McKinsey
Global Institute

Climate risk and response: Physical hazards and socioeconomic impacts

Will mortgages and markets stay afloat in Florida?

Case study
April 2020

McKinsey Global Institute

Since its founding in 1990, the McKinsey Global Institute (MGI) has sought to develop a deeper understanding of the evolving global economy. As the business and economics research arm of McKinsey & Company, MGI aims to provide leaders in the commercial, public, and social sectors with the facts and insights on which to base management and policy decisions.

MGI research combines the disciplines of economics and management, employing the analytical tools of economics with the insights of business leaders. Our "micro-to-macro" methodology examines microeconomic industry trends to better understand the broad macroeconomic forces affecting business strategy and public policy. MGI's in-depth reports have covered more than 20 countries and 30 industries. Current research focuses on six themes: productivity and growth, natural resources, labor markets, the evolution of global financial markets, the economic impact of technology and innovation, and urbanization. Recent reports have assessed the digital economy, the impact of AI and automation on employment, income inequality, the productivity puzzle, the economic benefits of tackling gender inequality, a new era of global competition, Chinese innovation, and digital and financial globalization.

MGI is led by three McKinsey & Company senior partners: James Manyika, Sven Smit, and Jonathan Woetzel. James and Sven also serve as co-chairs of MGI. Michael Chui, Susan Lund, Anu Madgavkar, Jan Mischke, Sree Ramaswamy, Jaana Remes, Jeongmin Seong, and Tilman Tacke are MGI partners, and Mekala Krishnan is an MGI senior fellow.

Project teams are led by the MGI partners and a group of senior fellows and include consultants from McKinsey offices around the world. These teams draw on McKinsey's global network of partners and industry and management experts. The MGI Council is made up of leaders from McKinsey offices around the world and the firm's sector practices and includes Michael Birshan, Andrés Cadena, Sandrine Devillard, André Dua, Kweilin Ellingrud, Tarek Elmasry, Katy George, Rajat Gupta, Eric Hazan, Acha Leke, Gary Pinkus, Oliver Tonby, and Eckart Windhagen. The Council members help shape the research agenda, lead high-impact research and share the findings with decision makers around the world. In addition, leading economists, including Nobel laureates, advise MGI research.

The partners of McKinsey fund MGI's research; it is not commissioned by any business, government, or other institution. For further information about MGI and to download reports for free, please visit www.mckinsey.com/mgi.

In collaboration with McKinsey & Company's Sustainability and Global Risk practicies

McKinsey & Company's Sustainability Practice helps businesses and governments reduce risk, manage disruption, and capture opportunities in the transition to a low-carbon, sustainable-growth economy. Clients benefit from our integrated, system-level perspective across industries from energy and transport to agriculture and consumer goods and across business functions from strategy and risk to operations and digital technology. Our proprietary research and tech-enabled tools provide the rigorous fact base that business leaders and government policy makers need to act boldly with confidence. The result: cutting-edge solutions that drive business-model advances and enable lasting performance improvements for new players and incumbents alike. www.mckinsey.com/sustainability

McKinsey & Company's Global Risk Practice partners with clients to go beyond managing risk to enhancing resilience and creating value. Organizations today face unprecedented levels and types of risk produced by a diversity of new sources. These include technological advances bringing cybersecurity threats and rapidly evolving model and data risk; external shifts such as unpredictable geopolitical environments and climate change; and an evolving reputational risk landscape accelerated and amplified by social media. We apply deep technical expertise, extensive industry insights, and innovative analytical approaches to help organizations build risk capabilities and assets across a full range of risk areas. These include financial risk, capital and balance sheet–related risk, nonfinancial risks (including cyber, data privacy, conduct risk, and financial crime), compliance and controls, enterprise risk management and risk culture, model risk management, and crisis response and resiliency—with a center of excellence for transforming risk management through the use of advanced analytics. www.mckinsey.com/business-functions/risk

Will mortgages and markets stay afloat in Florida?

Case study
April 2020

Authors
Jonathan Woetzel, Shanghai
Dickon Pinner, San Francisco
Hamid Samandari, New York
Hauke Engel, Frankfurt
Mekala Krishnan, Boston
Claudia Kampel, Stuttgart
Marlies Vasmel, Amsterdam

Introduction to case studies

In January 2020, the McKinsey Global Institute published *Climate risk and response: Physical hazards and socioeconomic impacts*. In that report, we measured the impact of climate change by the extent to which it could affect human beings, human-made physical assets, and the natural world. We explored risks today and over the next three decades and examined specific cases to understand the mechanisms through which climate change leads to increased socioeconomic risk. This is one of our case studies, focused on Florida.

We investigated cases that cover a range of sectors and geographies and provide the basis of a “micro-to-macro” approach that is a characteristic of McKinsey Global Institute research. To inform our selection of cases, we considered over 30 potential combinations of climate hazards, sectors, and geographies based on a review of the literature and expert interviews on the potential direct impacts of physical climate hazards. We found these hazards affect five different key socioeconomic systems: livability and workability, food systems, physical assets, infrastructure services, and natural capital.

We ultimately chose nine cases to reflect these systems and based on their exposure to the extremes of climate change and their proximity today to key physiological, human-made, and ecological thresholds (Exhibit 1). As such, these cases represent leading-edge examples of climate change risk. Each case is specific to a geography and an exposed system, and thus is not representative of an “average” environment or level of risk across the world. Our cases show that the direct risk from climate hazards is determined by the severity of the hazard and its likelihood, the exposure of various “stocks” of capital (people, physical capital, and natural capital) to these hazards, and the resilience of these stocks to the hazards (for example, the ability of physical assets to withstand flooding). We typically define the climate state today as the average conditions between 1998 and 2017, in 2030 as the average between 2021 and 2040, and in 2050 between 2041 and 2060. Through our case studies, we also assess the knock-on effects that could occur, for example to downstream sectors or consumers. We primarily rely on past examples and empirical estimates for this assessment of knock-on effects, which is likely not exhaustive given the complexities associated with socioeconomic systems. Through this “micro” approach, we offer decision makers a methodology by which to assess direct physical climate risk, its characteristics, and its potential knock-on impacts.

Climate science makes extensive use of scenarios ranging from lower (Representative Concentration Pathway 2.6) to higher (RCP 8.5) CO_2 concentrations. We have chosen to focus on RCP 8.5, because the higher-emission scenario it portrays enables us to assess physical risk in the absence of further decarbonization. (We also choose a sea level rise scenario for one of our cases that is consistent with the RCP 8.5 trajectory). Such an “inherent risk” assessment allows us to understand the magnitude of the challenge and highlight the case for action. Our case studies cover each of the five systems we assess to be directly affected by physical climate risk, across geographies and sectors. While climate change will have an economic impact across many sectors, our cases highlight the impact on construction, agriculture, finance, fishing, tourism, manufacturing, real estate, and a range of infrastructure-based sectors. The cases include the following:

— For livability and workability, we look at the risk of exposure to extreme heat and humidity in India and what that could mean for that country’s urban population and outdoor-based sectors, as well as at the changing Mediterranean climate and how that could affect sectors such as wine and tourism.

- For food systems, we focus on the likelihood of a multiple-breadbasket failure affecting wheat, corn, rice, and soy, as well as, specifically in Africa, the impact on wheat and coffee production in Ethiopia and cotton and corn production in Mozambique.

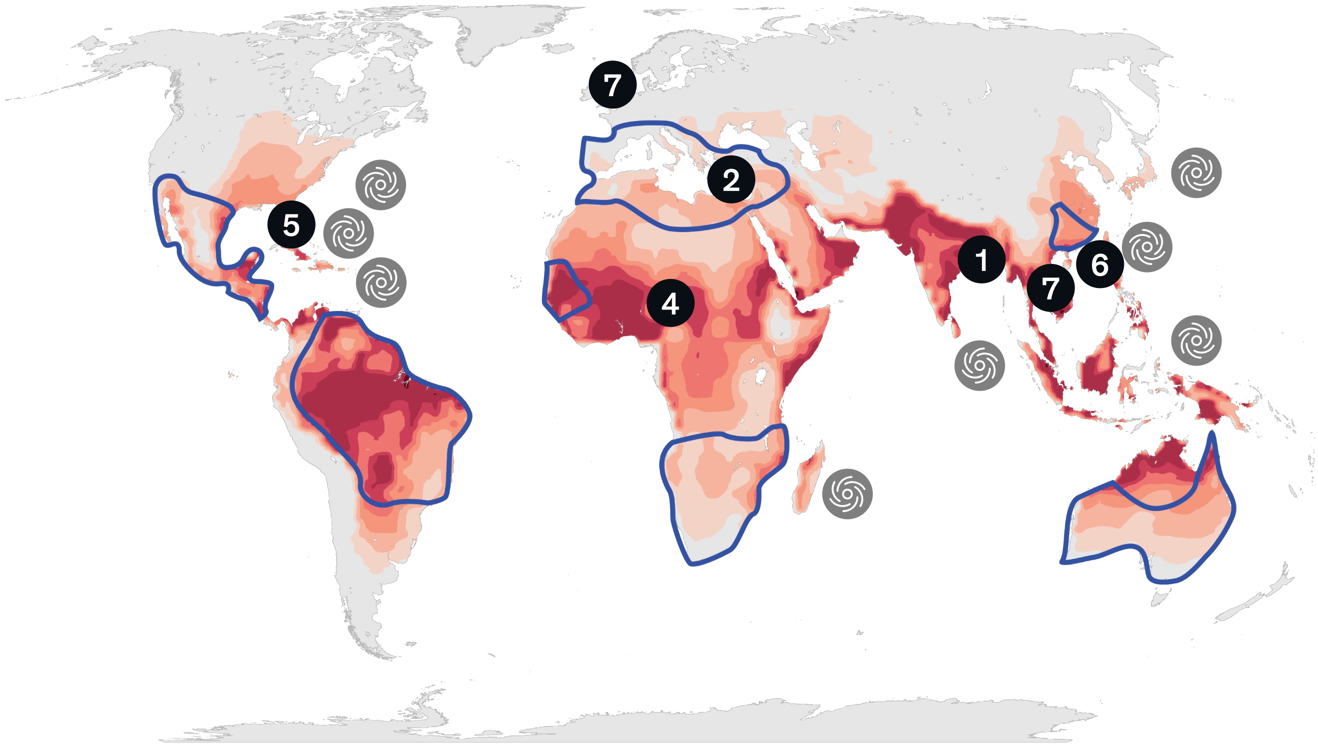
- For physical assets, we look at the potential impact of storm surge and tidal flooding on Florida real estate and the extent to which global supply chains, including for semiconductors and rare earths, could be vulnerable to the changing climate.

- For infrastructure services, we examine 17 types of infrastructure assets, including the potential impact on coastal cities such as Bristol in England and Ho Chi Minh City in Vietnam.

