Highlights

The Cloud Needs Water: Climate Physical Risk of Data Centers

J. Christopher Hughen

- We measure climate physical risk for US data centers and for data center REITs.
- A substantial share of US data centers sits in high or extremely high water stress.
- Facilities are under-represented in tracts with extreme expected building losses.
- Under the high climate change scenario, modeled impact on asset value is material.
- Corporate exposure to data center climate physical risk remains largely opaque.

The Cloud Needs Water: Climate Physical Risk of Data Centers

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ABSTRACT

Data centers are critical physical infrastructure for the modern economy. To evaluate the climate physical risk of these facilities, we geolocate US data centers, finding that a substantial share sits in high or worse water stress, even as facilities avoid census tracts with extreme expected building losses. In a second, firm-level sample of data center REITs and their global portfolios, physical risk exposure rises significantly under multiple climate change scenarios, with a material modeled financial impact on asset value by mid-century. Corporate exposure to the climate physical risk of data centers remains largely opaque, particularly to their investors.

1. Introduction

Data centers are buildings that contain critical IT infrastructure, including enterprise servers, storage systems, and networking equipment. Driven by the increasing demand for computing power, particularly from artificial intelligence, this sector will require nearly $7 trillion in capital investment by 2030 (Noffsinger et al., 2025). Much attention has been given to their demands *on* the environment, namely electricity, water, and emissions (Siddik et al., 2021). However, far less is known about the reverse exposure: how the facilities themselves confront climate physical risks.

Physical risk takes two forms. Acute hazards, such as floods, hurricanes, and wildfires, are sudden events that damage structures and dominate conventional physical risk assessments because they drive property losses. Chronic hazards, including extreme heat, water stress, and drought, rarely destroy a building but persistently impair its operation. This distinction is crucial because data centers are continuous-operation computing environments. Extreme heat degrades cooling efficiency precisely when heat waves strain regional grids, pushing facilities, which are among the largest loads on those grids, toward curtailment or backup generation. Many sites also evaporate large volumes of water for cooling; thus, drought threatens the cooling supply itself. A data center can therefore fail, with its building intact, as chronic hazards present as service interruptions rather than property damage. This is precisely what climate change amplifies and what damage-based risk measures weight least.

Asset-grounded evidence on this exposure consists of industry reports (First Street, 2026; XDI, 2026) and a few spatial studies (Kollar and Grady, 2025; Esparza et al., 2025). Those studies map where facilities and hazards coincide. We test siting against explicit statistical null hypotheses, measure hazard per dollar of building value rather than in total dollars, and track firm-level exposure alongside the modeled financial impact across four climate scenarios. Investors face challenges in measuring this risk because commercial firm-level physical risk scores diverge significantly among providers (Hain et al., 2022). This study extends the literature by assessing the climate physical risk of data centers at both the asset and firm levels.

Our study presents three findings. First, acute and chronic exposures diverge: data centers avoid tracts with high expected building losses, but their share in high or worse baseline water stress is statistically indistinguishable from the national base rate. Second, exposure is rising and scenario-sensitive, with extreme heat and water stress driving the modeled financial impact. Third, corporations are increasingly outsourcing IT infrastructure to data center operators, which face climate-driven service-interruption risks that are difficult to measure.

2. Data

Our asset-level analysis examines 3,157 U.S. data center properties sourced from S&P Capital IQ, which supplies operator identities and geocoded coordinates. We assess the physical risk of each facility's location using two independent, public datasets: WRI Aqueduct 4.0 baseline water stress and the FEMA National Risk Index (NRI). For

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the firm-level analysis, we examine data center REITs, which own 1,054 facilities (Table 1).[1] We capture their exposure to the ten climate hazards detailed in Table S1 (supplemental material) by utilizing the S&P Global Sustainable1 Physical Risk Scores and Financial Impact dataset (S&P Global Sustainable1, 2025). A key advantage of this dataset is that firm-level physical risk scores are value-weighted based on individual property exposures. We show shifts in risk exposure across four climate scenarios and decadal horizons from the 2020s to the 2090s. Additionally, we provide the modeled financial impacts for each scenario and horizon, expressed as a percentage of asset value.

[Insert Table 1 here.]

