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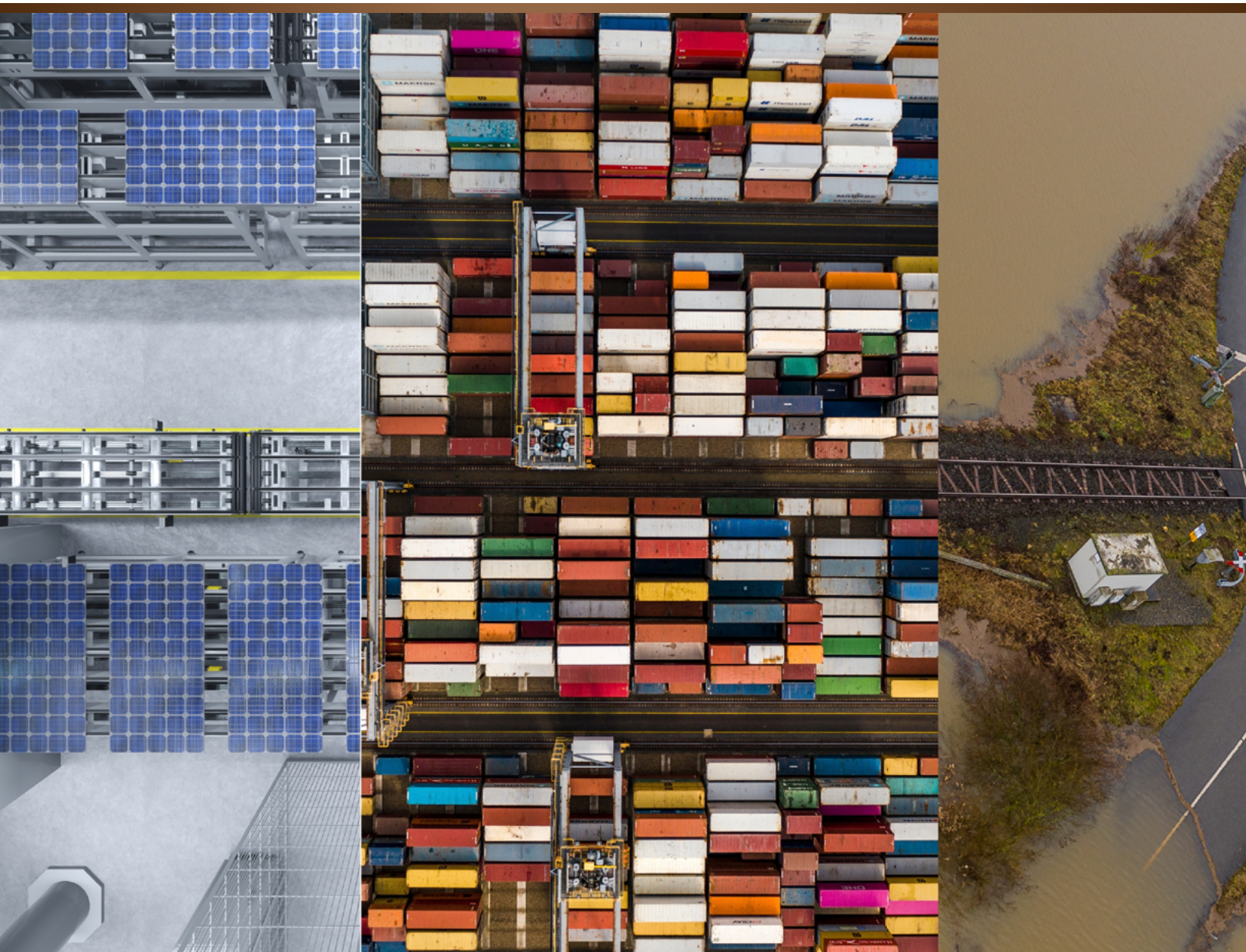
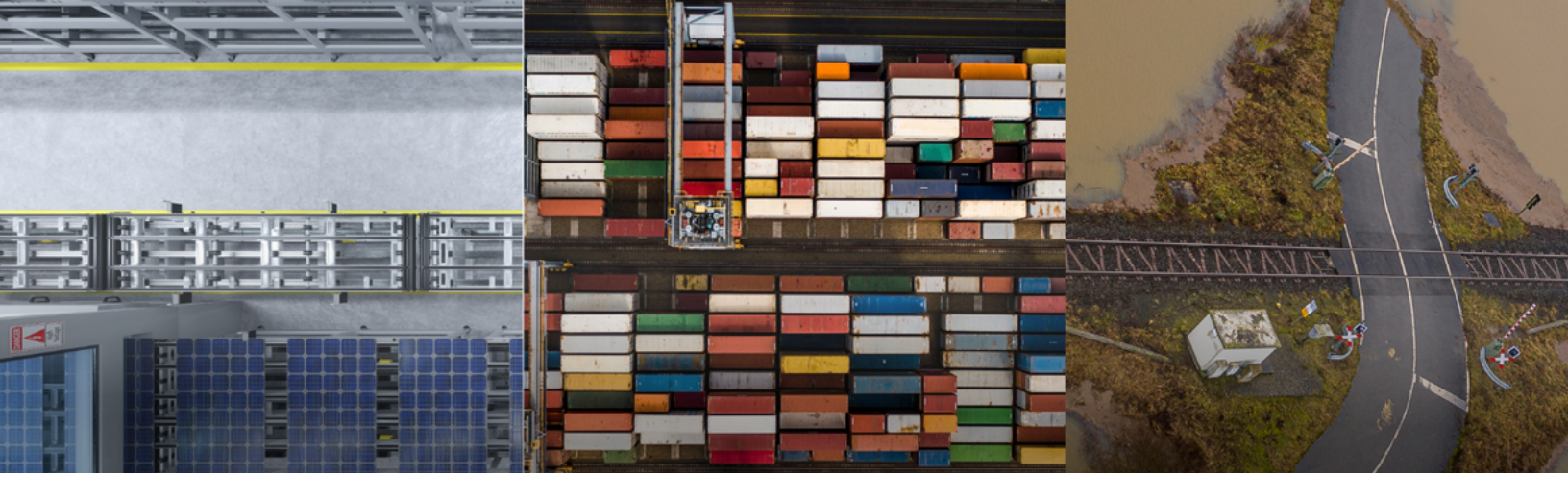
Building Resilience Through Climate Adaptation

Overcoming biases to position for new opportunities while minimizing losses





Executive Summary

Board rooms, investors and policymakers have mainly focused on climate mitigation (i.e., lower emissions or decarbonization) over climate adaptation (adjusting for present and future levels of climate change impacts). Spending for climate mitigation historically has accounted for more than 90% of total climate finance worldwide; globally climate adaptation finance has been below $65 billion a year, only 1/6th of expected needs by 2030.[i] There are two main reasons for this:

- Much of the historical climate action discussion has been on slowing or stopping climate change with the hope of avoiding climate impacts, focusing dollars and efforts toward addressing the highest upstream source of climate change
- Sufficient climate change to experience financial effects from extreme weather and climate events is only starting to be felt, with the science of attribution growing over the past 10 years to quantify how much climate change has occurred and its influence on damages[ii, iii]

Put another way, changes in the risk of extreme events from the past, present and future can now be quantified, with the body of research and data available showing financial risk also growing along with the probability and magnitude of extreme weather and climate events. The future risks of climate change are now finding the bottom line in the present. Climate adaptation is needed to build resilience to the effects felt today and into the future. It is not just a risk management tool, but can also be a strategic investment opportunity that can yield financial benefits over time.