- Finally, for natural capital, we examine the potential impacts of glacial melt and runoff in the Hindu Kush region of the Himalayas; what ocean warming and acidification could mean for global fishing and the people whose livelihoods depend on it; as well as potential disturbance to forests, which cover nearly one-third of the world's land and are key to the way of life for 2.4 billion people.

Exhibit 1

We have selected nine case studies of leading-edge climate change impacts across all major geographies, sectors, and affected systems.



Global case studies 3 8 9

Heat stress[1] Low — High | Highest drought risk in 2050[2] | Increase in hurricane/cyclone severity

Livability and workability	1	Will India get too hot to work?
	2	A Mediterranean basin without a Mediterranean climate?
Food systems	3	Will the world's breadbaskets become less reliable?
	4	How will African farmers adjust to changing patterns of precipitation?
Physical assets	5	Will mortgages and markets stay afloat in Florida?
	6	Could climate become the weak link in your supply chain?
Infrastructure services	7	Can coastal cities turn the tide on rising flood risk?
	8	Will infrastructure bend or break under climate stress?
Natural capital	9	Reduced dividends on natural capital?

1. Heat stress measured in wet-bulb temperatures.
2. Drought risk defined based on time in drought according to Palmer Drought Severity index (PDSI).

Source: Woods Hole Research Center; McKinsey Global Institute analysis

Car in surf after Hurricane Ivan at Pensacola, Florida.

Florida

Will mortgages and markets stay afloat in Florida?

Florida's beaches and climate make it a popular location to live in the United States. But like many coastal areas around the world today, Florida is increasingly subject to extreme flooding. In the United States alone, approximately 30 percent of the population lives in counties adjacent to the Atlantic Ocean, Pacific Ocean, or Gulf of Mexico, where flooding and storm hazards are projected to grow.[1] However, Florida, with its low-lying terrain, large coastline and share of population exposed to climate change effects, as well as its economic dependence on real estate, may be particularly at risk (see Box 1, "What makes Florida so vulnerable to flooding risk?"). In addition, the fact that multiple climate hazards occur in the same place can increase the overall risk profile. In this case study, we focus primarily on residential property in Florida exposed to flooding from storm surges and to tidal flooding, and assess the potential impact.[2]

Today, average annual losses for residential real estate due to storm surge damage in Florida are $2 billion and could increase to about $2.5 billion to $3 billion by 2030 and $3 billion to $4.5 billion by 2050, in our inherent risk assessment, absent adaptation and mitigation action.[3] However, these represent statistically average losses; losses in each year could be higher or lower. Damages from extreme 1-in-100-year storm surge events could be more substantial; damages from such extreme events are expected to be $35 billion today and could grow by 40 to 110 percent to $50 billion to $75 billion by 2050.[4] The frequency of tidal flooding from rising sea levels is expected to grow from a few days a year to 30 to 60 times per year in 2030 and more than 200 times per year in 2050.[5]

1 Darryl T. Cohen, "Coastline county population continues to grow," US Census Bureau, August 6, 2018.

2 The analyses in this case rely on sea level rise projections going forward. We have based the analyses on sea level rise in line with the US Army Corps of Engineers high curve, one of the recommended curves from the Southeast Florida Regional Climate Change Compact. See Southeast Florida Regional Climate Change Compact Sea Level Rise Work Group, *Unified sea level rise projection: Southeast Florida*, October 2015. High curve results in 1.5m eustatic sea level rise by 2100 and is within the range of RCP 8.5. Recent observational evidence finds that sea level rise is accelerating and may occur faster than previous models predicted. See M. Oppenheimer et al., "Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities," in *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate,* 2019; Jevrejeva et al., 2014 for details.

3 Lower end of range based on analysis by KatRisk (referred to as KatRisk 2019); direct average annual losses to all residential real estate (insured and uninsured properties). This is the long-term statistical average loss expected in any one year, calculated by modeling the probability of a climate hazard occurring multiplied by the damage should that hazard occur, and summing over events of all probabilities. Upper end based on assuming an increase in exposure of real estate based on historical rates of increase.

4 This analysis is based only on the impacts of storm surge, where sea level rise is expected to increase the damages from storm surge. More broadly, considering the hurricane hazard, while total hurricane frequency is expected to remain unchanged or to decrease slightly under increased global warming, cumulative hurricane rainfall rates, average intensity, and proportion of storms that reach Category 4–5 intensity are projected to increase, even for a 2°C or less increase in global average temperatures. Thomas Knutson et al., *Tropical cyclones and climate change assessment: Part II. Projected response to anthropogenic warming,* American Meteorological Society, 2019.

5 Analysis by First Street Foundation, 2019.

Location matters

The potential impact of storm surge is not spread evenly across the state: three counties (Miami-Dade, Lee, and Collier) account for roughly half of the average annual losses.[6] For extreme storm surge events, damages in Miami-Dade could amount to the equivalent of about 10 percent of total market value in a given year, about 30 percent in Lee, and about 20 percent in Collier.

Box 1.

What makes Florida so vulnerable to flooding risk?

Florida has a number of physical, economic, and demographic characteristics that make it vulnerable to flooding.

Physical vulnerabilities include:

— Multiple hazards drive risk: storm surge, wind speed, precipitation, and sea level rise.

— A porous limestone foundation makes it hard to protect with sea walls.

— Sea level rise pushes more saltwater inland and into the porous limestone foundation.

— Climate change increases the abundance of toxic algae blooms and seaweed piles on beaches, reducing the attractiveness of living near coastal waters.

Economic vulnerabilities include:

— 22 percent of GDP is from real estate (Florida's GDP is $1 trillion, comparable to the Netherlands').

— 30 percent of local government tax revenue comes from property taxes.

— 42 percent of median wealth in the United States is from real estate.

Demographic vulnerabilities include:

— Two-thirds of the population lives near the coastline (defined as counties that border coastal water or territorial seas).

— 10 percent of the population is located less than 1.5 meters above sea level.

— 27 percent of housing units are on a 100-year floodplain, an area that has a 1 percent chance of a flood in any given year.

— From 2010 to 2018, the population of Miami-Dade, a low-lying and populous part of the state, increased by 11 percent while building permits increased by over 200 percent.

— 6.5 percent of the US population lives in Florida, but accounted for 11 percent of all building permits issued in 2018.

6 Analysis supported by KatRisk; McKinsey Global Institute analysis.

Financial markets may recognize today's risk and future risk, resulting in knock-on impacts

Even if Florida is spared another destructive hurricane in the next ten to 30 years, climate change could affect the state's economy through adjustments in asset prices, as buyers start to recognize climate risk and as insurance premiums adjust. For example, home owners may change their expectations as properties and the roads adjacent to them are subject to increased tidal flooding. We estimate the potential impact of the progressive devaluation of homes. To do this, we rely on quantitative analysis that compares the prices of exposed properties to similar unexposed ones, as is typical in the literature.[7] We do not estimate if and how much prices of homes could rise or fall in absolute terms, but rather how much tidal flooding could impact the prices of exposed homes, all else being equal. Based on historical experience, we conservatively estimate a total devaluation of about $10 billion to $30 billion of affected homes by 2030, rising to $30 billion to $80 billion by 2050, or about the equivalent of a 5 to 15 percent impact in 2030 and 15 to 35 percent in 2050, all else being equal. The devaluation could be larger, and potentially result in an absolute decline in the value of homes relative to their prices today, for example, if flooding regularly affects public infrastructure or if home owners more aggressively factor climate risk into their buying decisions.

Other knock-on impacts

Lower real estate prices could in turn have further knock-on effects, including forgone property taxes, reduced wealth and spending by home owners, and changes in government spending. Business activity could be negatively affected, as could mortgage financing in high-risk areas.

While the pace and magnitude of home price adjustments and their knock-on effects are unclear and difficult to predict, what is clear is that without action, certain communities in Florida could eventually look vastly different than they do today. Communities in Florida have already started to adapt and plan for climate change effects, and more will need to be done.[8] Policy makers, home owners, and investors should consider strategically what to protect, how to protect it, and how to minimize exposure to climate risk. We explore these areas in greater detail below. Florida has an opportunity to plan effectively for the future and identify a path to sustainable, equitable adaptation that can help manage some of climate change's most severe effects and in the process, serve as a guide for other coastal communities around the world.

[7] Much of the literature on this topic finds that, at least historically, prices of exposed properties have risen slower than prices of unexposed properties, rather than observed a decline in absolute terms of exposed property prices to date. The impact of climate change on property prices is thus seen as a "lost appreciation." See, for example, Jesse M. Keenan, Thomas Hill, and Anurag Gumber, "Climate gentrification: From theory to empiricism in Miami-Dade County, Florida," *Environmental Research Letters*, May 2018, Volume 13, Number 5; Steven A. McAlpine and Jeremy R. Porter, "Estimating recent local impacts of sea level rise on current real-estate losses: A housing market case study in Miami-Dade, Florida," *Population Research and Policy Review*, December 2018, Volume 37, Number 6; and Asaf Bernstein, Matthew T. Gustafson, and Ryan Lewis, "Disaster on the horizon: The price effect of sea level rise," *Journal of Financial Economics*, November 2019, Volume 134, Number 2. Importantly, our analysis here is not a prediction, and home prices could devalue much more severely and much faster, and even decline in absolute terms relative to today, depending on how market sentiments evolve, how lending activity continues, and what adaptation measures are put in place.

[8] Since 2016, Miami-Dade County has adopted nearly 20 climate change resolutions, ranging from assessments to understand the risk of sea level rise and saltwater intrusion to developing TV programming on local stations that educates the public about rising waters.

An economically important and populous state, Florida is already experiencing the impact of climate change

Florida is the fourth-largest state economy and third-most-populous US state.[9] Its $1 trillion GDP is roughly the same size as the Netherlands', and its population has grown by 13 percent since 2010.[10] Florida's economy depends heavily on real estate. In 2018, real estate accounted for 22 percent of state GDP.[11] Real estate also represents an important part of household wealth for the 65 percent of Floridians who are home owners: primary residences represent 42 percent of median home owner wealth in the United States.[12] In a state without individual income tax, the public sector relies on real estate as a key source of revenue. Approximately 30 percent of local government tax revenue comes from property taxes directly tied to property values.[13]

Multiple physical vulnerabilities increase climate risk

At the same time, Florida's geography makes it vulnerable to climate change. Located in a tropical cyclone zone with low elevation and an expansive coastline, the state faces numerous climate hazards, including hurricane damage and tidal flooding that are worsened by sea level rise, and heat stress due to rising temperatures and changes in humidity. Other unique features include the state's porous limestone foundation which can exacerbate flooding as water seeps into properties from the ground below and also cause saltwater intrusion into water aquifers, making adaptation challenging.

