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Getting physical

Scenario analysis for assessing climate-related risks

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Introduction

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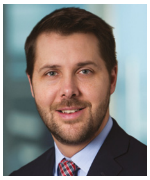

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A series of recent extreme weather events – from hurricanes and wildfires in the U.S. to heat waves in Europe and floods in Japan – have put a spotlight on climate-related risks. Yet the implications for investment portfolios – stemming from a rising frequency and intensity of such events – have been notoriously hard for investors to grasp.

Why? First, the effects of slower-moving physical changes such as rising sea levels can seem distant. This causes investors to discount pressing climate-related risks already lurking in portfolios. Second, the risks are hard to model. New climate patterns mean long-dated historical data are a poor guide to the future. Investors using models overly reliant on the past are missing the big picture. Third, the risks have been hard to pinpoint. Drilling down on physical risk to the exact geographical location and asset level is key for investors — think of potential damage to commercial real estate or electric power plant facilities. But analyzing huge amounts of climate data properly and effectively is a challenge.

The good news: Recent advances in climate and data science make it easier to overcome these hurdles and separate the signal from the noise. BlackRock's collaboration with Rhodium Group combines our asset-level expertise with the latest climate science and big-data capabilities. The result – generating some 160 terabytes of data – is a granular picture of investment-relevant physical climate risks. We can now assess direct physical risks to assets on a local level — today and under different future climate scenarios. We can also estimate knock-on effects, such as the impact on energy demand, labor productivity and economic activity.

These tools give us unique insight into the severity, dispersion and trajectory of climate-related risks. This helps us assess whether the risks are adequately priced by markets. Our early findings suggest investors must rethink their assessment of vulnerabilities. Weather events such as hurricanes and wildfires are underpriced in financial assets, including U.S. utility equities. A rising share of municipal bond issuance is set to come from regions facing climate-related economic losses. And many high-risk commercial properties are outside official flood zones.

Understanding and integrating these insights on climate-related risks can help enhance portfolio resilience, we believe. Our first step focuses on assets and companies in the U.S. We plan to extend the analysis across regions, asset classes and sectors as data availability improves. Yet our early work already strengthens our conviction that sustainable investing is increasingly a ***"why not?"*** proposition.

CONTENTS

Summary

- **We show how physical climate risks vary greatly by region, drawing on the latest granular climate modeling and big data techniques.** We focus on three sectors with long-dated assets that can be located with precision: U.S. municipal bonds, commercial mortgage-backed securities (CMBS) and electric utilities. Hurricanes pose a threat to the finances of southern U.S. states; rising sea levels make coastal real estate vulnerable; and power plants in the Southwest have exposure to extreme heat. A localized assessment of such risks under different climate scenarios can provide investors with 1) a sharp lens for risk management and diversification; and 2) an informed basis for engaging with companies and issuers about their climate resiliency and capital spending plans.

- **Extreme weather events pose growing risks for the credit worthiness of state and local issuers in the $3.8 trillion U.S. municipal bond market.** We translate physical climate risks into implications for local GDP – and show a rising share of muni bond issuance over time will likely come from regions facing economic losses from rising average temperatures and related events. Some 58% of metropolitan areas face climate-related GDP hits of 1% or more by 2060–2080 under a "no climate action" scenario, we find. We zoom in on the highest risk areas – and explain the importance of assessing muni issuers' resolve and financial ability to fund adaptation projects to mitigate climate risks. We see potential to extend this analysis to sovereign issuers, including emerging markets.

- **Hurricane-force winds and flooding are key risks to commercial real estate.** Our analysis of recent hurricanes hitting Houston and Miami finds that roughly 80% of commercial properties tied to affected CMBS loans lay outside official flood zones – meaning they may lack insurance coverage. This makes it critical to analyze climate-related risks on a local level. We show how the economic impacts of a warming climate could lead to rising CMBS loan loss rates over time.

- **Aging infrastructure leaves the U.S. electric utility sector vulnerable to climate shocks such as hurricanes and wildfires.** We assess the exposure to climate risk of 269 publicly listed U.S. utilities based on the physical location of their plants, property and equipment. A key conclusion: The risks are underpriced. Electric utilities with exposure to extreme weather events typically suffer temporary price and volatility shocks in the wake of natural disasters. We find some evidence that the most climate-resilient utilities trade at a premium. We believe this premium could increase over time as the risks compound and investors pay greater attention to the dangers.

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Setting the scene

We explain how changes to the climate – and related extreme weather events – pose tangible risks to investment portfolios today, not just years in the future.

The climate is changing, societies are adapting, and technologies are catching up. This dynamic creates risks and opportunities for investors. The implications of climate change are playing out across four key channels: physical, technological, regulatory and social. See BlackRock's ***Adapting portfolios to climate change*** of 2016 for more. Advances in data and analytics now give us growing conviction in our ability to measure and manage these key risks.

In this piece we go deep on physical risk. Increasing global temperatures are leading to measurable changes in our habitat, such as rising sea levels, droughts, wildfires and storms. The trend of rising average temperatures is boosting the frequency at which extreme weather events occur, as well as their intensity. These changes are affecting our economy *today*.

The implications for investors go beyond coastal real estate. Think of agriculture (crop yields), insurance (property and casualty premiums) and electric utilities (risks to plants; peak electricity demand). The damage from storms, floods and heat waves can also disrupt corporate supply chains – and pressure public finances, posing risks to municipal and sovereign bond holders.

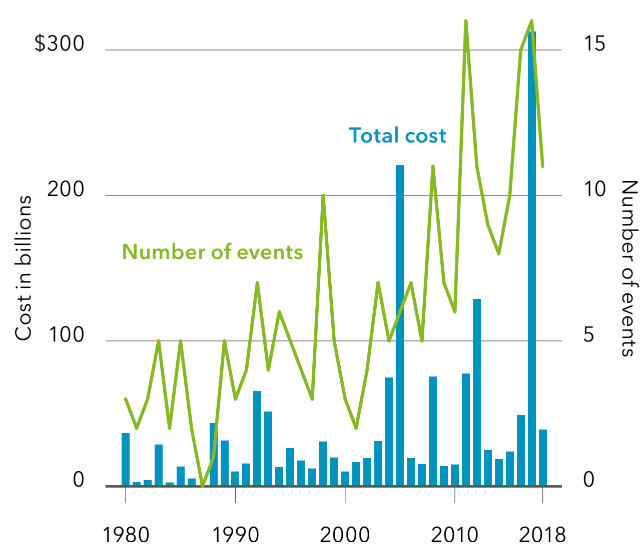
The number of natural disasters causing $1 billion-plus in damages has been on a steady rise, as shown in the *Mounting costs* chart. Related insurance claims hit a record $144 billion in 2017, but with much of the exposure uninsured, losses totaled $337 billion, according to 2018 ***Swiss Re data*****.** The data show wildfires caused a record $21 billion of damage globally in 2017, while a trio of hurricanes – Harvey, Maria and Irma – caused losses equivalent to 0.5% of U.S. GDP. This highlights a risk to investors. The rising incidence of extreme weather events over time could lead to spiking property and casualty insurance premiums, and reduced or even denied coverage if insurers shy away from underwriting risks that have become too great or uncertain. Investors need to get ahead of these risks.

We combine our asset-level expertise and cutting-edge climate modeling from Rhodium's work with a consortium of scientists and data experts to examine how the risks look today – and how they may evolve over time under different climate scenarios. See Rhodium's paper ***Clear, Present and Underpriced: The Physical Risks of Climate Change*** for a summary of its approach.

The climate modeling and data we purchased from Rhodium allow us to assess direct physical risks such as probabilities of flooding and hurricane-force winds – on a localized level across the U.S. This helps us estimate potential direct financial damages, as well as knock-on effects such as the impact of rising temperatures on crop yields or labor productivity. ***See page 7*** for details. We refer to these direct physical impacts and their indirect economic impacts collectively as climate-related risks. Many of the vulnerabilities are local. Example: Infrastructure on the U.S. Gulf Coast is at risk from wind and storm surge damage by hurricanes. Communities in the U.S. West are increasingly at risk from wildfires.

Mounting costs

U.S. billion-dollar disaster events, 1980–2018



Sources: BlackRock Investment Institute, with data from NOAA National Center for Environmental Information NCEI, October 2018. Notes: The line shows the number of climate events with losses exceeding $1 billion. The data include droughts, flooding, severe storms, tropical cyclones, wildfires, winter storms and freezes. The bars show the total cost. The data are adjusted for inflation using 2018 dollars.