When I first started speaking about climate adaptation to business leaders, many were confused by the admittedly complex technical terminology that scientists developed. With a light bulb, I've heard many call it "climate adoption," stating a need to "adopt new management strategies in response to climate." Others have defined it as business resilience to extreme weather and supply chain shocks, fundamental to everyday operations already underway, with a climate lens added to make sure they are properly calculating present and future statistics of revenues and losses. Others have shared how a single acute event or multi-year chronic event has driven new R&D for products to meet evolving consumer preferences driven by how a changing climate is already affecting everyday temperature, humidity and water availability. The effects of climate change vary, but leaders need that light bulb moment to build their climate intuition for climate adaptation.

Adaptation strategy is a management challenge: Under varying levels of uncertainty of present and future risk, at what point should we act? Does this change when the source of uncertainty is due to physics or human behavior? How does this calculus change when accounting for risk management or emerging opportunities? This article delves into frameworks for developing adaptation strategy, where action is taking place, the financial costs and investment opportunities at stake, and what sectors and geographies are adopting climate adaptation plans.

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What are climate adaptation and resilience?

We start with some definitions:

- **Climate adaptation:** The process of adjustment for experienced (present) or projected (future) climate and its impacts.[iv]
- **Climate adaptation in practice:** Actions made to position for opportunities and to reduce financial loss and operational exposure to extreme weather and climate events. Systematically, various adaptation measures build resilience to disruptions from the natural world. Done strategically, leaders can transform potential threats into catalysts for innovation and long-term success.
- **Resilience:** Confusingly, resilience is defined either as an umbrella term when one combines many adaptation actions to build resilience across social, economic and ecological systems[v] or used commonly interchangeably with adaptation. Here we will think of resilience as the end goal, which can comprise one or more climate adaptation actions (to build climate resilience), but also non-climate-related initiatives (to build general resilience). Put plainly: Climate adaptation always leads to resilience, but resilience in some cases may not be from climate adaptation.

Climate change effects are being felt on every continent and ocean. However, both society and ecosystems developed under assumptions of a stationary climate. As a result, varying levels of adaptation will be needed across industries and geographies to adjust to new conditions presented by climate change.

When to adapt? A question of risk tolerance for loss and opportunity

Climate science provides us an understanding of how the probability of certain conditions may change over time. These include:

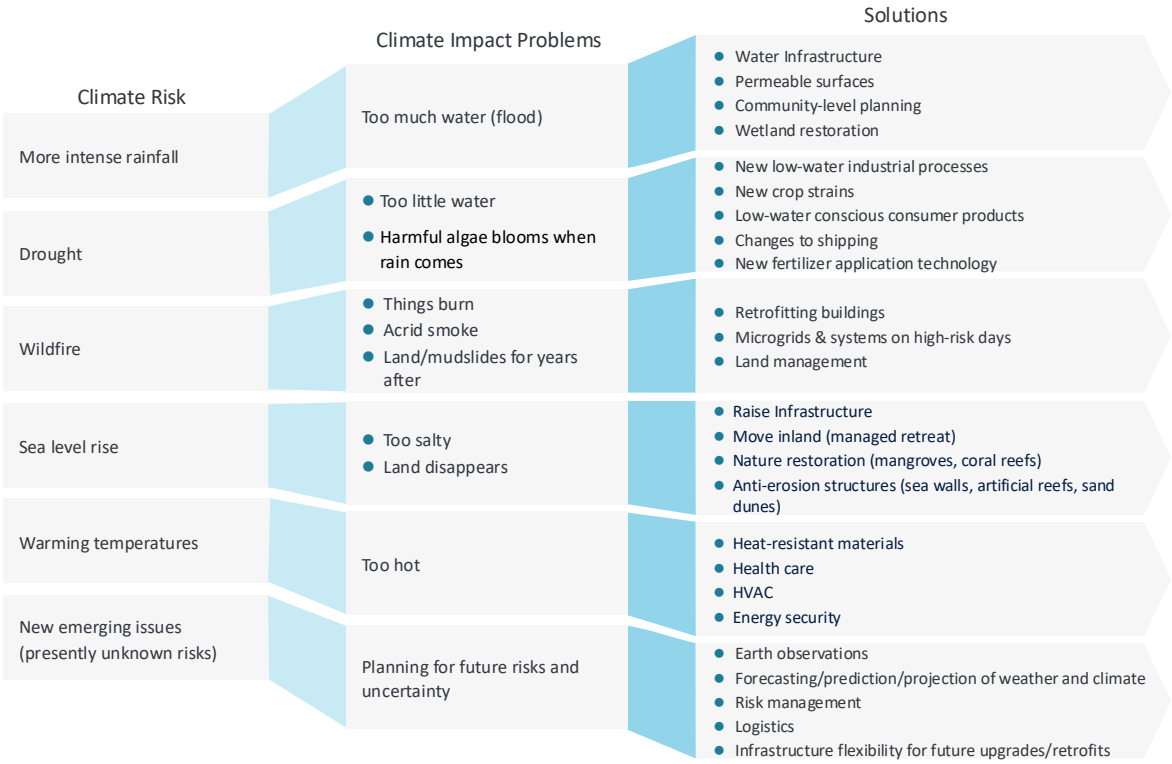
- **Acute risk:** extreme events or "tail risks" that happen infrequently, but are a major deviation from average conditions (e.g., heat wave on land or in the ocean, wildfire, extreme rainfall inducing floods and landslides). As additional climate change happens, these tail risks can even get "fatter," meaning once infrequent risks happen more often.[vi]
- **Chronic risk:** gradual changes in average conditions. However, these gradual changes can cause sudden impacts (e.g., sea level rise, while gradual, can overwhelm a pier at a specific level and cause failure).

Climate science provides predictions and projections of the future in the form of physical, biological and chemical risks. Some lend themselves more easily to action than others due to:

- The difficulty of translating these scientific outcomes into financial or business outcomes
- Varying levels of uncertainty of their impact over time due to a combination of physical differences and human activities

To visualize risks and adaptation responses, one way is to create a flowchart of climate risks into specific climate impact problems and then solutions to think through known ways to adapt. An example:

Figure 1: Flowchart of climate risks, climate impact problems, solutions



After doing this, we are faced with potential probabilities of an event to figure out how to act. Let's conceptualize this problem of planning for extreme weather and climate events that have never happened before. Imagine you have information that a flood will likely happen at some point in the next 30 years, destroying a critical physical asset and part of a material supply chain. A flood has never happened in this location. Today you know that an event is very likely to occur, but you have high uncertainty about when exactly (to the day, week, month, year) it will occur over the 30-year period. As time progresses, uncertainty declines as the risk of an event grows due to climate change. There may be a seasonal forecast saying it is more likely than not (with a 3- to 12-month window). Or show up in a weather forecast (within ~14 days) when there is limited time to reduce impacts. You have perfect certainty when the event is unraveling.

Figure 2: Climate adaptation is a risk management decision

At what point do you have enough information to act to protect your business? Given this can be a material risk, when do markets react to the information as uncertainty declines? When will credit ratings be downgraded without taking action to adapt? When will the asset lower in value due to its risk exposure?

