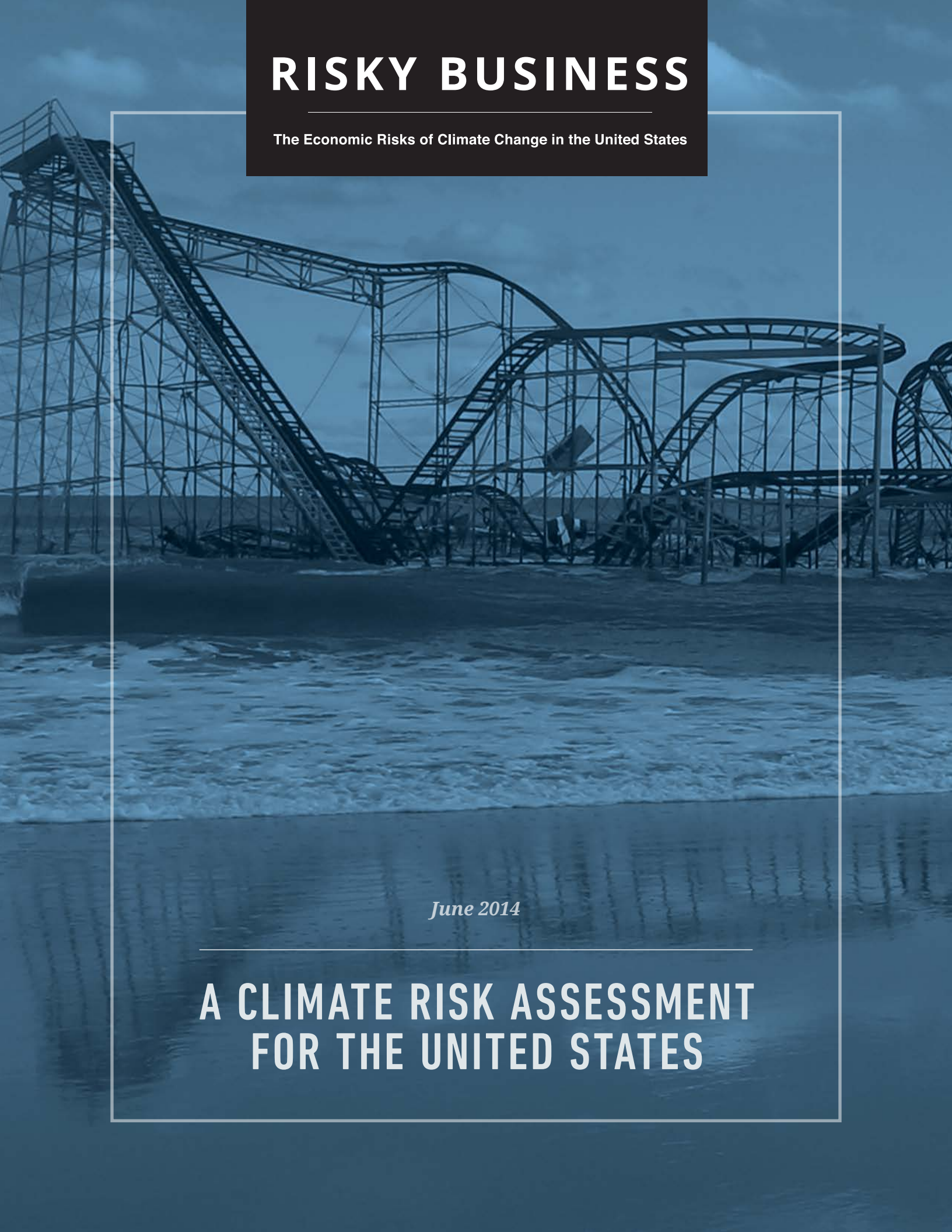
RISKY BUSINESS

The Economic Risks of Climate Change in the United States



June 2014

A CLIMATE RISK ASSESSMENT FOR THE UNITED STATES

RISKY BUSINESS: The Economic Risks of Climate Change in the United States

A Product of the Risky Business Project:

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Lead Authors Kate Gordon, Executive Director of the Risky Business Project, drawing from independent research commissioned by the Risky Business Project. Special thanks to Matt Lewis, Risky Business Project Communications Director, and Jamesine Rogers, Risky Business Project Manager, for their editorial support.

Research Risky Business Project co-chairs Michael R. Bloomberg, Henry Paulson, and Tom Steyer tasked the Rhodium Group, an economic research firm that specializes in analyzing disruptive global trends, with an independent assessment of the economic risks posed by a changing climate in the U.S. Rhodium convened a research team co-led by Dr. Robert Kopp of Rutgers University and economist Dr. Solomon Hsiang of the University of California, Berkeley. Rhodium also partnered with Risk Management Solutions (RMS), the world's largest catastrophe-modeling company for insurance, reinsurance, and investment-management companies around the world. The team leveraged recent advances in climate modeling, econometric research, private sector risk assessment, and scalable cloud computing (processing over 20 terabytes of climate and economic data) to provide decision-makers with empirically-grounded and spatially-explicit information about the climate risks they face. The team's complete assessment, along with technical appendices, is available at Rhodium's website, **climateprospectus.rhg.com**. Interactive maps and other content associated with the Risky Business Project are located at **riskybusiness.org**.

The research team's work was reviewed by an independent Risky Business Expert Review Panel composed of leading climate scientists and economists. A full list of the expert review panel is available on Rhodium's website.

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EXECUTIVE SUMMARY

> *Damages from storms, flooding, and heat waves are already costing local economies billions of dollars—we saw that firsthand in New York City with Hurricane Sandy. With the oceans rising and the climate changing, the Risky Business report details the costs of inaction in ways that are easy to understand in dollars and cents—and impossible to ignore.*
>
> **— Risky Business Project Co-Chair Michael R. Bloomberg** [1]

The U.S. faces significant and diverse economic risks from climate change. The signature effects of human-induced climate change—rising seas, increased damage from storm surge, more frequent bouts of extreme heat—all have specific, measurable impacts on our nation's current assets and ongoing economic activity.

To date, there has been no comprehensive assessment of the economic risks our nation faces from the changing climate. *Risky Business: The Economic Risks of Climate Change to the United States* uses a standard risk-assessment approach to determine the range of potential consequences for each region of the U.S.—as well as for selected sectors of the economy—if we continue on our current path. The Risky Business research focused on the clearest and most economically significant of these risks: **Damage to coastal property and infrastructure from rising sea levels and increased storm surge, climate-driven changes in agricultural production and energy demand, and the impact of higher temperatures on labor productivity and public health.**

Our research combines peer-reviewed climate science projections through the year 2100 with empirically-derived estimates of the impact of projected changes in temperature, precipitation, sea levels, and storm activity on the U.S. economy. We analyze not only those outcomes most likely to occur, but also lower-probability

high-cost climate futures. Unlike any other study to date, we also provide geographic granularity for the impacts we quantify, in some cases providing county-level results.

Our findings show that, if we continue on our current path, many regions of the U.S. face the prospect of serious economic effects from climate change. However, if we choose a different path—if we act aggressively to both adapt to the changing climate and to mitigate future impacts by reducing carbon emissions—we can significantly reduce our exposure to the worst economic risks from climate change, and also demonstrate global leadership on climate.

Climate Change: Nature's Interest-Only Loan

Our research focuses on climate impacts from today out to the year 2100, which may seem far off to many investors and policymakers. But climate impacts are unusual in that future risks are directly tied to present decisions. Carbon dioxide and other greenhouse gases can stay in the atmosphere for hundreds or even thousands of years. Higher concentrations of these gases create a "greenhouse effect" and lead to higher temperatures, higher sea levels, and shifts in global weather patterns. The effects are cumulative: By not acting to lower

SHORT-TERM CLIMATE THREATS

The American economy is already beginning to feel the effects of climate change. These impacts will likely grow materially over the next 5 to 25 years and affect the future performance of today's business and investment decisions in the following areas:

Coastal property and infrastructure. **Within the next 15 years, higher sea levels combined with storm surge will likely increase the average annual cost of coastal storms along the Eastern Seaboard and the Gulf of Mexico by $2 billion to $3.5 billion. Adding in potential changes in hurricane activity, the likely increase in average annual losses grows to up to $7.3 billion, bringing the total annual price tag for hurricanes and other coastal storms to $35 billion.**

Agriculture. **A defining characteristic of agriculture in the U.S. is its ability to adapt. But the adaptation challenge going forward for certain farmers in specific counties in the Midwest and South will be significant. Without adaptation, some Midwestern and Southern counties could see a decline in yields of more than 10% over the next 5 to 25 years should they continue to sow corn, wheat, soy and cotton, with a 1-in-20 chance of yield losses of these crops of more than 20%.**

Energy. **Greenhouse gas-driven changes in temperature will likely necessitate the construction of up to 95 gigawatts of new power generation capacity over the next 5 to 25 years—the equivalent of roughly 200 average coal or natural gas-fired power plants—costing residential and commercial ratepayers up to $12 billion per year.**

greenhouse gas emissions today, decision-makers put in place processes that increase overall risks tomorrow, and each year those decision-makers fail to act serves to broaden and deepen those risks. In some ways, climate change is like an interest-only loan we are putting on the backs of future generations: They will be stuck paying off the cumulative interest on the greenhouse gas emissions we're putting into the atmosphere now, with no possibility of actually paying down that "emissions principal."

Our key findings underscore the reality that if we stay on our current emissions path, our climate risks will multiply and accumulate as the decades tick by. These risks include:

- **Large-scale losses of coastal property and infrastructure**
  - » If we continue on our current path, by 2050 between $66 billion and $106 billion worth of existing coastal property will likely be below sea level nationwide, with $238 billion to $507 billion worth of property below sea level by 2100.
  - » There is a 1-in-20 chance—about the same chance as an American developing colon cancer; twice as likely as an American developing melanoma[2]—that by the end of this century, more than $701 billion worth of existing coastal property will be below mean sea levels, with more than $730 billion of additional property at risk during high tide. By the same measure of probability, average annual losses from hurricanes and other coastal storms along the Eastern Seaboard and the Gulf of Mexico will grow by more than $42 billion due to sea level rise alone. Potential changes in hurricane activity could raise this figure to $108 billion.
  - » Property losses from sea level rise are concentrated in specific regions of the U.S., especially on the Southeast and Atlantic coasts, where the rise is higher and the losses far greater than the national average.
- **Extreme heat across the nation—especially in the Southwest, Southeast, and Upper Midwest—threatening labor productivity, human health, and energy systems**
  - » By the middle of this century, the average American will likely see 27 to 50 days over 95°F each year—two to more than three times the average annual number of 95°F days we've seen over the past 30 years. By the end of this century, this number will likely reach 45 to 96 days over 95°F each year on average.
  - » As with sea level rise, these national averages mask regional extremes, especially in the Southwest, Southeast, and upper Midwest, which will likely see several *months* of 95°F days each year.
  - » Labor productivity of outdoor workers, such as those working in construction, utility maintenance, landscaping, and agriculture, could be reduced by as much as 3%, particularly in the Southeast. For context, labor productivity across the entire U.S. labor force declined about 1.5% during the famous "productivity slowdown" in the 1970s.[3]
  - » Over the longer term, during portions of the year, extreme heat could surpass the threshold at which the human body can no longer maintain a normal core temperature without air conditioning, which we measure using a "Humid Heat Stroke Index" (HHSI). During these periods, anyone whose job requires them to work outdoors, as well as anyone lacking

access to air conditioning, will face severe health risks and potential death.

» Demand for electricity for air conditioning will surge in those parts of the country facing the most extreme temperature increases, straining regional generation and transmission capacity and driving up costs for consumers.

- **Shifting agricultural patterns and crop yields, with likely gains for Northern farmers offset by losses in the Midwest and South**

» As extreme heat spreads across the middle of the country by the end of the century, some states in the Southeast, lower Great Plains, and Midwest risk up to a 50% to 70% loss in average annual crop yields (corn, soy, cotton, and wheat), absent agricultural adaptation.

» At the same time, warmer temperatures and carbon fertilization may improve agricultural productivity and crop yields in the upper Great Plains and other northern states.

» Food systems are resilient at a national and global level, and agricultural producers have proven themselves extremely able to adapt to changing climate conditions. These shifts, however, still carry risks for the individual farming communities most vulnerable to projected climatic changes.

The Risky Business Project is designed to highlight climate risks to specific business sectors and regions of the economy, and to provide actionable data at a geographically granular level for decision-makers. It is our hope that it becomes standard practice for the American business and investment community to factor climate change into its decision-making process. We are already seeing this response from the agricultural and national security sectors; we are starting to see it from the bond markets and utilities as well. But business still tends to respond only to the extent that these risks intersect with core short term financial and planning decisions.

We also know that the private sector does not operate in a vacuum, and that the economy runs most smoothly when government sets a consistent policy and a regulatory framework within which business has the freedom to operate. Right now, cities and businesses are scrambling to adapt to a changing climate without sufficient federal government support, resulting in a virtual "unfunded mandate by omission" to deal with climate at the local level.[4] We believe that American businesses should play an active role in helping the public sector determine how best to react to the risks and costs posed by climate change, and how to set the rules that move the country forward in a new, more sustainable direction.

With this report, we call on the American business community to rise to the challenge and lead the way in helping reduce climate risks. We hope the Risky Business Project will facilitate this action by providing critical information about how climate change may affect key sectors and regions of our national economy.

This is only a first step, but it's a step toward getting America on a new path leading to a more secure, more certain economic future.

New York Stock Exchange underwater after Hurricane Sandy

INTRODUCTION

Americans understand risk. Our ability to evaluate risk—to take calculated plunges into new ventures and economic directions and to innovate constantly to bring down those risks—has contributed immensely to the nation's preeminence in the global economy. From the private sector's pioneering venture-capital financing model to the government's willingness to invest in early-stage inventions like the computer chip or the solar panel, our nation's ability to identify and manage potential risks has moved the economy forward in exciting and profitable directions.

The Risky Business Project is designed to apply risk assessment to the critical issue of climate change, and to take a sober, fact-based look at the potential risks facing specific sectors and regions of the national economy. As in a classic business risk assessment, we analyzed not only the most likely scenarios, but also the scenarios that, while less likely, could have more significant impacts.

Our conclusion: The American economy faces multiple and significant risks from climate change. Climate conditions vary dramatically across the U.S., as does the mix of economic activity. Those variations will benefit our economic resilience to future climatic changes. But each region of the country has a different risk profile and a different ability to manage that risk. There is no single top-line number that represents the cost of climate change to the American economy as a whole: We must take a regional approach to fully understand our climate risk.

Given the range and extent of the climate risks the American economy faces, it is clear that staying on our current path will only increase our exposure. The U.S. climate is paying the price today for business decisions made many years ago, especially through increased coastal storm damage and more extreme heat in parts of the country. Every year that goes by without a comprehensive public and private sector response to climate change is a year that locks in future climate events that will have a far more devastating effect on our local, regional, and national economies. Moreover, both government and the private sector are making investment decisions today—whether in property, long-term infrastructure or regional and national supply chains—that will be directly affected by climate change in decades to come.