We focus on the evolution of flooding impact, a climate hazard that causes significant real estate damage across Florida. The frequency of tidal flooding is increasing in Florida due to sea level rise. Since 2007, southern Florida has experienced an average of more than two weeks of so-called nuisance tidal flooding annually.[14] In the prior decade, the region experienced just four days a year on average.[15] Over the past several decades, attribution studies have shown that at least three major landfalling hurricanes in the United States were made more likely or the impacts more severe due to climate change, including Hurricane Katrina, Hurricane Sandy, and Hurricane Harvey.[16] An increasing trend in hurricane intensity (in terms of wind speed, rainfall, and storm surge height), and the proportion of storms that reach Category 4 and 5, is projected to emerge given further warming.[17]

---

9 US Bureau of Economic Analysis, May 1, 2019; US Census Bureau Population Division, July 1, 2018, accessed July 2019.

10 In 2018, GDP in Florida (not seasonally adjusted) was roughly $1.04 trillion, and in the Netherlands, $912 billion, according to the Federal Reserve Bank of St. Louis FRED database and the World Bank. Florida's population was 18.8 million in 2010 and 21.3 million in 2018, according to US Census Bureau, December 2018.

11 National Association of Realtors, *The economic impact of a typical home sale in Florida*, 2018.

12 Federal Reserve Bank of St. Louis, FRED database, *Homeownership rate for Florida*, fred.stlouisfed.org/series/FLHOWN; Michael Neal, "Housing remains a key component of household wealth," *Eye on Housing*, National Association of Home Builders, September 4, 2013.

13 Other income sources are value-added taxes, fees, and business revenues. For more details, see *Household wealth & real estate*, UPFINA, September 2018.

14 Nuisance flooding is defined as 1.1 feet above mean higher high water (MHHW). Estimates based on tidal flooding risk; NOAA's Vertical Datum Transformation tool used to determine local mean sea level and local MHHW along the Florida coast. Future predicted sea levels are taken from the US Army Corps of Engineers. See Steven A. McAlpine and Jeremy R. Porter, "Estimating recent local impacts of sea level rise on current real-estate losses: A housing market case study in Miami-Dade, Florida," *Population Research and Policy Review*, December 2018, Volume 37, Number 6.

15 Steven A. McAlpine and Jeremy R. Porter, "Estimating recent local impacts of sea level rise on current real-estate losses: A housing market case study in Miami-Dade, Florida," *Population Research and Policy Review*, December 2018, Volume 37, Number 6.

16 S-Y Simon Wang et al., "Quantitative attribution of climate effects on Hurricane Harvey's extreme rainfall in Texas," *Environmental Research Letters*, May 2018, Volume 13, Number 5; Jennifer L. Irish et al., "Simulation of Hurricane Katrina (2005) under sea level and climate conditions for 1900," *Climatic Change,* February 2014, Volume 122, Number 4; Ning Lin et al., "Hurricane Sandy's flood frequency increasing from year 1800 to 2100," *Proceedings of the National Academy of Sciences*, October 2016, Volume 113, Number 43

17 Thomas Knutson et al., *Tropical cyclones and climate change assessment: Part II. Projected response to anthropogenic warming,* American Meteorological Society, 2019.

Physical hazards translate into economic impact

The physical effect of storms and flooding translates into real economic impact. Much of Florida's physical and human capital is located along its vulnerable coast. Two-thirds of the state's population lives near the coastline, exposing many of them to tidal flooding, and almost 10 percent is less than 1.5 meters above sea level.[18] Of Florida's roughly 7.0 million housing units, 1.9 million are in the current 100-year floodplain.[19] Of the ten costliest US tropical cyclones since 1900, half hit Florida, causing a total of more than $130 billion in damages.[20] The last three major tropical cyclones to hit the state—hurricanes Irma (2017), Wilma (2005), and Ivan (2004)—generated a cumulative $90 billion in damages within the state, equivalent to the entire state budget in fiscal year 2019.[21]

Because capital and people have continued to flow into exposed coastal areas, increasing exposure to climate hazards has contributed to increasing costs. Between 2010 and 2018, the population of Miami-Dade county grew by 11 percent and the number of building permits issued increased by more than 200 percent.[22] While Florida is home to about 6.5 percent of the US population, the state accounted for some 11 percent of US building permits issued in 2018.

Adaptation is already occurring but needs additional effort

As communities begin to recognize the threat of physical climate change, this is spurring adaptation efforts across southern Florida. While these measures are expected to help reduce climate-related damages in the future, they still represent costs today and require funding. Beach nourishment has been a regular investment along the coast for decades. Since 1980, some $1.7 billion has been spent on beach nourishment in Florida, nearly three-quarters of that total from federal sources.[23] Zones that have invested in nourishment account for more than half of the state coastline fronted by single-family homes and have both higher housing density and larger housing units than other areas.[24] Recent infrastructure investments also include the installation of pump stations to manage frequent flooding and the construction of desalination plants.[25] Construction of a single plant can cost hundreds of millions of dollars and take years.[26] Initiatives to date also include measures to increase natural flooding defenses. Urban development has reduced natural defenses such as mangroves and vegetated communities, but such ecosystems can be restored.[27] The largest restoration investment in the United States to date, at a cost of $10.5 billion, is the Comprehensive Everglades Restoration Plan that aims to "restore, preserve, and protect the south Florida ecosystem while providing for other water-related needs of the region, including water supply and flood protection."[28] In 2019, the county and the cities of Miami and Miami Beach released a strategy for the area, "Resilient305," that includes measures to bolster beaches, expand nature-based infrastructure, and identify opportunities to reduce storm surge risk.[29]

---

18 Ben Strauss, Claudia Tebaldi, and Scott Kulp, *Florida and the surging sea: A vulnerability assessment with projections for sea level rise and coastal flood risk*, Climate Central, April 2014; *National coastal population report: Population trends from 1970 to 2020*, NOAA and US Census Bureau, March 2013.

19 Stephanie Rosoff and Jessica Yager, *Housing in the U.S. floodplains*, NYU Furman Center, May 2017.

20 NOAA National Hurricane Center. Estimates include insured and uninsured losses.

21 Irma did approximately $50 billion in damage; Wilma and Ivan about $20 billion each. NOAA National Hurricane Center; News Service of Florida, "Hurricane Michael insured losses near $5.53 billion," *Panama City News-Herald*, February 7, 2019; Lawrence Mower, Emily L. Mahoney, Elizabeth Koh, and Samantha J. Gross, "$91.1 billion: Florida lawmakers consider the budget," *Tampa Bay Times*, May 1, 2019.

22 American Community Survey; US Census Bureau; Moody's Analytics.

23 In 2016 dollars. Scott B. Armstrong et al., "Indications of a positive feedback between coastal development and beach nourishment," *Earth's Future*, December 2016, Volume 4, Number 12.

24 Ibid.

25 Marcia Wendorf, "The fresh water crisis and desalination plants," *Interesting Engineering*, April 2019.

26 Craig Pittman, "Desalination plant, reservoir helping Tampa Bay endure Florida's fiery drought," *Tampa Bay Times*, April 18, 2017. In total, Florida has nearly 40 plants that together can produce approximately 300 million gallons of water per day, according to the South Florida Water Management District, sfwmd.gov/our-work/alternative-water-supply/desalination

27 Kathleen Sullivan Sealey, Ray King Burch, and P.-M. Binder, *Will Miami Survive? The Dynamic Interplay between Floods and Finance*, Cham, Switzerland: Springer, 2018.

28 National Park Service, *Comprehensive Everglades Restoration Plan (CERP)*, May 8, 2019.

29 Resilient 305, https://resilient305.com/

Many of these adaptation efforts are the work of state or federal agencies, and thus funded by taxpayers. For example, the US Army Corps of Engineers executes resilience projects to help states adapt to climate change, including $1.7 billion spent on flood risk management nationally in 2017.[30] In Miami, a new property tax will finance the $400 million Forever Bond to help repay debt incurred on the municipal bond market.[31] Nearly half of the funds will be directed toward decreasing flooding risks and managing sea level rise.[32]

The effects of a changing climate in Florida could increase over the next decade and beyond

Climate change is projected to exacerbate flooding due to storm surges, wind speed and precipitation intensity, and rising sea levels that increase tidal (also referred to as nuisance) flooding.[33] The frequency of tidal flooding is expected to grow from a few days a year to 30 to 60 times per year in 2030 and more than 200 times per year in 2050 for stations near Florida's coast (Florida-1).[34] The wind speed at Florida's south coast during a 100-year hurricane is projected to increase from about 120 knots to about 180 to 240 knots by midcentury. Precipitation during a 100-year hurricane event is projected to see a similar 50 to 100 percent increase, from about 60 centimeters to 90 to 120.[35]

Consider the impact of storm surge, which is expected to increase with sea level rise. Average annual damages from storm surges in Florida's residential real estate market total $2 billion today, a figure that could increase to $3 billion to $4.5 billion, by midcentury depending on whether the exposure is expected as constant or as seeing some buildup, absent adaptation and mitigation.[36] However, individual counties can see more extreme increases. Examples are Volusia, St. Johns, and Broward counties, which could see their average annual losses grow by approximately 80 percent by 2050. The counties with the highest absolute average annual damages are Miami-Dade, Lee, and Collier: together their losses account for roughly $1 billion today (Miami-Dade: ~$0.4 billion, Lee: ~$0.4 billion, Collier: ~$0.3 billion) and a potential $1.5 billion in 2050 (Miami-Dade: $0.6 billion, Lee: $0.6 billion, Collier: $0.5 billion).[37]

30 US Army Corps of Engineers, *Fiscal year 2017 United States Army Corps of Engineers annual financial report: A nation's strength, a people's security*, 2017.

31 Urban Resilience Project, "Making the 'Miami Forever Bond' a model for equitable climate adaptation," Medium, October 22, 2018.

32 Southeast Florida Regional Compact on Climate Change, "Financing resilience: City of Miami invests $400 million to build a stronger future," May 17, 2018.

33 Nuisance flooding is flooding during high tides that leads to public inconveniences (for example, frequent road closures, overwhelmed storm drains, and compromised infrastructure). NOAA; Thomas Knutson et al., "Tropical cyclones and climate change assessment: Part II. Projected response to anthropogenic warming," *Bulletin of the American Meteorological Society*, 2019.

34 Based on NOAA minor nuisance flooding thresholds of: Mayport, 1.44 feet mean higher high water (MHHW); Panama City, 1.15 feet MHHW; Virginia Key (Miami), 1.33 feet MHHW. First Street Foundation, 2019.

35 Woods Hole Research Center; Kerry Emanuel, *The Coupled Hurricane Intensity Prediction System (CHIPS)*, Massachusetts Institute of Technology, 2019.