Climate complacency

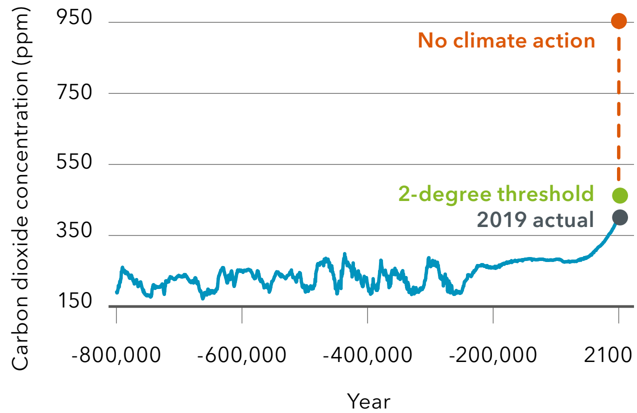
One of the most striking implications of our work drawing on the latest climate research: How much more pronounced the risks are today, compared with just a few decades ago. The risks that hurricanes pose to commercial properties, for example, have increased meaningfully, we find. ***See page 13*** for details. Investors who are not thinking about climate-related risks, or who view them as issues far off in the future, may need to recalibrate their expectations. Some physical changes – such as slowly rising sea levels – can seem outside of a traditional investment horizon. Yet the most pressing risks, such as exposure to hurricanes, wildfires and droughts, are clear and present – and often hidden in investors' portfolios *today*.

Our research suggests many of these risks are not priced in. Why? First, financial markets tend to be short-sighted – and underestimate risks that appear uncertain and distant. This may lead to a discounting of physical risks that are already biting. Second is a lack of tools and data. Example: Risk managers often rely on outdated flood zone maps to assess risks to real estate. Short-sighted policy and regulatory requirements can exacerbate this problem. Hurricane modelers look at 100 years of history to gauge future risks. But data prior to 1980 are patchy. And the past is of limited use as a guide to the future when averages (global temperatures and hurricane probability) are rising over time. Consider that Houston has seen three "one-in-500-year" flooding events since 2015, Houston's Harris County Flood Control District said in 2017. Bottom line: Looking backward over long periods results in underpricing the financial impact of climate-related risks.

Physical climate models can help fill the gap – and provide a more accurate assessment of the probability of a range of extreme weather events occurring in any given year. The challenge: Climate modeling is an evolving science. Different models point to different outcomes, with wide bands of uncertainty. Standard approaches to valuing the effects of rising global temperatures look at average predicted impacts for large regions – sometimes the entire globe. Yet recent computational advances make it possible for us to analyze the risks on a localized level.

Hockey stick

Global atmospheric concentration of CO_2, 800,000 B.C.–2100



Sources: BlackRock Investment Institute, with data from the U.S. Environmental Protection Agency, March 2019. Notes: The chart shows the concentration of carbon dioxide in the atmosphere over time, measured in parts per million (ppm). The data until 1950 are from historical ice core studies from the European Project for Ice Coring in Antarctica project. Post-1959 numbers are direct measurements taken at Mauna Loa, Hawaii. The 2019 actual data point is as of January 31. The 2-degree threshold is the CO_2 concentration at which global average temperatures are predicted to rise by 2°C from pre-industrial levels by end-century, as estimated by the IPCC. The "no climate action" scenario assumes ongoing use of fossil fuels and a CO_2 concentration of 940 parts per million (ppm) by 2100.

Hot today; hotter tomorrow

Scientists have long cited a clear linear relationship between the level of carbon dioxide (CO_2) in the atmosphere and warmer temperatures (the "greenhouse effect"). Temperatures over land and ocean have already gone up an average 1.2°C (2.2°F) since the mid-1800s, and significantly more at the Earth's poles, according to data from the National Oceanic and Atmospheric Administration (NOAA). CO_2 concentrations in the atmosphere are at a higher level than they have been for the past 800,000 years. See the *Hockey stick* chart.

How much warming can the Earth tolerate before experiencing the most destructive effects of climate change? The threshold of 2 degrees Celsius (3.6 °F) above "preindustrial" temperature levels rings alarm bells for many scientists. Recent trends in emissions suggest the 2-degree threshold is unlikely to hold. See the green dot in the chart. A "no climate action" trajectory (the orange dot) assuming ongoing use of fossil fuels would lead to a roughly 4°C (7°F) increase in average global temperatures by 2100, according to the Intergovernmental Panel on Climate Change (IPCC). Uncertainty around the path of carbon emissions means it is prudent to consider alternative scenarios when assessing climate-related risk. ***See page 7*** for more.

Investment applications

We detail our framework for assessing climate-related risks under different scenarios – and pinpoint the potential risks to assets across the U.S.

The physical risks posed by climate change were tough to model until recently. Advances in big data and cloud computing now enable us to zoom in on these risks on a 20 km (12 miles) by 20 km level across the U.S. We present a snapshot of our evolving research in this paper. It draws on Rhodium's work with the ***Climate Impact Lab***, combining historical climate and socioeconomic data with physical climate modeling. This work – a collaborative project between data gurus, econometricians and climate scientists – leverages millions of simulations. Our efforts to apply the data to U.S. assets required 600,000 hours of CPU processing power – and generated 160 terabytes of data – the equivalent of 120 million 1980's-era 3.5 inch floppy disks.

The analysis includes knock-on impacts of rising average temperatures. Many such effects are non-linear. Corn yields, for example, start to drop sharply when daily high temperatures exceed 84°F (29°C). And electricity demand tends to follow a U-shape, rising at extreme low and high temperatures. See the *Turning points* charts.

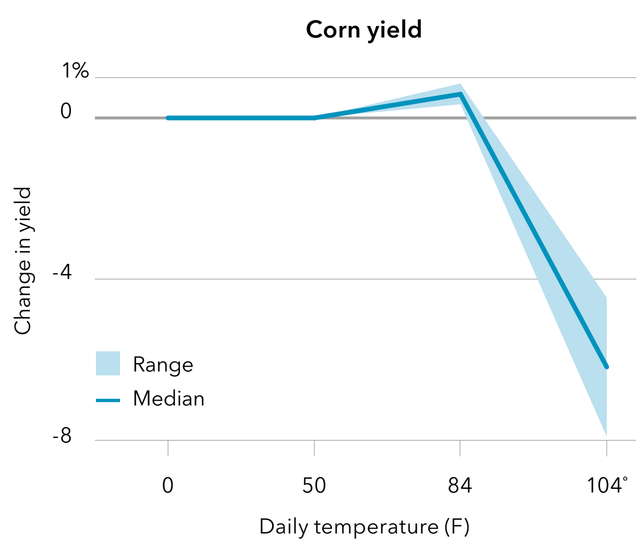
The focus of our initial work is U.S. municipal bonds (***pages 10–12***), CMBS (***pages 13–14***) and electric utility equities (***pages 15–17***). The reason: These asset classes are backed by long-duration physical assets of known location. We start by assessing the risks to these asset classes today. Too often, assessments of physical climate risk start by looking decades into the future. This overlooks risks that are already present.

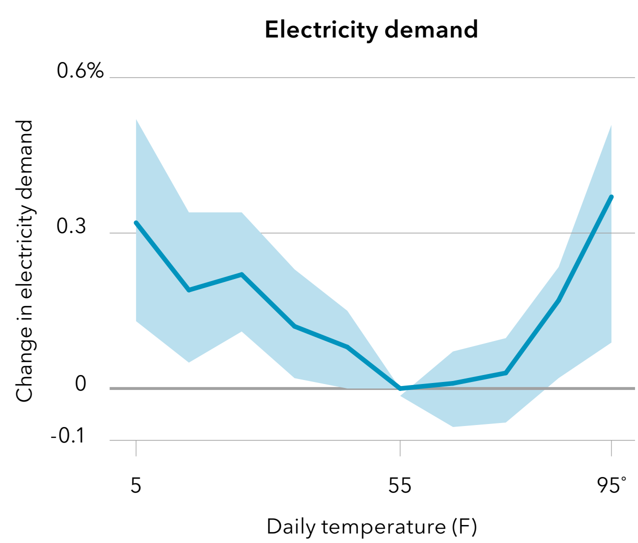
How to gauge the related risks on assets? Our process:

1. Determine which assets have a readily identifiable physical location (e.g., properties of CMBS loans).
2. Overlay the asset locations with climate data to assess exposures to relevant direct physical risks such as hurricanes – today and in the future.
3. Link climate data to relevant second-order financial and socioeconomic implications.
4. Analyze if these risks are priced in and/or insured, and determine if the company/issuer has the resolve and financial capacity to adapt.

Turning points

Changes in corn yields and electricity demand as a function of daily maximum temperatures





Sources: BlackRock Investment Institute, with data from Rhodium Group, March 2019. Notes: The ranges shown are the 95% confidence interval (two standard deviation range). All analysis is from Rhodium Group. Corn estimates draw on county-level U.S. agricultural production data from the U.S. Department of Agriculture over 1950–2005 to identify the relationship between temperature changes and average yields, using the methodology of *Schenkler and Roberts (2009)*. Electricity demand draws on two studies measuring the effect of climate variables on energy demand: *Deschenes and Greenstone (2011)* examine state-level annual electricity demand from 1968 to 2002 using data from the U.S. Energy Information Adminstration. *Auffhammer and Aroonruengsawat (2011)* study monthly building-level electricity consumption for California households.