Road washed away by extreme flood in Jamestown, Colorado

Our assessment finds that, if we act now, the U.S. can still avoid most of the worst impacts and significantly reduce the odds of costly climate outcomes—but only if we start changing our business and public policy practices today.

The Risky Business Project does not dictate the solutions to climate change; while we fully believe the U.S. can respond to these risks through climate preparedness and mitigation, we do not argue for a specific set or combination of these policies. Rather, we document the risks and leave it to decision-makers in the business and policy communities to determine their own tolerance for, and specific reactions to, those risks.

A couple is rescued from their home on Galveston Island, Texas, after a hurricane

UNDERSTANDING CLIMATE RISK

> *I know a lot about financial risks—in fact, I spent nearly my whole career managing risks and dealing with financial crisis. Today I see another type of crisis looming: A climate crisis. And while not financial in nature, it threatens our economy just the same.*
>
> **— Risky Business Project Co-Chair Henry Paulson [5]**

In order to know how to best respond to climate change, we first need to fully understand the risks it presents. This is our core principle. As Risky Business Project Co-Chair Michael Bloomberg observes, "If you can't measure it, you can't manage it."[6]

Assessing and managing risk is how businesses, militaries and governments are able to remain productive and successful in an increasingly complex, volatile, and unpredictable global economy.

DEFINING RISK

The risk of a future event can be described as *the probability (or likelihood) of that event combined with the severity of its consequences.* The combination of likelihood and severity determines whether a risk is high or low. For instance, a highly likely event with minimal consequences would register as a moderate risk; a low probability event, if it has potentially catastrophic impacts, could constitute a significant risk. These low-probability/high-impact risks are generally referred to as "tail risks."

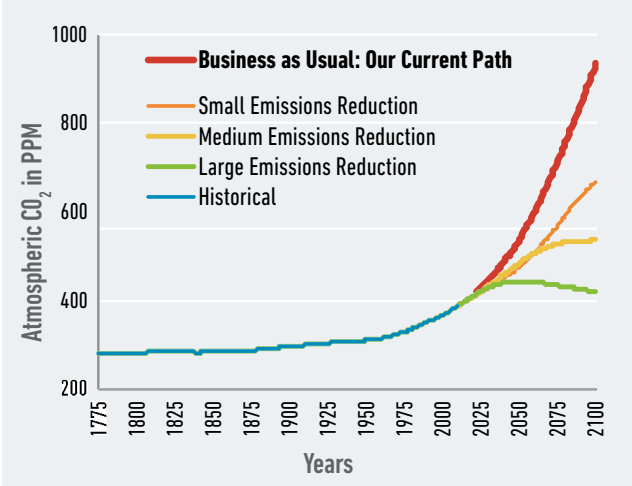
The Risky Business assessment evaluates a range of economic risks presented by climate change in the U.S., including both those outcomes considered most likely to occur and lower probability climate futures that would be either considerably better or considerably worse than the likely range. This is a common risk assessment approach in other areas with potentially catastrophic outcomes, including disaster management, public health, defense planning, and terrorism prevention.

In presenting our results we use the term *"likely"* to describe outcomes with at least a 67% (or 2-in-3) chance of occurring. In discussing tail risks, we generally describe results as having a *1-in-20* chance (or 5%) of being worse than (or better than) a particular threshold. Where the science allows it, we also describe *1-in-100* outcomes, or those with a 1% chance of occurring.

UNDERSTANDING CLIMATE RISK

The risk approach is well suited to the issue of climate change. Even the single term "climate change" is shorthand for a diverse array of impacts, mostly stemming from increased heat in the atmosphere and oceans, but also radiating outward in myriad and geographically diverse ways. For example, in some regions sea levels will likely rise, while in others they may actually fall. In some areas we will likely see increased droughts, whereas in others the combination of heat and humidity could lead to physically unbearable outdoor conditions, with increased risk of heat stroke for the many Americans who work outdoors in sectors such as construction, utility maintenance, transportation, and agriculture.

Figure 1: Global Emissions Scenarios



Our research examines the risks of the U.S. continuing on its current path, or "business as usual." Alternate pathways that include investments in adaptation or policy efforts to mitigate climate change through lowering carbon emissions could significantly reduce these risks.

Data Source: Rhodium Group

Moreover, all these conditions can and will change based on the actions we take today and into the future, as well as on unknowable factors such as the precise rate of Arctic and Antarctic ice melt. Thus the "change" part of climate change is the crux of the matter: **To plan for climate change, we must plan for volatility and disruption.**[7]

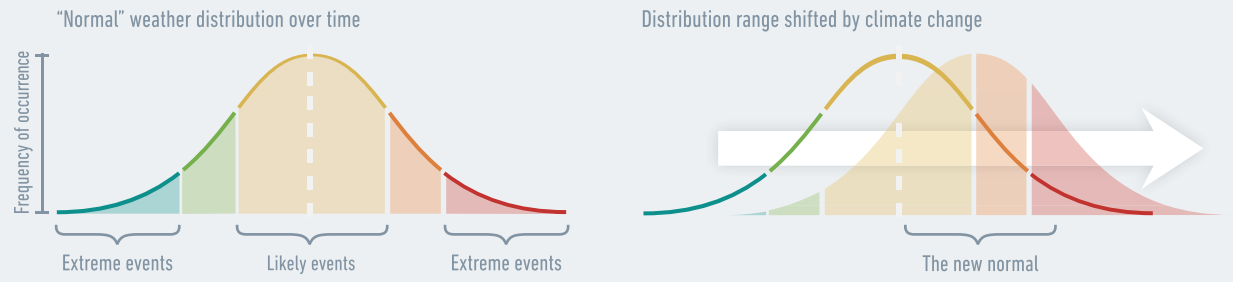
Risk assessment gives businesses a way to plan for change. From PricewaterhouseCoopers's 2008 primer, "A Practical Guide to Risk Assessment":

> The ability to identify, assess, and manage risk is often indicative of an organization's ability to respond and adapt to change. Risk assessment . . . helps organizations to quickly recognize potential adverse events, be more proactive and forward-looking, and establish appropriate risk responses, thereby reducing surprises and the costs or losses associated with business disruptions. This is where risk assessment's real value lies: in preventing or minimizing negative surprises and unearthing new opportunities.[8]

The Risky Business Project examines the risks of the U.S. continuing on its current path, or "business as usual." This assumes no new national policy or global action to mitigate climate change and an absence of investments aimed at improving our resilience to future climate impacts. Taking these policy and adaptive actions could significantly reduce the risks we face, as illustrated in Figure 1.

Our research analyzes the risks of "business as usual" to specific critical sectors of the economy and regions of the country. We focus in particular on sectors that are already making large, expensive investments in

Figure 2: How Extreme Weather Events Become the Norm



Human society is structured around "normal" weather, with some days hotter than average and some colder. At the distant "tails" are extreme events such as catastrophic weather. Climate change shifts the entire distribution curve to the right. Old extremes become the new normal, new extremes emerge, and the process continues until we take action.

Source: Risky Business

infrastructure that will likely last well into the future: **agriculture, energy, and coastal infrastructure.** We also look at the impact of climate change on America's **labor productivity and public health,** which influence multiple economic sectors. These latter impacts also are deeply connected to our shared future quality of life.

As with any risk assessment, our investigation looks at not only the most likely outcomes, but also climate futures that have a lower probability of occurring but particularly severe consequences should they come to pass. (See "Defining Risk" sidebar, p. 9.) This focus on "tail risks" is not unique to climate change. After all, households and businesses pay a premium for insurance to protect themselves against those tail risks, such as the possibility of flood or fire, that they deem unacceptable. The military plans for a wide range of possible (and sometimes highly unlikely) conflict scenarios, and public health officials prepare for pandemics of low or unknown probability.

When looking at climate change, it's particularly important to consider the outlier events and not just the most likely scenarios. Indeed, the "outlier" 1-in-100 year event today will become the 1-in-10 year event as the Earth continues to warm. Put another way, **over time the extremes will become the "new normal."**

> “Risk is like fire: If controlled it will help you; if uncontrolled it will rise up and destroy you.”
>
> *— Theodore Roosevelt*

RESULTS: RISKS VARY BY REGION & SECTOR

> *Talking about climate change in terms of U.S. averages is like saying, 'My head is in the refrigerator, and my feet are in the oven, so overall I'm average.'*
>
> **— Risky Business Project Co-Chair Tom Steyer** [9]

Our risk assessment begins with the straightforward fact that human-induced climate change leads to rising temperatures.

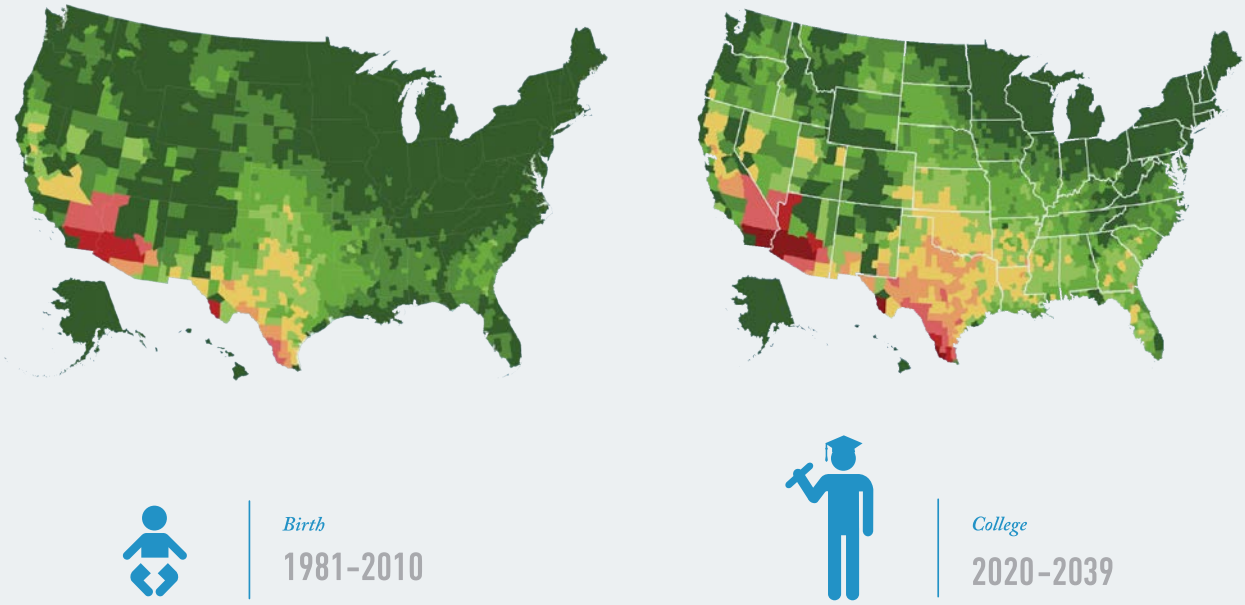
If we continue along our current path, with no significant efforts to curb climate change, the U.S. will likely see significantly more days above 95°F each year. By the middle of this century, the average American will likely see 26 to 50 days over 95°F each year—from double to more than triple the average number of 95°F days we've seen over the past 30 to 40 years. Climate change impacts only accelerate with time, so that by the end of this century we will likely see 45 to 96 days per year over 95°F. That's between one and a half and three months of the year at what are now considered record hot temperatures. To put this in context, by the end of the century, Oregon, Washington, and Idaho could well have more days above 95°F each year than there are currently in Texas.

These are only the most likely scenarios; there are possible lower and higher estimates outside the most likely range. Within that range, there are also disparities, of course: As the maps that follow demonstrate, some regions of the country will be far harder hit by extreme heat than others, and some will experience rising temperatures in terms of warmer winters rather than unbearable summers.

What matters isn't just the heat, it's the humidity—or, in this case, a dangerous combination of the two. One of the most striking findings in our analysis is that increasing heat and humidity in some parts of the country could lead to outside conditions that are literally unbearable to humans, who must maintain a skin temperature below 95°F in order to effectively cool down and avoid fatal heat stroke. The U.S. has never yet seen a day exceeding this threshold on what we call the "Humid Heat Stroke Index," but if we continue on our current climate path, this will change, with residents in the eastern half of the U.S. experiencing 1 such day a year on average by century's end and nearly 13 such days per year into the next century.

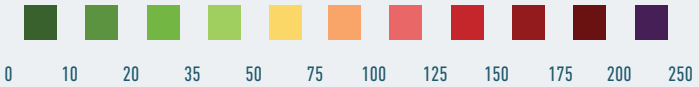
RESULTS: RISKS VARY BY REGION & SECTOR

Figure 3: Average Days Over 95°F: Projections Mapped Over a Lifetime



Heat Map Key:

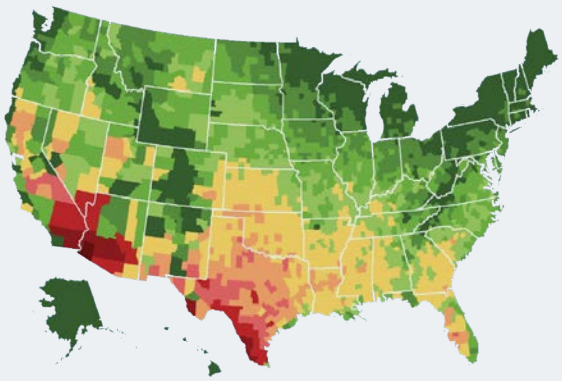
Average Days Per Year Over 95°F

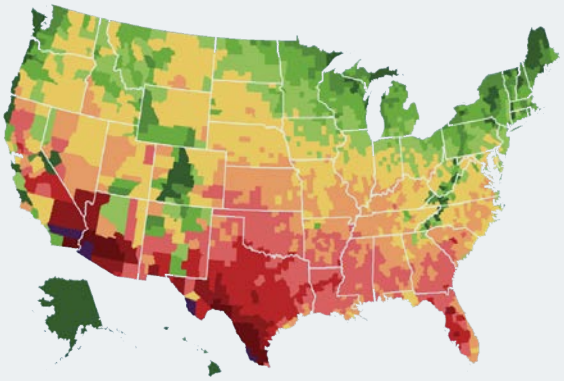


On our current path, the U.S. will likely see significantly more days above 95°F each year. Some regions of the country will be hit far harder by extreme heat than others, and some will experience rising temperatures in terms of warmer winters rather than unbearable summers. But by the end of this century, the average American will likely see 45 to 96 days per year over 95°F.

Data Source: Rhodium Group

RESULTS: RISKS VARY BY REGION & SECTOR





Adulthood

2040–2059

Retirement

2080–2099

By the end of the century, Oregon, Washington, and Idaho could well have more days above 95°F each year than there are currently in Texas; babies being born right now in the Southwest could see nearly four additional months of days over 95°F within their lifetimes.