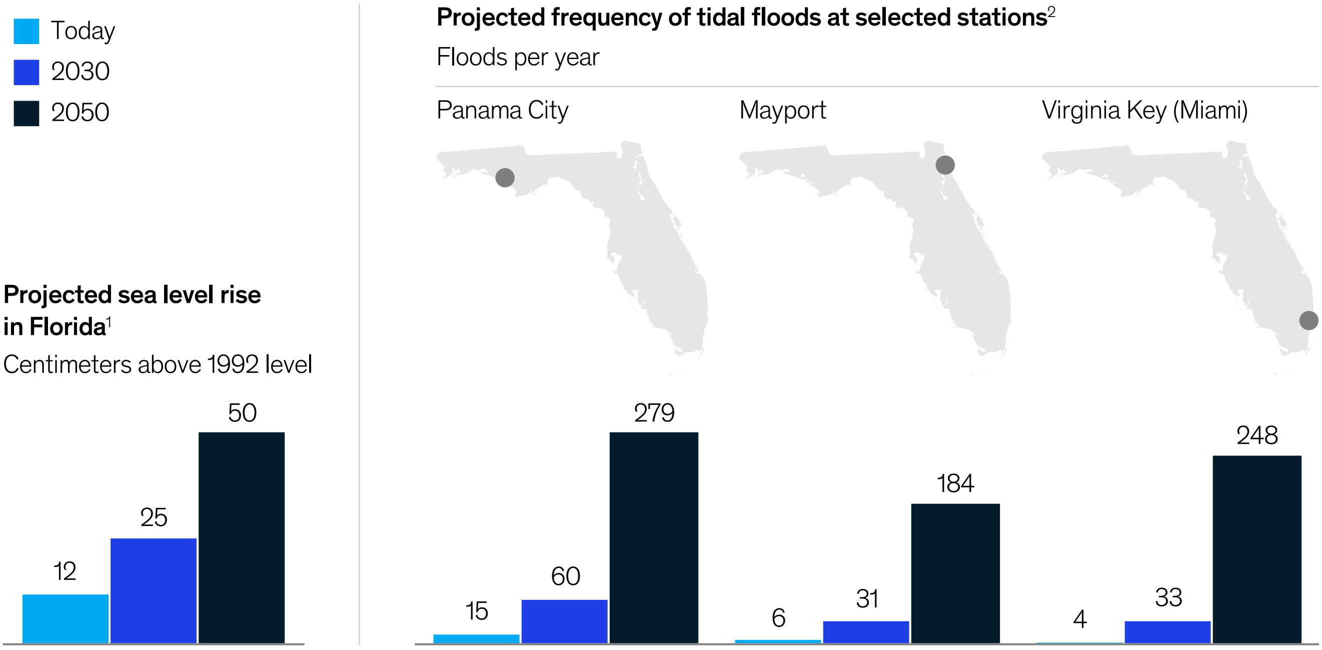
36 Lower end of range based on analysis by KatRisk, 2019; direct average annual losses to all residential real estate (insured and uninsured properties). Upper end based on assuming an increase in exposure of real estate based on historical rates of increase. Analyses based on sea level rise in line with the US Army Corps of Engineers high curve.

37 Figures may not sum to 100 percent because of rounding.

Case study Florida-1

Tidal flooding in Florida is projected to increase nonlinearly over the next decade and beyond.

Based on USACE high scenario



1. Based on US Army Corps of Engineers (USACE) high curve at Key West, Florida. High curve results in 1.5 meter eustatic sea level rise by 2100 (within range of RCP 8.5 scenario; see, for example, Jevrejevaet et al., 2014).
2. Based on USACE high curve and NOAA minor nuisance flooding thresholds at Mayport, 1.44 feet mean higher high water (MHHW); Panama City, 1.15 feet MHHW; Virginia Key (Miami), 1.33 feet MHHW.

Note: We define "today" based on sea level rise in 2018. See Technical Appendix of the full report for why this climate scenario was chosen.
Source: First Street Foundation, 2019; Southeast Florida Unified Sea Level Rise Projection

"Tail" events could become even more disruptive

Rising sea levels also increase the damage caused by "tail" events in all counties. Florida's real estate losses during storm surge from a 100-year storm surge event are expected to be $35 billion today and could grow to $50 billion to $75 billion by 2050 (Florida-2). For Miami-Dade, the expected damages from such a tail event could be about 10 percent of total market value, about 30 percent in Lee, and about 20 percent in Collier. To put the likelihood of such a large loss into context, in the lifetime of a 30-year mortgage, a 100-year storm (that is, an event with a likelihood of 1 percent) has a 26 percent chance of occurring at least once. Finally, the level of losses that are observed during today's 100-year event (that is, an event of a 1 percent likelihood today) are projected to become more frequent; by 2050, such losses could happen approximately every 60 years, that is, almost doubling the likelihood of such an event (Florida-3).

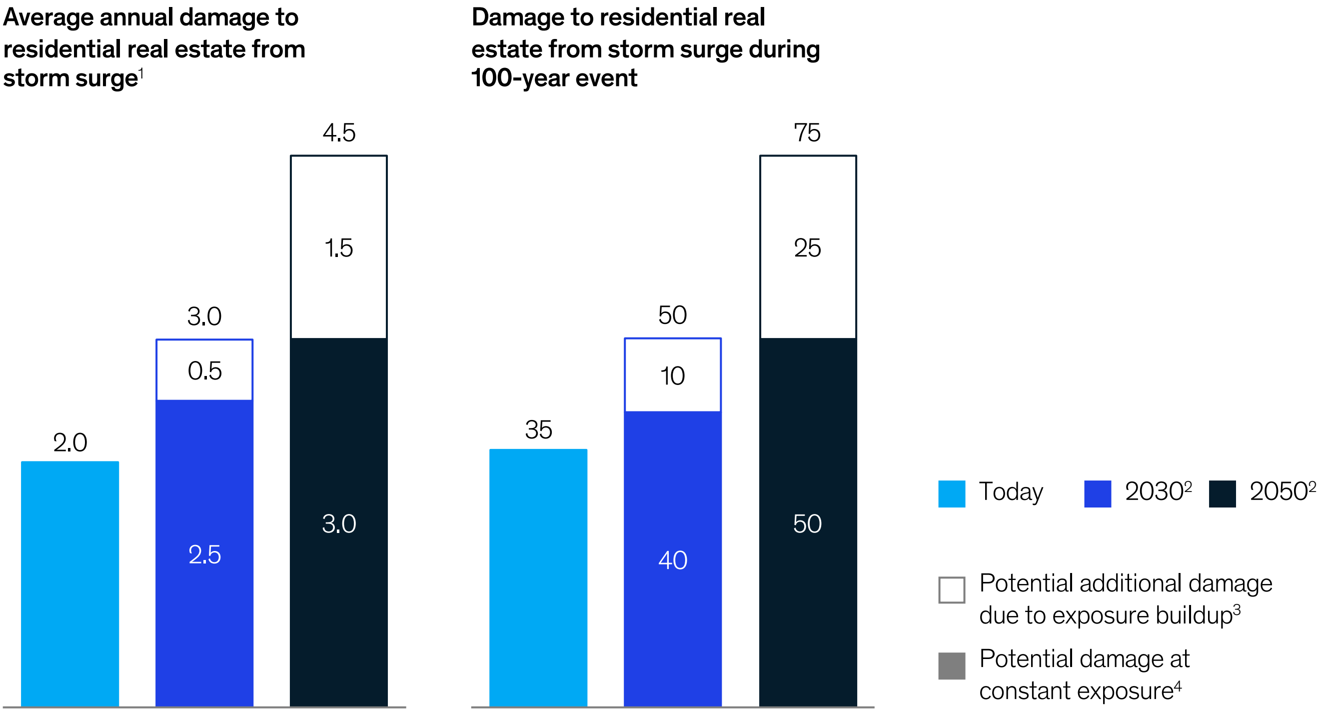
Case study Florida-2

Damage from a 100-year storm surge event in Florida could increase from $35 billion today to $50 billion in 2030 and $75 billion in 2050.

Based on USACE high scenario

Losses due to damage

$ billion, 2018 dollars



1. Damage to insured and uninsured properties. Figure represents long-term average loss expected in any one year, calculated by modeling probability of a climate hazard occurring multiplied by damage should that hazard occur, and summing over events of all probabilities.
2. Sea level rise based on USACE high curve.
3. Estimate based on buildup of residential real estate at equal rate throughout Florida, and for new homes having similar adaptation levels to existing homes.
4. Historical exposure takes into account data from KatRisk, 2019.

Note: Not to scale. Figures rounded to nearest 0.5 for the average annual damage, and nearest 5 for the 100-year event. We define "today" based on sea level rise in 2018. See Technical Appendix of the full report for why this climate scenario was chosen.

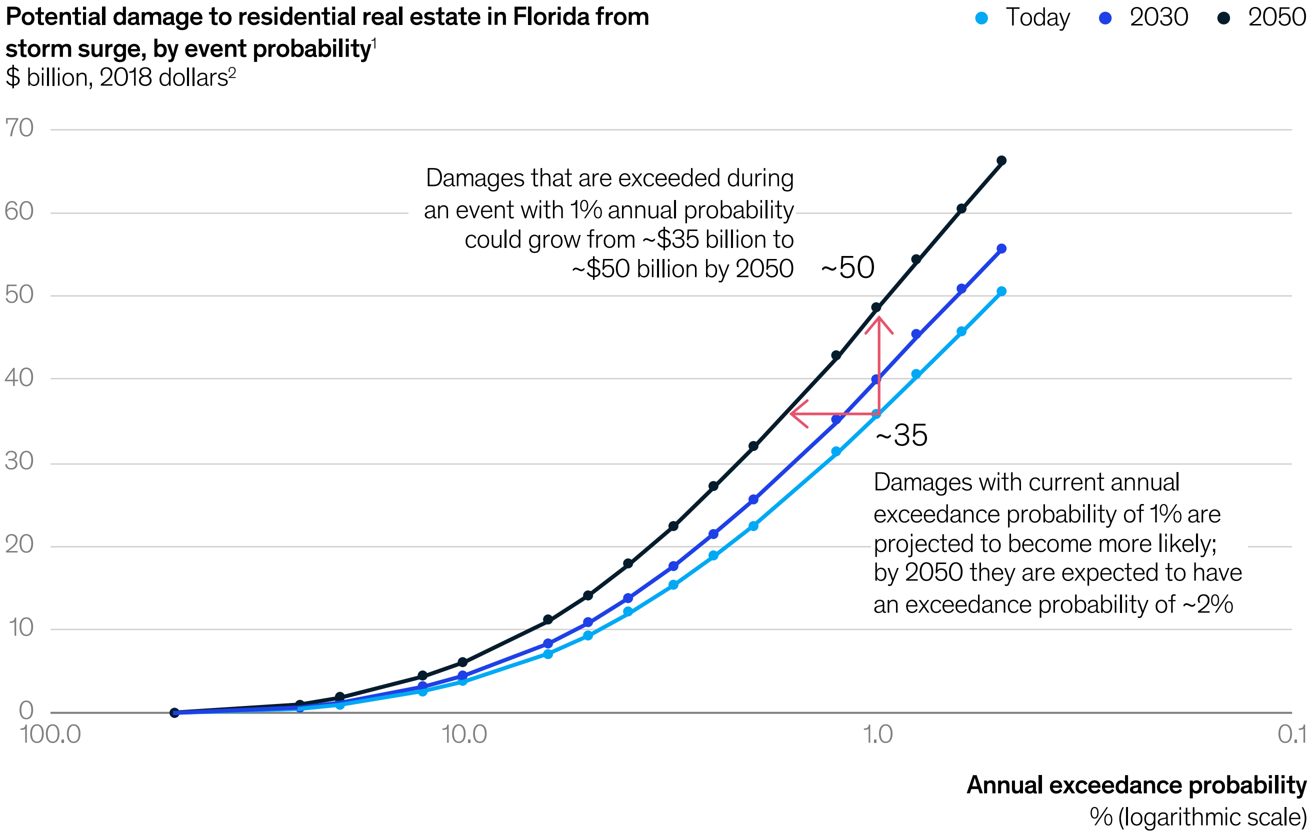
Source: KatRisk; Moody's Analytics; US Census Bureau; McKinsey Global Institute analysis

Case study Florida-3

"Tail" events are projected to cause more damage; losses from an event with 1 percent annual probability in Florida could grow from approximately $35 billion to approximately $50 billion by 2050.