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Plotting paths

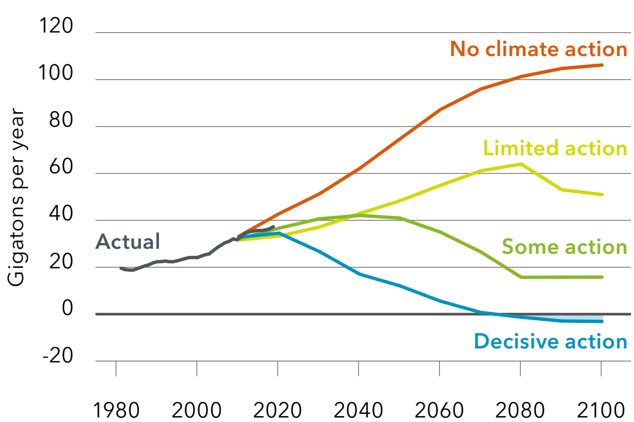
Global climate scenarios are central to our analysis. The climate modeling community has settled on several plausible pathways for the future path of carbon emissions. To account for uncertainty around these future pathways, we consider four scenarios, reflected in the *Plotting paths* chart below: These range from the "no climate action" scenario (orange line) that assumes continued burning of fossil fuels; to a "decisive action" scenario (blue line) that assumes aggressive policy actions to curb emissions.

The latter is the goal of the 2015 Paris Climate Agreement, which aims to keep the average increase in global temperatures to well below 2°C by the end of the 21st century. Actual emissions growth (gray line in the chart) has the world on a path to higher-warming scenarios, posing risks to assets.

Rhodium draws on 21 advanced global climate models to calculate probability-weighted indicators of physical climate changes – such as temperature, rainfall and hurricane risk – for each of these emissions scenarios. See ***Rhodium's article*** in the Journal of Applied Meteorology and Climatology (Oct 2016) for details. The goal: to answer what we know both about the physical risks today, and how those risks may evolve in the future.

Plotting pathways

Scenarios for fossil fuel-related CO_2 emissions, 1980–2100



Sources: BlackRock Investment Institute, with data from Rhodium, March 2019. Notes: CO_2 emissions include fossil fuel combustion and cement production. The chart lays out the four representative concentration pathways (RCPs) commonly used as scenarios in climate modeling, as defined by the Intergovernmental Panel on Climate Change. "No climate action" (known as RCP 8.5) assumes ongoing fossil fuel use, with atmospheric CO_2 concentrations reaching 940 ppm by 2100. "Limited action" (RCP 6.0) sees CO_2 concentrations rising to around 670 ppm by 2100. In "some action" (RCP 4.5), CO_2 concentrations stabilize at around 550 ppm. Decisive action (RCP 2.6) sees aggressive policy action resulting in negative net emissions (see shaded blue area) by late in the century, with CO_2 concentration of 384 ppm by 2100.

SCENARIO ANALYSIS

How can governments, companies and investors best incorporate climate risks into their decision making? Scenario analysis plays a key role. The Financial Stability Board's ***Task Force on Climate-Related Financial Disclosures*** has resulted in a hearty pick-up in analysis. The TCFD, of which BlackRock is a member, separates climate risks into two categories.

- **Transition risks:** The risks to businesses or assets that arise from policy, legal, technological and/or market changes as the world seeks to transition to a lower-carbon economy. See ***Sustainability: the future of investing*** for details on our approach.
- **Physical risks:** The risks to entities or assets from the climate changes already occurring and expected to continue in the years ahead under different greenhouse gas emissions scenarios.

Physical risks pose the greatest threat in the "no climate action" or "limited action" scenarios, both of which likely lead to significant increases in average global temperatures. Transition risks take on greater relevance in a "decisive action" scenario that involves tough regulatory actions to curb emissions, breakthroughs in clean energy, and a more limited rise in temperatures.

Given our focus on physical risks in this piece, we concentrate on the "no climate action" scenario. We see this as a tough, but plausible, scenario for stress-testing investment portfolios. This is in line with the TCFD's recommendation that entities consider "challenging" scenarios for risk management. Scenarios are not forecasts. And they do not equal sensitivity analysis (to a particular factor). The idea is to challenge conventional wisdoms about the future.

Scenarios draw attention to key factors that will drive future developments. This, in turn, can help in assessing how resilient an organization is against potential disruptions. Does it have the ability to adapt to the changes – and take advantage of related opportunities? Does it have plans in place to mitigate the risks? Scenarios can provide investors with a framework for answering such questions.

A glimpse into the future

How might some of the risks play out? Average temperatures show some striking potential changes under a "no climate action" risk scenario of ongoing fossil fuel use.

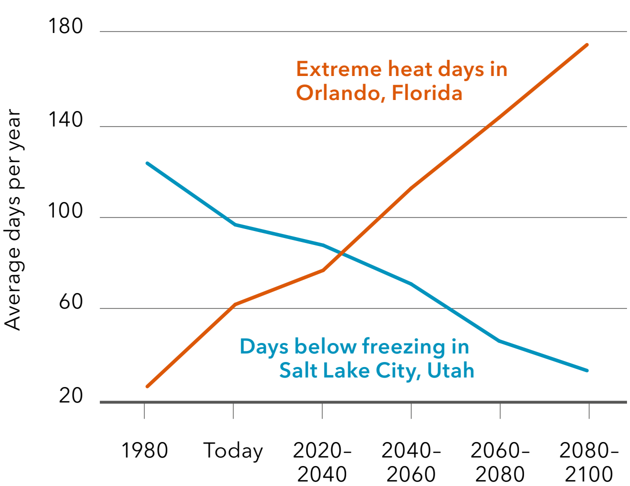
Example: The number of freezing days in Salt Lake City, Utah, could fall by as much as 75% by the end of the century from 1980 levels. By contrast, Disney World in Orlando, Florida, could see the average number of annual days with extreme heat spike to almost half the year. See the *A tale of two cities* chart below.

Up to 26% of U.S. metropolitan areas would likely see more than 100 days a year of 95°F (35°C) heat by 2060–2080, versus around 1% today, the estimates show. This would have important knock-on implications:

- Lower productivity in regions that rely on outdoor labor such as agriculture and construction work;
- Rising mortality rates as the incidence of extreme heat rises in hotter states such as Texas;
- Greater energy expenditure to cool buildings, particularly in the U.S. South West;
- Lower agricultural output due to declining crop yields in hotter states such as Arizona.

A tale of two cities

Average number of cold and hot days in two U.S. cities, 1980–2100



Sources: BlackRock Investment Institute, with data from Rhodium, March 2019. Notes: The chart shows the average annual number of cold days in Salt Lake City, Utah, when the temperature falls below 32°F (0°C), and the number of hot days in Orlando, Florida above 95°F (35°C). 1980 data are actual. "Today" represents the 2010–2030 estimate. Estimates are from Rhodium and assume a "no climate action" scenario. We show the upper bound of the 66%, or "likely" range. Rhodium's estimates draw on 21 general circulation models to assess probabilities of temperature, precipitation and other climate variables.

Changing world

Estimated "no climate action" impacts vs. 1980, 2019–2100

	Today	2020–2040	2040–2060	2060–2080	2080–2100
Sea level rise (feet)					
Houston	1.2	1.6	2.5	3.6	4.9
New York	0.9	1.2	1.9	2.9	4.0
Hurricane damage (annualized % GDP loss)					
New York	0.2	0.2	0.2	0.4	0.6
Miami	2.5	2.5	2.8	3.3	3.9
Change in agricultural output (annualized % GDP gain/loss)					
Pine Bluff, Ark.	-0.9	-1.2	-2.7	-3.7	-3.8
Jamestown, N.D.	1.0	2.4	5.2	6.5	5.0
Change in energy expenditure (annualized as % of GDP)					
Tucson, Ariz.	0.3	0.5	0.8	1.2	1.6
Minneapolis	-0.11	-0.12	-0.13	-0.14	-0.14

Sources: BlackRock Investment Institute, with data from Rhodium Group, March 2019. Notes: All estimates are from Rhodium Group and assume a "no climate action" scenario. We show the upper bound of the 66%, or "likely" range of outcomes to illustrate a plausible risk scenario. Sea level rise (in feet) is from 1980. Hurricane damage, agricultural output and energy expenditure show annualized GDP gains/losses as a result of physical changes in the climate since 1980. For details on Rhodium's methodology see *Estimating economic damage from climate change in the United States*, Science (June 2017).

How large are the potential effects? Pretty big, under a "no climate action" scenario. Tucson, Arizona, for example, would be spending more than 1% of GDP annually on additional energy costs by late century. See the *Changing world* table above. Declining potential for agriculture, as extreme heat reduces crop yields, would be shaving up to 4% annually off the GDP of Pine Bluff, Arkansas. By contrast, Jameston, North Dakota, for example, would gain a GDP boost from warming.

Sea levels are set to rise meaningfully, exposing much coastal property to potential losses. Rhodium's work shows that sea levels in Houston are more than a foot higher today than in 1980. This rise is likely to swell to as much as five feet by the end of the century under current emissions trends, the estimates show. New York City would see likely sea level rises of up to three feet by 2080, exposing roughly $73 billion of property to potential losses. Hurricanes are a key driver. We can estimate potential damages by combining historical loss rates with building-level exposure data and cutting-edge hurricane modeling. The result: Potential annualized storm hits of as much as 3% of GDP to Miami and other coastal cities.