3. Empirical results

3.1. Water Stress

Figure 1 maps the 3,157 US data centers, colored by baseline water stress. We score each site by intersecting its coordinates with WRI Aqueduct 4.0, which measures baseline water stress as the ratio of water demand to renewable supply in the site's basin (Sutanudjaja et al., 2018; Kuzma et al., 2023). Aqueduct reports the measure on a 0–5 scale and in standard categories ranging from Low to Extremely High. This dataset is open, global at sub-basin resolution, built on a peer-reviewed hydrological model, and the most widely used tool for corporate water-risk assessment and disclosure.

[Insert Figure 1 here.]

Table 2 quantifies the water stress and benchmarks it against the country: 38.0% of scored facilities sit in High or worse water stress, against 35.5% of US census tracts equal-weighted, 37.1% population-weighted, and 35.0% weighted by building value. Because water stress varies at the basin level and the facilities occupy only 276 basins, we test the share with basin-clustered standard errors, and none of the gaps approaches significance ($p = 0.70$, 0.89, and 0.64). Collapsing to basins gives the same answer as 29.7% of the basins containing facilities are High or worse, against 28.6% of US basins ($p = 0.69$). Within the stressed range, the data centers tilt toward High (22.3% of facilities versus 16.8% of tracts) and away from Extremely High (15.4% versus 18.4%), but the aggregate share matches the national base rate. Overall, data center exposure to water stress mirrors the broader US built environment.

[Insert Table 2 here.]

3.2. Extreme-risk locations

A natural test of whether data centers crowd into extreme-risk locations is to compare their census tracts with the national tract distribution on a common hazard measure. The NRI dataset is well suited for this task: it is open, produced by FEMA, covers every US census tract consistently across eighteen natural hazards, and serves as the standard nationwide baseline for natural hazard risk (Zuzak et al., 2022). However, the NRI composite risk score has adjustments for social vulnerability and community resilience, community characteristics that describe the resident population rather than corporate infrastructure. We therefore use the NRI building EAL *rate*: expected annual building loss per dollar of building value, in basis points (bps) per year. The rate isolates location-hazard intensity and is comparable across urban and rural tracts; the baseline is the 85,107 US census tracts with positive building value.

Table 3 reports the comparison at two levels: the 3,157 facilities and the 1,340 unique tracts that contain them. We report both levels because facilities cluster within tracts, and the tract is the independent siting choice. Data centers are significantly *under*-represented in extreme-risk tracts. Only 7.7% of facilities exceed the national P90 of the EAL rate and 1.6% exceed the P95, against proportional-siting nulls of 10% and 5% ($p < 0.001$ at both levels). The median facility's tract loses 9.2 bps of building value per year versus 12.4 bps for the median US tract, and the average facility sits at the 37th percentile of the national distribution. The p column reports two-sided facility-level tests: exact binomial for the tail shares, Mann–Whitney for the median, two-sample Kolmogorov–Smirnov for the distance. All p-values are below 0.001 at the tract level, and every EAL-rate deviation is in the direction of safer siting.

[Insert Table 3 here.]

[1] Real Estate Investment Trusts (REITs) are tax-advantaged entities that own, operate, or finance income-producing real estate and often specialize in a particular property sector.

The result is robust to the choice of counterfactual. Against a building-value-weighted baseline, the shares above the P90 are 8.3% and below the 10% null. Nor is the pattern an urban artifact: within its own county, the average facility sits at the 36th percentile of the county EAL-rate distribution, so operators select comparatively safe tracts even within a metropolitan market.

The comparison also shows why headline NRI scores mislead for corporate assets. The facilities' tracts average the 61st national percentile by EAL in dollars but the 39th by EAL rate; their apparent riskiness reflects the value of the surrounding building stock, not elevated hazard. The EAL rate measures siting rather than expected facility losses, since it prices locations with average-building vulnerability rather than hardened data-center construction. It also assigns essentially no building losses to heat and drought, chronic hazards this study measures separately. On acute building hazard, US data centers are not generally sited in extreme-risk zones.