Based on USACE high scenario

Potential damage to residential real estate in Florida from storm surge, by event probability[1]
$ billion, 2018 dollars[2]



1. Sea level rise based on USACE high curve. High curve results in 1.5 meter eustatic sea level rise by 2100 (within range of RCP 8.5 scenario; see, for example, Jevrejeva et al., 2014). Based on current exposure. Buildup of additional residential real estate in areas prone to storm surge could further increase expected damage.
2. Based on damages if event occurs; damages not adjusted for likelihood of event. Damages based on constant exposure, ie, increase in potential damages to 2030 or 2050 is due to change in expected hazards.

Note: See the Technical Appendix of the full report for why this climate scenario was chosen. We define "today" based on sea level rise in 2018.

Source: Analysis conducted by KatRisk

The knock-on effects of climate change on the Florida economy could be even more significant

While the Florida residential real estate market remains robust today, climate risk poses a potential threat to asset prices. It is difficult to know the timing and magnitude of impacts; indeed, they are influenced by myriad factors such as how quickly home owners recognize current and future risk, the availability and price of insurance, the willingness of lenders to lend, occupancy rates of rented accommodation or second homes, household debt levels, employment levels, the timing of major disasters, the attractiveness of communities and school districts, and adaptation measures taken to protect homes and communities and the cost of those measures. All of these play a role in influencing home prices and housing demand. A climate-related devaluation of property prices in Florida would cascade throughout the state economy, affecting government tax revenue, GDP, commercial development, and population growth.

Signs indicate that climate risk may already be beginning to affect home prices. Researchers have found evidence in Florida, as well as more broadly in the United States, that prices of properties at risk of tidal flooding and exposure to sea level rise are lower, and are appreciating at a slower pace compared with similar unexposed properties, indicating that buyers are beginning to recognize climate risk.[38] For example, Bernstein et al. (2018) find that nationally, houses exposed to sea level rise are valued at a 7 percent discount compared with similar unexposed properties.[39] And risk may still be under-recognized. For example, the researchers find that only "sophisticated" owners (the term used by the authors to describe non-owner-occupied properties) are factoring climate risk into their prices, and even for those owners, price discounts that they apply to exposed properties have been increasing over time.[40]

As buyers experience flooding, prices of affected homes may also adjust

Single severe acute events such as a Category 4 or 5 hurricane may alter home buyers' expectations. Homes damaged by Hurricane Sandy in 2012 in New York experienced an initial 17 to 22 percent drop in value, and while they recovered somewhat, as of 2017 they remained at about an 8 percent discount relative to similar properties elsewhere in the city— and surprisingly, this was close to the impact on prices of homes that were not directly damaged by the storm, but in flood zones.[41] The First Street Foundation estimates that, to date, properties that are exposed to flooding have on average seen a 3 percent price discount compared with similar unexposed properties. Properties exposed to disruptive flooding—where more than 25 percent of a property lot or nearby roads are flooded—on average have lost 11 percent of their value compared with similar unexposed properties.[42] This has already resulted in a total devaluation today of $5 billion of affected residential properties in Florida.[43]

Tidal flooding with frequency more than 50 times a year is projected to affect properties worth $50 billion by 2050

Going forward, more homes will be exposed to tidal flooding, and those exposed to disruptive flooding are also expected to increase. About 25,000 homes in Florida already experience flooding at frequencies of more than 50 times per year (almost once a week on average). With

---

38 See, for example, Jesse M. Keenan, Thomas Hill, and Anurag Gumber, "Climate gentrification: From theory to empiricism in Miami-Dade County, Florida," *Environmental Research Letters*, May 2018, Volume 13, Number 5; Steven A. McAlpine and Jeremy R. Porter, "Estimating recent local impacts of sea level rise on current real-estate losses: A housing market case study in Miami-Dade, Florida," *Population Research and Policy Review*, December 2018, Volume 37, Number 6; and Asaf Bernstein, Matthew T. Gustafson, and Ryan Lewis, "Disaster on the horizon: The price effect of sea level rise," *Journal of Financial Economics*, November 2019, Volume 134, Number 2.

39 Asaf Bernstein, Matthew T. Gustafson, and Ryan Lewis, "Disaster on the horizon: The price effect of sea level rise," *Journal of Financial Economics*, November 2019, Volume 134, Number 2.

40 For example, across the United States, buyers who are climate aware have been found to discount home values an average of six additional percentage points relative to those who are less aware. Asaf Bernstein, Matthew T. Gustafson, and Ryan Lewis, "Disaster on the horizon: The price effect of sea level rise," *Journal of Financial Economics*, November 2019, Volume 134, Number 2.

41 Francesc Ortega and Süleyman Taspinar, "Rising sea levels and sinking property values: The effects of Hurricane Sandy on New York's housing market," *Journal of Urban Economics*, July 2018, Volume 106.

42 Analysis by First Street Foundation, 2019.

43 Analysis by First Street Foundation, 2019; McKinsey Global Institute analysis.

rising sea levels, 40,000 coastal properties representing about $15 billion of value could run this risk by 2030, and 100,000 properties worth $50 billion in 2050. This value represents 4 percent of Florida's $1.3 trillion residential real estate market.[44] These properties may see resale prices drop significantly due to severe and frequent flooding, even falling to zero if there are no prospective buyers.[45]

Putting this together, we estimate that the projected increase in tidal flooding frequency and severity could result in a $10 billion to $30 billion devaluation by 2030, and $30 billion to $80 billion by 2050, all else being equal (Florida-4).[46] Today, First Street estimates that roughly 375,000 homes have seen devaluation impacts, and by 2050, that figure could be about 550,000. By 2050, the average devaluation of affected homes is expected to increase to 15 to 35 percent, all else being equal. These estimates are conservative for two reasons. First, our analysis largely assumes that the relationship between the magnitude of flooding and home price devaluation remains constant in the future. With the severity and frequency of flooding damage increasing, that relationship could change, for example as home owners become increasingly less tolerant to frequent flooding.[47] Second, as flooding worsens, home owners could also expect that the future will look worse than the past. Expectations of worsening impacts could further decrease current home prices. The magnitude of such devaluations would depend on the pace with which climate hazards intensify and on how home buyers factor worsening hazard into their decisions (see Box 2, "How climate hazards impact demand for homes").

Real estate buyers may price in expectations of future hazards and other factors

Home prices may be influenced not just by today's level of hazard, but also by expectations of how hazards could evolve. The resale potential, maintenance costs, and comfort and convenience of a home in the future are all factors buyers consider. Once buyers become aware of and price in expectations of future hazards, home prices may adjust in advance of significant climate-induced property destruction or flooding-related inconvenience. For example, homes adjacent to properties that are frequently affected by tidal flooding or storm surges could see prices drop as prospective buyers grow concerned. Increased incidence of toxic algae blooms in coastal waters and of seaweed piles on beaches may further reduce the attractiveness of coastal properties.[48] Individual tolerances to withstand frequent flooding and damages could also shift. If public infrastructure assets are affected, for example from frequent flooding, that could reduce the desirability of entire communities.

44 First Street Foundation, 2019. Properties are at flooding risk if 3 percent of the lot is below daily maximum tide height; home values are based on the value of the home used for tax purposes, not on market value.

45 The Union of Concerned Scientists finds a similar result: that in 2030, roughly 21,000 homes will be at risk of flooding more than 26 times per year, and before midcentury, the number could rise to approximately 64,000. The difference in magnitude is driven by different thresholds defining whether a property is flooded; "New study finds 1 million Florida homes worth $351 billion will be at risk from tidal flooding," Union of Concerned Scientists, June 18, 2018; under 2014 National Climate Assessment high SLR scenario (2.0 m above 1992 by 2100).

46 This analysis was conducted by the First Street Foundation specifically for this MGI report. In summary, the First Street Foundation model is a property-level analysis of the relationship between real estate trends and the local experience of tidal flooding events. The tidal model is a high-precision model created from observed tide gauge readings, digital elevation models, and sea level rise adjustments, whereas the real estate transactions are all drawn from publicly available local sources that have been compiled and standardized. The analysis identifies differential appreciation rates for properties that experience tidal flooding in comparison to those that do not, with the former seeing a slower rate of appreciation over the study period (2005–17). For further details on the First Street methodology, see Steven A. McAlpine and Jeremy R. Porter, "Estimating recent local impacts of sea level rise on current real-estate losses: A housing market case study in Miami-Dade, Florida," *Population Research and Policy Review*, December 2018, Volume 37, Number 6, and firststreet.org/research/methodology. Note that these numbers quantify a loss of appreciation among properties affected by tidal flooding; they do not necessarily indicate an absolute decrease in value, but rather a difference in value between affected and unaffected homes. For example, changes in supply and demand may be much more important to explain the absolute change in price, but there will still be a deviation between the price evolution of homes that are exposed to flooding versus those that are not.

47 Furthermore, parts of Florida could experience higher or lower degrees of impact based on their specific socioeconomic conditions. For example, urban areas with robust local economies may find themselves more resilient to price impacts, because those areas continue to be attractive to prospective buyers and potentially can more easily finance adaptation spending.