Net impacts

How to gauge the overall economic impact of climate-related risks on a region? Rhodium's work allows us to estimate this under different scenarios. To illustrate, the *Mapping the damage* graphic below visualizes the expected changes to GDP across the U.S. under a "no climate action" scenario in 2060–2080.

The biggest likely losers: the Gulf Coast region, the South Atlantic seaboard and much of Arizona. See the orange tones in the map. A handful of colder states see potential for modest GDP gains. Yet the risks are asymmetric: Some 58% of U.S. metro areas would see likely GDP losses of up to 1% or more, with less than 1% set to enjoy gains of similar magnitude, we estimate. Florida tops the danger zones, with Naples, Panama City and Key West seeing likely annual GDP losses of up to 15% or more, mostly driven by coastal storms. Note these are average annual estimates; losses would likely come in big weather-driven shocks that could be much larger for a given year. The losses are not baked in: Decisive action could mitigate carbon emissions and cities can spend on adaptation measures to increase their resiliency. But the vulnerabilities revealed in the analysis have important implications for municipal bond issuers and investors, as discussed in the next chapter.

58% Estimated share of U.S. metro areas with 1%-plus climate-related GDP losses by 2080

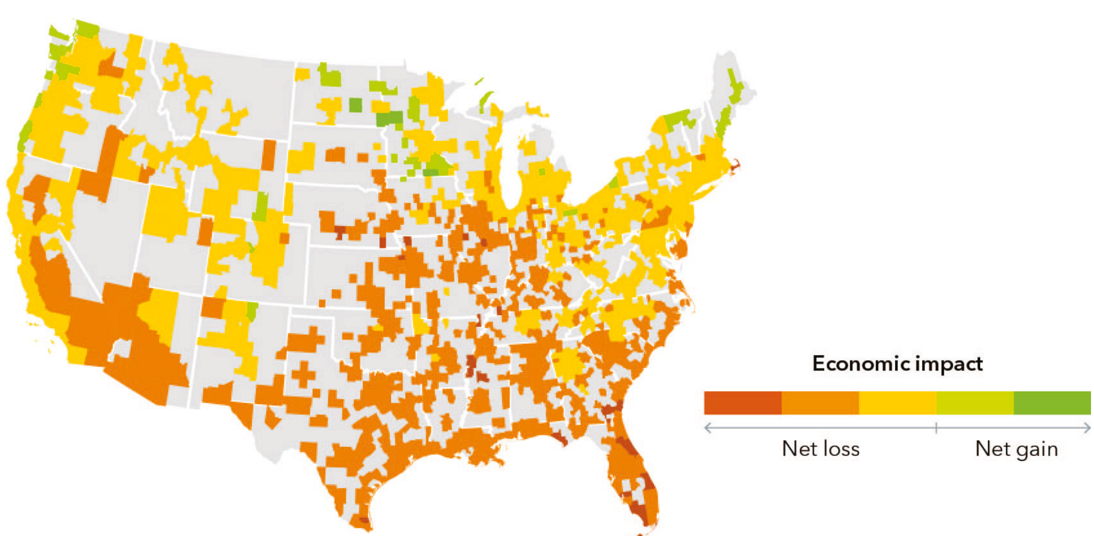
Getting a better handle on physical climate risk, down to the asset level, can add an important tool to an investor's toolkit. This is particularly valuable for portfolios of assets that are geo-locatable – and have decades-long lifespans. This is why we initially focus on U.S. municipal bonds, CMBS and electric utilities.

Our analysis is just a first step. We aim to extend the work to other regions, asset classes and sectors. Future challenges include applying the methodology to multinationals with complex supply chains, as well as to services companies. The latter requires assessing how exposed a company's key markets are to climate risks.

There is inherent uncertainty in climate modeling and weather scenarios. This means there is uncertainty in our estimates of that risk today – and even more so in the future. Yet we believe our work to better measure physical risks today – and under different scenarios in the future – is an important starting point. It can help reveal risks that may be mispriced in portfolios today, and how those risks may change over time.

Mapping the damage

Estimated net economic impact on U.S. regional GDP under "no climate action" scenario, 2060-2080



Sources: BlackRock Investment Institute, with data from Rhodium Group, March 2019. Notes: The map shows the projected GDP impact in 2060–2080 on U.S. metropolitan areas under a "no climate action" scenario. Climate changes are measured relative to a 1980 baseline. The analysis includes the effect of changes in crime and mortality rates, labor productivity, heating and cooling demand, agricultural productivity for bulk commodity crops, and expected annual losses from coastal storms. It accounts for correlations across these variables and through time – and excludes a number of difficult to measure variables such as migration and inland flooding. See Rhodium Group's March 2019 paper *Clear, Present and Underpriced: The Physical Risks of Climate Change* for further details on its methodology. Forward-looking estimates may not come to pass.

Municipal bonds

We show how climate-related risks threaten the economies – and creditworthiness – of many U.S. state and local issuers, and provide a framework for assessing these risks.

Climate-related risks are underappreciated in the U.S. municipal bond market. Hurricanes, floods and other extreme weather pose a host of financial challenges for state and local issuers. A lot is at stake: The market has $3.8 trillion of outstanding debt, according to late-2018 Federal Reserve data. Consider the following:

- The cost of cleanups after extreme weather, funding mitigation projects to forestall future damages, and rising flood insurance premiums can lead to higher debt levels. This has big implications for general obligation (GO) bonds – those backed by the credit and tax power of states and cities.
- The tax base of a municipality could shrink if large-scale natural disasters lead to a population drain (such as that experienced by Puerto Rico in the wake of Hurricane Maria in 2017) and declining property prices. Some municipalities offer property tax relief in the aftermath of natural disasters, exacerbating the hit to their revenues.
- Gradual changes to the climate – such as rising temperatures and sea levels – can change patterns of land use, employment and economic activity. Businesses may relocate to other regions, also eroding the local tax base.
- Revenue bonds tied to specific projects – such as those issued by water and sewer utilities – may suffer direct harm from sea level rise, floods or droughts.

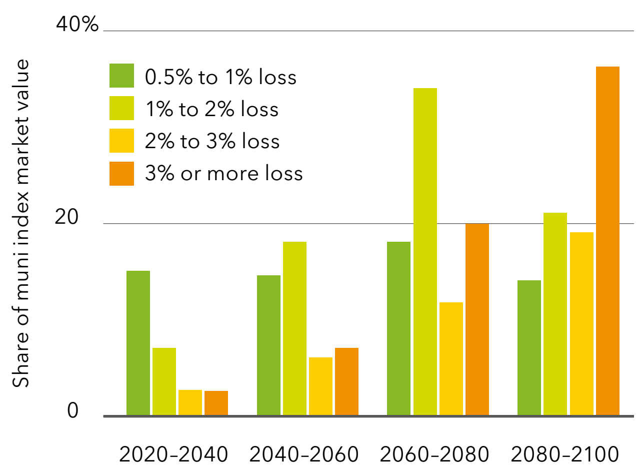
Credit rating agencies are paying increased attention to these risks. Moody's in 2017 warned that climate change would have a growing negative impact on the creditworthiness of U.S. state and local issuers – particularly those without sufficient adaptation and mitigation strategies. Yet such strategies can be costly. One example: Florida's governor in January said the state wanted to spend $2.5 billion over four years to address environmental issues, including the effects of rising sea levels.

Climate models suggest such financial challenges are only set to intensify. Our work shows a rising share of U.S. metropolitan statistical areas (MSAs) will likely face escalating climate-related risks in the coming decades. This analysis breaks down the potential net economic impact – relative to where GDP would have been absent the effects of climate change – on each of the 383 U.S. MSAs under a "no climate action" scenario. It includes estimates of direct impacts, such as the expected losses from hurricane damage, as well as second-order effects such as changes in mortality rates, labor productivity, energy demand and crop yields.

Within a decade, more than 15% of the current S&P National Municipal Bond Index (by market value) would be issued by MSAs suffering likely average annualized economic losses of up to 0.5% to 1% of GDP. See the *A growing burden* chart. This would have big implications for the creditworthiness of MSAs – and their ability to fund adaptation projects. The impacts are set to grow more severe in the decades ahead, as the chart shows.

A growing burden

Muni index share at risk of climate-related GDP loss, 2020–2100



Sources: BlackRock Investment Institute, with data from Rhodium Group, March 2019. Notes: We use the S&P National Municipal Bond Index to represent the muni market. The chart shows the estimated market value share of the muni market exposed to GDP losses of various magnitude through 2100 under a "no climate action" scenario. For example, roughly 20% of the market value of the current muni index is expected to come from regions suffering annualized average losses of up to 3% or more of GDP from climate change by 2060–2080. We use the upper bound of the 66%, or "likely," range of losses to illustrate a plausible risk scenario.