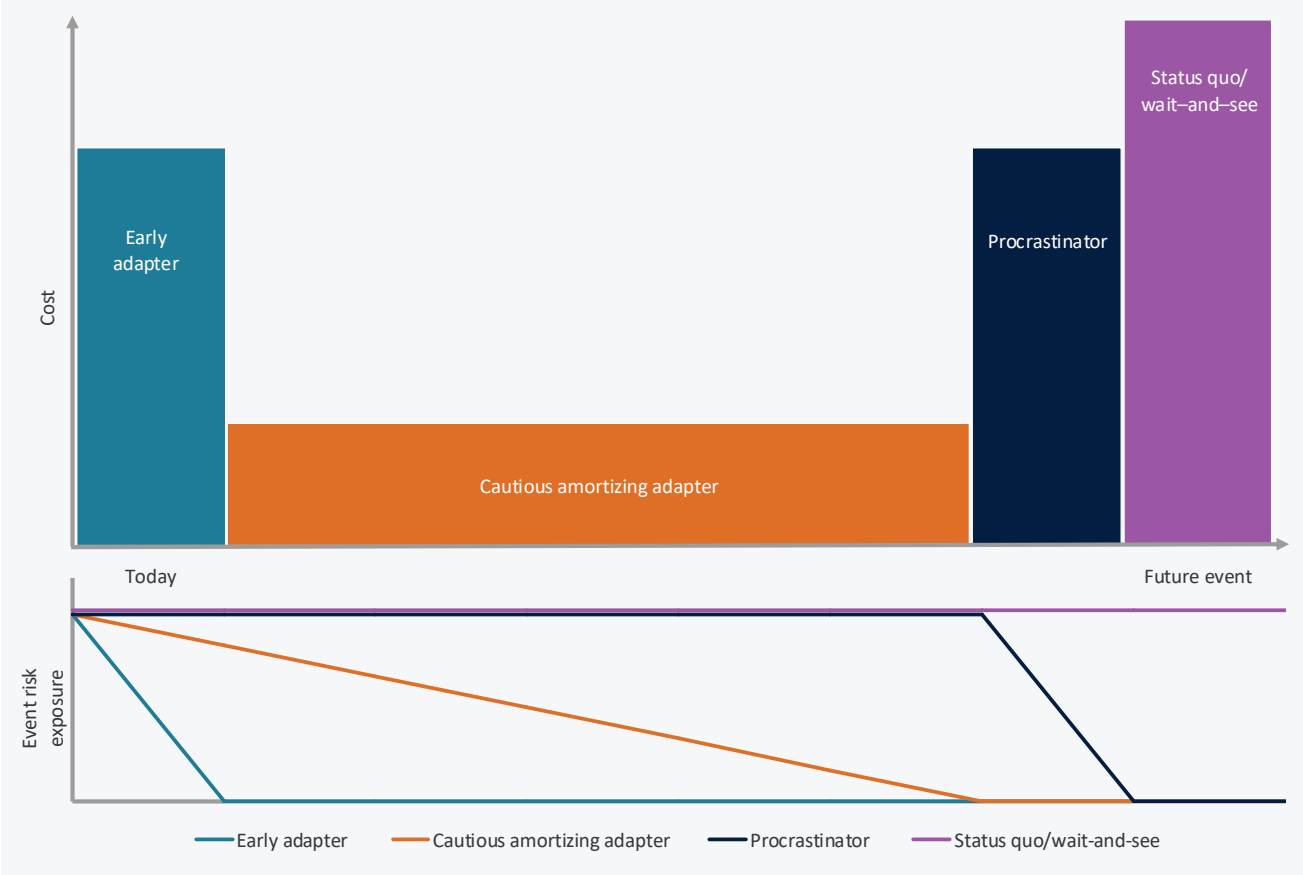
Would your decisions have changed if I told you this flood will be from saltwater storm surge along the coast? Or a flood along a river? In those scenarios, people generally know a flood is possible and there may have been historic floods in that location or ones like it. What if it is a flood that has never happened before due to a 1-in-1,000-year rainfall event, overwhelming storm sewers in a recently paved and highly developed town, concentrating floodwaters in a way never seen before?

We saw this recently with the 2024 flood in Asheville, North Carolina, from hurricane Helene. Previous major floods have happened, with a devastating one in 1916. Analysis of regional precipitation risk showed increasing risks due to climate change that large quantities of water could fall from the sky. The city even developed a climate adaptation plan in 2023 to guide future activities and spending.[vii] Seasonal forecasts for hurricanes made in May predicted an active season with more storms than average.[viii] And the weather forecasts from the National Weather Service in Greenville-Spartanburg, South Carolina, warned of historic flooding comparable to or greater than the 1916 event in the days before it happened.[ix]

There are deferring risk management approaches to climate adaptation. I have observed four general behaviors emerge in my discussions across public and private sector leaders.

Figure 3: Sample management approaches to climate adaptation

highly illustrative



- **Early adapters** work to adapt when they are made aware of a future risk. Their risk tolerance or analysis of future financial exposure leads to a decision to be ready early. They may even have an opinion that the ability to adapt may get more difficult closer to an event—due to the time to prepare or scarcity of supplies or funding to adapt when they need to. They may feel a moral obligation to adapt to avoid the worst outcomes. This comes with an up-front cost to avoid future losses of uncertain timing. Or in seeking opportunities, to pre-position to be ready before anyone else.

- **Cautious amortizing adapters** take a gradual approach, building adaptation over time. They decide to budget their adaptation actions over a longer time and allow for changing their plans as uncertainty declines and new adaptation solutions become available.
- **Procrastinators** wait until much closer to an event to do something. They fear investing in action too early. This may be due to competing financial interests and priorities. It can also be a high-risk threshold before action takes place. They may see opportunities emerging, but want more certainty about how events will unfold. They may want to learn from the mistakes of others how to efficiently manage adaptation spending.
- **Status quo/wait-and-see** actors have a different approach. They may think the safest path is to choose to maintain the status quo. They may assume an event will never happen, or they want more certainty before starting to invest in adaptation—bringing themselves closer to missing out on a market shift if others act. If nothing happens, they are validated that they saved money and did not adapt. But if an event happens without adaptation, they can experience high costs with few (or no) options to reduce exposure during an event.

To determine how much adaptation to undertake requires quantifying present and future exposure to climate change—and setting risk tolerances for specific outcomes (losses or opportunities) to determine when to act.

Takeaway: When to adapt is a management question. Entities respond based on their risk tolerance and cost-benefit analysis of adaptation, requiring a mapping of risks, impacts and potential solutions. Maintaining the status quo may seem like the lowest cost option—and one can be lucky and miss impacts—until an event occurs leaving few (or no) options to avoid costs.

Recency bias and unintuitive statistics lulls us into finding false safety in the status quo

Recency bias is a cognitive bias where a decision-maker strongly remembers recent events over other longer-term data. Even if climate data suggests a growing risk in a region, individuals may remember recent events (where no events have occurred) and assume this will be maintained into the future, when it may just be luck that an event was avoided. While the risk of an event may be low, over time those risks can accumulate, making an event more likely. To visualize this, we can compare the likelihood of an individual event in a given year versus a multi-year time horizon.

Figure 4: Likelihood of a flood over several years

using binomial cumulative risk formula

		Probability of occurring at least once in			
Common-Name Flood	Probability in a given year	5 years	10 years	20 years	30 years
1-in-100yr	1%	4.9%	9.6%	18.2%	26.0%
1-in-20yr	5%	22.6%	40.1%	64.2%	78.5%
1-in-5yr	20%	67.2%	89.3%	98.8%	99.9%

While a 1-in-100-year flood has a chance of occurring only 1% every year, it has a 26% chance of happening over a 30-year period.

Going back to Figure 2, when you choose to follow the status quo and no event happens, it enforces the belief that the status quo is the lowest cost option. This recent experience creates a bias into expecting past experiences being maintained. Even if the risk of an event is low in a given year, if a planning horizon is over a longer period, that risk is actually cumulative and therefore risk of loss is much higher.