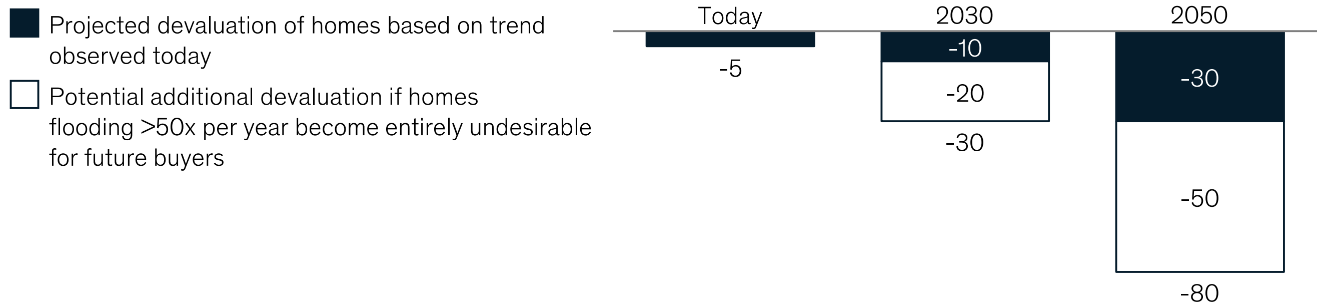
48 Mengqiu Wang et al., "The great Atlantic Sargassum belt," *Science*, July 2019, Volume 365, Number 6448.

Case study Florida-4

Tidal flooding has caused an estimated $5 billion devaluation in real estate, which could grow to $30 billion to $80 billion by 2050.

Projected devaluation of Florida real estate market due to tidal flooding[1]

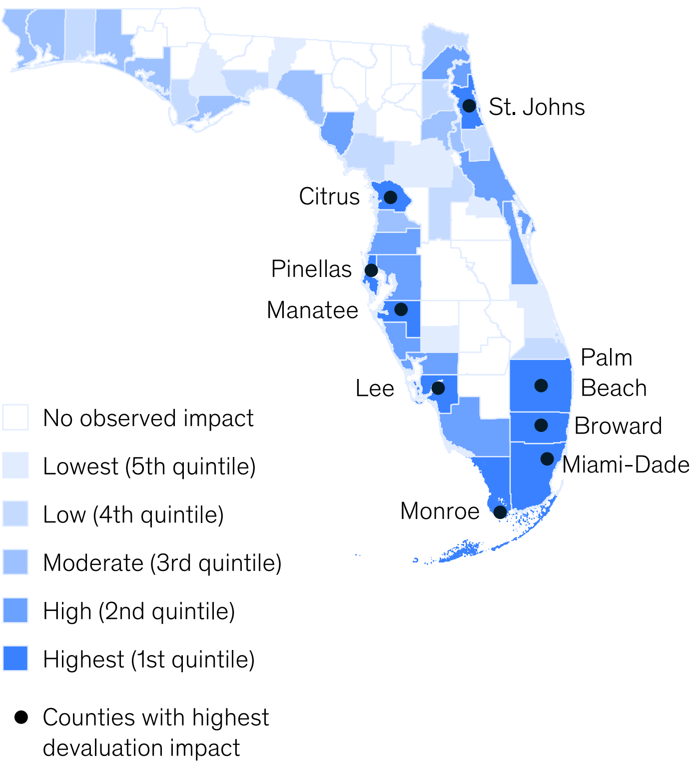
$ billion, 2018 dollars



	Today	2030	2050
Average devaluation compared to unexposed homes %	~5	5–15	15–35
Number of impacted homes Thousand		470	550

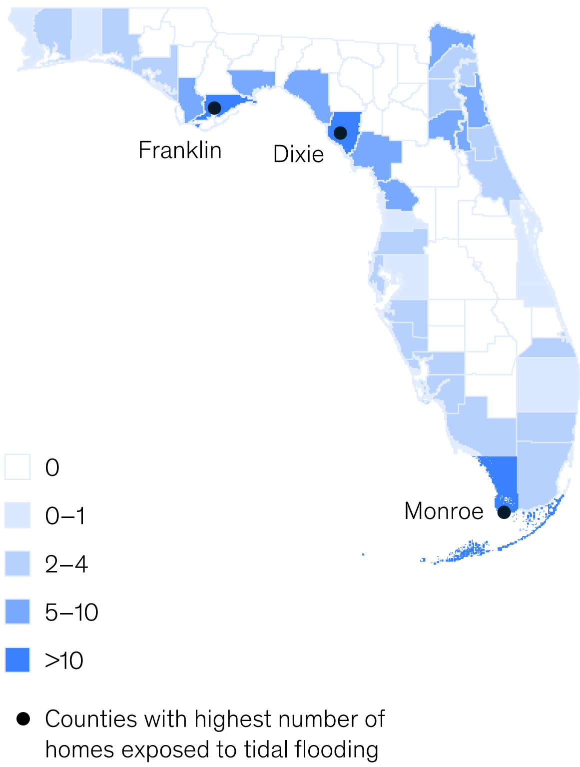
Level of devaluation by county by 2050

Quintile (by total value, $)



Homes exposed to tidal flooding >50x per year by 2050

Share of total number of homes in each county, %



1. Based on First Street Foundation's property-level analysis of relationship between real estate trends and local experience of tidal flooding events. Analysis identifies differential appreciation rates for properties that experience tidal flooding in comparison to those that do not, with the former seeing a slower rate of appreciation over study period (2005–17). Analysis relies on assumption that future relationship between flooding impact and home value devaluation equals historical relationship. Low end of rage based on historical devaluation; high end assumes homes flooded >50x per year see 100% devaluation.

Note: See the Technical Appendix for why we chose RCP 8.5. All projections based on RCP 8.5, CMIP 5 multimodel ensemble. Following standard practice, we define current and future (2030, 2050) states as average climatic behavior over multidecade periods. Climate state today is defined as average conditions between 1998 and 2017, in 2030 as average between 2021 and 2040, and in 2050 as average between 2041 and 2060. $ figures rounded to nearest 5, % figures rounded to nearest 5%.

Source: First Street Foundation 2019; McKinsey Global Institute analysis

Box 2.

How climate hazards impact demand for homes

Notably, in some locations in the United States, acute as well as chronic climate events have already driven managed retreat. For example, Isle de Jean Charles, Louisiana, has lost 98 percent of its area to erosion, sinking land, rising seas, and hurricane damage, creating the need for inland resettlement. In some communities (such as the village of Mastic Beach in New York), this type of migration has already been observed and encouraged through buyout programs in neighborhoods that experienced repetitive or severe repetitive losses.[1] However, most large-scale retreat to date has typically been driven by major acute events, and this may remain a challenge, particularly as climate change makes destructive hurricanes more likely. In New Orleans, Hurricane Katrina in 2005 destroyed or rendered uninhabitable an estimated 300,000 homes.[2] After 80 percent of the city flooded, the population halved, and even ten years later it had not returned to its original levels.[3] After the storm, non-local mortgage lenders largely exited the market.[4] The situation in New Orleans also illustrated that catastrophic weather events do not affect all neighborhoods equally. For example, while ten years later the populations of most neighborhoods had returned to their original level, that was not the case for the most geographically and socially vulnerable neighborhoods, to which in some cases less than half of the population had returned.[5]

1 Robert Freudenberg et al., *Buy-in for buyouts: The case for managed retreat from flood zones*, Lincoln Institute of Land Policy, 2016.
2 US Executive Office of the President, *The federal response to Hurricane Katrina: Lessons learned*, February 2006.
3 Ibid.; the population in 2015 was approximately 15 percent lower than before the hurricane, according to the US Census Bureau.
4 Justin Gallagher and Daniel Hartley, "Household finance after a natural disaster: The case of Hurricane Katrina," August 2017, *American Economic Journal: Economic Policy*, Volume 9, Number 3.
5 W. A. Lascell and P. R. Baumann, "Lower 9th Ward, New Orleans: Recovery and rebuilding," *Middle States Geographer*, 2015, Volume 48.

Impacts are not evenly distributed over Florida

The numbers above represent averages across the state of Florida, but the impact on specific communities and counties could be much more extreme. In many communities, affected homes could be concentrated in the same neighborhoods, where devaluation can have a large local impact. We identify three counties, Dixie, Monroe, and Franklin, where by 2030 more than 10 percent of homes are projected to flood 50 times or more per year, and eight others where 5 percent or more homes see such an impact.

Insurance premiums and availability for homes in high-risk areas may change

Real estate prices reflect expectations of the future and often extend beyond a single decade; mortgages are typically set on 15- or 30-year time horizons. Conversely, insurance premiums are repriced annually. At the national level, the largest provider of residential flood insurance (which is typically excluded from home owners' insurance) is the federal government. Since 1968, the Federal Emergency Management Agency (FEMA) has provided flood insurance to residents through the National Flood Insurance Program (NFIP). If premiums grow accordingly with the potential average annual loss (about 50 percent by 2050), the average annual premium could increase by about 50 percent from $800 to $1,200, with high-risk properties seeing a much higher jump.[49] Such a hike could further affect future property values. If home buyers factor increased premium contributions into a home's current value, this could cause a decline of about $3,000 in the average value of a home, or a statewide devaluation of about $5 billion.[50] Home owners in hazard high-risk areas may see much larger impacts from FEMA's premium revamp as part of Risk Rating 2.0 (see Box 3, "The role of flood

49 Willis Tower Watson, 2019 for current premiums.
50 Based on the 1.7 million policies in force in Florida today; FEMA.

insurance in managing climate risk"). In the past, premiums have tripled in hazard high-risk areas after such adjustments.[51] Similar increases could lead to devaluations on the order of $15,000 to $20,000 for affected home owners, which could translate into roughly 5 percent of devaluation for individual homes.

Devaluation of home prices could affect statewide financial resilience

Impact on real estate prices would directly impact local government tax revenues, potentially affecting financial resilience. For example, if homes that flood more than 50 times per year are abandoned, that could correspond to 4 percent of forgone property tax revenues by 2050. Rough estimates suggest that the price effects discussed above could impact property tax revenue in some of the most affected counties by about 15 to 30 percent (though impacts across the state could be less, at about 2 to 5 percent).

Home owners who are frequently affected by climate hazards may also find it more difficult to finance repairs due to financial distress, particularly if their communities also raise taxes to counter the impact on property prices and to finance adaptation measures. In addition, local and regional banks that own concentrated portfolios of mortgages on coastal properties may find themselves especially vulnerable to near-term climate events that could affect a disproportionate slice of their asset portfolios.

The question of how long commercial financing and insurance provision will remain viable in parts of Florida prone to climate hazards is unresolved. Some emerging research has started to explore these issues in areas experiencing rising climate risk, and how they can be managed, though further work is needed.[52] As one example, a recent NBER working paper suggests that mortgage lenders may be changing their behavior in high-risk areas.[53] After billion-dollar hurricanes between 2004 and 2012, the research finds that lenders increased their approval rates for loan amounts close to the conforming loan limit. They find that the probability of foreclosure for mortgages obtained in hurricane areas is higher than average, and the researchers believe that this behavior essentially causes a transfer of risk to taxpayers.[54] The likelihood of mortgage foreclosures could increase with intensifying climate hazards: damages from extreme events may cause financial distress for home owners, and even home owners who are not financially distressed may choose to strategically default if their homes fall steeply in value and are not expected to recover. As mortgage lenders start to recognize these risks, they could turn to additional securitization, change lending rates for risky properties, or, in some cases, eliminate long-term lending in the form of 30-year mortgages. More work is needed to better understand the effect of climate change on lending pricing and risk, the magnitude of risk and who bears it, and potential responses.