3.3. Climate change scenarios

We examine how climate change will affect data center REITs, which own 1,054 facilities. At the firm level, S&P Global models exposure scores (1–100) for ten climate hazards under the four CMIP6 scenario combinations that are widely adopted in TCFD-aligned disclosure (Riahi et al., 2017; TCFD, 2017; S&P Global Sustainable1, 2025). Each scenario pairs a Shared Socioeconomic Pathway with a Representative Concentration Pathway, ranging from the Low scenario (SSP1-2.6) to the High scenario (SSP5-8.5). In the supplemental material, Table S2 details each scenario, and Table S3 defines key measurement terminology.

Figure 2 shows the mean firm-level composite across scenarios and horizons. The trajectory starts at about 52 in the 2020s regardless of scenario; the paths separate after the 2030s and diverge sharply thereafter. Under SSP5-8.5 the composite reaches 66 by the 2050s and 80 by the 2090s, whereas under the Paris-aligned SSP1-2.6 it plateaus near 60. For this asset class, mitigation is worth roughly twenty points of exposure score by the end of the century.

[Insert Figure 2 here.]

We next investigate the modeled financial impact, which is built from impact functions for the asset type (S&P Global Sustainable1, 2025). For each asset type and hazard, S&P Global identifies the material impact pathways, like cooling costs for a data center, and quantifies each pathway's response per unit change in the hazard from the research literature. Each response is scaled by the share of the asset's replacement value that the affected value driver represents and converted into a percentage loss of asset value.

Figure 3 translates exposure into modeled financial impact, plotting the three costliest hazards and the sum of all others by scenario. The ranking mirrors the operational profile of the asset class: extreme heat and water stress dominate, reaching 6.6% and 6.1% of asset value in the 2050s under SSP5-8.5 and 12% and 8% in the 2090s, followed by drought. The remaining hazards combined stay below 2.5% of asset value even in the highest scenario. Aggregated across hazards, the modeled impact by the 2050s ranges from 11.5% of asset value under SSP3-7.0 to 16% under SSP5-8.5. Water stress and drought constrain cooling water supplies; extreme heat raises thermal loads. Furthermore, these hazards are physically coupled; because soil-moisture deficits amplify heat extremes, dry and hot conditions mutually reinforce one another (Mukherjee and Mishra, 2021; Tripathy et al., 2023).

[Insert Figure 3 here.]

The financial impact under a scenario is the modeled reduction in asset value that would result if the decade's average climate under that scenario prevailed, relative to baseline-climate conditions. The estimates are undiscounted, and each decadal horizon is scored independently.

4. Discussion

4.1. Implications for investors

To illustrate the challenges investors face in analyzing climate physical risk, consider attributing assets to Digital Realty Trust. As of December 31, 2025, roughly 29% of its reported data centers resided in unconsolidated joint ventures and investments accounted for under the equity method. Exposure measurement is complicated because the headline portfolio counts overstate the assets controlled by a firm. Additionally, the economic exposure per facility varies from full ownership to a small minority stake (Digital Realty Trust, Inc., 2026).

4.2. Differentiating structural and operational climate risk

Traditional commercial real estate vulnerability is structural: the threat is acute damage to the building, and standardized models such as the NRI expected annual loss are designed to capture it. Data centers add an operational dimension. Because they are continuous-operation computing environments, environmental conditions can force a facility to throttle capacity, absorb sharply higher utility costs, or shut down to protect hardware even when the building is undamaged. Extreme heat and water stress drive this operational risk. A robust assessment must therefore pair structural property-damage metrics with local measures of heat and water stress, the approach taken in this study.

4.3. Implications for disclosure

Companies increasingly outsource computing to cloud and colocation providers, and enterprise spending on cloud infrastructure services is estimated to reach $500 billion in 2026 as these services have become a utility for the knowledge economy.[2] Climate physical risk propagates along such supply chains, and customers of climate-exposed suppliers experience real effects (Pankratz and Schiller, 2024; Custódio et al., 2026).

Emerging disclosure regimes can reduce the opacity of climate physical risk. IFRS S2, effective in adopting jurisdictions for reporting periods beginning in 2024, and the European CSRD (ESRS E1) require firms to quantify the anticipated financial effects of climate physical risk and the share of assets materially exposed (International Sustainability Standards Board, 2023; European Commission, 2023). Our estimates suggest these disclosures will be material for digital infrastructure, with modeled impacts of 11.5–16% of asset value by the 2050s depending on the scenario.