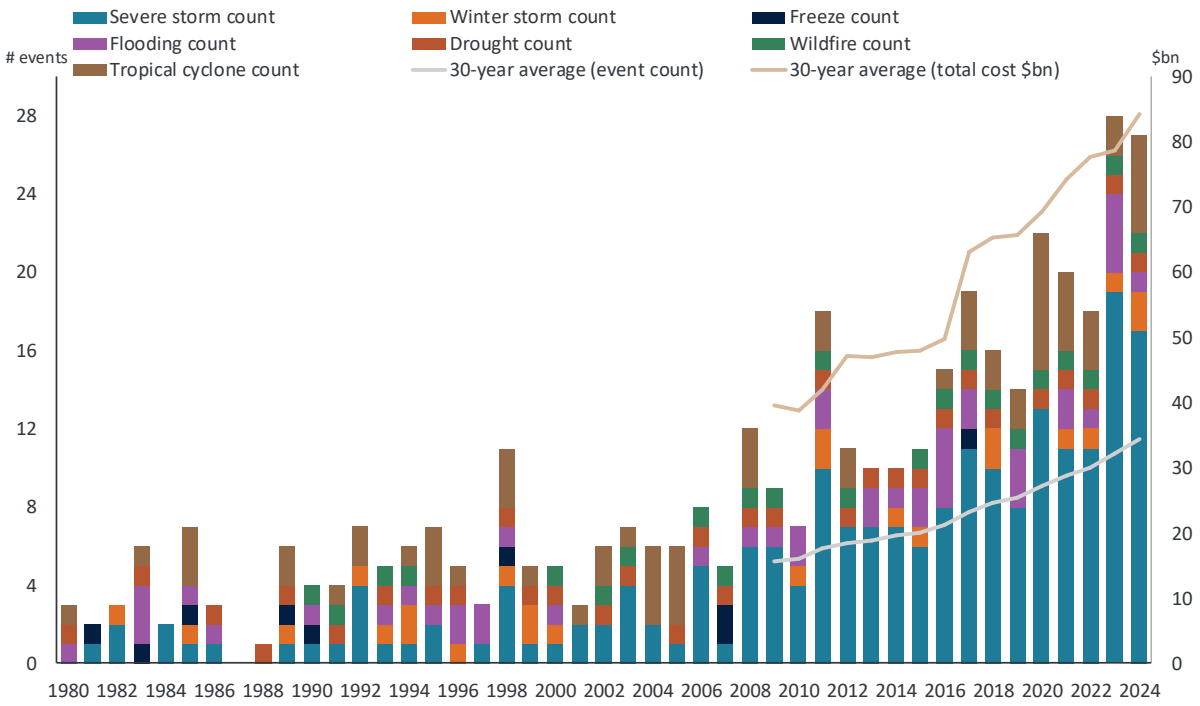
Further complicating this, the above analysis is for a static climate. Over time, the risk of extreme events may be growing, increasing the likelihood of risks over a multi-year time horizon. Many readers know the investment disclaimer: past performance is not indicative of future results. Here we have physics telling us the world is changing. We just don't always know when an event will happen precisely.

Takeaway: Unintuitive statistics and recency bias can lull us into finding false safety in the status quo.

The hidden cost of maintaining the status quo: financial estimates of extreme weather and climate events

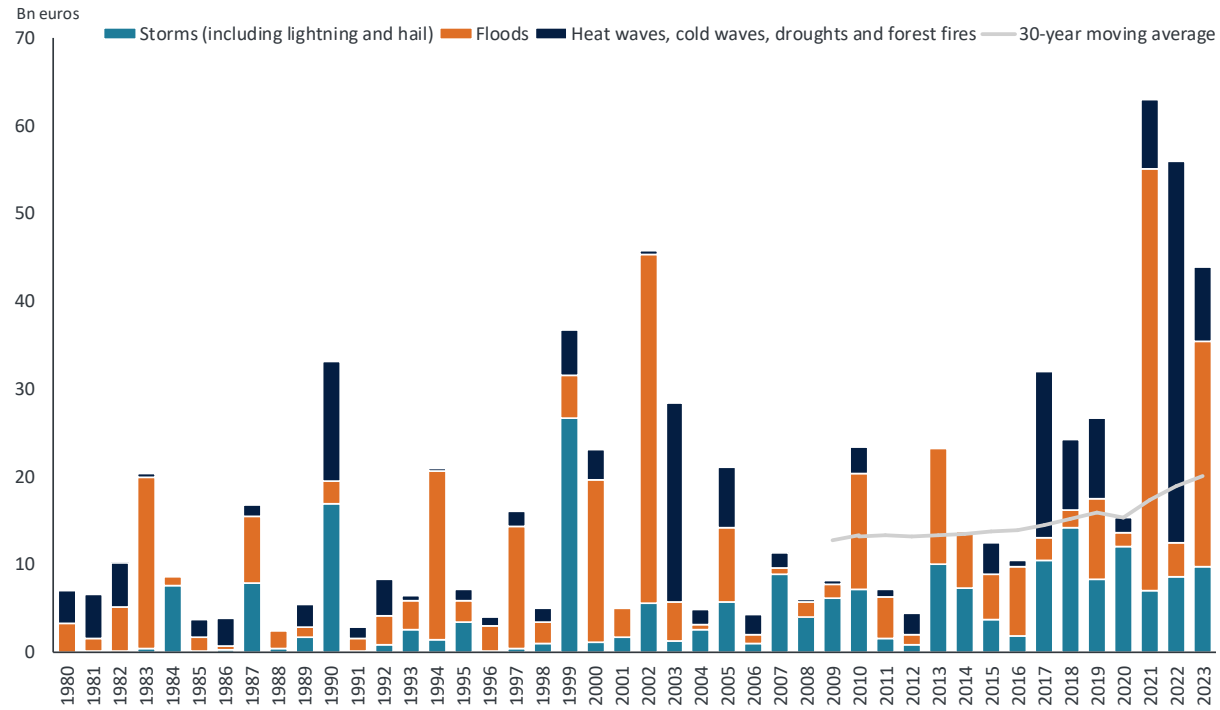
The U.S. and the European Union have catalogued both the economic losses and types of extreme weather and climate over the past several decades. In the U.S., the costliest individual events have historically been from tropical cyclones (hurricanes, when winds reach >74 mph), but severe convective storms have been happening more frequently in recent years. In Europe, flood events have historically caused the greatest economic losses.

Figure 5: U.S. billion-dollar weather disasters 1980-2024 (CPI adjusted)
Frequency of extreme weather and climate events (bars) and related financial costs (line)



Source: NOAA "Billion-Dollar Weather and Climate Disasters" as of April 2025 (link) Note that inflation impacts the ability to compare costs over time. To reflect this, the graphic shows events with less than $1B in damage at the time of the event, but after adjusting inflation (using Consumer Price Index), now exceed $1B in damage.