Regional Impacts Key:

Decreased Labor

Sea Level Rise

Property Loss

Mortality

Heat Stroke

Extreme Heat

Crop Yields

Storm Surge

Energy

RESULTS: RISKS VARY BY REGION & SECTOR

Heat is a critical issue for the health of businesses as well as that of human beings. On their own, rising temperatures can have significant negative impacts on health and also labor productivity. But high temperatures are also at the root of several other important climate impacts that have long been recognized by scientists:

- Hotter air on the Earth's surface leads to higher ocean temperatures, which causes ocean expansion and sea level rise;
- Higher temperatures accelerate the rates at which land ice melts, further elevating average sea levels;
- A warmer atmosphere makes extreme precipitation more likely, which is expected to make wet regions even wetter, but could also make dry regions even drier.

Because the U.S. is such a large and geographically diverse country, it will experience every one of these climate impacts in the next century. Even the individual sectors we studied have regional variations: For agriculture, for instance, the national story is one of an industry able to adapt by changing where and what farmers plant; at the same time, the story within particular regions is quite different, as individual farmers potentially abandon traditional crops or move away from the farming business altogether. For the energy industry, the story in the warming North is starkly different than in the increasingly unbearably hot South. Sea levels, too, vary significantly across the U.S., and even across cities along the same coastline: For example, sea level rise at New York will likely be higher than at Boston, and sea level rise at San Diego will likely be higher than at San Francisco.

As in a standard business risk assessment, we looked at the data to see exactly where the greatest risks lie, and confirmed that some regions and economic sectors face extreme and unacceptable risks. These are some of our gravest concerns:

Rising seas and greater coastal storm damage already threaten the financial value and viability of many properties and infrastructure along the Eastern Seaboard and Gulf Coast. If we stay on our current climate path, some homes and commercial properties with 30-year mortgages in places in Virginia, North Carolina, New Jersey, Alabama, Florida, and Louisiana and elsewhere could quite literally be underwater before the note is paid off.

Rising temperatures will also reduce labor productivity, as some regions—especially the Southeast and Southwest—become too hot by mid-century for people to work outside during parts of the day.

Heat will also put strains on our energy system, simultaneously decreasing system efficiency and performance as system operators struggle to cool down facilities, and increasing electricity consumption and costs due to a surge in demand for air conditioning.

As parts of the nation heat up, the worst health impacts will be felt among the poor—many of whom work or even live outdoors or can't afford air conditioning at home—and among those too elderly or frail to physically withstand the heat or get themselves to air-conditioned facilities.

More than any other factor, our direct economic exposure to climate change will be determined by where we do business. For that reason, we present our findings below in terms of the major regions of the U.S., and then identify how climate change will affect critical sectors within those regions. Still, as any business person knows, these impacts won't be contained within regional boundaries; the ripple effects are likely to resonate throughout the economy. Put another way, just because it's not hot where you are doesn't mean you won't feel the heat of climate change.

Man wades through floodwaters in Immokalee, Florida, after Hurricane Wilma

THE REGIONS

The Risky Business analysis builds on the research and analytical work done over the past several decades by international climate scientists and economists, including the recent National Climate Assessment (NCA), released in early May 2014. The Risky Business Project takes as our unit of measurement the National Climate Assessment regions, which are organized loosely around shared geologic characteristics and climate impacts.[10] These are: Northeast, Southeast, Midwest, Southwest, Great Plains, Northwest, Alaska, and Hawaii.

However, we went even deeper than the NCA, conducting analysis down to the county level in some cases, and also focusing on key economic sectors. We overlaid our regional climate impact findings with an economic analysis showing the potential cost of these impacts within those regions and sectors. Below, we explore the most striking findings from each region. We encourage readers to go to **riskybusiness.org** to explore these regional impacts in more depth and to **climateprospectus.rhg.com** for the independent research team's complete risk assessment.

WHY REGIONS MATTER

In a country as large and diverse as the U.S., it does not make sense to aggregate the highly localized economic impacts of climate change into one headline number. Take the case of Hurricane Katrina: In the last quarter of 2005, every state in the nation prospered except the state of Louisiana, which lost 1.6% of Gross State Product (GSP) as businesses were shuttered and workers stayed home;[11] meanwhile the following year, storm recovery activities in Louisiana (e.g., construction) actually *increased* the national Gross Domestic Product (GDP) by half a percent.[12] Indeed, most economic successes and disasters in the U.S. happen at the individual metropolitan, state, and occasionally multi-state level.

Regions also have a cultural dimension: Americans often think of themselves as "belonging" to specific regions, according to Joel Garreau's famous 1981 book *The Nine Nations of North America*. Garreau posits that Americans live in nine completely different cultural and economic zones. He writes: "Each has a peculiar economy; each commands a certain emotional allegiance from its citizens. These nations look different, feel different, and sound different from each other, and few of their boundaries match the political lines drawn on current maps."[13] Garreau's observations underscore the fact that as mobile as many Americans are, we're still often unwilling or unable to move out of our home regions simply because of weather or economic changes.

The regional nature of climate impacts and the regional nature of the overall American economy and cultural identity mean that there may not be one single national response to the risks highlighted by the Risky Business Project. But the reality of these impacts, especially in the Southwest and Southeast—which will likely experience the most extreme heat and sea level rise over this century—may also mean that Americans have no choice but to migrate to cooler and more livable areas, disrupting lives, livelihoods, and regional identities formed over generations.

NORTHEAST

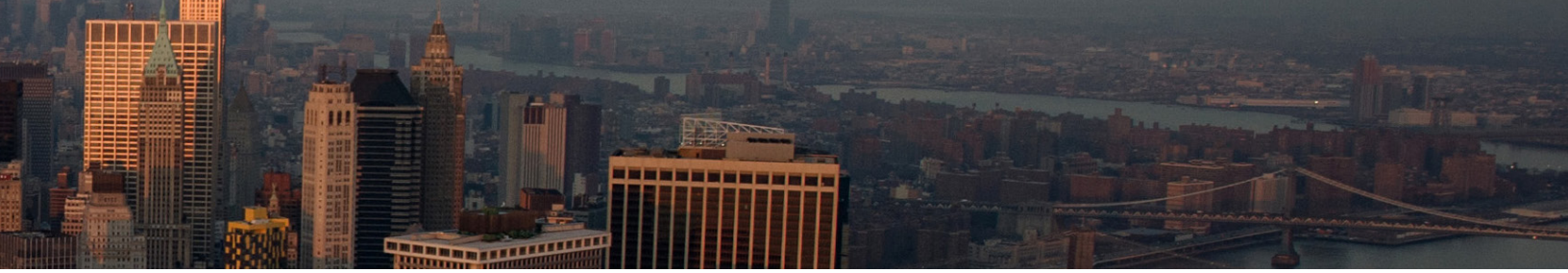
While the Northeast region of the U.S. is expected to experience a sizeable increase in temperatures and average number of extremely hot days over the course of the century, the region's major climate impact will be sea level rise and its effect on coastal infrastructure.

Rising sea levels are a direct consequence of rising temperatures: As the oceans warm, they expand. This phenomenon is further exacerbated by land-ice melt, particularly the Antarctic and Greenland ice sheets. Scientists have recently found evidence of accelerating and perhaps unstoppable land ice melt in West Antarctica.[14] A further (and more minor) contributor to sea level rise is groundwater withdrawal, which can literally sink the land adjacent to the ocean. All of these factors—thermal expansion, ice melt, and groundwater withdrawal—can lead to higher water levels along the coasts.

Why do sea levels matter to the American economy? First and foremost, sea level rise threatens the communities and industries along our coastlines. The coasts are critical to the Northeast region's economy: Its major cities are on the water, as are many of its major industries, from New York's Wall Street to the fisheries in Portland, Maine. All told, 88% of the population of this region lives in coastal counties, and 68% of the region's Gross Domestic Product (GDP) is generated in those counties. As a result, much of the region's residential, commercial, and energy infrastructure is also at or near sea level, making these assets particularly vulnerable to climate impacts.

Homeowners look over damage from New York City storm

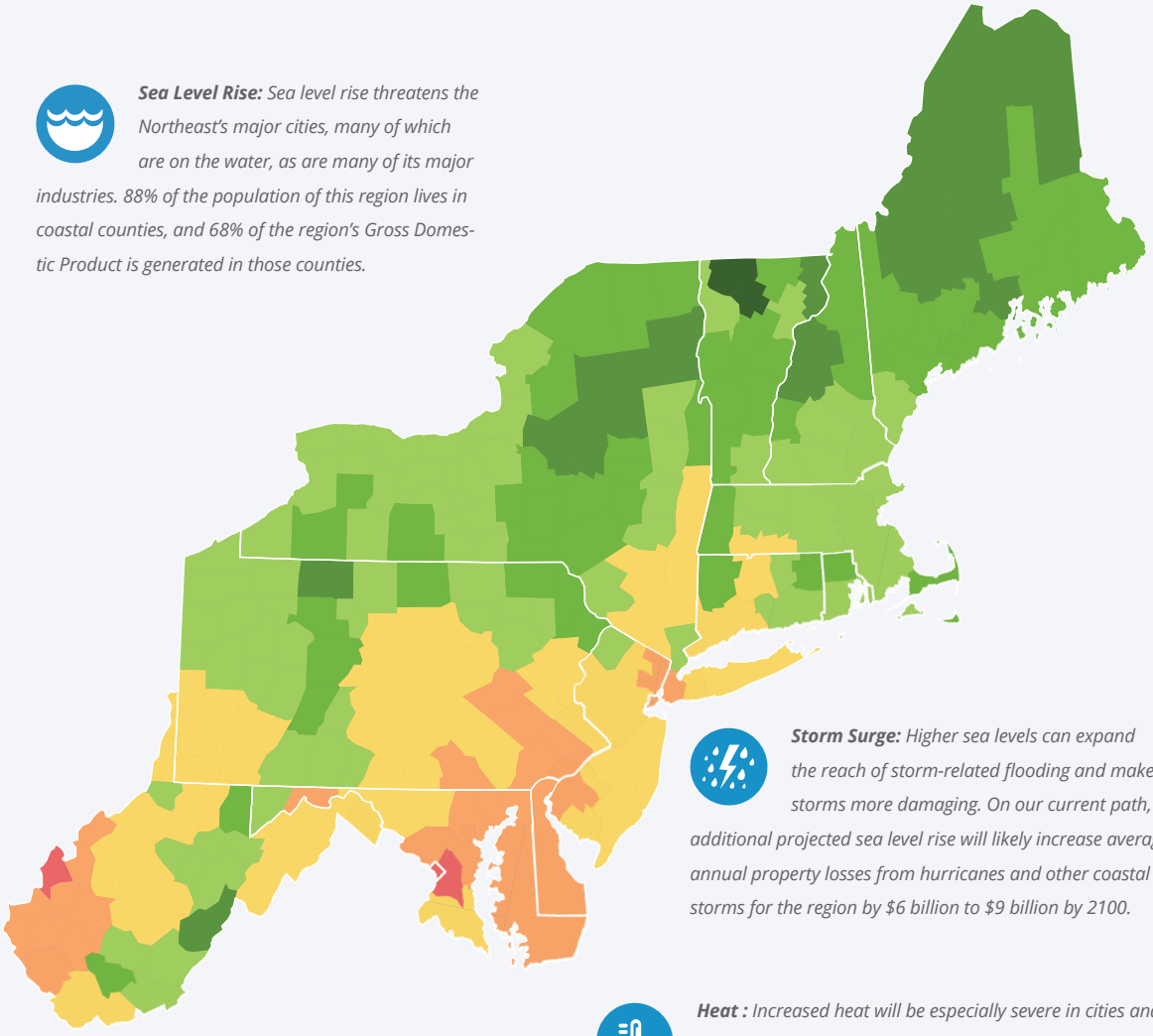
The Risky Business analysis shows that if we continue on our current path, sea levels at New York City will likely rise by an additional 0.9 feet to 1.6 feet by mid-century, and between 2.1 feet and 4.2 feet by the end of the century. Because our risk assessment includes less likely but higher-impact possibilities, we also found a 1-in-100 chance that New York City could experience up to 6.8 feet of sea level rise by the end of the century. The story for New Jersey is even more concerning because of that state's groundwater withdrawal: It's likely that, on our current path, Atlantic City will see 2.4 feet to 4.5 feet of sea



NORTHEAST

NORTHEAST: AVERAGE SUMMER TEMPERATURE BY 2100 & KEY IMPACTS

Sea Level Rise: *Sea level rise threatens the Northeast's major cities, many of which are on the water, as are many of its major industries. 88% of the population of this region lives in coastal counties, and 68% of the region's Gross Domestic Product is generated in those counties.*



Storm Surge: *Higher sea levels can expand the reach of storm-related flooding and make storms more damaging. On our current path, additional projected sea level rise will likely increase average annual property losses from hurricanes and other coastal storms for the region by $6 billion to $9 billion by 2100.*

Heat : *Increased heat will be especially severe in cities and metro regions with more than 1 million people, where the high concentration of concrete and lack of natural cooling systems like streams and forests create an "urban heat island" effect that can raise average temperatures by as much as 5.4°F during the day and 22°F in the evening over the surrounding rural areas.*

Data Source: Rhodium Group

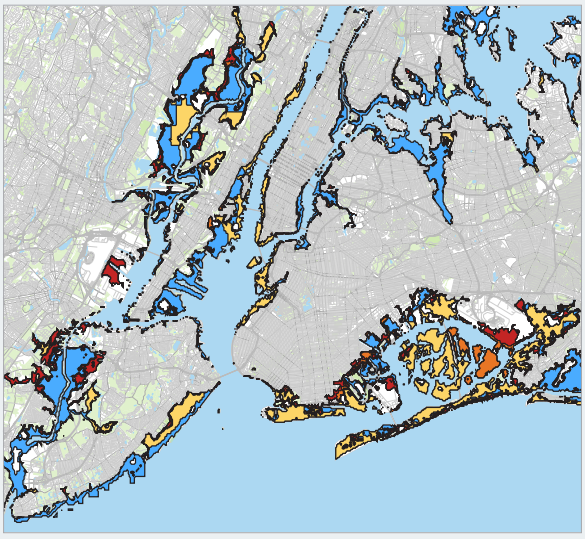
level rise by end of this century. North of New York City, the rise is slightly smaller: Boston will likely experience 2 feet to 4 feet by 2100, and Portland is likely to experience a rise of 1.7 feet to 3.8 feet in the same period.

Just looking at the simple rise in sea levels masks the impact these higher levels can have during a major storm. Sea level rise that had already occurred over the past century exacerbated storm surge during Hurricane Sandy, expanding the reach of the storm-related flooding and making the storm more costly. Our research shows that, if we continue on our current path, additional projected sea level rise will likely increase average annual property losses from hurricanes and other coastal storms by $6 billion to $9 billion over the course of the century. Potential changes in hurricane activity, also caused by atmospheric warming, would raise these estimates to $11 billion to $17 billion—a 2-to-3-fold increase from current levels.