BIIM0419U-804111-10/20

Location, location, location

The impact of climate-related risks varies widely, with coastal and southern states hit hardest. The *What's the damage?* chart shows the range of projected effects over time for the 15 largest MSAs, which make up almost 40% of the muni market. Our work suggests all major MSAs are already suffering mild to moderate losses today – the result of cumulative changes to the climate since our 1980 baseline year. Topping the list of damages: Miami, Florida, with estimated annualized GDP losses of more than 1% today – and potential for these losses to grow to an annualized 4.5% of GDP by the end of the century. These would be mostly driven by hurricanes and rising sea levels. Note this is a high-risk scenario; aggressive global efforts to curb carbon emissions would put projected losses on a more moderate path.

Seattle, with its relatively temperate climate, shows the most resilience with little projected damage to GDP over time. The New York City region faces annual losses equivalent to roughly 1% of GDP by late century. The projected losses are not set in stone. Larger, more diversified MSAs such as New York are in a better position to fund adaptation and mitigation projects. The city has pledged to spend $20 billion over 10 years to make buildings and infrastructure more climate resilient.

Blissful ignorance?

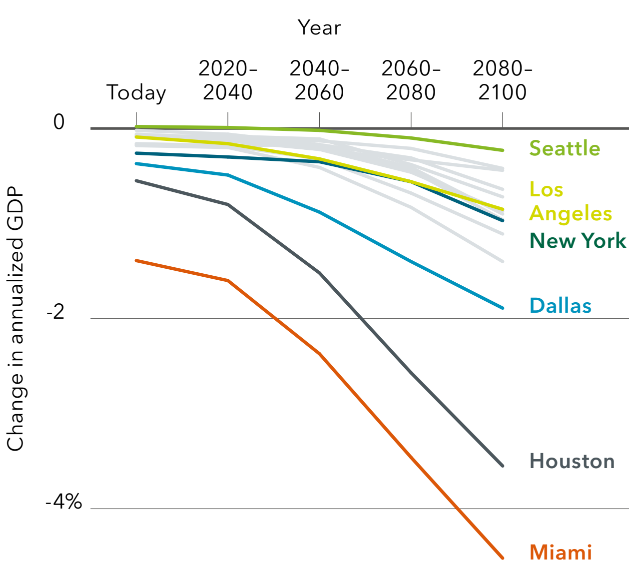
Are markets pricing in any of these future risks? One approach to finding out is to compare similar bonds located in climate-sensitive and non-climate-sensitive areas and review their prices (spreads). Such comparative spot-checks of municipal bonds do not reveal significant differences in valuation, we find.

For example, we considered two bonds with similar characteristics: Jupiter, Florida is an area beset by the hurricanes that affect the greater Miami region. Jupiter's location and its numerous waterways make the city especially vulnerable to tropical storms and hurricanes. By contrast, Neptune, New Jersey is far more insulated against severe storms.

We compared a Jupiter water revenue bond against a Neptune bond with fairly similar characteristics (taking coupon, maturity, callability, and the sector into account). The result: They had almost identical yields after adjusting for the credit quality of the two bonds (AA vs A rating). If climate-related risks were being considered as a key factor, we would have expected the Neptune bond to carry a lower yield (higher price) than the Jupiter bond. We found similar results for other spot checks of bonds in areas of high and low climate risk.

What's the damage?

Estimated climate impact on GDP of top-15 U.S. MSAs by economic weight, 2018–2100



	GDP ($ bln)	Debt ($ bln)	Share of muni index
New York	1,718	203	9.5%
Los Angeles	1,044	86	3.9%
Chicago	680	74	3.3%
Dallas	535	64	3.0%
Washington D.C.	530	45	2.0%
San Francisco	500	71	3.3%
Houston	490	51	2.4%
Philadelphia	445	25	1.2%
Boston	439	67	3.2%
Atlanta	385	34	1.6%
Seattle	356	30	1.4%
Miami	345	33	1.5%
San Jose	275	13	0.6%
Detroit	261	12	0.6%
Minneapolis	260	25	1.2%

Sources: BlackRock Investment Institute, with data from Rhodium Group, March 2019. Notes: The cities shown represent the top-15 U.S. metropolitan statistical areas (MSAs) by GDP. The chart shows projected annualized GDP losses (upper bound of the 66%, or "likely," range) due to cumulative changes in the climate since 1980 under a "no climate action" scenario. Today is represented by a 2010–2030 estimate. The table shows the GDP, total outstanding municipal bond issuance, and each MSA's weight in the S&P National Municipal Bond Index. The MSAs shown are greater urban areas; for example, Los Angeles includes Long Beach and Anaheim, California.

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The FEMA put

How to explain the municipal bond market's apparent complacency around climate-related risks? We offer a handful of possible explanations:

- **Lack of attention:** Investors have been slow to give serious consideration to climate change, partly due to a lack of granular data for modeling the risks. This mindset is slowly changing. Credit analysts often note that they do consider the location of revenue sources but don't quantify their concerns by building an additional risk premium into spreads.
- **Time horizon:** The most dire projected impacts will come in future decades, beyond the traditional time horizon of most investors and credit rating agencies – and the duration of the average muni bond (16 years). This may lead to a discounting of risks that are already present today.
- **Insurance:** Bonds in climate-sensitive regions are often insured, thus diminishing investor concerns about storm hits. This is a key reason why muni bond prices tend to fall after heavy storm damage, but recover quickly after.
- **The "FEMA put:"** Areas devastated by storms have typically been rebuilt with funding from the Federal Emergency Management Agency (FEMA). Investors assume the bonds are insulated from climate-related risks, with FEMA providing something akin to a put option that preserves the bonds' par value.

We find little evidence that climate-related risks are priced into the municipal bond market today. Yet this dynamic should change over time, in our view. Insurance coverage in climate-affected areas is likely to become more costly – if still available.

The "FEMA put" could become less reliable if mounting disaster costs were to overwhelm FEMA's financial capacity or political will to respond. Political uncertainty around FEMA's structure and mandate only exacerbate this risk. And large-scale extreme weather events such as recent U.S. hurricanes could jolt investor sentiment. As these trends intensify and some of the risks play out, we could see a climate-proof premium emerging. We believe bonds issued by climate-resilient states and cities are likely to trade at a premium to those of vulnerable ones over time.

Assessing resilience

Our analysis shows climate-related risks are real and growing for the municipal bond market. This suggests long-term climate predictions should be taken into account when assessing an issuer's debt structure. And it makes it increasingly important for investors to look at the preparedness of states and municipalities when assessing their creditworthiness.

Some issuers are tapping the green bond market to fund mitigation efforts. Columbia, South Carolina, for example, recently issued the first tranche of a $95 million project to shore up its stormwater drainage system. How to gauge if such efforts are sufficient? Among the key questions we believe investors should be asking:

- Does the issuer have long-term plans – and the financial capacity to finance projects that increase resilience against climate risks?
- Do local ordinances or policies encourage inefficient rebuilding (in vulnerable areas) after storm hits?
- Is insurance coverage adequate for the most relevant risks?
- Do water and sewer utilities have plans in place for droughts and floods?
- Is the local economy diversified enough to absorb climate-related shocks?

Limited disclosure on such plans is one of the challenges investors face. This challenge cuts across asset classes. Providing a disclosure framework is a key goal of the TFCD described on page 8.

We believe our work connecting climate data and assets forms a starting point for assessing the risks. Pinpointing areas that are likely to expect the greatest climate impacts in coming decades can inform asset allocation and security selection decisions. And we see potential to use similar techniques to shine a light on climate risks faced by sovereign issuers, including emerging markets. Bottom line: Climate risk exposure analysis can help assess vulnerabilities of U.S. municipal issuers. We see this as a useful risk-management tool – and a valuable starting point for institutional investors to engage with issuers about their mitigation and adaptation measures.

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Commercial real estate

Extreme weather and other climate-related events pose a risk to commercial real estate. We zoom in on hurricane and flood risk and estimate potential losses to the sector.

Climate-related risks are a growing concern for owners of commercial mortgage backed securities. Assets underlying CMBS loans – such as office buildings, retail properties and lodging – can have lifespans of several decades, subjecting them to climate risks that are set to intensify over time. Many assets underpinning CMBS portfolios are located in regions that are vulnerable to the increasing incidence of severe storms. Case in point: New York, Houston and Miami alone made up one-fifth of CMBS properties by market value in the Bloomberg Barclays Aggregate Index, as of March 2019.

Two hurricanes in 2017 illuminated these risks:

- Hurricane Harvey, a Category 4 storm that hit the Houston area, affected over 1,300 CMBS loans. This was roughly 3% of the market as of late 2017, based on our estimates that overlaid impacted properties on to FEMA flood zone maps. Irma, a Category 4 storm that made landfall in Florida, affected almost 1,000 CMBS loans, or 2% of the CMBS universe.
- Some 80% of the commercial properties damaged in both storms, according to our analysis, lay outside official flood zone maps. This indicates they could have had insufficient flood insurance.