Exposure to climate risk may also influence corporate relocation and investment in coastal Florida. Companies may decide to relocate headquarters inland or to a different state altogether. In that case, Floridians could feel job and wage implications from climate change beyond the impact on their real estate wealth. Should Florida's job market lose key corporate investment, population growth and talent drain could carry knock-on effects for growth and GDP far larger than the initial real estate devaluation or property effects.

---

51 Debra Kahn, "Insurers see smoldering risk after California's worst wildfire," E&E News, October 16, 2018.

52 See for example "Life's a beach," Economic Housing Research Insight, Freddie Mac, April 2016; Jessica Lamonda and Edmund Penning-Rowsell, "The robustness of flood insurance regimes given changing risk resulting from climate change," *Climate Risk Management*, Volume 2, 2014; Lloyd Dixon et al., *The Cost and Affordability of Flood Insurance in New York City: Economic Impacts of Rising Premiums and Policy Options for One- to Four-Family Homes*, RAND Corporation, 2017; "Strategies to Address Climate Change Risk in Low- and Moderate-Income Communities," *Federal Reserve Bank of San Francisco Community Development Innovation Review*, Volume 14, Issue 1, 2019.

53 Amine Ouazad and Matthew E. Kahn, *Mortgage finance in the face of rising climate risk*, National Bureau of Economic Research working paper number 26322, Issued in September 2019, Revised in April 2020.

54 See also Christopher Flavelle, "Climate risk in the housing market has echoes of subprime crisis, study finds," *New York Times*, September 27, 2019.

Box 3.

The role of flood insurance in managing climate risk

Insurance plays a key role in helping communities adapt to climate change. Residents with insurance are more resilient to disasters than those without it. Typically, those without insurance are forced to rely on friends, family, or uncertain government disaster relief programs. For example, after Hurricane Irma, National Flood Insurance Program (NFIP) policyholders received an average payment of $52,000, but the individual assistance government relief program disbursed only a few thousand dollars each to those eligible.

In the state of Florida, hurricane wind insurance and flood insurance have been growing. The NFIP now covers about $1.3 trillion of assets nationally. Among all states, Florida accounted for the most NFIP policies in force (1.7 million, or 34 percent of the national total) in 2018. To date, flood insurance premiums collected by the NFIP in Florida have more than covered insured losses in Florida: from 1978 to 2008, premiums outstripped claims in Florida by $10 billion, and in only one year did claims exceed premiums. But significant issues remain and more can be done to improve access to insurance and insurance products themselves. Today, given premium subsidies, risks may not be clear to stakeholders in the Florida real estate ecosystem, and in many instance, the public sector - and therefore taxpayers - may be acting as the ultimate backstops.

First, the NFIP is already in debt as a result of several catastrophic years since 2005 (it can borrow from the US Treasury to pay for unfunded claims). As of September 2018, the program had $20.5 billion in debt even though Congress had canceled $16 billion in debt in October 2017. More frequent flooding and hurricanes creating massive storm surges would be very challenging for the program to absorb under its current operating model.

Second, while cross-subsidy is inherent to the original design of this national program, a study by actuarial firm Milliman suggests that roughly 80 percent of single-family home owners in Florida could be overpaying for their insurance today but 14 percent would have to pay at least double their NFIP premium to reflect their true risk.[1] As climate hazards worsen and damage in high-risk areas increases, premiums may not be sufficient to cover claims—unless they are significantly increased in the most flood-prone areas of the state. Today this risk may not be clear to stakeholders in the Florida real estate ecosystem, and in many instances, the public sector—and therefore taxpayers—is ultimately assuming the risks of climate change.

Third, the flood insurance system may also elevate home prices and increase exposure in risky areas by creating the false perception that short-term risk is less severe or relevant for a particular property than reality indicates. Banks may rely on insurance for mortgages, but the ability to annually reprice insurance could mean lenders and home owners bear more risk than they realize.

There are moves underway to reduce the risk within the insurance system by matching premiums more closely to risk. For 2021, FEMA plans to unveil its new Risk Rating 2.0 program, aimed at providing a much more granular pricing approach. As premiums better reflect future versus historic risk, insurance will provide a clearer economic signal of the level of exposure. As FEMA and the private sector develop better and more granular knowledge of flood risk, risk maps will be improved. With the aid of technology, it will soon be possible to determine risk at the property level, providing a very detailed view of flood exposure for each individual in the state. A simple scoring mechanism will then be possible, facilitating communication. However, the rise in premiums that high-risk home owners will experience will require some form of glide path to prevent disruptive effects for individual home owners, and for the housing market more broadly.

This will come with its own challenges. In California, for example, wildfires have grown so costly and damaging that insurance companies have increasingly been canceling people's policies in fire-prone parts of the state. In December 2019, however, the state of California imposed a one-year moratorium preventing insurers from dropping customers in or alongside ZIP codes struck by recent wildfires. The moratorium covers at least 800,000 homes around the state.[2]

1 Nancy Watkins, *Could private flood insurance be cheaper than the NFIP?* Milliman briefing paper, July 2017.
2 Christopher Flavelle and Brad Plumer, "California bans insurers from dropping policies made riskier by climate change," *New York Times*, December 5, 2019.

In the face of considerable uncertainty about the knock-on effects of intensifying climate hazards, one consequence of climate change in Florida is becoming increasingly clear: ultimately, the related economic and financial risk could fall on home owners and taxpayers. While home owners can insure against the direct damages of flooding, they cannot insure against property devaluation. Prospective home owners could also be affected, as banks may stop providing 30-year mortgages in high-risk areas. Finally, with the state and federal governments often subsidizing premiums and needing to finance adaptation measures, all taxpayers could be affected (see Box 4, "Who bears the risk?").

Florida can minimize costs and risks by increasing ecosystem-wide awareness and mobilizing for adaptation

To help Florida manage climate risk, policy makers, home owners, and investors should consider strategically what to protect, how to protect (for example, fortifying infrastructure and increasing financing), when to protect, and how to minimize climate risk exposure.[55] These factors are relevant to stakeholders not only in Florida, but also in places facing similar challenges. This includes locations with high coastal real estate values (including San Francisco, Singapore, and Taiwan), coastal locations where a significant share of local revenue comes from property taxes (such as New York City, where that proportion is about 30 percent), and states where housing markets rely heavily on federal insurance systems (such as Florida, Louisiana, and Texas, which account for 60 percent of NFIP contracts).[56] The state and communities will face hard choices in the face of rising sea levels and worsening hazards. But planning today can help manage the consequences and minimize the costs of climate change in the future. In this section we outline steps stakeholders in Florida should consider: increase public- and private-sector awareness and transparency of climate change risk, build resilience at the local level and accelerate adaptation investment, and mobilize funds and assistance to vulnerable communities.

Increase awareness and transparency of climate change risk

Banks, investors, and the real estate sector could explore opportunities to provide funding, transparency, and solutions while increasing awareness and transparency of physical climate risk. The following options may be considered: include flood maps as part of online real estate home searches, issue mortgages with 30-year insurance premium forecasts based on increasing flood risk, pledge a proportion of local real estate investment to "climate opportunity zones," and include climate change risk in interest rate models to both increase bank resilience and be more transparent to home owners.

Build resilience at the local level

Building resilience at the local level may also involve strengthening community-based networks and organizations that can provide not only information but also economic and technical assistance to help with adaptation, and an emergency natural-disaster response network. Some cities, such as New York, have set aside funds to allow for participatory budgeting, giving local residents a voice in how to spend tax dollars on investment in their community. Designating vulnerable communities as climate opportunity zones and allowing locals to vote on the resilience measures they find most appealing could also encourage innovation while spurring spending on local adaptation.

55 Miami Beach Rising Above, *Resiliency strategy*, mbrisingabove.com/your-city-at-work/resiliency-strategy; Southeast Florida Regional Compact on Climate Change, *What is the compact?*; Tampa Bay Regional Planning Council Resiliency Coalition, *Benefits of collaborating on resilience*.

56 New York City Council; Carolyn Kousky et al., *The emerging private residential flood insurance market in the United States*, Wharton Risk Management and Decision Processes Center, July 2018.

Box 4.
Who bears the risk?

Managing risk in Florida's residential real estate market involves a complex set of transactions between different economic agents: home owners, public and private insurers, government-sponsored enterprises, and the federal government, to name a few (Florida-5). Each of these entities plays a role in managing risk from hazards like floods, wind, and fire. However, as climate change intensifies these hazards, the key question is who bears the increased risk?

While it is difficult to know for certain, a few things stand out:

— Consider home owners. While they can insure, they are sometimes subject to insurance caps. Additionally, they often have long-term mortgages, 15 to 30 years, while insurance is re-priced every year, creating a duration mismatch. If insurance premiums adjust, home owners will need to bear additional costs that they may be unprepared for. Moreover, home owners are also subject to the impact of devaluation of their homes, which cannot be insured against.