Engineering only partially mitigates this operational risk. Operators back service-level commitments with layered power infrastructure, including uninterruptible power supplies, on-site fuel storage, and emergency generation. Digital Realty discloses that failure of these systems could leave it unable to satisfy customer obligations, and Equinix discloses that backup generation and fuel storage may not prevent downtime in long-term or large-scale outages (Digital Realty Trust, Inc., 2026; Equinix, Inc., 2026).

4.4. Caveats

Our study has several limitations. Exposure scores characterize the hazard at a location, not a facility's vulnerability or the value at risk there, so our estimates describe where hazards and assets coincide rather than expected losses. Vendor physical risk scores also embed model uncertainty and diverge across providers (Hain et al., 2022), which is why we triangulate the S&P Global Sustainable1 figures against independent, open hazard layers.

5. Conclusion

This study measures the climate physical risk of US data centers at two levels, geolocating 3,157 facilities against open hazard layers and tracking S&P Global Sustainable1 physical risk scores for data center REITs that own 1,054 properties. The asset-level evidence shows a sector that avoids acute hazard but not chronic hazard. Facilities are significantly under-represented in census tracts with extreme expected building losses. Yet 38% sit in high or worse baseline water stress, and this is a share that matches the national base rate rather than falling below it. The firm-level evidence shows the chronic exposure rising: composite exposure climbs from about 52 to 80 by the 2090s under the high climate change scenario, with a modeled financial impact reaching 16% of asset value by the 2050s, led by extreme heat and water stress, the hazards that govern cooling.

For investors, the central problem is opacity. Corporations increasingly rent computing from a supplier network whose physical climate risk they neither control nor easily observe. Ownership structures obscure the ultimate bearer of physical risk for individual facilities, while firm-level scores compress the underlying heterogeneity of the portfolio. Emerging disclosure regimes will require firms to quantify these effects; our results suggest that the amounts will be material and that the value of the disclosures will depend on facility-level granularity rather than portfolio aggregates.

[2] In the traditional on-premise model, businesses own and operate data centers for their own use; that model's share of capacity fell from 56% in 2018 to 32% at the end of 2025. The workload has shifted to private cloud hosting, infrastructure as a service, and platform as a service, with spending growing at a 35% annual rate. Source: Synergy Research Group, 2026.

CRediT authorship contribution statement

J. Christopher Hughen is the sole author and was responsible for the conceptualization, methodology, software, validation, formal analysis, investigation, data curation, visualization, project administration, and the writing of the original draft and its revision.

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None.

Declaration of competing interest

None.

Data availability

The S&P Global Sustainable1 Physical Risk data and S&P Capital IQ data are licensed; code and instructions to reproduce all exhibits are available from the author. The WRI Aqueduct and FEMA NRI datasets are public.

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Table 1
Data center REITs: S&P Global coverage and facility footprint.

REIT	Ticker	Total facilities	Facilities (US)	US share (%)
Digital Realty	DLR	462	211	45.7
Equinix	EQIX	385	111	28.8
Switch	SWCH	26	26	100.0
CyrusOne	CONE	70	55	78.6
QTS Realty	QTS	61	59	96.7
CoreSite	COR	50	50	100.0
All six REITs		1,054	512	48.6

This table lists the data center REITs with their S&P Global coverage and facility footprint. Equinix and Digital Realty remain listed; QTS (Aug. 2021), CoreSite (Dec. 2021), CyrusOne (Mar. 2022), and Switch (Dec. 2022) were taken private, and S&P Global continues to score them. Source: S&P Global Sustainable1 Physical Risk Scores and Financial Impact data.

Table 2
Baseline water stress (WRI Aqueduct 4.0) of the 3,157 US data-center facilities versus the national census-tract distribution.