Hurricanes pose big risks to commercial property in the form of extreme winds (from blown windows to structural damage) and flooding (damage to basements and electrical systems). Category 4 and 5 wind speeds, in particular, can create outsized damage to properties. These risks are already a reality.

To illustrate, we overlaid Rhodium's hurricane modeling onto the U.S. CMBS market, as proxied by roughly 60,000 commercial properties in BlackRock's proprietary CMBS database. The median risk of one of these properties being hit by a Category 4 or 5 hurricane has risen by 137% since 1980, we found. Within three decades, the risk of being hit by a Category 5 hurricane is projected to rise 275% under a "no climate action" scenario. See the *Stormy weather* chart.

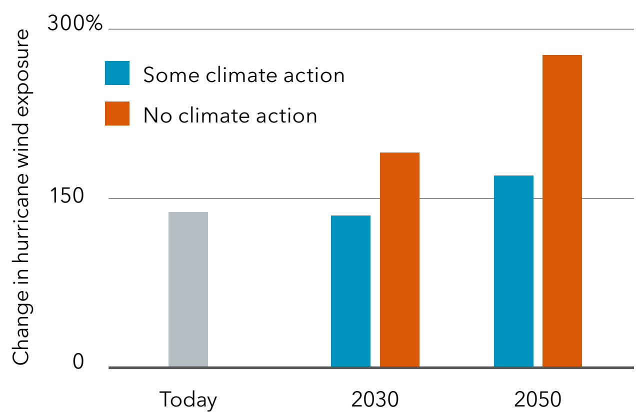
275% Rise in Category 4/5 hurricane risk by 2050

The risks to the CMBS market posed by rising average temperatures are varied, and go beyond the direct physical damages from storms and floods. They include:

- Higher insurance premiums or decreased insurance coverage.
- Rising operational costs such as energy use for air cooling systems.
- Greater capex needs to make buildings more resilient (think of backup generators, water-pumping systems and reinforcement of building exteriors).
- Increased delinquencies as tenants default or walk away from properties after extreme weather events.
- Potential hits to valuations and declining liquidity of properties in vulnerable areas.

Stormy weather

Change in Category 4/5 hurricane wind exposure since 1980



Sources: BlackRock Investment Institute, with data from Rhodium Group, March 2019. Notes: The chart shows the change in median hurricane wind exposure in the CMBS market, represented by around 60,000 commercial properties in BlackRock's CMBS database. The bars represent the estimated change in the median probability of Cat 4 or 5 hurricane winds touching properties relative to 1980 under "no climate action" and "some climate action" scenarios. "Today" is a 2010–2030 estimate. We use the Saffir-Simpson Wind Scale ("Cat" 1–5) to rate hurricane wind speed. Wind fields are estimated by Rhodium using the LICRICE wind field model. For details see S. Hsiang and A. Jina, *"The Causal Effect of Environmental Catastrophe on Long-Run Economic Growth: Evidence From 6,700 Cyclones,"* NBER Working Paper, Jul. 2014.

Focus on flooding

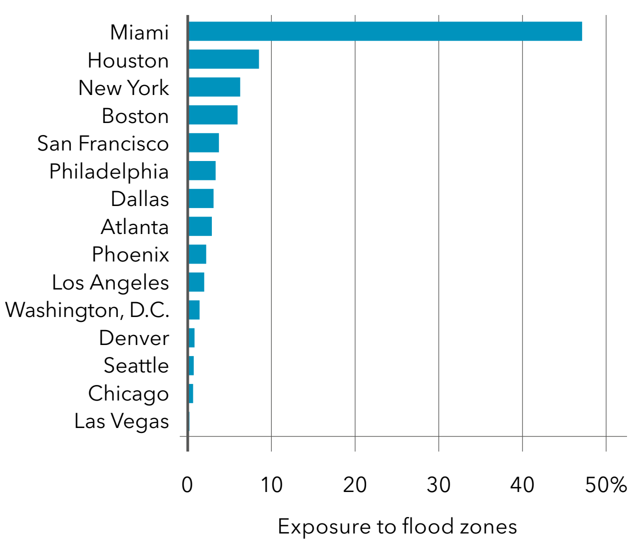
Borrowers contributing assets to CMBS deals are required to have wind insurance as part of their broader "hazard insurance." This does not cover flood risk. Flood insurance is required only if the commercial property is located within FEMA-designated flood zones.

To estimate the official footprint of the flood hazard, we mapped 60,000 properties in our CMBS universe onto FEMA flood maps, using an algorithm that sorted through 830,000 geospatial blocks across the U.S. Based on our analysis, around 6% of the properties in the CMBS market lie in FEMA flood zones. This percentage varies greatly by region. Miami tops the exposures, with almost half of commercial properties situated in flood zones. See the *Flood water* chart.

Recent hurricanes hitting cities such as Houston suggest FEMA flood maps understate true risks. And flood risk is set to intensify. Based on our mapping of the CMBS universe onto Rhodium's data, the number of properties subject to 1% or more storm surge risk per annum would rise by 1800% by 2060–2080 under "no climate action." To be sure, many commercial real estate sponsors take out flood insurance even when properties lie outside flood zones. Yet such insurance may not always be available, and "uninsured" flood exposure is set to rise.

Flood water

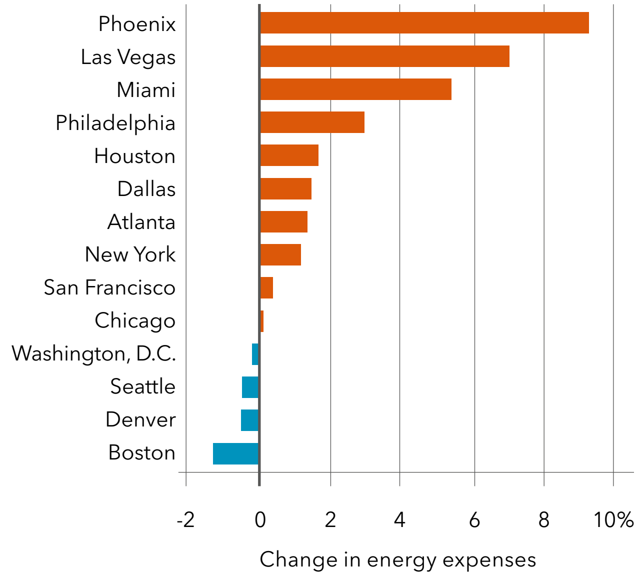
U.S. CMBS market exposure to official flood zones, 2019



Sources: BlackRock Investment Institute, with data from FEMA and BlackRock's CMBS property database, March 2019. Notes: The chart shows the market value share of properties in the U.S. CMBS market that lie within FEMA-designated flood zones in selected U.S. urban centers. We use BlackRock's CMBS property database, containing around 60,000 underlying commercial properties, as a proxy for the CMBS market.

Rising bills

Impact of climate change on energy expenses, 2060–2080



Sources: BlackRock Investment Institute, with data from Rhodium Group, 2019. Notes: The analysis assumes a "no climate action" scenario and takes the upper bound of the 66%, or "likely" range, to illustrate a plausible risk scenario.

Energy or utility expenses make up around 15% of operating expenses for commercial buildings, according to our analysis of 100,000 property financial records. Rising temperatures could inflate these bills. Based on Rhodium's data, energy expenses would rise by up to 9% (Phoenix) under "no climate action." See the *Rising bills* chart. These estimates likely underestimate the costs, as they do not account for electricity rate rises.

What impact could this have on property cash flows and commercial loan defaults? We used an illustrative CMBS model to estimate changes in default rates on commercial mortgages in the Bloomberg Barclays Aggregate Index. Our inputs: CMBS properties' current financials and Rhodium's estimated GDP changes by MSA over 2060–2080 under "no climate action." We then projected the impact on key real estate metrics such as vacancies, rents and tenant renewals. The result: The average expected loss rate on CMBS deals would rise to 3.8% from 3.2% absent the climate-related impact. Defaults and losses would be higher in areas of greatest impact. The estimates do not include the direct financial damages caused by storm hits. More frequent storms may also inflate building maintenance and insurance costs, which by our calculation average roughly 20% in CMBS properties. Bottom line: Climate-related risks are significant today – and set to grow in the future.

Electric utilities

We find extreme weather events are not priced into the equities of U.S. electrical utilities – and introduce a climate risk exposure framework that can help uncover such risks.

Climate-related risks pose big challenges for the electric power sector. Aging infrastructure and older design standards leave power generating assets vulnerable to extreme weather events such as wildfires and hurricanes. Power outages as a result of such incidents pose broader risks to the economy – via lost productivity. They can also trigger capital losses for investors. Utilities can mitigate some of the risks via insurance, disaster recovery plans and physical hardening of facilities, but many companies are likely underprepared.

Are climate-related risks priced into the equities of electric utilities? We sought to find out. Our analysis starts by examining the geolocation of every U.S. electric power plant, as well as planned generation as reported to the U.S. Department of Energy. We plot the locations below, by fuel source, with the size of the bubbles indicating generation capacity. We then traced the ownership of the 4,500 power plants that were publicly owned, aggregating them into a hypothetical portfolio of 269 traded utility companies.