The Northeast will also suffer from increased heat, especially because so many of the region's residents live in cities that have higher temperatures due to the so-called "heat island effect." In cities and metro regions with more than 1 million people, the high concentration of concrete and lack of natural cooling systems like streams and forests can raise average temperatures by as much as 5.4°F during the day and 22°F in the evening over the surrounding rural areas. [15]

Figure 4: Expected Flooding From a 1-in-100 Year Storm

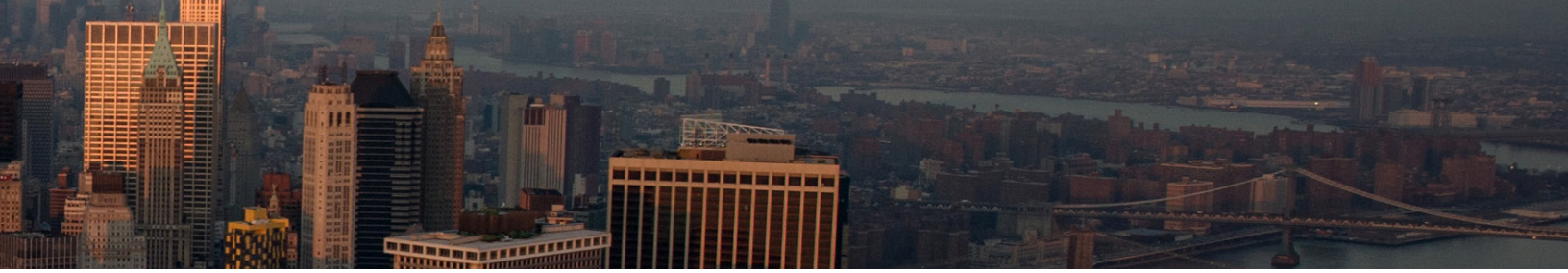
New York City



Current expected flooding from 1-in-100 year storm

Increase by 2030 | Increase by 2050 | Increase by 2100

Source: Risk Management Soultions (RMS)

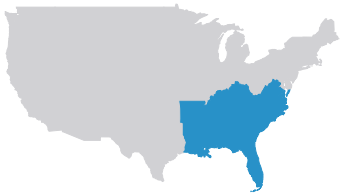


NORTHEAST

Right now, the Northeast is actually rather temperate in the summer, with only 2.6 days over 95°F on average each year—a temperature we refer to throughout our research as "extremely hot." By mid-century, the average resident in the Northeast will likely see between 4.7 and 16 additional extremely hot days; by late century this range will likely jump to between 17 and 59 additional extremely hot days, or up to two additional months of extreme heat. As we discuss further in the Southeast section below, these increasingly hot summers will have serious negative effects on health, mortality, and labor productivity.

A man tries to cool down during a Philadelphia heat wave

SOUTHEAST



Like the Northeast, the Southeastern U.S. has many coastal communities, though in this region only 36% of residents live in coastal counties, with 33% of GDP coming from those counties.

However, **sea level rise could seriously threaten the Southeast's coastal infrastructure,** given that some of the regions major cities (e.g., New Orleans) are at or below sea level while others (e.g., Miami) are built on porous limestone that allows water inundation even in the presence of a sea wall. Much of the region's critical infrastructure—including roads, rails, ports, airports, and oil and gas facilities—also sits at low elevations.

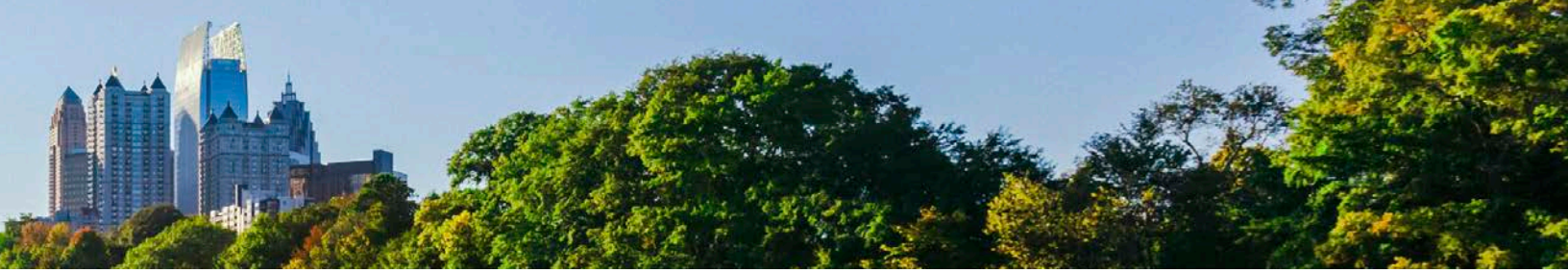
Our research shows a significant risk to this region from sea level rise. On our current path, by mid-century, mean sea level at Norfolk, Virginia—home to the nation's largest naval base—will likely rise between 1.1 feet and 1.7 feet, and will rise 2.5 feet to 4.4 feet by the end of century. However, there is a 1-in-100 chance that Norfolk could see sea level rise of up to 6.5 feet by the end of the century (Figure 7).

In Florida, because of the porous limestone on which the major southern cities are built, even modest sea level rise comes at a significant economic cost. Under current projections, between $15 billion and $23 billion of existing property will likely be underwater by 2050, a number that grows to between $53 billion and $208 billion by the end of the century. There is a 1-in-20 chance that more than $346 billion in current Florida property will be underwater by the end of this century, and a 1-in-100 chance that more than $681 billion in property will be below mean sea levels. An additional $240 billion in property will likely be at risk during high tide that is not at risk today.

A resident kayaks down a flooded street of Norfolk, Va.

As in the Northeast, greater flooding during hurricanes and other coastal storms, plus potential changes in hurricane activity, pose even greater and more immediate economic risks than mean sea level rise.

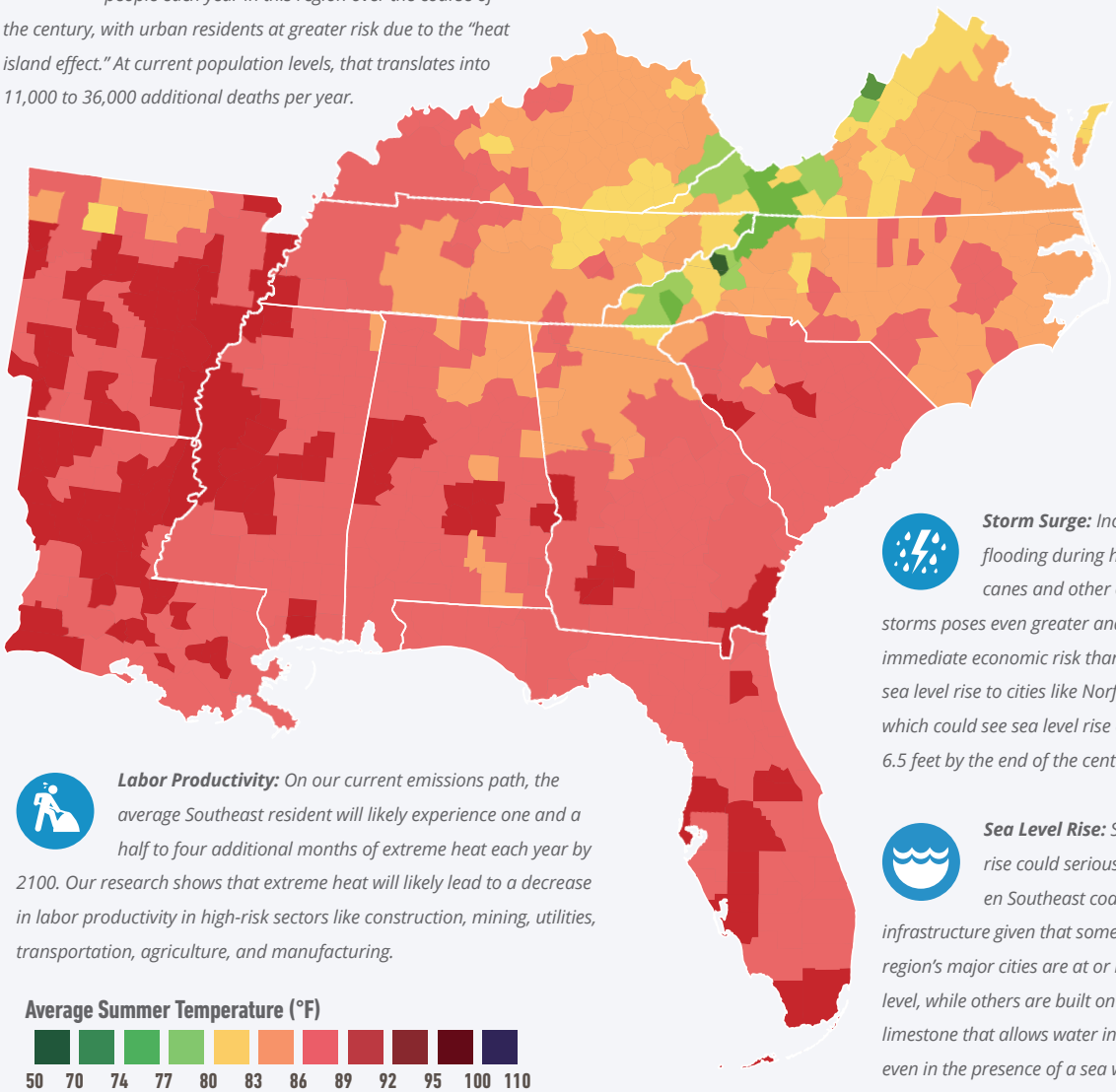
The Southeast will also likely be hit hardest by heat impacts. Over the past 30 years, the average resident of this region has experienced about 8 days per year at 95°F



SOUTHEAST

SOUTHEAST: AVERAGE SUMMER TEMPERATURE BY 2100 & KEY IMPACTS

Heat-Related Mortality: *Heat-related mortality will likely cause 15 to 21 additional deaths per 100,000 people each year in this region over the course of the century, with urban residents at greater risk due to the "heat island effect." At current population levels, that translates into 11,000 to 36,000 additional deaths per year.*



Storm Surge: *Increased flooding during hurricanes and other coastal storms poses even greater and more immediate economic risk than mean sea level rise to cities like Norfolk, which could see sea level rise of up to 6.5 feet by the end of the century.*

Labor Productivity: *On our current emissions path, the average Southeast resident will likely experience one and a half to four additional months of extreme heat each year by 2100. Our research shows that extreme heat will likely lead to a decrease in labor productivity in high-risk sectors like construction, mining, utilities, transportation, agriculture, and manufacturing.*

Sea Level Rise: *Sea level rise could seriously threaten Southeast coastal infrastructure given that some of the region's major cities are at or below sea level, while others are built on porous limestone that allows water inundation even in the presence of a sea wall.*

Data Source: Rhodium Group

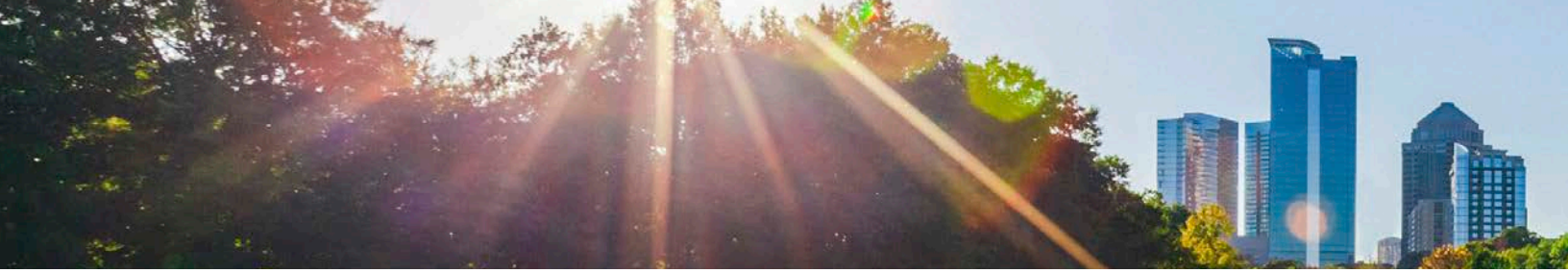


Figure 6: Mean Sea Level Rise in Miami by 2100

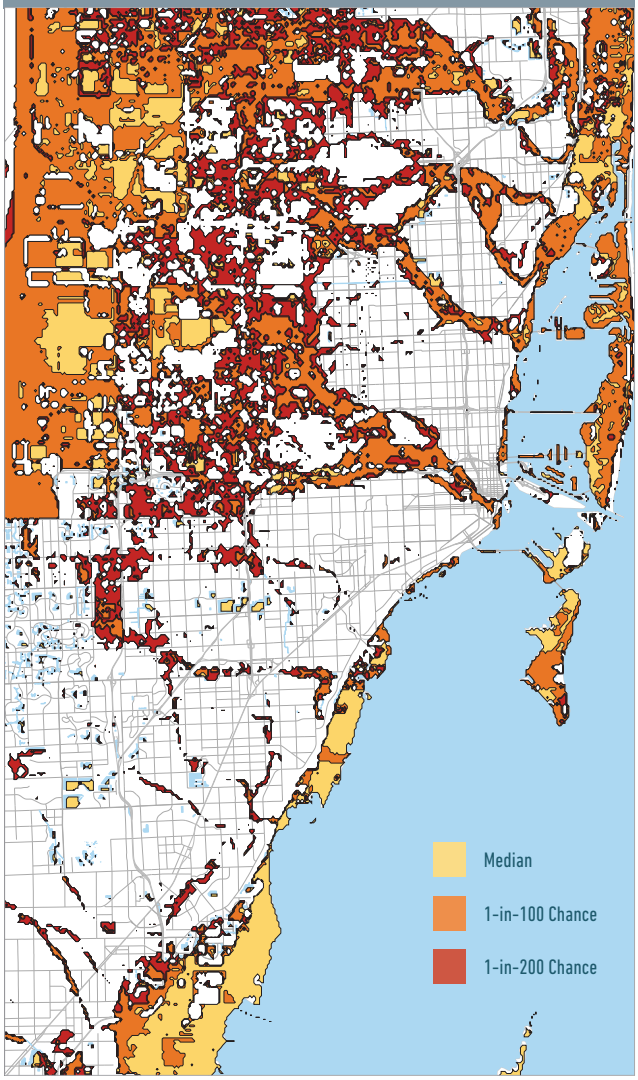
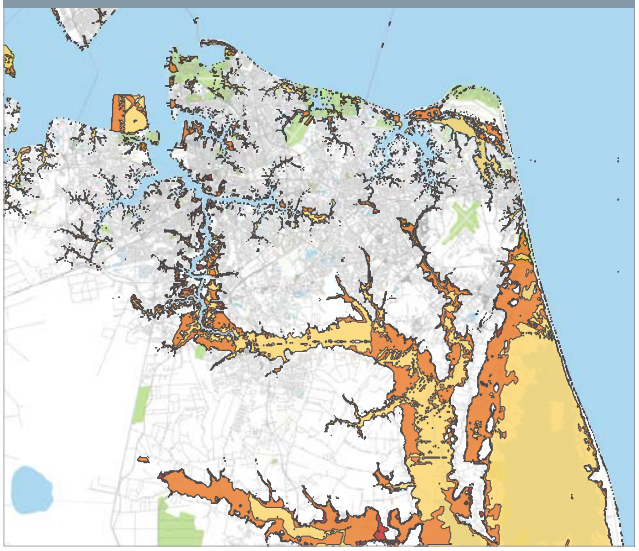


Figure 7: Mean Sea Level Rise in Norfolk by 2100



Source: RMS

or above. Looking forward, if we continue on our current emissions path, the average Southeast resident will likely experience an additional 17 to 52 extremely hot days per year by mid-century and an additional 48 to 130 days per year by the end of the century. That's one and a half to four additional months of extreme heat each year.