Baseline water-stress category	Facilities	Share (%)	Tracts equal-wtd (%)	Tracts pop.-wtd (%)	Tracts value-wtd (%)
Low (<10%)	864	27.4	25.2	24.0	25.2
Low–Medium (10–20%)	480	15.2	15.1	14.8	15.5
Medium–High (20–40%)	610	19.4	24.2	24.0	24.4
High (40–80%)	702	22.3	16.8	17.6	17.1
Extremely High (>80%)	484	15.4	18.4	19.3	17.6
Arid and Low Water Use	12	0.4	0.3	0.2	0.3
No Data	5	—	—	—	—
High or worse	1,198	38.0	35.5	37.1	35.0

This table compares the distribution of WRI Aqueduct baseline water stress across US data centers with the national census-tract distribution. The baseline columns assign each tract the water stress of the Aqueduct basin containing its 2020 population-weighted centroid (84,610 of 85,154 NRI tracts scored) and weight the scored tracts equally, by NRI tract population, and by NRI tract building value; share columns are percentages of scored facilities and scored tracts. "High or worse" comprises the following categories: High, Extremely High, and Arid and Low Water Use.

Table 3
FEMA NRI building expected annual loss rate of the 3,157 US data-center facilities' census tracts versus all US tracts.

Siting statistic	Facilities	DC tracts	US tracts	p
Median EAL rate (bps/year)	9.2	9.9	12.4	<0.001
Mean EAL rate (bps/year)	12.5	12.7	16.2	—
Share above national P90 (%)	7.7	5.6	10.0	<0.001
Share above national P95 (%)	1.6	2.5	5.0	<0.001
Mean national percentile	36.5	38.8	50.0	—
Mean within-county percentile	35.6	37.8	50.0	—
Kolmogorov–Smirnov distance	0.211	0.165	—	<0.001

This table compares the FEMA NRI expected annual loss (EAL) rate for buildings, the expected annual building loss per dollar of building value, in the data center facilities' census tracts against the 85,107 US tracts with positive building value. "Facilities" weights each of the 3,157 facilities equally; "DC tracts" uses the 1,340 unique tracts containing at least one facility; "US tracts" is the national baseline of 85,107 tracts with positive building value, whose P90 and P95 of the EAL rate are 32.2 and 41.0 bps. National (within-county) percentile is the facility's tract percentile in the national (own-county) EAL-rate distribution; within-county placement uses counties with at least five tracts (3,090 facilities, 1,310 tracts).

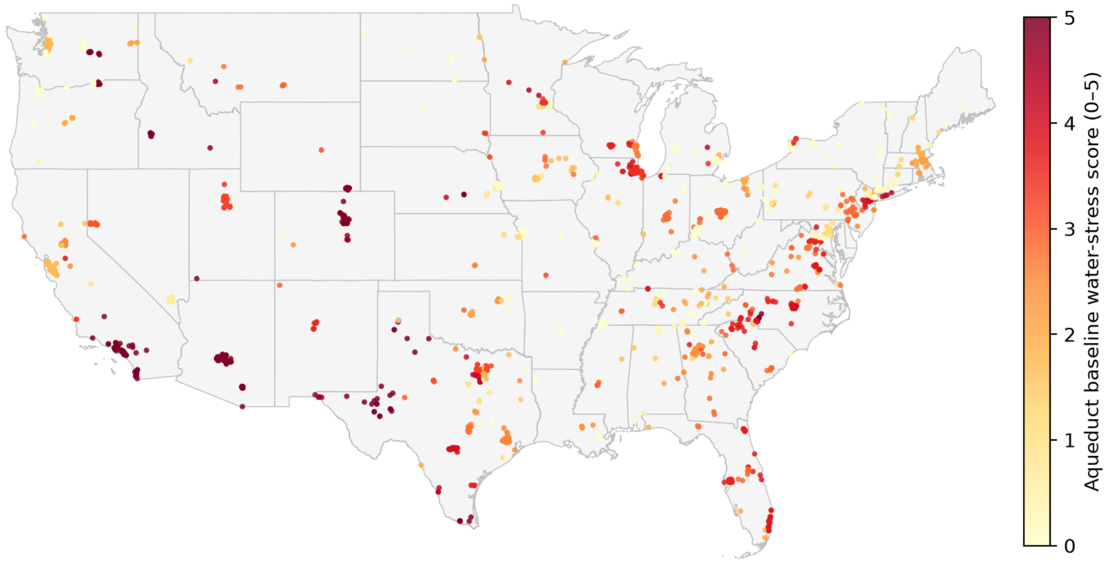

Figure 1: US data centers colored by WRI Aqueduct baseline water-stress score. The map shows the 3,142 facilities in the contiguous United States; 15 facilities in Alaska, Hawaii, and US territories lie outside the extent. Source: S&P Capital IQ; WRI Aqueduct 4.0.