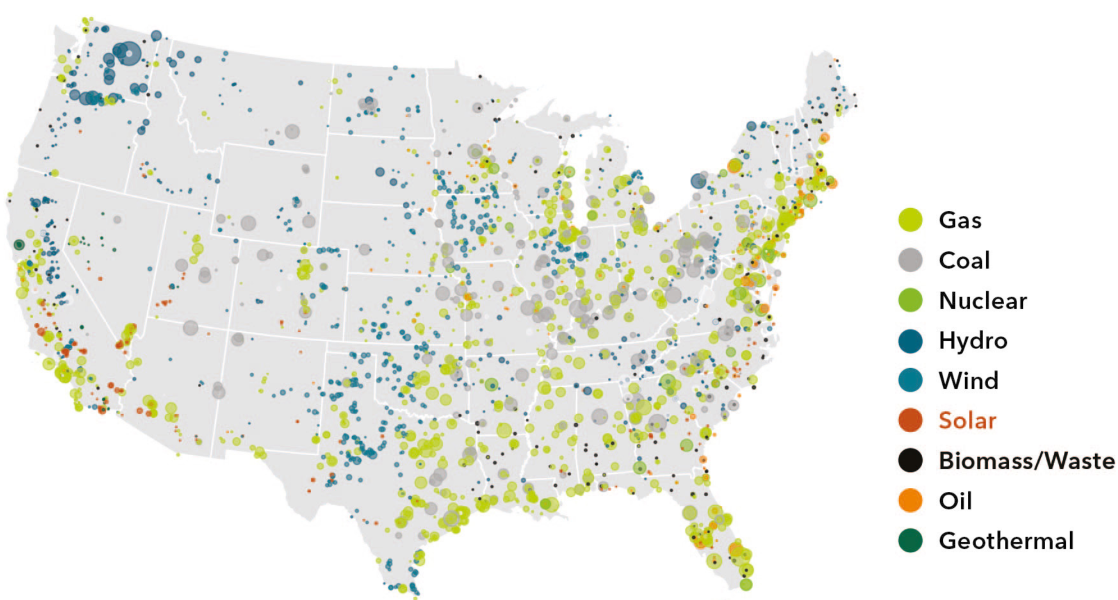
Our analysis divides weather events into two types of shocks: acute shocks with immediate impact, such as hurricanes and wildfires; and chronic events such as high temperatures, flooding and droughts.

Acute climate shocks have the most severe direct physical impact, such as damage to generating facilities. Chronic events tend to play out over longer time periods and wider areas of impact. Droughts, for example, affect thermal coal-fired or nuclear plants that require cooling water drawn from rivers or reservoirs. Declining intake water levels can hurt plant efficiency, or even trigger temporary shutdowns that cause financial losses.

Our historical study included 233 extreme weather events across the United States – those causing more than $1 billion in damages as estimated by the NOAA – dating back as far as 1980. We choose first to zoom in on hurricanes. These made up roughly 15% of these historical events – and have typically caused the most damage.

Sources of power

U.S. electric utility plants by fuel source, 2019



Sources: BlackRock Investment Institute and BlackRock Sustainable Investing, with data from EIA, March 2019. Notes: The chart plots the location of more than 8,000 U.S. electric power plants, as well as planned generation as reported to the U.S. Department of Energy. The bubbles are sized in proportion to each site's power generation capacity.

Not priced

Our hypothesis: Extreme weather risks already threaten utility stocks – and are set to rise in frequency and intensity over time – but are not fully priced in. To measure this embedded risk, we evaluate the impact on company valuation that results from an extreme weather event. If investors believe utilities have fully mitigated their exposure to climate-related risks, then stock prices should not react to the event. Our methodology:

1. Determine an "epicenter" location and the day of occurrence ("day zero"). For hurricanes, this was the date and location where the storm made landfall.
2. Establish a zone of influence; this is 300 kilometers for a hurricane (the average radius).
3. Isolate the power plants operating in the affected zone and the listed parent companies that own them. Calculate the megawatt capacity of each affected power plant as a share of that utility's total generative capacity. This gives us a proxy for the revenue of each company that may be disrupted.
4. Create a hypothetical portfolio of the affected companies, weighted in proportion to the percentage of revenues affected.
5. Study the financial impact of the weather event on stock prices and volatility.

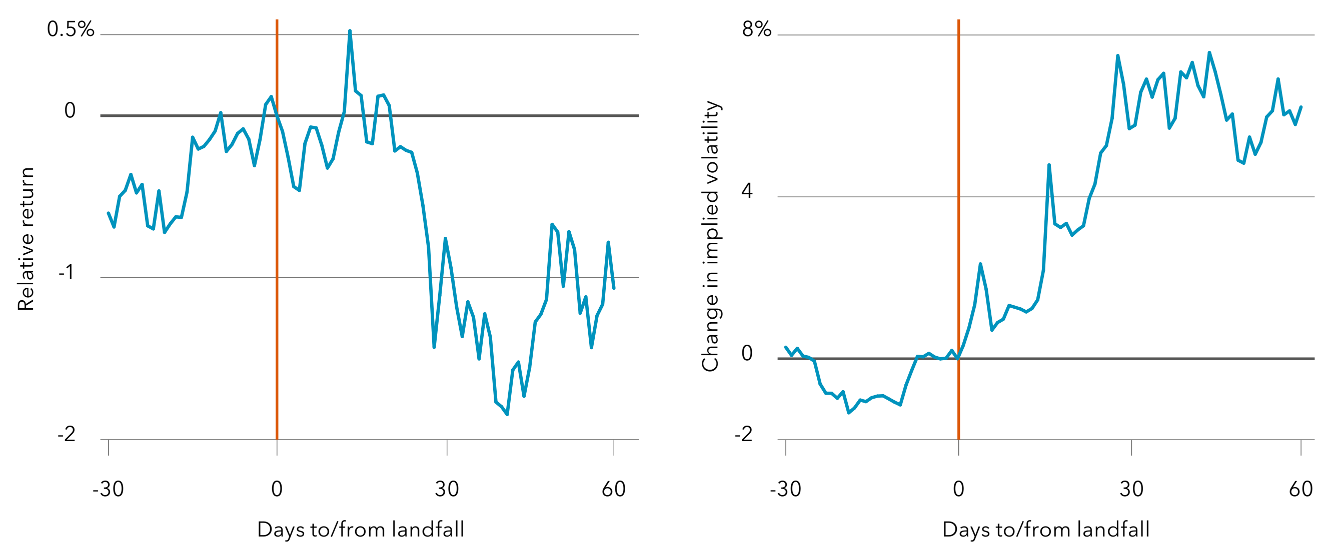
We first investigated if hurricane impacts had a broad effect on the utility sector by analyzing the price response of the S&P Utility Index around such events. We found no discernable impact on prices. Next, we studied the price and volatility impacts from hurricanes on the affected utilities and found the following results:

- Stock prices typically come under pressure for a period of about 40 days after the event – and incur a loss of about 1.5% relative to the sector index.
- The implied volatility of options on impacted utilities increases by about 6 percentage points in the 30 days after impact.
- After a short period, stock returns tend to converge back toward industry averages, while volatility eases from peaks. See the *Storm shock* charts.

Our analysis told a similar story for wildfires, albeit with more muted price effects. What does all of this tell us? Investor reaction ahead of forecasted hurricanes is muted because the exact location of landfall – and the power plants that will be affected – are not known with certainty. After the event, investors sell stocks of affected utilities, reflecting concern that the true economic losses are not fully known. The swift recovery of utility stocks suggests investors perceive an "over-reaction" to the hurricane impacts – and eventually "forget" the event.

Storm shock

Stock price and volatility reaction of U.S. electric utility equities around hurricanes, 1980–2019



Sources: BlackRock Investment Institute and BlackRock Sustainable Investing, with data from Bloomberg and NOAA, March 2019. Notes: Our study includes all hurricanes in the NOAA's database since 1980. Day zero is the day of each hurricane landfall. We isolate the power plants within 300 km from the location of the landfall, and identify their parent companies. We then form a hypothetical portfolio of affected companies, weighted in proportion to their revenues affected as implied by their generation capacity as a share of the total capacity of the group. We compare the total return of this hypothetical portfolio to the S&P 500 Utilities Index to arrive at the relative return. Implied volatility is calculated from the OptionMetrics database.

Scoring utilities

Our next step: Developing a framework to estimate the climate risk exposures of publicly traded utilities, in a bid to quantify hidden risks for investors. We do this by combining the exposure to extreme weather at each power plant location with an assessment of the materiality of that exposure, based on historical losses and forward-looking climate modeling. For details, see ***Climate Risk in the U.S. Electric Utility Sector: A case study***, by A. Bertolotti, D. Basu and K. Akallal (2019).