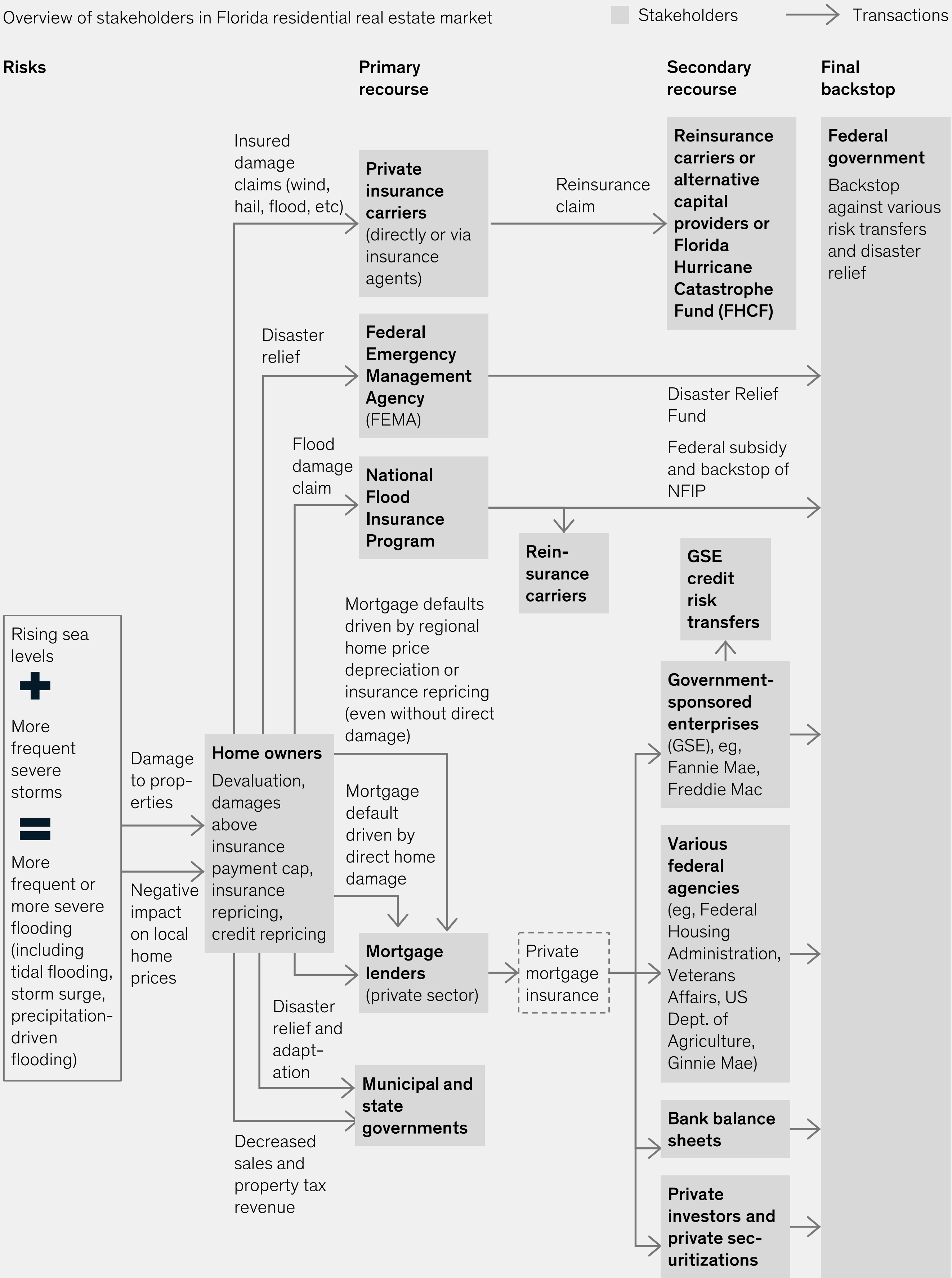
— Lenders similarly might be at risk from defaults since they provide loans assuming the viability of insurance. However, securitization, as discussed previously, is increasingly being used by lenders to manage risk.

— As hazards intensify, this will raise demands on the federal government to provide disaster relief funds. This means that much of the risk could ultimately fall on taxpayers.

Case study   Florida-5

Who holds the risk?

Overview of stakeholders in Florida residential real estate market



Source: McKinsey Global Institute analysis

Accelerate adaptation investment

As flooding hazards intensify and hurricane severity increases, the need for adaptation measures to protect coastal property will also increase.[57] As with our other cases, we find the adaptation tool kit could include measures to protect assets and people, build resilience, and reduce exposure, all supported by appropriate financing and insurance.

Spending on adaptation today does more than prevent more extreme damage from occurring; it can prevent bond rating downgrades, which would increase borrowing costs and make funding critical long-term infrastructure even more expensive.[58] Adaptation measures in locations that can safely withstand the long-term impact of climate change not only protect homes against damage, but also keep home prices elevated and may go a long way toward countering the asset price adjustment we estimate.[59] The value of adaptation in Florida has already been recognized in initiatives such as its $400 million Forever Bond.

Policy makers might consider the following: how drainage could be improved, where seawalls might be built, whether development should be restricted in vulnerable areas, whether sewers could be upgraded to prevent wastewater from contaminating streets or property, hardening and improving resiliency of existing infrastructure, installing new green infrastructure, whether to introduce incentives to encourage coastal residents to move inland, and how to preserve equity and keep communities intact while discouraging development in areas most susceptible to the effects of climate change. Individual home owners might also consider adaptation steps such as elevating ground floors or "sacrificing" street-level areas in buildings to help minimize flood damage (as is already happening in parts of Florida), creating additional retention ponds to help manage flooding and rainwater runoff, exploring whether rain barrels or green roofs could help absorb intense rain on a specific property, and planning for increases in insurance premiums should a region become more prone to flooding.[60]

Knowing when and what to protect vs retreat

The state's expansive coastline and limestone foundation may increase the cost of adaptation. And the state's expansive coastline and limestone foundation may mean that such coastal protection measures may not be viable everywhere. Florida will need to manage the impact of saltwater intrusion from rising seas into water systems and the challenges of protecting against sea level rise given the limestone foundation of much of the state. Investments will be needed for other measures like establishing pumping systems, hardening water and sewage treatment facilities, and even supporting the relocation of communities in some cases.

Quantifying the total investment required to defend coastal Florida is extremely difficult. The Center for Climate Integrity estimates the cost to protect Florida using seawalls by 2040 to be $76 billion.[61] To help dimensionalize this, such a cost, spread over 20 years ($3.8 billion per year), represents about 0.4 percent of Florida's GDP, or about 10 percent of the GDP of Florida's construction industry.[62] Costs will vary strongly between communities. Jacksonville may require $3.5 billion, and Tampa may spend up to $1 billion. In some communities, the annual cost of protecting against a typical storm could be as much as $15,000 per resident by 2040.[63]

---

57 See, for example, the most recent report by the Global Commission on Adaptation, *Adapt now: A Global Call for Leadership on Climate Resilience*, September 2019.

58 Florida Department of Environmental Protection Florida Coastal Management Program and NOAA, Florida adaptation planning guidebook, June 2018.

59 Seung Kyum Kim, *The economic effects of climate change adaptation measures: Evidence from Miami-Dade County and New York City*, Joint Center for Housing Studies of Harvard University, May 2019.

60 University of Maryland and Texas A&M University, *The growing threat of urban flooding: A national challenge*, 2018.

61 The Center for Climate Integrity estimates that 9,200 miles of seawalls would be necessary to protect Florida by 2040, at a cost of $76 billion. Center for Climate Integrity, Florida in 2040, climatecosts2040.org/costs/florida.

62 Bureau of Economic Analysis.

63 Center for Climate Integrity.

Adaptation for sea level rise projections in 2100 could be even more challenging. Consider one example. Zillow estimates that at 1.8 meters of sea level rise—a possibility by 2100, according to some scenarios—almost one million homes would be permanently underwater.[64] Costs to defend against rising seas may also grow. For example, estimates suggest that coastal protection costs could rise to as much as $110 billion in Florida by 2100.[65] Put together, this suggests that protecting coastal Florida could cost hundreds of billions of dollars, requiring the mobilization of the entire ecosystem and diverse sources of funding.

Rising adaptation costs will create real choices about which infrastructure to prioritize for near-term defense. Policy makers, engineers, investors, and community-based organizations could develop criteria. Thoughtfully undertaking adaptation measures is critical because they can unintentionally encourage behavior that amplifies risk. Adaptation investment is already associated with the construction of more and larger structures.[66] These solutions must therefore be balanced by taking risk exposure into account when upgrading current structures or developing new structures to avoid amplifying risks further.

Understanding what has worked in other locations provides a guide for initiatives to be evaluated for costs and benefits. For example, Louisiana has unveiled a first-of-its-kind strategy to map population centers by flood exposure and has proposed financing and migration options to move coastal communities inland.[67] The state has also pledged about $50 billion over the next 50 years for protection of 7,700 miles of coastline, with a focus on both manufactured and natural solutions (restoring swampland will account for roughly half of the planned expenditure).[68] Or in the wake of Hurricane Sandy, New York City doubled its investment in developing manufactured resiliency solutions and publicized new building guidelines with ten-year climate change projections in mind.[69]

---

64 Lauren Bretz, *Climate change and homes: Who would lose the most to a rising tide?*, Zillow Research, October 18, 2017.
65 The Center for Climate Integrity Resilient Analytics, *High tide tax: The price to protect coastal communities from rising seas*, June 2019.
66 Gabriele Manoli et al., "Delay-induced rebounds in CO_2 emissions and critical time-scales to meet global warming targets," *Earth's Future,* December 2016, Volume 4, Number 12.
67 Louisiana's Strategic Adaptations for Future Environments (LA SAFE), May 2019; Christopher Flavelle and Mira Rojanasakul, "Louisiana unveils ambitious plan to help people get out of the way of climate change," Bloomberg, May 15, 2019.
68 *Louisiana's comprehensive master plan for a sustainable coast,* Coastal Protection and Restoration Authority of Louisiana, June 2017.
69 NYC.Gov, "Mayor de Blasio announces resiliency plan to protect Lower Manhattan from climate change," March 14, 2019, www1.nyc.gov/office-of-the-mayor/news/140-19/mayor-de-blasio-resiliency-plan-protect-lower-manhattan-climate-change.

Mobilize funds and assistance to vulnerable communities

Today's adaptation interventions help manage and reduce residents' risk from climate-related damage and increase the affordability of home ownership in Florida. However, to manage resilience going forward, the amount of funding needed for adaptation could grow substantially.[70] While some residents of coastal metropolitan areas have already agreed to higher taxes to pay for these measures, the pressure to increase funding for adaptation will continue as hazards intensify.[71] Possible solutions include targeted tourist taxes (as seen in New York City), usage fees for protection solutions, public-private partnerships and federal support, and encouraging private adaptation investment through tax exemptions.

The capacity to cope with real estate devaluations, spend on flooding mitigation, and recover from disaster will be markedly different across the state and for different demographic groups, with the potential to exacerbate existing inequities for vulnerable populations.[72] Home owners' decisions to rebuild or relocate will be limited by the availability of recovery money as well as the viability of getting a new mortgage elsewhere.[73] For low- and middle-income families who may lack sufficient access to credit or the ability to finance recovery, affordable flood insurance remains an important mechanism for financial stability.[74] Ensuring that sufficient funding flows to communities without the means to adapt on their own, and giving local residents a voice in decisions about adaptation versus managed retreat at an early stage, could create more equitable solutions to increased climate risk. Creating systems that can increase individuals' financial resilience (such as automatic savings accounts for families below the poverty line) can help provide an additional backstop.

---

70 Elizabeth A. Stanton and Frank Ackerman, *Florida and climate change: The costs of inaction*, Tufts University, 2007; Martin Parry et al., *Assessing the costs of adaptation to climate change: A review of the UNFCCC and other recent estimates,* International Institute for Environment and Development and Grantham Institute for Climate Change, August 2009.

71 Miami Forever, *About us*, miamiforever.org/about.

72 University of Maryland and Texas A&M University, *The growing threat of urban flooding: A national challenge*, 2018.

73 Kathleen Sullivan Sealey, Ray King Burch, and P.-M. Binder, *Will Miami Survive? The Dynamic Interplay between Floods and Finance*, Cham, Switzerland: Springer, 2018.

74 Carolyn Kousky et al., *The emerging private residential flood insurance market in the United States*, Wharton Risk Management and Decision Processes Center, July 2018.

McKinsey Global Institute
April 2020

Designed by the McKinsey Global Institute

www.mckinsey.com/mgi

@McKinsey
@McKinsey