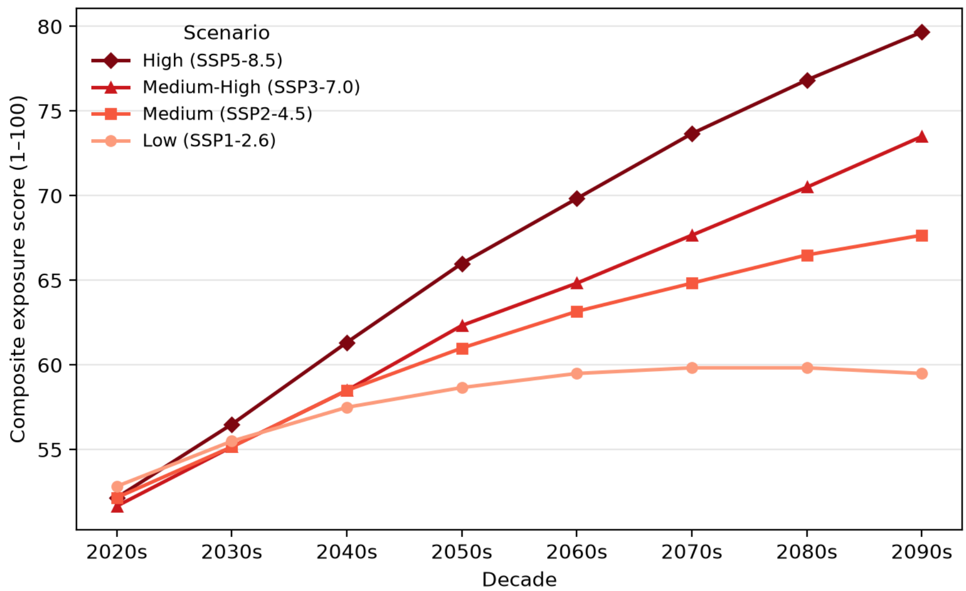

Figure 2: Mean composite physical risk exposure of the data center REITs, which own 1,054 properties. Results are shown by decade and climate scenario. Source: S&P Global Sustainable1 Physical Risk Scores and Financial Impact data.