This kind of weather could have serious economic impacts: Our research shows a **decrease in labor productivity in high-risk sectors** like construction, mining, utilities, transportation, agriculture and manufacturing of up to 3.2% by the end of the century in this region, and a smaller but still noticeable impact on labor productivity in low-risk sectors like retail trade and professional services.

We are also likely to see an additional 15 to 21 deaths per 100,000 people every year in this region over the course of the century due to **increases in heat-related mortality**, with urban residents at greater risk due to the heat island effect. At the current population of the Southeast, that translates into 11,000 to 36,000 additional deaths per year.

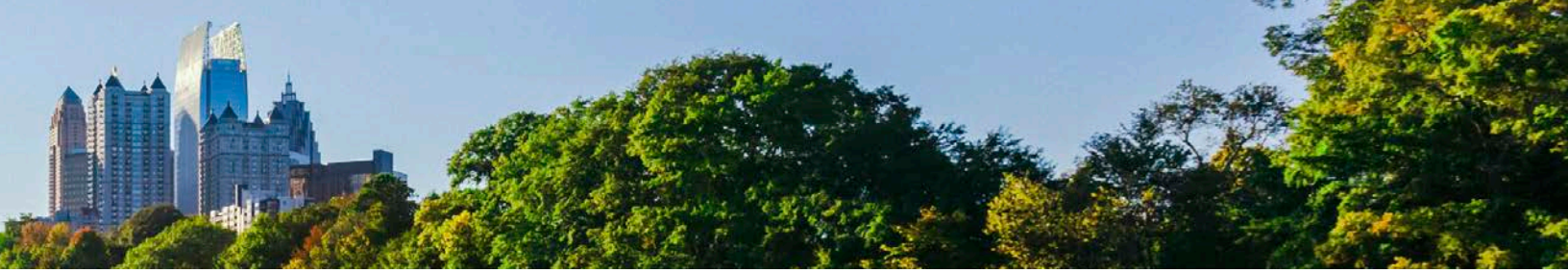
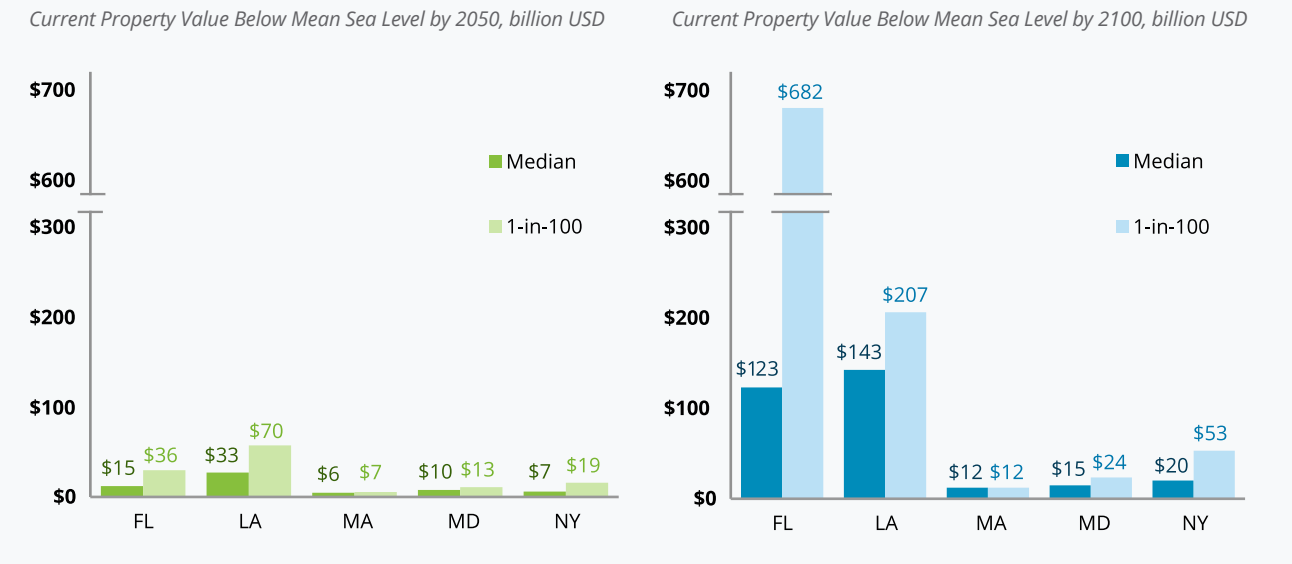


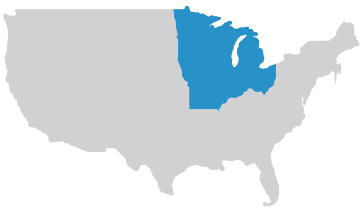
Figure 8: Value of State Property Below Mean Sea Level



Data Source: Rhodium Group

As Risk Committee member Dr. Alfred Sommer has pointed out, extreme heat will have a major impact on the capacity of local hospitals: "We just don't have the surge capacity left in the medical system anymore. . . . If these [impacts] occur in rural areas you're particularly in trouble."[16] He goes on to note that in Chicago during the 1995 heat wave, local officials "didn't even have a place to properly store [bodies from] the 700 deaths . . . that occurred over a small number of days." [17]

MIDWEST



The upper Midwest economy is dominated by commodity agriculture, with some of the most intensive corn, soybean, and wheat growing in the world.

Overall, the agricultural industry in this region includes more than 520,000 farms valued at $135.6 billion per year as of 2012, and the region accounts for 65% of national production of corn and soybeans alone.[18] For the Midwest, commodity agriculture is a crucial business, and the health and productivity of the agricultural sector is inextricably intertwined with climate conditions. Our research shows that under the "business as usual" scenario and assuming no significant adaptation by farmers, some states in the region, like Missouri and Illinois, face up to a 15% likely average yield loss in the next 5 to 25 years, and up to a 73% likely average yield loss by the end of the century. Assuming no adaptation, the region as a whole faces likely yield declines of up to 19% by mid-century and 63% by the end of the century.

Yet while the agricultural industry will clearly be affected by climate change, it is also probably the best equipped to manage these risks. Farmers have always adapted to changing weather and climate conditions, with adaptation and flexibility built into their business models. Armed with the right information, Midwest farmers can, and will, mitigate some of these impacts through double- and triple-cropping, seed modification, crop switching

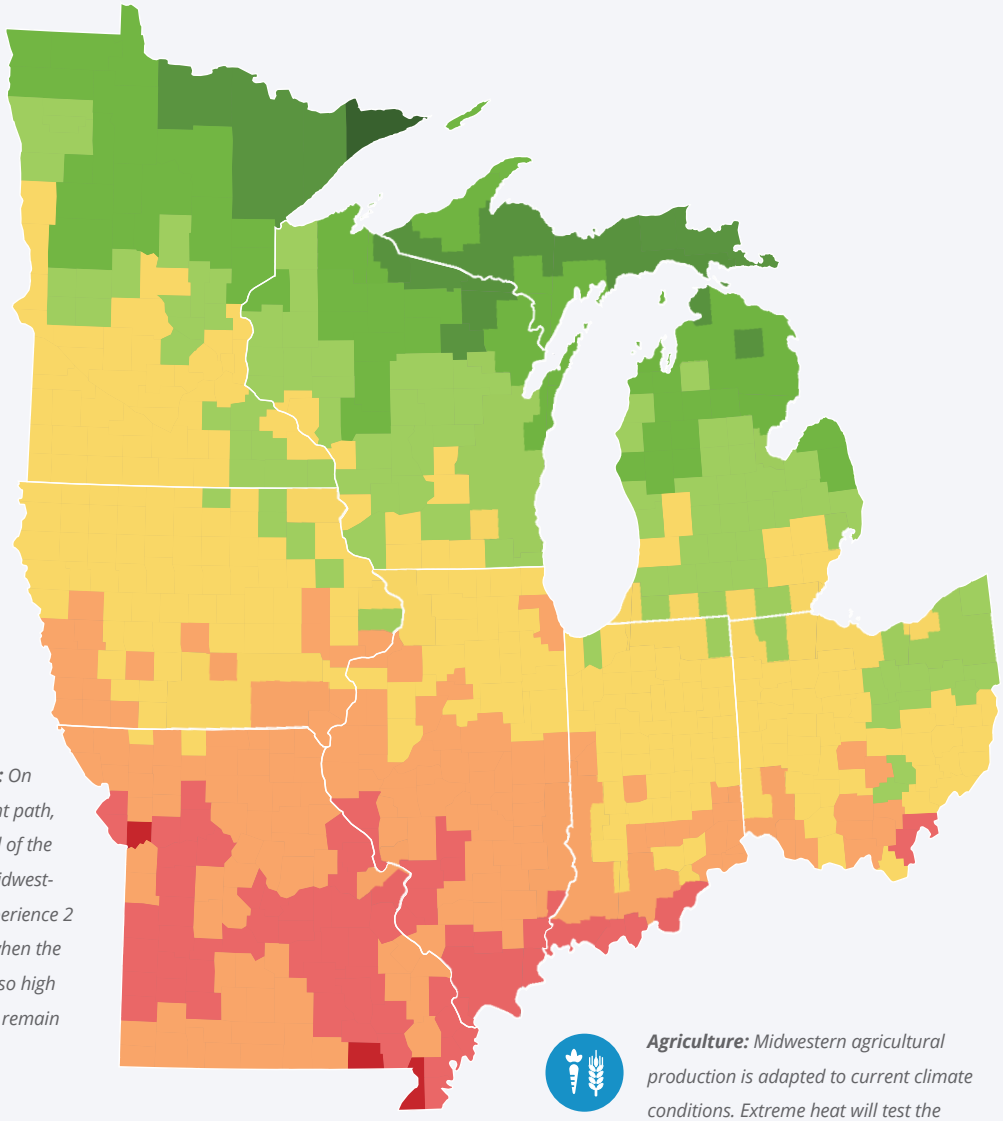
A farmer surveys his dry pond bed in Ashely, Illinois

and other adaptive practices. In many cases, crop production will likely shift from the Midwest to the Upper Great Plains, Northwest, and Canada, helping to keep the U.S. and global food system well supplied. However, this shift could put individual Midwest farmers and farm communities at risk if production moves to cooler climates.

The projected increase in Midwest surface air temperatures won't just affect the health of the region's crops; it will also put the region's residents at risk. Over the past 40 years, the Midwest experienced only 2.7 days on average over 95°F. If we stay on our current climate path, the average Midwest resident will likely experience an additional 7 to 26 days above 95°F each year by mid-century, and 20 to 75 additional extreme-heat

MIDWEST

MIDWEST: AVERAGE SUMMER TEMPERATURE BY 2100 & KEY IMPACTS



Mortality: *On our current path, by the end of the century, the average Midwesterner can expect to experience 2 days in a typical year when the heat and humidity are so high that it will be unsafe to remain outdoors.*

Agriculture: *Midwestern agricultural production is adapted to current climate conditions. Extreme heat will test the limits of crop innovations, and may result in reduced crop yields—unless farmers employ new adaptive practices.*

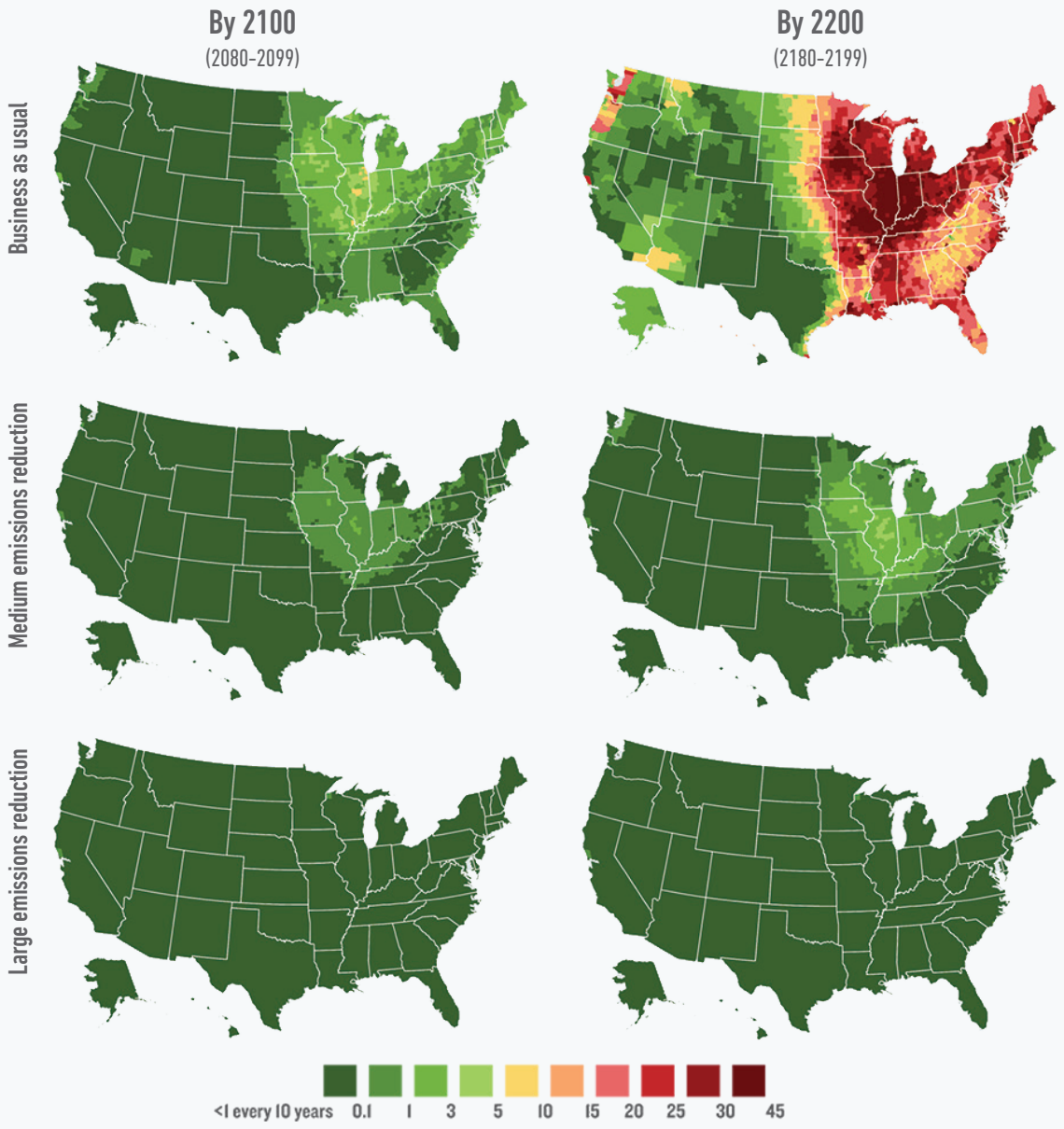
Average Summer Temperature (°F)

50 70 74 77 80 83 86 89 92 95 100 110

Data Source: Rhodium Group

Figure 9: Humid Heat Stroke Index

Days per year when the heat and humidity could be so high that it will be unsafe for humans to remain outdoors (HHSI >92°F)



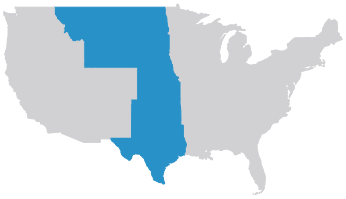
Data Source: Rhodium Group

days—potentially more than 2 additional months per year of extreme heat—by the end of the century. On the other hand, the region will also experience fewer winter days with temperatures below freezing.