Figure 6: EU states' economic losses from weather and climate related events with 30-year running average



Source: European Environment Agency: "Annual economic losses caused by weather-and climate-related extreme events in the EU Member States" (link)

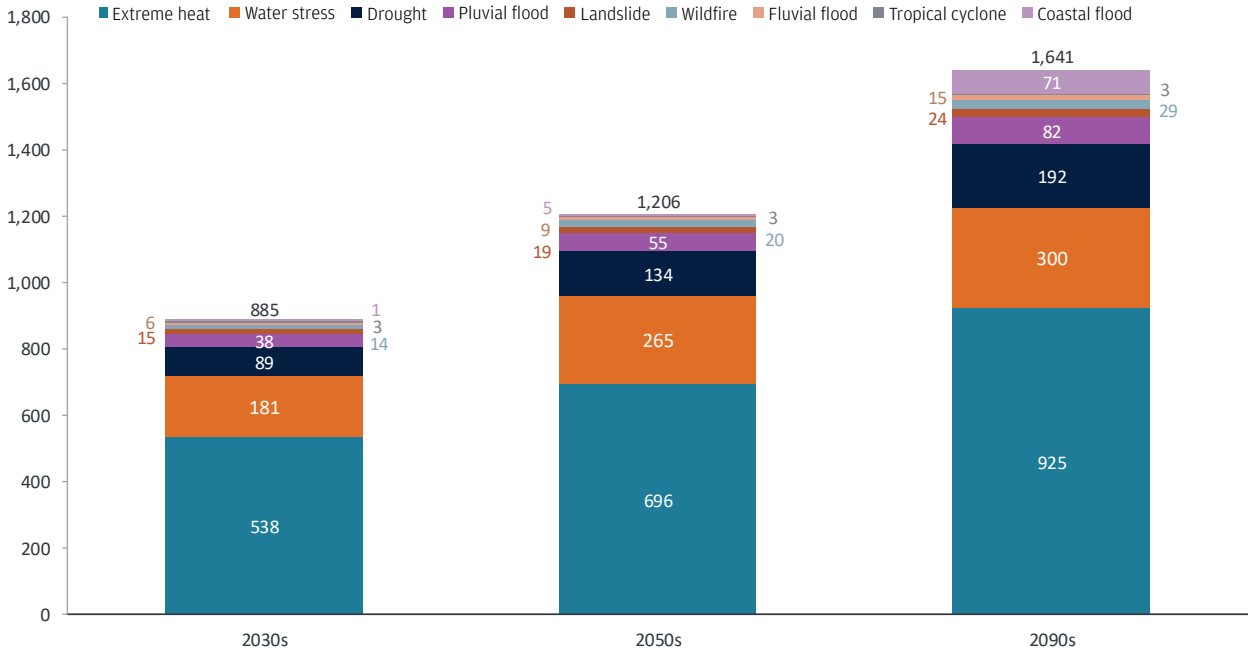
The frequencies and costs of these events have been growing. To have a financial impact, an extreme weather and climate event must occur in a place of economic value that is also vulnerable to economic losses. To reduce these growth trends, we need to reduce the sources of change:

- Climate change can be curtailed through emissions reductions
- Investment in resilience can reduce vulnerability

These trends mirror observed losses emerging and attributable to climate change in the insurance industry that we recently explored in depth.[xi]

Observed data can also drive analyses to project corporate exposures to climate change. As financial impacts become measurable today, they can be used to provide empirical analysis of exposure to build financial models of the future. S&P has built such a model for the S&P Global 1200, projecting future losses if no adaptation measures are taken and without adjustment for future inflation.[xii] These costs are broad, measuring the exposure of physical assets (e.g., increased operational expenses to lost revenues due to business interruption through to physical damage and costs to repair assets). By the 2050s, costs reach $1.2 trillion per year with utilities representing the largest sector of losses ($244 billion).[xiii] To put this in perspective, total damage from major extreme weather and climate events in the U.S. since 1980 have totaled $2.9 trillion.[xiv] Projected annual exposure far exceeds multi-decade levels of damages.

Figure 7: Large companies are projected to face $1.2 trillion yearly in physical risk costs in the 2050s That's the likelihood if we maintain the current trajectory toward a 2.7°C world by 2100



Source: S&P Global Sustainable1; 2025 S&P Global Note: As of Feb. 24, 2025. SSP=Shared Socioeconomic Pathway. SSP2-4.5 is a medium climate change scenario that contemplates strong mitigation, in which total greenhouse gas emissions stabilize at current levels until 2050 and then decline to 2100. This scenario is expected to result in global average temperatures rising by 2.7°C (2.1°C - 3.5°C) by the end of the century. No inflation assumptions are applied, and results are presented in nominal 2024 prices

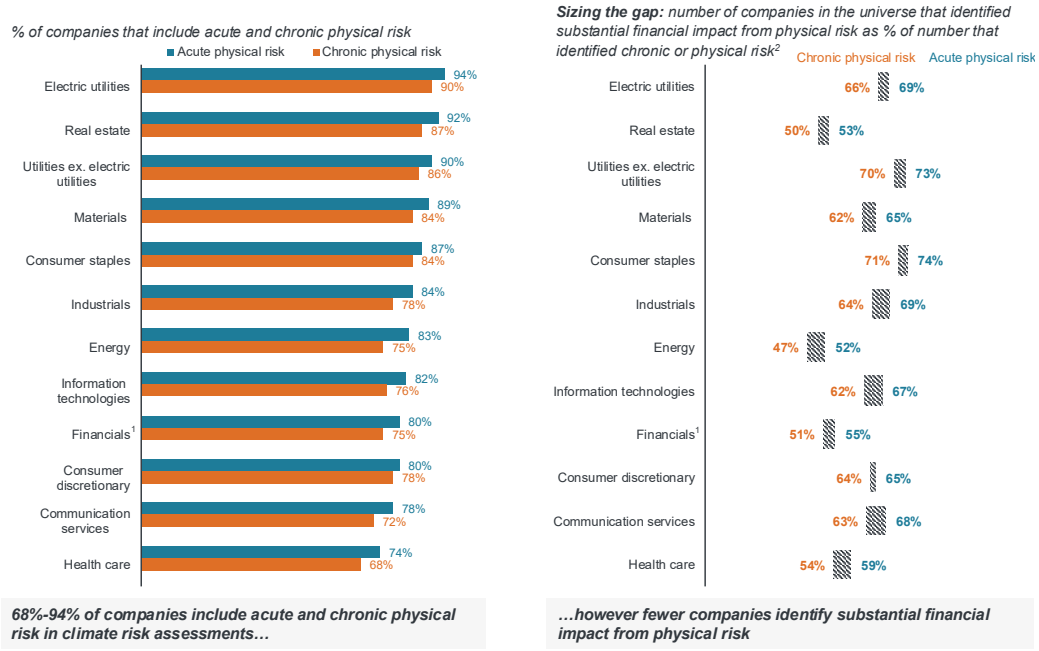
Takeaway: Economic losses due to extreme weather and climate events have been growing in the U.S. and European Union. As more climate change develops and the effects of climate change are manifested financially, data grows to build quantitative exposure models to project future exposure. They currently show $1.2 trillion of potential loss a year in large corporates by the 2050s without adaptive measures. Put simply: Maintaining the status quo without adaptation destroys value.

Are companies taking action today? Which sectors are investing in climate adaptation?

There are no uniform standards for reporting climate adaptation, where climate mitigation can be reduced to changes in carbon dioxide equivalent emissions, climate adaptation relates to any adjustment in response to climate that reduces vulnerability. This is also showing up with the plethora of climate adaptation investment guides and frameworks being developed by investors, business groups and non-profits.[xv, xvi]

The S&P Global Corporate Sustainability Assessment clearly surveys companies to see if they have assessed climate-related physical risks and whether they have financial materiality. It includes ~13,000 companies globally.[xvii]

Figure 8: Physical risk assessments have become common practice however fewer companies are identifying a substantive financial impact



Source: S&P Global Sustainable1; 2025 S&P Global Note: [1] Financial impact for the financials sector does not reflect portfolio exposure. As of March 3, 2025. Results based on responses from participating companies in the 2024 CSA assessed on the topics of climate risk management and financial risks of climate change. The sample sizes are 3,200 companies assessed on climate risk management and 2,655 companies assessed on the financial risks of climate physical hazards; [2] JPM analysis of S&P Global Corporate Sustainability Assessment data (Potential substantive financial impact identified / chronic (acute) physical risk assessments), original data can be found here.