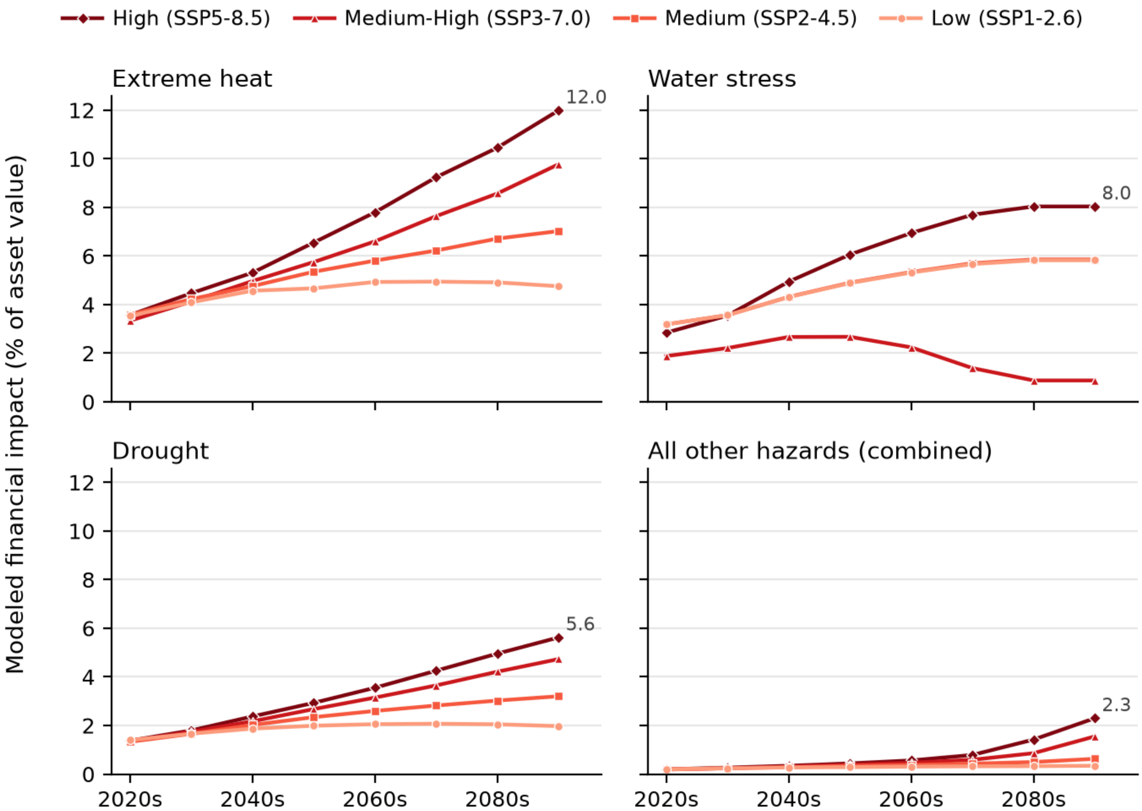

Figure 3: Mean modeled financial impact (% of asset value) by hazard and scenario (data center REITs), 2020s–2090s. Panels show the three hazards with the largest impact under High/SSP5-8.5 at the 2050 horizon; the fourth panel sums the remaining hazards (coastal flood, fluvial flood, tropical cyclone, wildfire, pluvial flood, landslide; extreme cold has no financial-impact metric). Low and Medium coincide for water stress, where the underlying hydrological projections are near-identical across the two pathways. Water stress under Medium-High (SSP3-7.0) falls below the other scenarios because SSP3's slow economic growth implies the weakest water-demand growth. Water stress is a demand-over-supply measure, and scenario ordering does not follow radiative forcing.

Supplementary material for “The Cloud Needs Water: Climate Physical Risk of Data Centers”

ABSTRACT

Data centers are critical physical infrastructure for the modern economy. To evaluate the climate physical risk of these facilities, we geolocate US data centers, finding that a substantial share sits in high or worse water stress, even as facilities avoid census tracts with extreme expected building losses. In a second, firm-level sample of data center REITs and their global portfolios, physical risk exposure rises significantly under multiple climate change scenarios, with a material modeled financial impact on asset value by mid-century. Corporate exposure to the climate physical risk of data centers remains largely opaque, particularly to their investors.

This supplement contains Tables S1–S3, referenced in the main article.

Table S1
Climate Hazards

Hazard	Measurement of the hazard exposure
Water stress	Withdrawals for households, industry, irrigation, and livestock as a share of the surface and groundwater actually available, once upstream use and dams are netted out. Higher readings mean users are competing harder for a tighter supply.
Drought	Average proportion of months per year in which the Standardized Precipitation Evapotranspiration Index falls at or below the location's historical 10th percentile, the threshold S&P uses for severely or extremely dry months. The Index nets evaporative demand against precipitation.
Extreme heat	The share of days a year when the daytime high exceeds the 90th percentile of the site's historical range, taken from downscaled climate-model output.
Extreme cold	The share of days when the nighttime low drops below the 10th percentile of the local baseline.
Wildfire	Days of fire-prone weather, graded with the Canadian Fire Weather Index and counted once danger reaches high or above. A land-cover screen removes ground carrying too little burnable vegetation.
Fluvial flood	River flooding, measured as the change in the return period of the historical 100-year discharge. S&P relates that discharge statistically to basin topography and precipitation covariates. WRI Aqueduct inundation extents identify the land that floods.
Pluvial flood	Flooding driven straight by heavy rainfall rather than rivers. An extreme-value fit to downscaled daily precipitation gives the rising frequency of what used to be a 100-year downpour.
Coastal flood	Storm-tide levels stacked on sea-level-rise projections and routed inland across fine elevation data, expressed as how often today's 100-year coastal flood would return.
Tropical cyclone	The yearly rate of Category 3 or stronger storms, from a track-simulation model tied to sea-surface temperature. Because uncertainty climbs quickly, values are projected only through the 2040s and then held flat.
Landslide	Rain-triggered slope failure, pairing a seven-day running rainfall index with terrain-susceptibility maps and counting days that push past the historical 95th-percentile soaking.