But the real story in this region is the combined impact of heat and humidity, which we measure using the **Humid Heat Stroke Index**, or **HHSI**. The human body's capacity to cool down in the hottest weather depends on our ability to sweat, and to have that sweat evaporate on our skin. Sweat keeps the skin temperature below 95°F, which is required for our core temperature to stay around 98.6°F. But if the outside temperature is a combination of very hot and very humid—if it reaches a HHSI of about 95°F—our sweat cannot evaporate, and our core body temperature can rise until we actually collapse from heat stroke. Even at an HHSI of 92°F, core body temperatures can get close to 104°F, which is the body's absolute limit.

To date, the U.S. has never experienced heat-plus-humidity at this scale. The closest this country has come was in 1995 in Appleton, Wisconsin, when the HHSI hit 92°F. (At the time, the outside temperature was 101°F and the dew point was 90°F.) The only place in the world that has ever reached the unbearable HHSI of 95°F was Dhahran, Saudi Arabia, in 2003 (outside temperature of 108°F, dew point of 95°F). Our research shows that if we continue on our current path, the average Midwesterner could see an HHSI at the dangerous level of 95°F two days every year by late century, and that by the middle of the next century, she or he can expect to experience 20 full days in a typical year of HHSI over 95°F, during which it will be functionally impossible to be outdoors.

GREAT PLAINS



The Great Plains region stretches from the far north (Montana) to the far South (Texas). Climate impacts will be felt very differently in the northern and southern parts of this region.

In the southern states of the Great Plains region (Texas, Oklahoma, and Kansas), our research shows an increase in extremely hot days. The average resident of these states experienced 39 days per year over 95°F in the past 30 years. This number will likely increase by 28 to 60 additional extremely hot days by mid-century and 60 to 114 days per year by the end of the century—for a total of between three and four months of additional extreme hot days per year.

At the same time, the northern parts of the region will likely see a significant *decrease* in extremely cold days: from the average of 159 days per year of below-freezing weather over the past 30 years, to between 117 and 143 freezing days at mid-century, and between 79 and 122 freezing days by the end of the century.

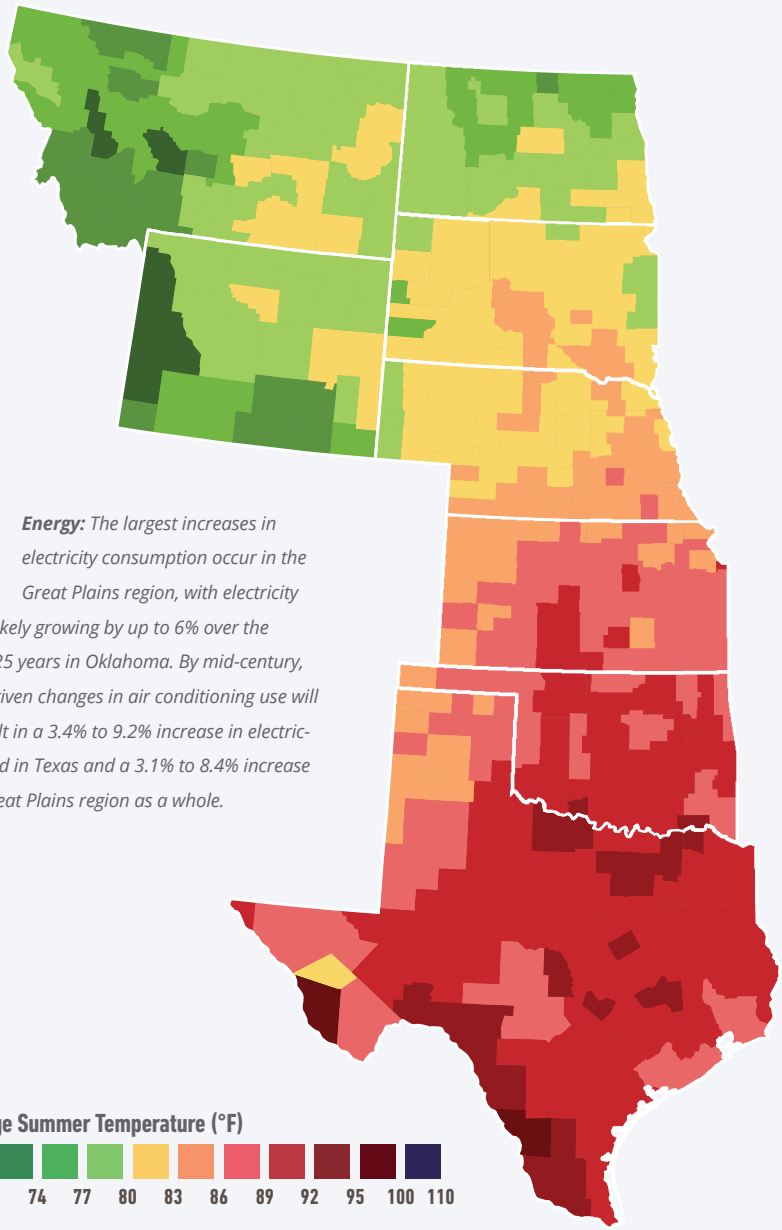
The southern and coastal parts of this region will also experience the **sea level rise impacts on coastal communities** that we've already discussed. In Texas, for instance, where about one-third of the state's GDP is generated in coastal counties, sea levels will likely rise by 1.5 to 2 feet by mid-century and 3.2 to 4.9 feet by the end of the century, with a 1-in-100 chance of a 7.0-foot rise.

Though the north and south sub-regions of the Great Plains have starkly different climates, all the states in this region rely on two important climate-sensitive industries: agriculture and energy.

Altogether, 80% of the region is devoted to cropland, pastures, and range land, which produce $92 billion in agricultural products each year. The story for the region's agricultural sector is mixed: The more southern states may see declining crop yields as temperatures continue to rise, while the northern states may actually see yield gains, though this will depend on a number of factors, including water availability. (See the Southwest section for a more detailed discussion of this factor.)

GREAT PLAINS

GREAT PLAINS: AVERAGE SUMMER TEMPERATURE BY 2100 & KEY IMPACTS



Energy: *The largest increases in electricity consumption occur in the Great Plains region, with electricity demand likely growing by up to 6% over the next 5 to 25 years in Oklahoma. By mid-century, climate-driven changes in air conditioning use will likely result in a 3.4% to 9.2% increase in electricity demand in Texas and a 3.1% to 8.4% increase for the Great Plains region as a whole.*

Agriculture: *The southernmost states may see declining crop yields as temperatures continue to rise, while the northern states may see yield gains.*

Sea Level Rise: *The southern and coastal parts of this region will experience sea level rise impacts on coastal communities. In Texas, sea levels will likely rise by 3.2 to 4.9 feet by 2100.*

Data Source: Rhodium Group

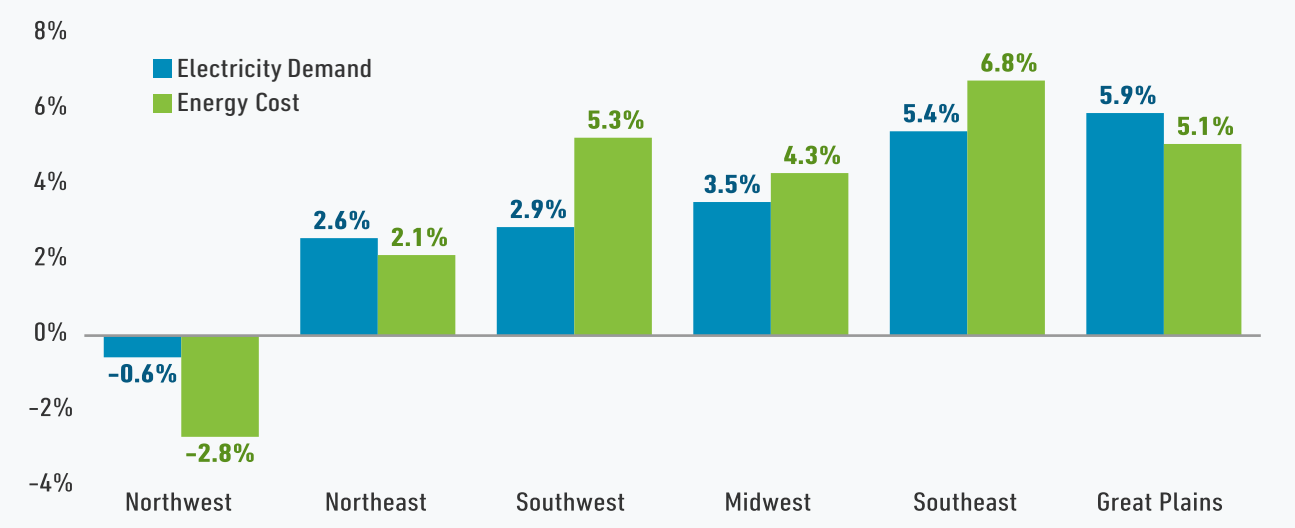
GREAT PLAINS

At the same time, the region is a major energy producer for the nation, making **climate impacts on the energy sector** particularly important for this area. Texas and Wyoming alone produce half of U.S. energy (primarily from crude oil and natural gas in Texas and coal in Wyoming), and North Dakota has recently become a major oil and gas producer. Power generation facilities in the region currently meet about 17% of the nation's overall electricity needs.[19]

If we stay on our current path, our research shows a significant increase in demand for air conditioning over the course of the century which, when combined with other heat-related impacts such as reductions in power generation and in transmission efficiency and reliability, could place a considerable burden on the electricity power sector. As soon as 5 to 25 years from now, our research shows a 0.8% to 2.2% likely increase in nation-wide electricity consumption. The country will likely see a roughly corresponding decline in demand for heating, as temperatures warm up in the northern states, but the switch from natural gas and fuel oil-driven heating demand to electricity powered cooling demand has significant implications for the U.S. energy system.

The largest increases in electricity consumption occur in the Great Plains region, with likely electricity demand growth in Texas and Oklahoma of up to 5% and 6% respectively over the next 5 to 25 years. By mid-century, climate-driven changes in air conditioning will likely result in a 3.4% to 9.2% increase in electricity demand in Texas and a 3.1% to 8.4% increase for the Great Plains region as a whole.

Figure 10: Change in Electricity Demand and Energy Costs by Region, Mid-Century (2040-2059)



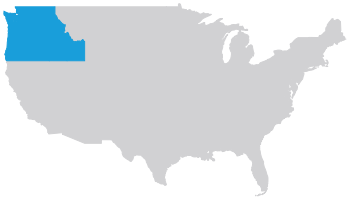
Data Source: Rhodium Group

Shipping cranes at the Port of Houston

Most of this increase will occur during times of the day when electricity consumption is already high. Meeting higher peak demand will likely require the construction of up to 95 GW of additional power generation capacity over the next 5 to 25 years, the rough equivalent of 200 average-size coal or natural gas power plants. Constructing these new power-generation facilities will, in turn, raise residential and commercial energy prices. Our research concludes that climate-driven changes in heating and cooling will likely increase annual residential and commercial energy costs nationally by $474 million to $12 billion over the next 5 to 25 years and $8.5 billion to $30 billion by the middle of the century.

All of this could have a significant impact on the economy of the Great Plains. In addition, many of the region's current energy-production facilities—from power plants to oil and gas platforms—are at risk from climate-driven increases in storm surge and potential changes in hurricane activity. If these facilities are flooded, the region will lose electricity and energy resources just as the country's need for them is growing.

NORTHWEST



The Pacific Northwest is a good example of the general truth that similar climate impacts may be felt differently from one region to another.

For example, by mid-century this area will have fewer additional extremely hot days than, say, the Southeast—but the average Northwest resident will likely go from experiencing only 5 days of 95°F or warmer temperatures per year on average for the past 30 years to an additional 7 to 15 extremely hot days by mid-century, and to an additional 18 to 41 extremely hot days by the end of the century. This represents an increase of *3 to 8 times* the number of hot days for the region per year, which is a significant change from historic norms.