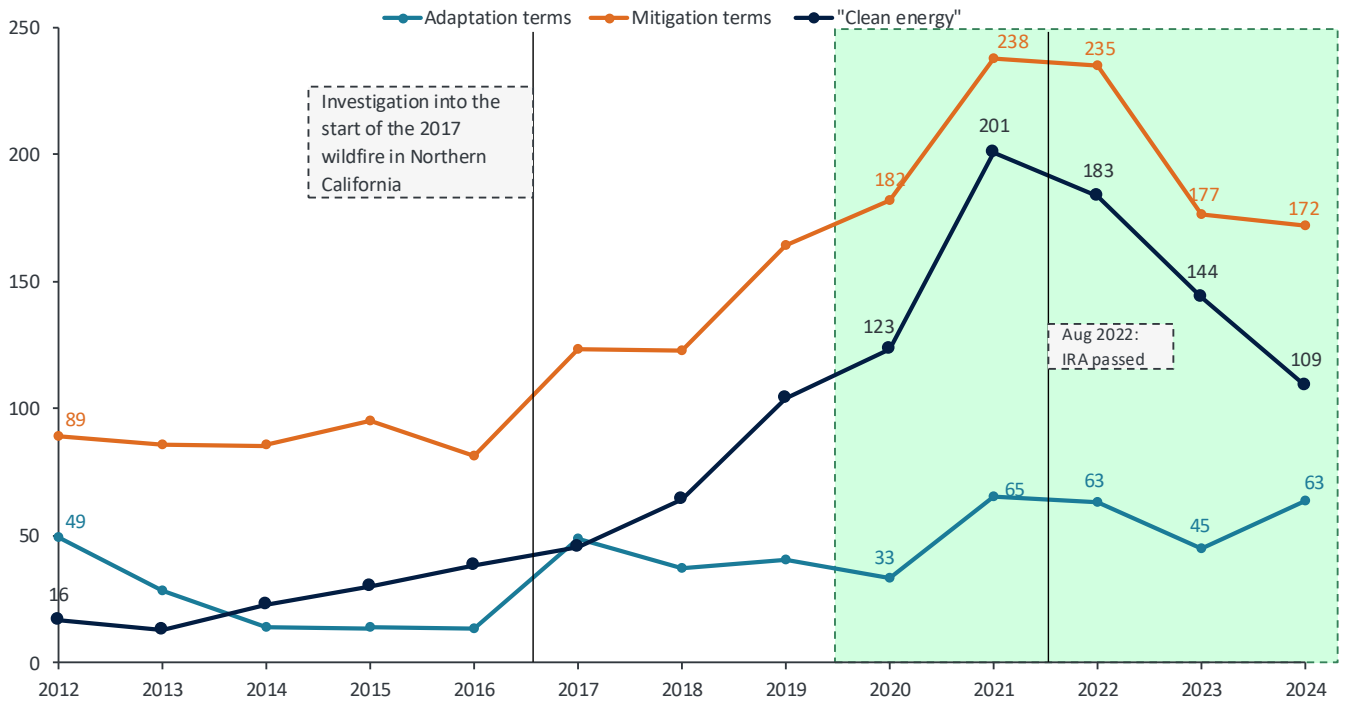
A few observations from these results:

- Real estate, utilities and consumer are the usual sectors people think have exposure to climate due to physical assets, and agriculture has exposure from weather and climate extremes, but all sectors include exposure to acute (extreme events) and chronic (gradual change) risks.
- Extremes events (acute risk) affect companies more than do gradual changes (chronic risk). This may be due to the capacity being higher to adjust activities to gradual change versus shocks.
- A smaller subset identified substantive financial impacts from physical risk. Of those identifying risks, the majority found substantive financial impact. This may be due to adaptive measures already in place, or companies have been well suited to current climate conditions.

In summary, 68% to 94% of companies include acute and chronic physical risk in climate risk assessments, but only an estimated 47% to 74% of those physical risks are identified as having a potential substantive financial impact.

Since these surveys are static, we were curious how companies have been talking about climate adaptation and mitigation over time. Choosing the sector with the greatest self-identified risks, we focus on S&P 1500 utility firm transcripts.

Figure 9: Tracking transcripts for discussions of climate-related terms
Keyword frequency in S&P 1500 Utilities firms' transcripts (# per 100 meetings)



Source: FactSet, as of 1/22/2025

Notes: Transcripts include management discussion and Q&A sections of M&A announcements, analyst days, business update calls, investor days, investor meetings, earnings calls, and conferences

Since 2012, climate mitigation terms,[xviii] climate adaptation terms[xix] and "clean energy" have regularly been found in call transcripts. However, noticeable changes appeared around specific events.

- After investigations into PG&E for the start of the 2017 wildfire in Northern California, there was a noticeable increase in adaptation terms being used in utility transcripts.
- Mitigation terms and "clean energy" clearly increased after 2015 (potentially responding to investor interest in the 2015 Paris Agreement), peaking in 2021 before passage of the Inflation Reduction Act.
- While mitigation terms have reduced in use since 2021, climate adaptation terms have remained steady, more than doubling in usage from a decade prior.
- Mentions of mitigation happened 2.7x more frequently than adaptation in 2024.

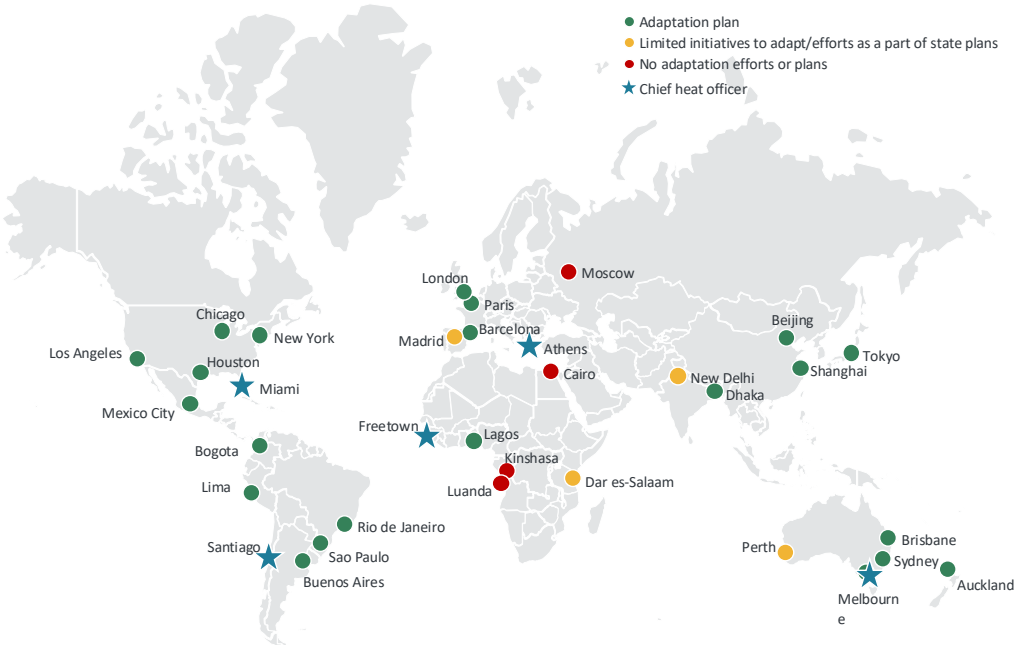
So while utilities have physical risk exposure today with financial impact, the majority of conversation relates to mitigation.

Takeaway: A significant number of companies across various sectors are assessing both acute and chronic climate physical risks, but fewer are identifying these risks as having a substantive financial impact, possibly due to existing adaptive measures or suitability to current conditions. This may change with shifting climate conditions; in the utility sector, while mentions of mitigation are declining, those of climate adaptation have been growing.

Where have local governments analyzed their physical risk exposure to develop adaptation plans?

