitigation.
3 · Reliability of the physical risk estimates		
High security coverage can coexist with materially lower coverage of companies' underlying economic footprint.	How much of the issuer's actual operations and fixed assets is captured by the physical risk assessment? Could important exposures remain outside the model?	Review economic footprint coverage alongside security coverage. Treat apparently precise AAL estimates cautiously where underlying asset mapping is incomplete.
Sector classification can materially influence modelled company losses even when asset locations are unchanged.	How sensitive is the physical risk estimate to assumptions about the economic activity conducted at an exposed location?	Test material exposures against alternative classifications where appropriate and treat sector dependent model outputs as estimates rather than purely geographic measurements.
4 · Extreme losses and risk transfer		
A portfolio with moderate AAL can still contain significant tail risk.	Could a severe physical event create losses that are material to the asset, mandate or portfolio despite relatively modest expected annual loss?	Examine RPL and Expected Shortfall alongside AAL. Stress test concentrated exposures and assess insurance, liquidity and financial capacity to absorb extreme losses.
Insurance can transfer part of the financial loss but does not eliminate the underlying physical exposure.	What losses are insured, what exclusions and deductibles apply, and could insurance availability or pricing change as risk increases?	Assess insurance quality and future insurability alongside physical risk. Consider adaptation where it can reduce both residual risk and dependence on risk transfer.
5 · From physical exposure to investment decisions		
Sovereign physical risk can transmit through economic output, fiscal capacity, credit quality and yields.	Could climate related economic deterioration affect sovereign creditworthiness or required returns over the holding period?	Incorporate physical risk into sovereign credit analysis and scenario testing, particularly for more exposed issuers and longer duration holdings.
Physical economic loss does not translate mechanically into investment loss.	Through which financial channel could the identified physical exposure affect this particular security? Is the risk already reflected in valuation?	Translate physical metrics through instrument specific transmission channels before changing portfolio exposures. Consider profitability, leverage, insurance, adaptation, valuation and market pricing.
High physical exposure does not by itself determine whether an investment should be held or sold.	Is the investor adequately compensated for the risk, and can adaptation materially improve resilience or value?	Compare physical exposure with resilience, adaptation capacity and valuation. Consider engagement, adaptation investment, repricing or portfolio adjustment according to the investment case.

Glossary and abbreviations

AAL	Average Annual Loss. The expected annual loss from physical hazards, obtained by weighting the losses from all possible events by their annual probability. It describes an average annual burden, not the loss expected in any single year. For companies (MSCI), Total AAL is expressed relative to annual output plus fixed asset value; for real estate (CLIMADA Technologies), relative to property market value.
AD	Asset Damage. The component of MSCI's modelled loss that captures direct physical damage to a company's fixed assets, expressed relative to fixed asset value.
BI	Business Interruption. The component of MSCI's modelled loss that captures lost economic activity from physical hazards, including production disruption and lower labour productivity, expressed relative to annual company output.
CMIP6	Coupled Model Intercomparison Project, Phase 6. The set of global climate model simulations underpinning the IPCC Sixth Assessment Report and many hazard projections.
CT	CLIMADA Technologies. Provider of the property-level physical risk modelling used for real estate in this study, built on the open-source CLIMADA platform originally developed at ETH Zurich.
ES100	Expected Shortfall at the 100-year return period. The average loss in years when losses exceed the 100-year return period loss, i.e. the average of the worst 1% of annual outcomes. It measures the severity of the tail, not just its threshold.
Hazard, exposure, vulnerability	The three elements of physical risk: the climate event or condition (hazard), the assets or activities located where it can occur (exposure), and how severely they are affected (vulnerability).
IG	Investment Grade. Bonds rated BBB- / Baa3 or higher by the major credit rating agencies.
NACE	Statistical Classification of Economic Activities in the European Community. Sector classification used by MSCI's model to set a company's fixed-asset base and Business Interruption loss functions; assigned by the authors for the Private Equity sample.
NGFS	Network for Greening the Financial System. A network of central banks and supervisors that publishes reference climate scenarios for financial risk analysis.