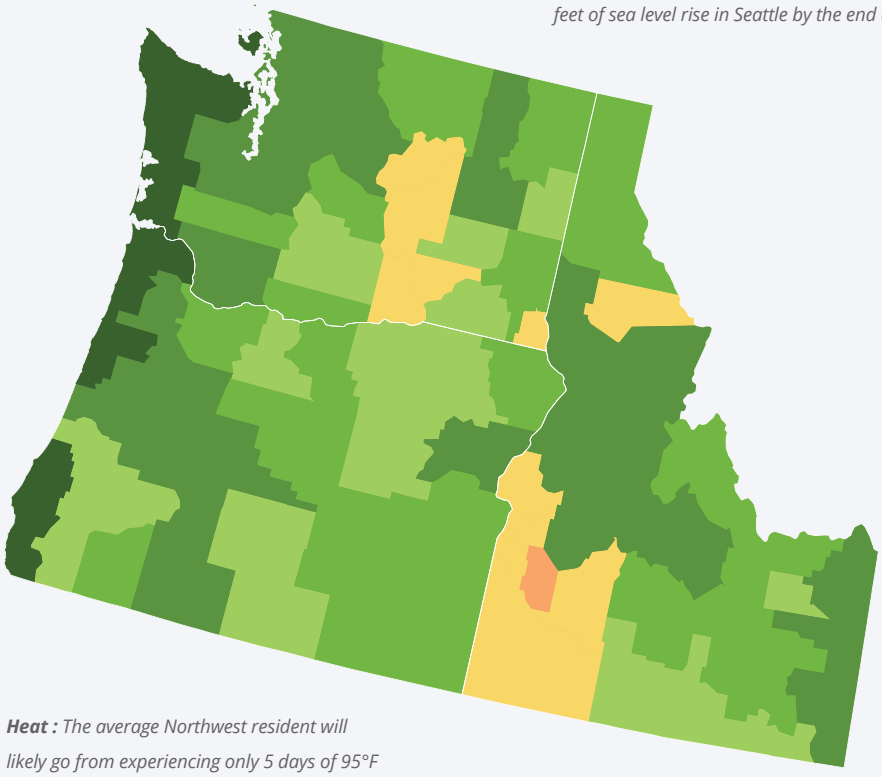
This region is also coastal, but the extent of expected sea level rise here is more varied than the east coast. Because the area is relatively close to the Alaskan glaciers, the Earth's gravitational field may lead to the ice melt in Alaska actually lowering sea levels off Washington and Oregon. At the same time, West Antarctic melt may lead to higher sea level rise in the Northwest over the long term. This latter effect is captured in our analysis of the "tail risk" of sea level rise in the Northwest. Overall, our research shows that if we stay on our current path, sea level at Seattle will likely rise by 0.6 to 1.3 feet between 2000 and 2050 and by 1.6 to 3.0 feet between 2000 and 2100. Looking out to the tail risks, though, there is a 1-in-100 chance of up to 5 feet of sea level rise by 2100 in Seattle.

The economy of the Northwest is dependent on its coastlines, but it is also heavily dependent on its forests. Oregon and Washington are the number one and two softwood-producing states in the nation, respectively;[20] these two states plus Idaho produce more than $11 billion in primary wood product sales.[21] Our review of existing research suggests the Northwest's forests will experience significant potential impacts from climate change, in particular from wildfire—due to both increased drought and to wood damage from pests surviving warmer winters. One study we reviewed found that if temperatures rise 3.2°F by mid-century, this could lead to 54% increase in the annual area burned in the western U. S.[22] The same study found that the forests of the Pacific Northwest and Rocky Mountains will likely experience the greatest increases in annual burn area (78% and 175%, respectively).

NORTHWEST

NORTHWEST: AVERAGE SUMMER TEMPERATURE BY 2100 & KEY IMPACTS

Sea Level Rise: *If we stay on our current path, sea level at Seattle will likely rise by 0.6 to 1.0 feet by mid-century and by 1.6 to 3.0 feet by 2100. Looking out to the tail risks, though, there is a 1-in-100 chance of up to 5 feet of sea level rise in Seattle by the end of the century.*



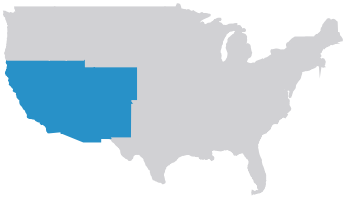
Heat : *The average Northwest resident will likely go from experiencing only 5 days of 95°F or warmer temperatures per year on average for the past 30 years to an additional 18 to 41 extremely hot days by the end of the century.*

Average Summer Temperature (°F)

50 70 74 77 80 83 86 89 92 95 100 110

Data Source: Rhodium Group

SOUTHWEST



The Southwest region includes the traditional Southwest states—Arizona, Colorado, Nevada, New Mexico, Utah—and also California. As such, it is an extremely diverse region that in some ways serves as a microcosm of all the climate impacts we've discussed so far.

This region is already warm and dry—about 40% of this area is covered by desert[23]—and is likely to become more so in the coming decades. Over the past 30 years, the average Southwest resident experienced 40 days per year of temperatures of 95°F or more. If we continue on our current path, by mid-century the average Southwest resident will likely see 13 to 28 additional extremely hot days. By the end of the century, this number will likely rise to an additional 33 to 70 days of extreme heat due to climate change. That translates to one to two additional months of days over 95°F each year within the lifetime of babies being born right now in this region—one of the fastest-growing in the United States.

Because it includes California, the Southwest is not just one big desert; it is also an extremely coastal region. Eighty-seven percent of all Californians live in coastal counties, and 80% of the state's GDP is derived from those counties. Along the coastline of San Diego, if we continue on our current path, sea level will likely rise by 0.7 to 1.2 feet before the middle of the century, and by 1.9 to 3.3 feet by the end of the century. But the real sea level risk in this region is in the tails. The California coastline is more exposed to sea level rise resulting from Antarctic melt than the global average, and there is a 1-in-100 chance that sea levels could rise by as much as 5.5 feet by 2100 in San Diego.

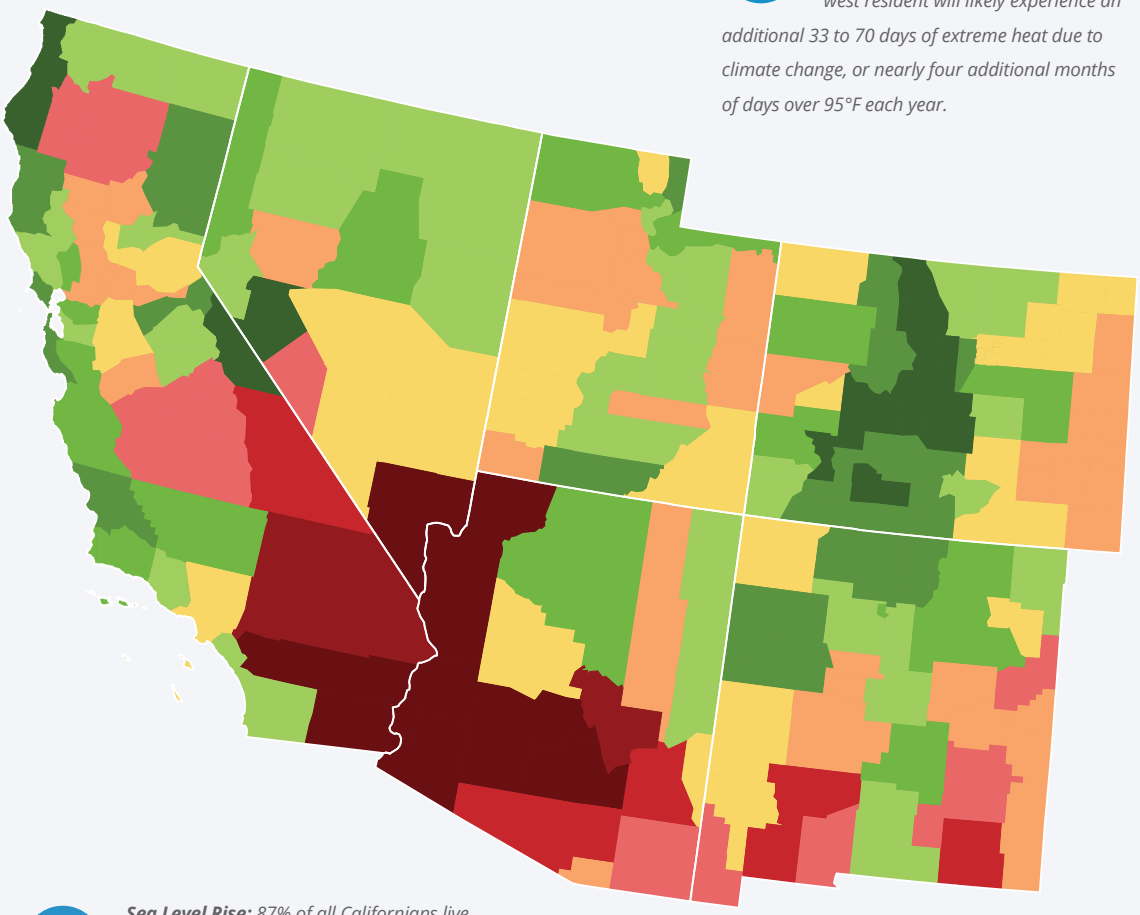
Wildland Firefighter

San Diego is of strategic importance to the U.S. military: The city is home to three Marine installations, including Marine Corps Base Camp Pendleton, three naval bases, and a Coast Guard station. Fortunately, the military is one of our country's leading institutions in terms of acknowledging the potential impact of climate risk on its installations here and throughout the U. S. The Department of Defense's 2010 Quadrennial Defense Review called for a climate impact assessment at all DOD's permanent installations, and several studies are already underway.[24]

SOUTHWEST

SOUTHWEST: AVERAGE SUMMER TEMPERATURE BY 2100 & KEY IMPACTS

Heat: *On our current path, by the end of the century, the average Southwest resident will likely experience an additional 33 to 70 days of extreme heat due to climate change, or nearly four additional months of days over 95°F each year.*

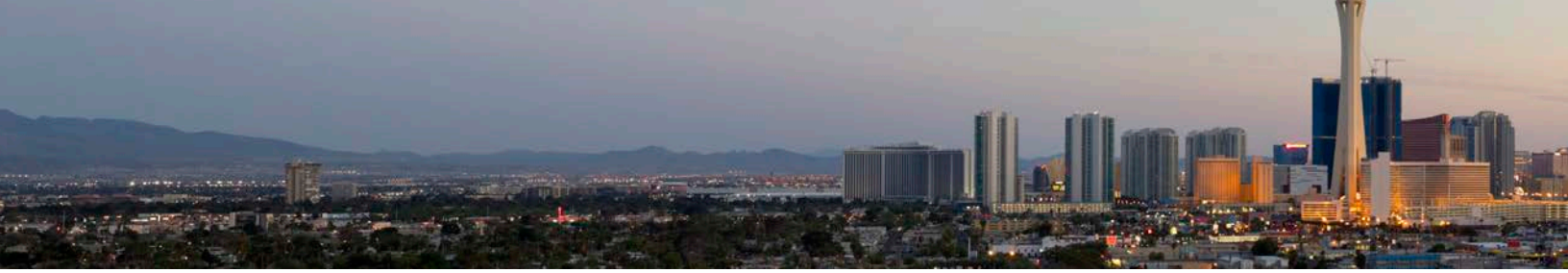


Sea Level Rise: *87% of all Californians live in coastal counties, and 80% of the state's GDP is derived from those counties. Along the coastline of San Diego, if we continue on our current path, sea level will likely rise by 1.9 to 3.4 feet by 2100.*

Average Summer Temperature (°F)

50 70 74 77 80 83 86 89 92 95 100 110

Data Source: Rhodium Group



SOUTHWEST

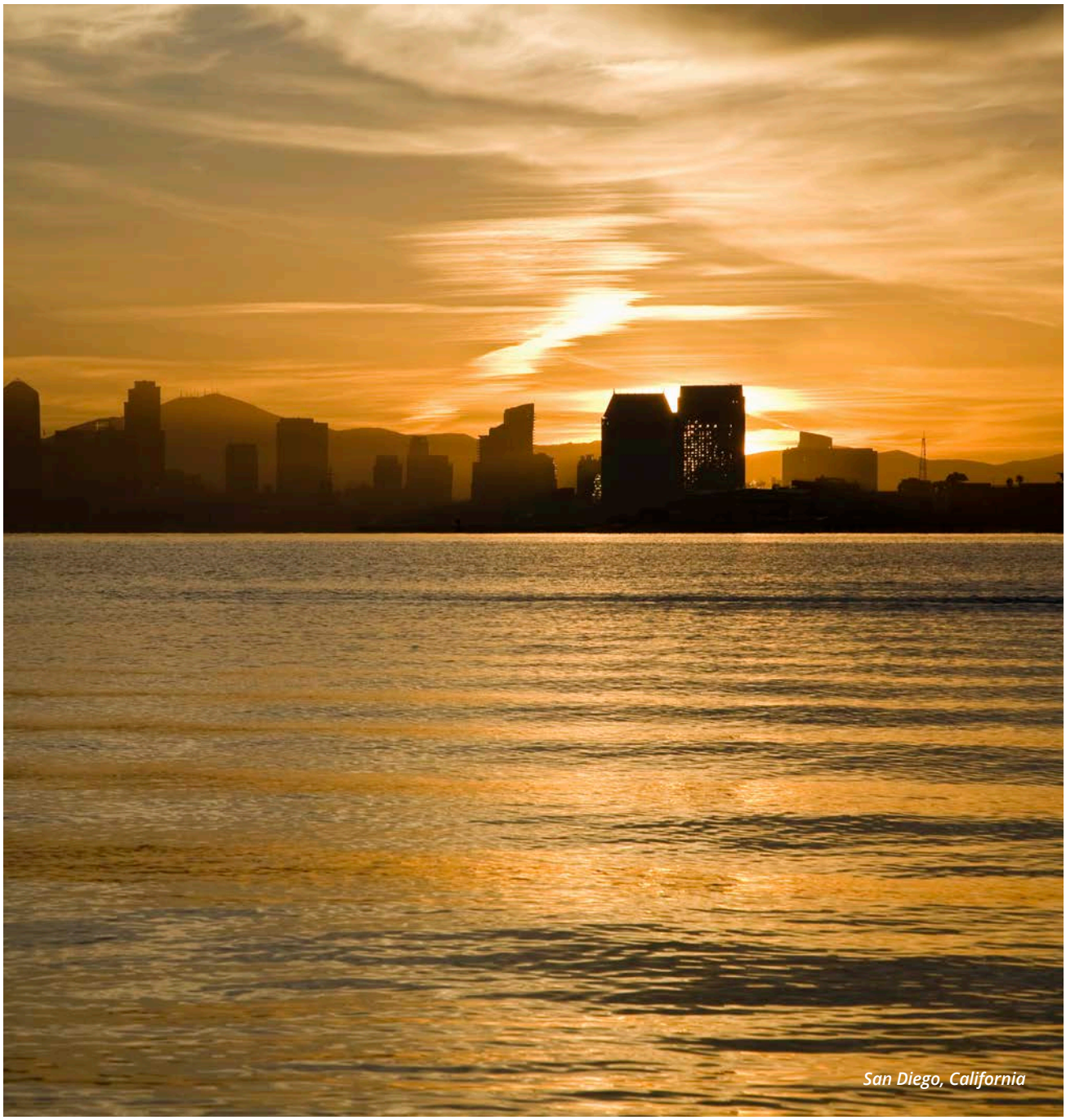
In part because of tectonic plate activity in California, sea level rise will vary across the state: Los Angeles (1.5 to 2.9 feet by 2100), Santa Monica (1.7 to 3.1 feet by 2100), and San Francisco (1.8 to 3.2 feet by 2100) will likely see lower rise than San Diego.