An individual entity can quantify its physical risk exposure and take adaptation measures, but the surrounding community and infrastructure also matter for keeping supply chains open post disaster, allowing people to get back to work after an event, maintaining infrastructure and attracting new business exiting other physically risky locations.

Figure 10: Locations of global city adaptation plans

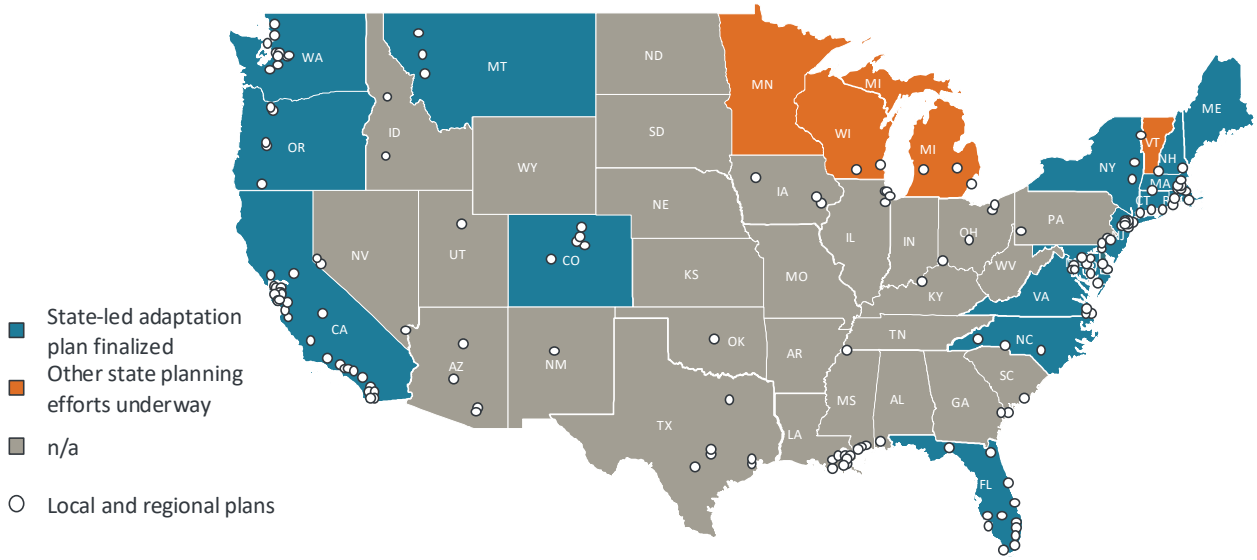


Source: Government websites and public disclosures

Note: Shows status of adaptation efforts across 5 largest cities on each continent

Around the world, cities announcing climate adaptation plans are typically located along coasts, but also include some inland cities concerned about future impacts (e.g., extreme heat, drought, wildfire). In the United States, adaptation plans have been developed at the state and local levels. The majority of state plans are along the salty coasts, but city plans are spread across the U.S. with new state efforts inland.

Figure 11: Locations of U.S. state and city adaptation plans and efforts



Source: Georgetown Climate Center

It remains to be seen if this information will percolate into the markets. Slight bond rating score increases have been seen in cities developing adaptation plans, from below average to comparable scores from 1995 to 2018, but the sample size was small.[xx] Despite known risks for wildfire in Los Angeles, municipal bonds were downgraded after the wildfires when reports of potential liability surfaced with additional questions raised about adequacy of insurance coverage.[xxi]

Takeaway: Cities and states worldwide are developing adaptation plans to address climate risks, with many located along coasts. There is limited evidence of its impact on municipal markets.

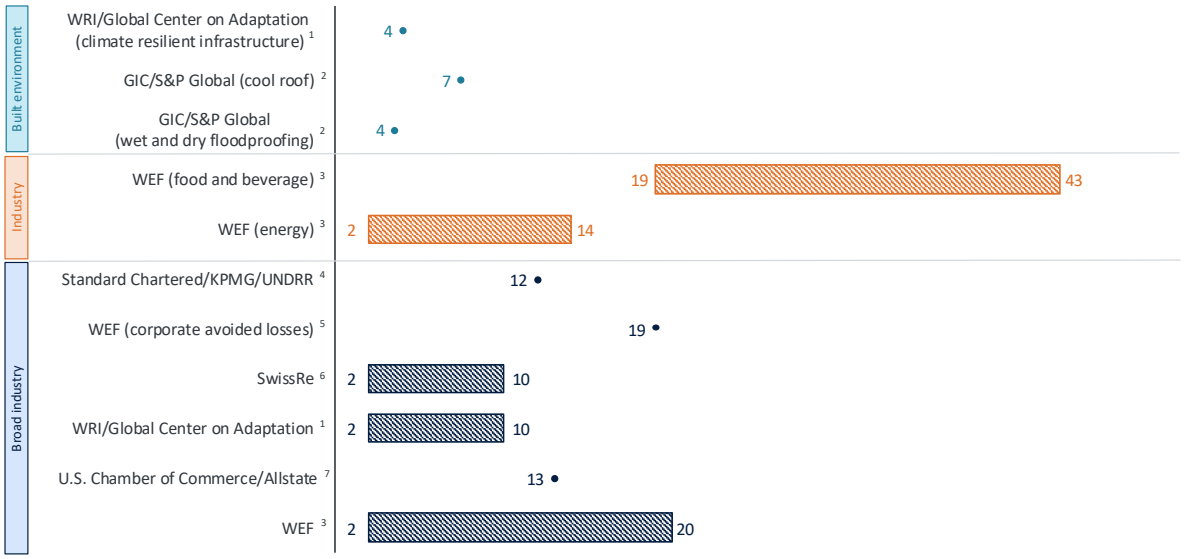
What is the return on investment of climate adaptation and resilience?

Much discussion about financial impacts of climate change focuses on potential future losses. It's a pure risk framework—adapt now or avoid negative impacts tomorrow. But is there a financial return to adapting?

With increased awareness of the growing financial exposure to climate change, attitudes are now shifting. Insurers, the World Economic Forum, investors, data providers and think tanks have recently put out analyses with estimates of the ROI of climate adaptation and resilience. Across recent studies, spending $1 has an ROI of $2 to $43.

Figure 12: Comparisons of ROI of climate adaptation and resilience studies

(economic benefit per $1)



Sources: [1] WRI, Global Center on Adaptation, "Adapt now: a global call for leadership on climate resilience" (link). [2] GIC, S&P Global, "Integrating Climate Adaptation into Physical Risk Models" (link). [3] WEF, "Climate Adaptation: Unlocking Value Chains with the Power of Technology" (link). [4] Standard Chartered, KPMG, UNDRR, "Guide for adaptation and resilience finance" (link). [5] WEF, "Climate risks are set to slash corporate earnings. Here's what CEOs and boards can do" (link). [6] SwissRe, "We need to talk about climate adaptation" (link). [7] U.S. Chamber of Commerce: "The Preparedness Payoff: The Economic Benefits of Investing in Climate Resilience" (link)

Adaptation spending to achieve resilience is also starting to be rewarded. On March 27, 2025, Moody's upgraded PG&E Corp. and its Pacific Gas & Electric subsidiary, citing " the organization's continued improvement in mitigating wildfire risk over the last few years as well as its ability to strengthen both its financial profile and its relationships with key stakeholders."[xxii]

Academic research is also now balancing mitigation and adaptation scenarios to understand how costs associated with investments in both leads to positive economic outcomes. In recent research, Duan et al. 2025 used a macroeconomic model to model climate investment strategies. They found that compared to spending on reducing emissions, investing in adaptation brought economic benefits much sooner (12-24 years for their scenario).[xxiii]

Takeaway: Investments in climate adaptation do offer returns. For our original conceptual framework in Figure 2, this means a status quo/wait-and-see approach can also come with missing out on future opportunities and growth. The returns may be more than a decade off (if using the academic average), or earlier if a physical event occurs or the market responds to perceptions of growing risk.