OAK BV	Oberaufsichtskommission Berufliche Vorsorge. The Swiss Occupational Pension Supervisory Commission, whose annual survey is the basis of the reference asset allocation.
PACTA	Paris Agreement Capital Transition Assessment. A methodology for assessing the alignment of financial portfolios with climate scenarios; used in the Swiss climate tests coordinated by the Federal Office for the Environment.
PoP	Point of Presence. A physical network access node, such as a regional interconnection site, through which data traffic enters or leaves a telecommunications network.
RCP	Representative Concentration Pathways. Greenhouse gas concentration scenarios from the IPCC Fifth Assessment Report. The sovereign analysis uses RCP 2.6 (low emissions) and RCP 8.5 (very high emissions).
RPL	Return Period Loss. The loss level associated with a given annual probability of being exceeded. A 100-year RPL has about a 1% chance of being exceeded in any year; a 250-year RPL about 0.4%.
SSP	Shared Socioeconomic Pathways. Scenarios from the IPCC Sixth Assessment Report combining socioeconomic narratives with levels of climate forcing, e.g. SSP1-2.6 (low emissions), SSP2-4.5 (intermediate) and SSP5-8.5 (very high emissions, used here as a high physical risk stress scenario).
Supply chain AAL	MSCI's estimate of expected physical risk costs transmitted to a company from its Tier 1 and Tier 2 suppliers, expressed relative to company revenue and available for current climate only.

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Models, data and scenarios

The results are model-based estimates derived from third-party data and methodologies, including MSCI physical climate risk data, CLIMADA Technologies property-level modelling and the sovereign framework of Klusak et al. (2023). They depend on assumptions about hazards, exposure, vulnerability, asset locations, sector classifications and economic transmission, and they do not cover all hazards, assets or indirect effects. Different models, data vintages or assumptions could produce materially different results. Climate scenarios describe possible conditions under specified assumptions and are not forecasts. Physical and economic loss estimates are not estimates of investment losses, and no portfolio-level financial loss is estimated in this report.

The reference portfolio and the analytical samples are constructed for research purposes and do not represent the holdings or risk of any specific pension fund. Some samples are small and not representative of their asset class, as described in Chapter 3.

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Conflicts of interest

Rosa Sangiorgio is the founder of RSg Impact Investing, which advises clients on sustainable and impact investing. She is Chair of the Swiss Platform for Impact Investing, a Board Member of Impact SGR, an Executive Ambassador at RepRisk and an advisor to several start-ups. Nadir Franca is affiliated with Women in Sustainable Finance International and has no other interests to declare. Data and modelling were provided by MSCI and CLIMADA Technologies free of charge. This study received no external funding. Neither data providers nor funders had the right to approve the findings or conclusions.

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- **Model Uncertainty:** Climate models are based on complex algorithms and assumptions. Different models may produce varying results due to differences in methodologies, parameters, and data inputs.
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- **Model Calibration and Validation:** While climate models undergo calibration and validation processes, they cannot perfectly replicate past climate conditions or guarantee future accuracy. Model performance may vary across different regions and time periods.
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- **Vulnerability modelling:** The employed vulnerability models account for variations in key asset characteristics, but are designed to represent a broad range of assets. As such, results are indicative and cannot replace detailed engineering evaluations that incorporate asset-specific structural features, site conditions, and construction quality.
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By acknowledging these limitations, users of climate risk analytics and future climate modelling can better understand the scope and constraints of the information provided. CLIMADA Technologies regularly updates the models to ensure the most accurate and relevant insights are obtained.

Swiss pension funds invest around CHF 1.2 trillion over horizons that run for decades. This study looks through the securities they hold to the companies, economies and buildings underneath. It shows that physical climate risk is already measurable, that it rarely sits where portfolio labels suggest, and what pension funds can do to move from exposure to resilience.

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