Climate hazards are climate-driven events capable of damaging physical assets. A hazard becomes a risk when it coincides with exposed, vulnerable assets. Source: S&P Global Sustainable1 (2025).

Table S2
Climate physical risk terminology

Term	Definition
Climate risk (hazard, exposure, vulnerability)	The Intergovernmental Panel on Climate Change (IPCC) frames climate risk as the interaction of three elements (IPCC, 2023): *hazard*, the potential occurrence of a damaging physical event at a location; *exposure*, the presence of assets or systems in places that could be harmed; and *vulnerability*, the propensity of exposed assets to be damaged.
Representative Concentration Pathways (RCPs)	RCPs are greenhouse gas concentration trajectories adopted by the IPCC that describe different levels of additional radiative forcing (difference in incoming and outgoing energy in the atmosphere, measured in Watts per square meter) by the year 2100. These model the physical climate outcomes, such as temperature increases and precipitation changes, based on the total volume of emissions accumulated in the atmosphere (van Vuuren et al., 2011).
Shared Socioeconomic Pathways (SSPs)	SSPs are scenarios projecting global socioeconomic changes up to 2100, focusing on variables such as population demographics, economic growth, urbanization, and technological development. They provide the narrative framework for how global society might evolve, determining the baseline societal challenges associated with mitigating greenhouse gas emissions and adapting to physical climate risks (Riahi et al., 2017).
CMIP6 and statistical downscaling	The Coupled Model Intercomparison Project, Phase 6: the coordinated framework in which climate-modeling groups worldwide run a common set of experiments, including the SSP–RCP scenario runs (Eyring et al., 2016; O'Neill et al., 2016). Hazard projections are built on NASA's statistically downscaled CMIP6 dataset (NEX-GDDP-CMIP6), at roughly 25 km resolution (S&P Global Sustainable1, 2025).
CMIP6 scenario	Modern climate modeling uses illustrative pathways that combine an SSP (the cause) and an RCP (the effect). For example, the climate scenario SSP1-2.6 models a highly sustainable socioeconomic narrative (SSP1) combined with aggressive climate mitigation, resulting in total radiative forcing (the extra heat energy trapped in the atmosphere) being limited to 2.6 Watts per square meter by the year 2100 (RCP 2.6).
Exposure score	The 1–100 rank of a company's asset-weighted hazard intensity against the global distribution for that hazard in the S&P Global Sustainable1 Physical Risk Scores and Financial Impact dataset (S&P Global Sustainable1, 2025).
Financial impact	Trucost's translation of hazard exposure into expected loss, obtained by passing an asset through hazard-specific damage functions. Results are reported as a share of asset value (S&P Global Sustainable1, 2025).
IFRS S2	When a jurisdiction adopts IFRS S2, companies are required to disclose information on "the resilience of the entity's strategy and business model to climate-related changes, developments and uncertainties" and "[t]he entity shall use climate-related scenario analysis to assess its climate resilience". See paragraph 22 in International Sustainability Standards Board (2023).

Exposure carries two senses in this table. IPCC exposure is the presence of assets in harm's way. S&P Global Sustainable1 Physical Risk Scores rank hazard intensity at those locations, combining the IPCC hazard and exposure elements but not vulnerability.

Table S3
Climate change scenarios.

Scenario	Pathway	Emissions trajectory and end-of-century warming
Low	SSP1-2.6	Aggressive mitigation; CO_2 emissions decline to net zero after mid-century and then turn net negative; warming of 1.3°C–2.4°C.
Medium	SSP2-4.5	Intermediate emissions; CO_2 near current levels until mid-century before declining; warming of 2.1°C–3.5°C.
Medium-High	SSP3-7.0	Limited mitigation; CO_2 emissions roughly double by 2100; warming of 2.8°C–4.6°C.
High	SSP5-8.5	Minimal mitigation; CO_2 emissions roughly double by 2050; warming of 3.3°C–5.7°C.

Each scenario combines a Shared Socioeconomic Pathway (SSP) with a Representative Concentration Pathway. Warming is the very likely end-of-century range relative to 1850–1900 (IPCC, 2021, Table SPM.1, Box SPM.1).

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