While extreme heat days in the Midwest and Southeast will likely be coupled with high humidity, here in the Southwest the days will likely be hot and dry, increasing the potential of wildfires and drying up water sources. While we did not quantify the impact of climate change on either forestry or water availability, these are significant climate risks in the Southwest region, and both are ripe for further analysis.

As the Southwest climate heats up, the region is likely to see significantly less snow in the mountains, leading to decreases in spring runoff especially in California and the Southern Rockies. Extreme heat may also lead to higher evaporation of existing reservoirs. This translates into less available groundwater for critical industries such as agriculture, as well as for simple drinking and bathing. Even as temperatures rise, increased energy demand from air conditioning will likely lead to increased water demand, since electricity generation is heavily water-dependent. Decreased water availability is also likely to be the most significant impact on this region's agricultural industries, which tend to be non-commodity crops (tree nuts, fruits, etc.) and therefore are not included in our quantitative analysis of the agricultural sector.

> *"A broad range of issues impact real estate, construction, and urban development. Obviously coastal inundation is one of those. Another is the implication of extreme weather events even within the internal parts of the country. . . . Some of the most water scarce areas of the country are due to get less precipitation. Areas that are dry are going to get drier. And that has immense implications for cites in the west."*
>
> **— Risk Committee member Henry Cisneros**[25]

SOUTHWEST



San Diego, California

ALASKA

Alaska is ground zero for U.S. climate impacts. The state relies heavily on three climate-sensitive commodities: oil and gas, minerals, and seafood.

More than 80% of the state's GDP comes from oil and gas production, and so increases in energy demand (as discussed above) will dramatically affect this region. Meanwhile, fisheries and tourism, the third and fourth largest contributors to the Alaska economy, depend on healthy oceans and coastal ecosystems.

Alaskan fisheries rely heavily on healthy oceans

Our research shows major climactic changes in Alaska over this century. If we continue on our current path, by mid-century Alaska's average temperature will likely rise to between 4.5°F to 8.0°F warmer than it has been over the past forty years. By the end of the century, temperatures will likely rise by 7.6°F to 16°F, but there is a 1-in-20 chance that they will rise even higher, by as much as 21°F. The bulk of this warming is likely to happen in the winter months, significantly decreasing the number of extremely cold days that Alaska now experiences. Up until 2010, Alaska experienced about 188 days per year below freezing; our current path will likely decrease these freezing days by 14% to 25% by mid-century, and by 30% to 50% by the end of this century.

The state is heavily coastal: 84% of Alaskans live in coastal counties, and 86% of the state's GDP comes from these counties. Sea level is variable around the state, due to the proximity of the glaciers and to shifting tectonic plates. As in the Pacific Northwest, the state may actually see sea levels go *down* over the course of this century: Our research shows that sea level at Juneau will likely fall by 1.6 to 2.0 feet between 2000 and 2050 and by 2.4 to 3.5 feet between 2000 and 2100. On the other hand, Anchorage will likely experience between a 0.6 feet sea level fall and a 1.2 feet sea level rise by the end of the century, with a 1-in-100 chance of a 3.2 foot rise. Prudhoe Bay is likely to experience 2.1 feet to 3.8 feet of sea level rise by 2100, with a 1-in-100 chance of a 6.6 foot rise.

HAWAII

As Alaska is at the center of climate impacts from melting ice, Hawaii is at the center of impacts from sea level rise. This state is 100% coastal in both its population and GDP.

Hawaii is expected to get significantly warmer: On our current path, by mid-century average temperatures will likely be between 1.6°F to 3.6°F warmer than temperatures over the past 40 years. By the end of the century, temperatures will likely increase between 3.9 and 7.7°F. There is also a small but not insignificant chance that Hawaii's average temperatures could rise as much as 10°F by the end of the century.

Sea level rise in Hawaii is greater than the global average, and the extreme dependence of this state on the coasts will only intensify this impact. If we continue on our current path, sea level rise at Honolulu is likely 0.8 inches to 1.2 feet greater by mid-century, and 2.1 to 3.7 feet by the end of the century. Looking out at the 1-in-100 tail risk, sea level at Honolulu could rise by as much as 6.1 feet by 2100.

Hawaii cannot reasonably be looked at as a stand-alone region, however: This state imports the vast majority of its food and energy, and is interdependent with the rest of the U. S. as well as the rest of the world. The recent tsunami in Japan and typhoon in the Philippines have awakened many businesses to the impact of a changing climate on global supply chains,[26] and ultra-dependent regions like Hawaii are by necessity very sensitive to these realities. Changing agricultural yields on the mainland may have a significant effect on Hawaii in terms of food cost and availability. Similarly, higher energy costs in the continental U.S. are likely to drive the cost of imported energy even higher for Hawaii. The state is pushing forward to diversify its energy resources and rely more on domestic renewable sources; however, most of these installations are along the vulnerable coastlines.

"I think we have to begin by recognizing the reality and severity of this threat to our economies, both United States and globally, and really to life on earth more broadly as we know it. We also have to recognize that this problem needs to be dealt with now. We cannot wait because greenhouse gases in the atmosphere, once they're there, remain there for centuries so that every year is greater and more severe in terms of greenhouse gas emissions cumulatively than had been the case the year before."

— Risk Committee member Robert E. Rubin[27]

FROM RISK ASSESSMENT TO RISK MANAGEMENT: NEXT STEPS

> *If we were told—in any sphere—that we had at least a 90% chance of averting a disaster through changes we ourselves could make, wouldn't we take action?*
>
> **— Risk Committee member Olympia Snowe[28]**

Taking a classic risk assessment approach to climate change in the U.S. leads to the inescapable conclusion that if we continue on our current climate path, the nation faces multiple risks across every region.

But risk assessment is not just about identifying risks and leaving it at that. Our research also shows that if we act today to move onto a different path, we can still avoid many of the worst impacts of climate change, particularly those related to extreme heat. We are fully capable of managing climate risk, just as we manage risk in many other areas of our economy and national security—but only if we start to change our business and public policy decisions today.

The Risky Business Project was not designed to dictate a single response to climate risk. We know that there will be a diversity of responses to our analysis depending on the particular risk tolerance of individual business and policy actors, as well as their particular region or sector of the economy. But the Risk Committee does believe, based on this project's independent research and the significance of the climate risks it demonstrates, that it is time for all American business leaders and investors to get in the game and rise to the challenge of addressing climate change. The fact is that just as the investments and economic choices we made over the past several decades have increased our current vulnerability to climate change, so will the choices we make today determine what our nation looks like in 15 years, at mid-century, and by 2100.

In short, we have a choice whether we accept the climate risks laid out above or whether we get on another path. **This is not a problem for another day. The investments we make today—this week, this month, this year—will determine our economic future.**

NEXT STEPS

There are three general areas of action that can help to minimize the risks U.S. businesses currently face from climate change:

BUSINESS ADAPTATION

Changing everyday business practices to become more resilient.

Some of the climate impacts we analyzed are already being felt across the nation; indeed, some are already an unalterable part of our economic future. Rational business actors must adapt. The agricultural sector is on the front lines of climate adaptation. As Risk Committee member Greg Page has noted, "Farmers are innovators and consummate optimizers. . . . They persistently demonstrate the ability to adapt to changes in the environment and successfully adopt new technologies." [29] In coastal communities, too, private and public sector decision-makers are beginning to adapt to present climate impacts, building sea walls and changing building codes to recognize the reality of rising sea levels and increased storm surge.

But this adaptation may come at a price: Some farmers in Midwest counties, for instance, may suffer economic losses shifting to new crops (with required new equipment and expertise), if they can afford to shift at all. Meanwhile, coastal states and cities are being forced to adapt to climate realities without adequate financial support from the federal government. [30] These public sector adaptation costs will only grow as the private insurance industry continues its exodus from the business of insuring coastal real estate and the bond market begins to wake up to the vulnerability of key infrastructure investments to climate change. [31] As Donna Shalala, President of the University of Miami and Risk Committee member, has noted , "People in Florida really have thought through some of the consequences . . . to the extent that they can do some things themselves through their local governments, through the state, they certainly have stepped up to do many of those things . . . but it's not enough. This is going to take a national investment." [32]

INVESTOR ADAPTATION

Incorporating risk assessment into capital expenditures and balance sheets.

Another area where today's business investments have a direct relationship to tomorrow's climate impacts is in long-term capital expenditures, which will live well into the middle of the century and beyond. Today, ratings agencies are evaluating infrastructure projects with a multi-decade lifespan. Utilities are making investments in new power plants and pipelines, and signing long-term power purchase agreements that rely on those investments. And real estate investors are making multiple bets on residential and commercial properties. These investments must be evaluated in terms of the actual climate risk specific regions face as we approach the middle of this century. In 2010, recognizing this reality, the Securities and Exchange Commission (SEC) issued Interpretive Guidance on climate disclosure, giving companies some idea of how to consider their "material" risks from climate change; unfortunately, as of 2013, over 40% of companies listed on the Standard & Poor's 500 Index were still not voluntarily disclosing climate risks. [33]

NEXT STEPS

PUBLIC SECTOR RESPONSE

Instituting policies to mitigate and adapt to climate change.

Ultimately, climate change is not just an issue for specific sectors and regions: It is a global issue that demands an effective policy response from the U.S. According to the latest Intergovernmental Panel on Climate Change report, the world may have as little as 15 years to "keep planetary warming to a tolerable level," through an aggressive push to bring down carbon emissions. [34]

In the Risky Business Project, we focused primarily on modeling our current economic path and the attendant climate risks. Because this is the path we're now following as a nation, we need to better understand the potential risks it poses and decide how to respond to those risks—especially those that are already embedded in our economy because of decisions we made decades ago.

But the path we're on today does not have to be the path we choose to follow tomorrow. Our analysis also looks at alternate pathways that include investments in adaptation and policy efforts to mitigate climate change through lowering greenhouse gas emissions. These alternate pathways could significantly change the climate impacts we discuss above. For example, modest global emission reductions can avoid up to 80% of projected economic costs resulting from increased heat-related mortality and energy demand.

Our goal in this risk assessment is not to dictate those policy pathways. However, we do strongly urge the American business community to play an active role in the public discussion around climate mitigation and preparedness, which we believe is the single most effective way for businesses to decrease the risks we have identified in this project.

FROM RISK ASSESSMENT TO RISK MANAGEMENT: NEXT STEPS

With this project, we have attempted to provide a common language for how to think about climate risk—built upon a common language of risk that is already part of every serious business and investment decision we make today. If we have a common, serious, non-partisan language describing the risks our nation may face from climate change, we can use it as the springboard for a serious, non-partisan discussion of the potential actions we can take to reduce those risks.

CONCLUSION

When Risk Committee member George Shultz was serving as President Reagan's Secretary of State in 1987, he urged the President to take action on that decade's hotly-contested scientific issue: the ozone layer. As Shultz later said in an interview with *Scientific American*, "Rather than go and confront the people who were doubting it and have a big argument with them, we'd say to them: Look, there must be, in the back of your mind, at least a little doubt. You might be wrong, so let's all get together on an insurance policy."[35] That insurance policy became the Montreal Protocol on Substances that Deplete the Ozone Layer, an international treaty still in effect to this day.

Our goal with the Risky Business Project is not to confront the doubters. Rather, it is to bring American business and government—doubters and believers alike—together to look squarely at the potential risks posed by climate change, and to consider whether it's time to take out an insurance policy of our own.

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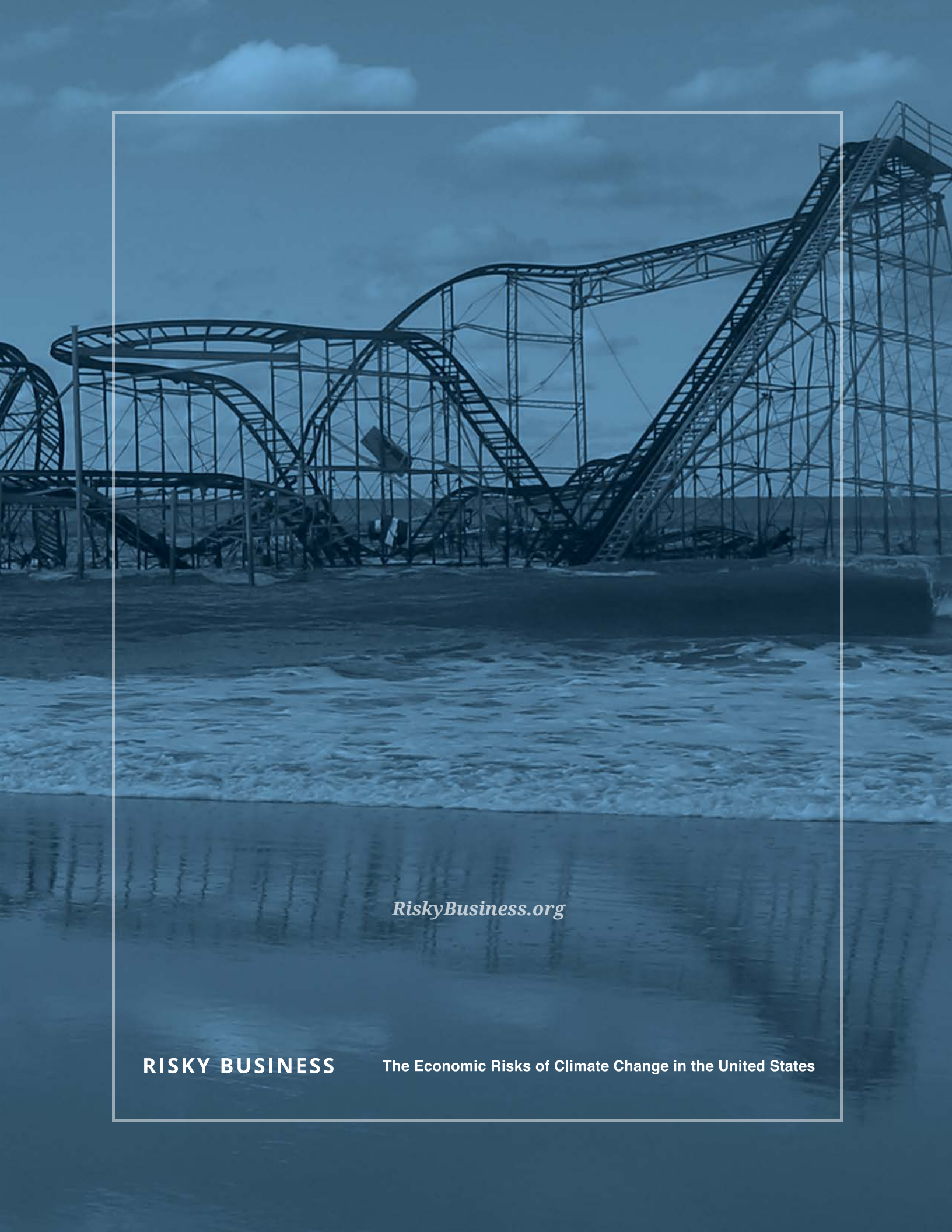

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