Look out for curveballs

Surprising or disruptive conditions present uncertainty in building adaptation plans without knowing how much adaptation will be needed.

- **Migration:** You only need to adapt if you have people and commerce that need to respond. If people and businesses leave a region, the need to adapt reduces. Financially, this leads to property devaluation, stranded assets, reduced tax bases.
- **Maladaptation:** Even with best intentions, decision-making under uncertainty can lead to mistakes. Adaptation that makes an entity worse off instead of better is referred to as maladaptation. This is an argument against early adaptation to allow for adjustment as more information is received and uncertainty reduced.
- **Fortress of solitude:** If you build your own facility to be resilient, but the surrounding infrastructure community doesn't follow, you can end up with a fortress of solitude. It may be operational, but workers and supplies cannot reach it post disaster. For example: Buildings with backup generators on high floors and flood-allowing bottom infrastructure may keep a building standing and power on after a major storm, but if the infrastructure of roads and transportation are destroyed, it may be open but not accessible. City and state adaptation matters in these cases.

- **Tipping points:** it's possible that future climate change and impacts will not follow gradual shifts in probabilities, but abrupt shifts from one state to another with extreme difficulty to return. This is an emerging scientific field. We will explore this thinking in a future piece.

Final word

While the focus has historically been on mitigation, there are opportunities to build resilience to climate impacts. This requires overcoming recency bias and understanding the statistics of extreme events over varying time horizons. Losses from extreme weather and climate events are growing, with corporate annual exposures (without adaptation) of over $1 trillion by the 2050s. Adaptation assessments and action plans are expanding, but not necessarily showing up in markets.

Given the direction of travel, as more losses are experienced, calls for adaptation and resilience should grow. We are already seeing this in the insurance and homeowner markets. Increased awareness of risks and opportunities may push a shift in the market toward rewarding adaptation. There are early indications of this in cities adopting climate adaptation plans, and emerging frameworks for investing in adaptation. Analyses of returns of investment in climate adaptation and resilience range from $2 to $43 for every dollar spent.

As the market begins to recognize and reward these efforts, businesses that invest in adaptation will not only protect themselves from escalating climate risks but also position themselves to capitalize on new opportunities. Developing strategies for climate adaptation does not just help avoid risk; it's emerging as a forward-thinking action to realize returns. There will be arbitrage for those who can identify well positioned adapters across the early to wait-and-see adapter profiles.

Integrating climate adaptation into your strategic evaluations can unlock value. By identifying businesses for investment, acquisition or supply chain sourcing that are proactively adapting, one can diversify for resilience and capitalize on emerging market shifts. This approach not only hedges potential risks but also positions to leverage new growth opportunities shifting in response to a changing climate. Adaptation may act as a key differentiator, allowing those who act earlier to gain a competitive edge, facilitating long-term success in a changing world.

FOOTNOTE

[i] https://www.climatepolicyinitiative.org/publication/global-landscape-of-climate-finance-2024/

[ii] https://www.jpmorgan.com/insights/sustainability/climate/navigating-the-new-climate-era

[iii] Callahan, C.W., Mankin, J.S. Carbon majors and the scientific case for climate liability. Nature 640, 893-901 (2025).

[iv] Adapted from: IPCC, 2022: Annex II: Glossary [Möller, V., R. van Diemen, J.B.R. Matthews, C. Méndez, S. Semenov, J.S. Fuglestvedt, A. Reisinger (eds.)]. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2897-2930, doi:10.1017/9781009325844.029.

[v] Ibid.

[vi] https://www.jpmorgan.com/insights/sustainability/climate/navigating-the-new-climate-era

[vii] https://www.ashevillenc.gov/department/sustainability/climate-initiatives/municipal-climate-action-plan/

[viii] https://www.noaa.gov/news-release/noaa-predicts-above-normal-2024-atlantic-hurricane-season

[ix] "This will be one of the most significant weather events to happen in the western portions of the area in the modern era. Record flooding is forecasted and has been compared to the floods of 1916 in the Asheville area." Captured in: https://www.charlotteobserver.com/news/weather-news/article293109734.html

[x] The calculated probabilities assume a stationary probability in a given year for flood over time with every year being an independent event and a binomial distribution. (No climate change altering probability_in_a_given_year from year 1 to n). So the probability of occurring at least once over n years is found by the formula: Probability = 1-(1-probability_in_a_given_year)^n. So a 1-in-100 yr flood has a probability in a given year of 1/100 = 1%. Over a 30-yr period, the probability of happening at least once is therefore: 1-(1-1%)^30 = 1-.99^30 = 26%.

Calculator from the NOAA National Weather Service: https://www.weather.gov/epz/wxcalc_floodperiod

[xi] https://www.jpmorgan.com/insights/sustainability/climate/homeowners-insurance-future

[xii] https://www.spglobal.com/esg/insights/featured/special-editorial/ceraweek-physical-risk

[xiii] Ibid.

[xiv] https://www.ncei.noaa.gov/access/billions/time-series

[xv] https://www.tailwindclimate.com/

[xvi] GARI released its climate adaptation and resilience report and investor toolkit for climate resilience solutions at the Financial Times Climate Capital Live conference in March 2024 in partnership with MSCI Sustainability Institute, The Lightsmith Group, the Bezos Earth Fund and ClimateWorks Foundation. https://garigroup.com/investor-guides

[xvii] https://www.spglobal.com/esg/insights/featured/special-editorial/ceraweek-physical-risk

[xviii] Climate mitigation terms include: alternative refrigerants, biogas, carbon capture, carbon neutral, carbon sequestration, decarbonization, photovoltaic, electric cars, electrification, energy efficiency, fuel cell, geothermal, hydropower, offshore wind, renewable energy, virtual power plant.

[xix] Climate adaptation terms include: burying lines, cable trenching, climate adaptation, climate risk assessment, climate scenario, coastal defense, coastal flood, coastal resilience, coastal zone, disaster recovery, emergency preparedness, flood defense, grid resilience, hail, heat wave, heatwave, hurricane, line burial, line resilience, living shorelines, microgrids, operational flexibility, resilient infrastructure, saltwater intrusion, prevention, sea wall construction, severe weather response, shoreline stabilization, smart grids, storm hardening, storm preparedness, storm surge, storm-resilient, stormwater management, subsurface infrastructure, subsurface lines, subterranean lines, subterranean utilities, supply chain resilience, tornado, tropical cyclone, underground cabling, underground lines, underground power, undergrounding, weatherization.

[xx] Ko, I., Prakash, A. Signaling climate resilience to municipal bond markets: does membership in adaptation-focused voluntary clubs affect bond rating?. Climatic Change 171, 9 (2022).

[xxi] https://disclosure.spglobal.com/ratings/pt/regulatory/article/-/view/sourceId/13382294

[xxii] https://www.utilitydive.com/news/moodys-upgrades-pge-pacific-gas-credit-wildfire/743811/

FOOTNOTE

[xxiii] Duan, Lei, Angelo Carlino, and Ken Caldeira. “Near-term benefits from investment in climate adaptation complement long-term economic returns from emissions reduction.” Communications Earth & Environment 6, no. 1 (2025): 14.

[xxiv] The term “fortress of solitude” references the fictional headquarters for Superman, only reachable by him.

[xxv] https://www.jpmorgan.com/insights/sustainability/climate/homeowners-insurance-future

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