Note: Our analysis is plant-centric. It does not account for potential damages to transmission and distribution networks; liability risks; or increased capex needs over time as increased energy demand for cooling burdens grids with higher peak loads in summertime. We assign each type of weather event a relative impact score on a 1-10 scale. Hurricanes sit at the top of this scale, posing direct physical threats to generating plants and water intake structures. See the *Risk by risk; plant by plant* table below. The potential impact of climate events on power plants varies not only by location but also by the fuel source. Example: Wind energy is vulnerable to variations in wind patterns caused by severe storms. Solar energy, by contrast, is more exposed to extreme heat, which curbs the efficiency of photovoltaic panels.

We reflect these nuances by assigning a weight to each type of weather event by fuel source. We see gas (35% of total U.S. generation capacity according to 2018 EIA data) and coal-fired power plants (27%) as exposed to a broader swath of climate risks, including wildfires, high temperatures, floods and drought.

High temperatures, defined as days with a maximum temperature above 95°F (32°C), pose a meaningful risk to almost all types of fuel sources across the U.S. – and are often associated with other types of weather shocks such as wildfires.

For wind energy (representing around 7% of U.S. generating capacity) we assign a high risk weight to hurricanes – the main material climate risk we see for this fuel source. Wind turbines are typically designed to cut out in extreme wind, to prevent damage to rotors.

For hydroelectric power plants, hurricanes, droughts (drops in reservoir levels reduce generation efficiency) and floods (potential structural damage) are the greatest risks in our framework.

Our work with Rhodium suggests the type of extreme weather events detailed below are likely to intensify in frequency and magnitude in the decades ahead. This means investors need to start assessing the risks today.

Risk by risk; plant by plant

BlackRock's climate risk exposure framework for electric utilities

	Extreme weather event	Hurricanes	Wildfires	High temperatures	Floods	Droughts
	Relative impact (1-10 scale)	10	7	5	4	4
		Weight of extreme weather exposure (%)				
Fuel source	Gas (35% of U.S. generation capacity)	38	13	19	15	15
Fuel source	Coal (27%)	38	13	19	15	15
Fuel source	Nuclear (19%)	38	13	19	15	15
Fuel source	Hydro (7.0%)	26	18	13	21	21
Fuel source	Wind (6.6%)	63	22	16	0	0
Fuel source	Solar (1.6%)	49	17	24	10	0
Fuel source	Geothermal (0.4%)	44	16	22	18	0

Sources: BlackRock's Sustainable Investing and BlackRock Investment Institute, with data from EIA, U.S. Department of Energy, Rhodium Group and Verisk Maplecroft, March 2019. Notes: The table illustrates how we combine plant-level climate exposure scores into a single parent company exposure score. "Relative impact" shows BlackRock's assessment of the financial materiality of each type of extreme weather event, on a scale of 1–10, with 10 being the most material. Impact scores are based on historical loss rates. We then determine which type of weather events are most material for each fuel source. Weather events that pose direct risks to a particular fuel source are assigned a weight of 1; those posing indirect risks are given a weight of 0.5; and those with no impact are assigned a zero weight. We multiply these impact weights by the relative impact score for each event type. The results are translated into percentage exposure weights that sum to 100 for each fuel source. Share of generation capacity figures are based on 2018 EIA data.

Putting it all together

We aggregate the average physical risk across all power plants to arrive at a total climate risk score for each utility. This enabled us to examine another key question: Do utilities with greater climate resilience trade at a premium? We examined the relationship between the climate scores of the utilities in our study with each companies' 10-year average price-to-earnings ratio. The result of this regression analysis: The most climate-resilient utilities tend to trade at a slight premium to their peers, while the most vulnerable carry a slight discount. We found similar results using price-to-book ratios. This gap may become more pronounced over time as weather events turn more extreme and frequent – and more investors factor climate change into their risk/return analysis.

There are limits to our scoring approach. It aggregates the average physical risk across all power plants for each utility. Yet catastrophic losses can occur if the financial impacts caused to or by a single power plant extend beyond the damages to the actual plant. This was the case for a California utility in 2018, when the liabilities from fires caused by its equipment crippled the company. See the *How exposed is my power plant?* map below for a geographic representation of our climate risk scores by power plant.

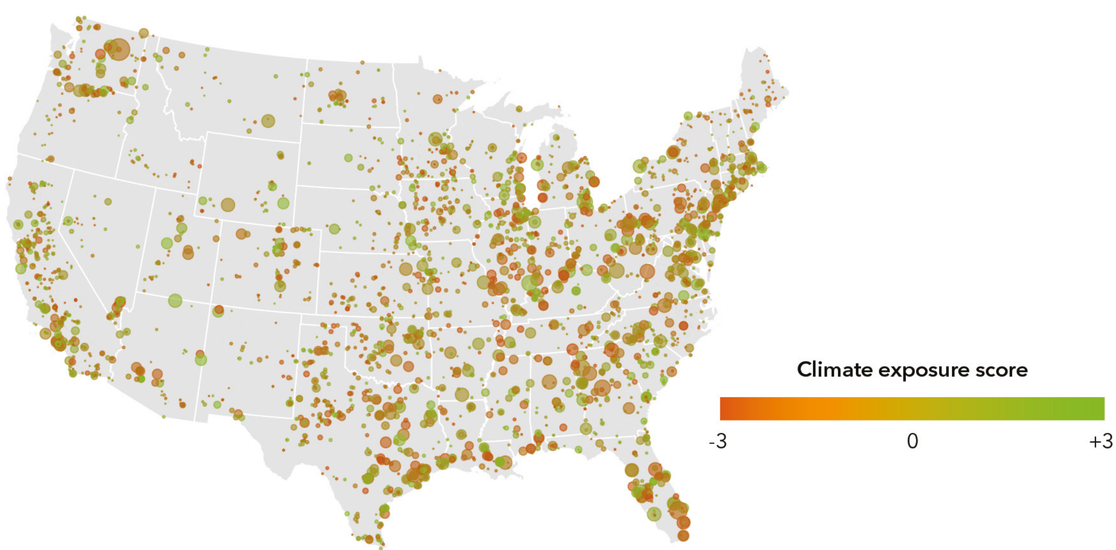
How can investors use this information? Two potential applications:

1. **Risk management:** Geolocating power plants and determining their physical climate exposure allows utilities investors to better assess their exposures – and any concentration of risk to a particular type of extreme weather event. Geographic diversification can help offset these risks, since the most acute climate risks tend to strike in specific locations.
2. **Engagement:** Are companies doing enough to mitigate the rising risk of financial damage from climate events? Are their capex plans aligned? Granular analysis of the risks facing a particular utility – reflected in our risk exposure scores – can form the basis for larger investors to engage with corporate management teams on issues of concern.

We conclude that climate-related risks are real for utilities, but mostly not priced in. This has important implications. Overweighting companies with low climate risk exposure and underweighting those with high exposure may pay off as the risks compound over time. Investors also will need to include climate-related risks in their analysis of financial risks and opportunities. This is most relevant for long-term investors, as the probability of experiencing more frequent and intense extreme weather rises the longer a position is held.

How exposed is my power plant?

BlackRock Climate Exposure Scores for U.S. power plants, 2019



Sources: BlackRock Investment Institute, with data from Rhodium Group, Verisk Maplecroft and U.S. Department of Energy, 2019.
Notes: The chart plots the location of each U.S. electric power plant and is color coded according to BlackRock's assessment of its climate exposure, according to the framework presented on page 17. For illustrative purposes only. Risk is expressed in standard deviations. A score of -3 (high climate risk) points to an exposure that is three standard deviations worse than the mean exposure of the plants in our study.

RELATED RESOURCES FROM BLACKROCK

Adapting portfolios to climate change, September 2016
https://www.blackrock.com/corporate/literature/whitepaper/bii-climate-change-2016-us.pdf

BlackRock ESG Investment Statement, July 2018
https://www.blackrock.com/corporate/literature/publication/blk-esg-investment-statement-web.pdf

BlackRock Mission Statement on Sustainability, 2018
https://www.blackrock.com/corporate/literature/publication/blk-sustainability-mission-statement-web.pdf

BlackRock's Approach to Sustainability, 2018
https://www.blackrock.com/corporate/responsibility

Exploring ESG: A practitioner's perspective, June 2016
https://www.blackrock.com/investing/literature/whitepaper/viewpoint-exploring-esg-a-practitioners-perspective-june-2016.pdf

Sustainability: the future of investing, January 2019
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The Investment Stewardship Ecosystem, July 2018
https://www.blackrock.com/corporate/literature/whitepaper/viewpoint-investment-stewardship-ecosystem-july-2018.pdf

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Bertolotti, Andre, Debarshi Basu, Kenza Akallal and Brian Deese. "Climate Risk in the US Electric Utility Sector: A case study." Available at SSRN: ***https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3347746***

Deschênes, Olivier and Michael Greenstone. "***Climate Change, Mortality, and Adaptation: Evidence from Annual Fluctuations in Weather in the US***." American Economic Journal: Applied Economics, Vol. 3, No. 4, October 2011

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Rhodium Group (March 2019). "***Clear, Present and Underpriced: The Physical Risks of Climate Change***."

Schlenker, Wolfram and Michael J. Roberts. **"*Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change***." Proceedings of the National Academy of Sciences of the United States of America, Sept. 15, 2009

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