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Florida Climate Outlook

Assessing Physical and Economic

Impacts through 2040

Daniel Raimi, Amelia Keyes, and Cora Kingdon

"Climate change is affecting Florida today, and those effects will become more significant in the years to come"

About the Authors

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About RFF

Resources for the Future (RFF) is an independent, nonprofit research institution in Washington, DC. Its mission is to improve environmental, energy, and natural resource decisions through impartial economic research and policy engagement. RFF is committed to being the most widely trusted source of research insights and policy solutions leading to a healthy environment and a thriving economy. The views expressed here are those of the individual authors and may differ from those of other RFF experts, its officers, or its directors.

Acknowledgments

Sharing Our Work

Introduction

Climate change is affecting Florida today, and those effects will become more significant in the years to come. This introduction provides basic information on recent temperature trends in Florida, along with projections over the next 20 years. This report discusses the implications of these changing temperatures along with changes in other climatic conditions that will affect Floridians. The report addresses the following topics:

We examine these effects under two plausible scenarios: a moderate emissions scenario, where global greenhouse gas emissions rise by roughly 1 percent annually over the next 20 years; and a high emissions scenario, where emissions rise by 3 percent annually. These scenarios are drawn from an extensive literature and correspond with climate scenarios known as Representative Concentration Pathways (RCP) 4.5 and 8.5. We apply similar scenarios for future sea level rise. For details on these scenarios, and our rationale for selecting them, please see the Appendix.

Historical and Projected Temperature Trends in Florida

Summer temperatures in Florida have increased by roughly 1°F since 1950, averaging 81.4°F from 1991 to 2010. In the next 20 years, average summer temperatures are projected to rise above 83°F under both moderate and high emissions scenarios.[1,2] There is more uncertainty surrounding future temperatures under a high emissions scenario than under a moderate emissions scenario.

Figure 1

Statewide Average Summer Temperatures (°F)
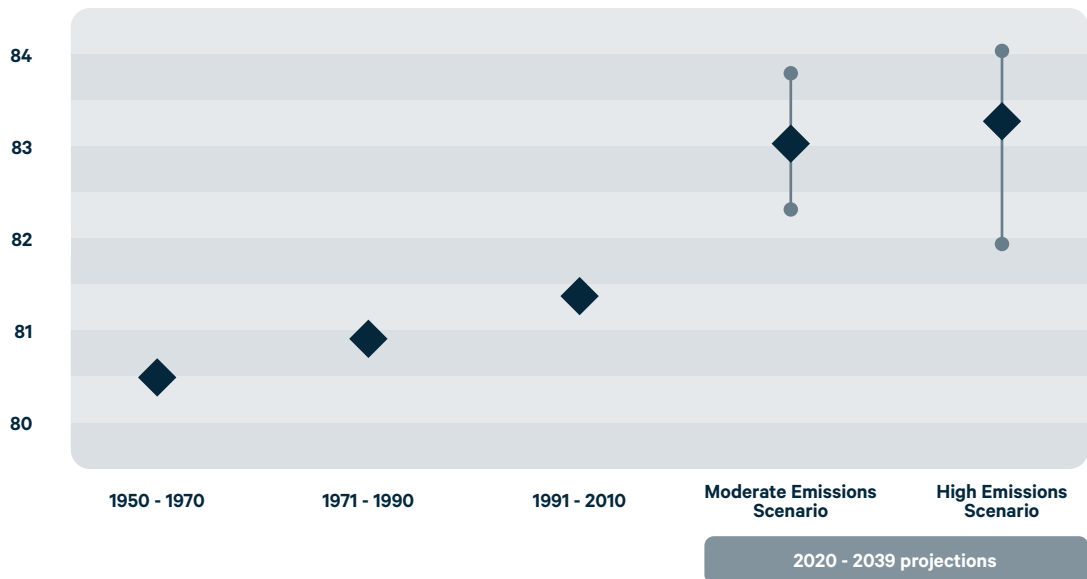
Note: Diamonds indicate median temperatures (for 1950-2010) and median temperature projections (for 2020 onwards). Grey dots show the 5th and 95th percentile range of projections between 2020 and 2039. "Moderate emissions scenario" and "High emissions scenario" refer to RCP 4.5 and RCP 8.5, respectively. See Appendix A for details. "Summer" refers to June, July, and August. Historical data from Southeast Regional Climate Center; projections from Climate Impact Lab.

From 1981 to 2010, Floridians experienced, on average, high temperatures exceeding 95°F roughly 7 days per year. Under moderate and high emissions scenarios, this number is projected to grow to 22 and 26 days per year, respectively.[1]

Statewide Average Number of Days with Highs Above 95°F

Note: Diamonds indicate median number of days (for 1981-2010) and median number of days in projections (for 2020 onwards). Grey dots show the 5th and 95th percentile range of projections between 2020 and 2039. "Moderate emissions scenario" and "High emissions scenario" refer to RCP 4.5 and RCP 8.5, respectively. See Appendix A for details. Data from Climate Impact Lab.

From 1950 to 1970, winter temperatures in Florida averaged 57.4°F. In the following decades, temperatures rose by more than 2°F, averaging 59.5°F between 1991 and 2010. In the next 20 years, average winter temperatures are projected to rise above 60°F under both moderate and high emissions scenarios.[1,2]

Figure 3

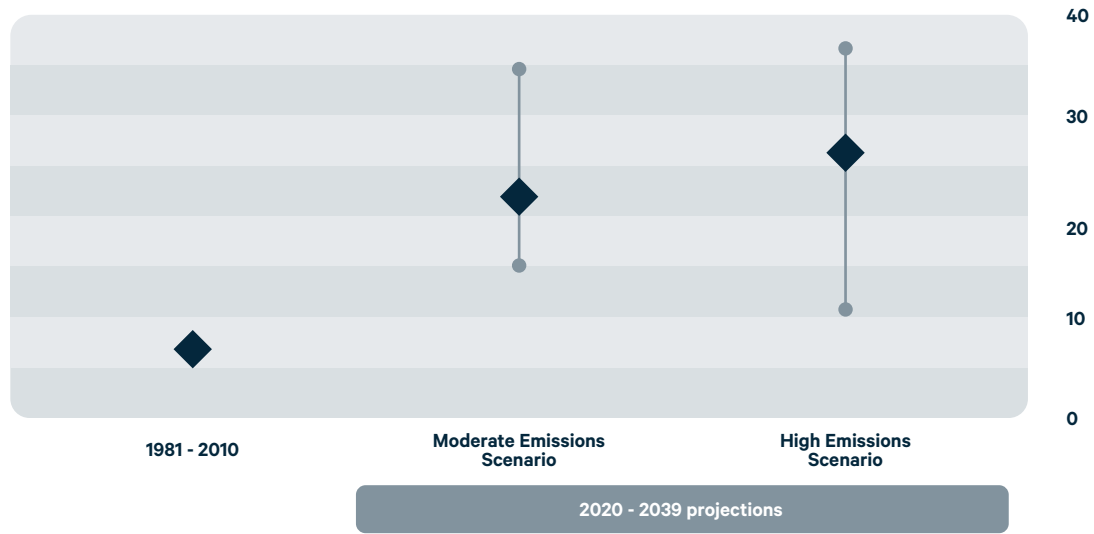## Statewide Average Winter Temperatures (°F)
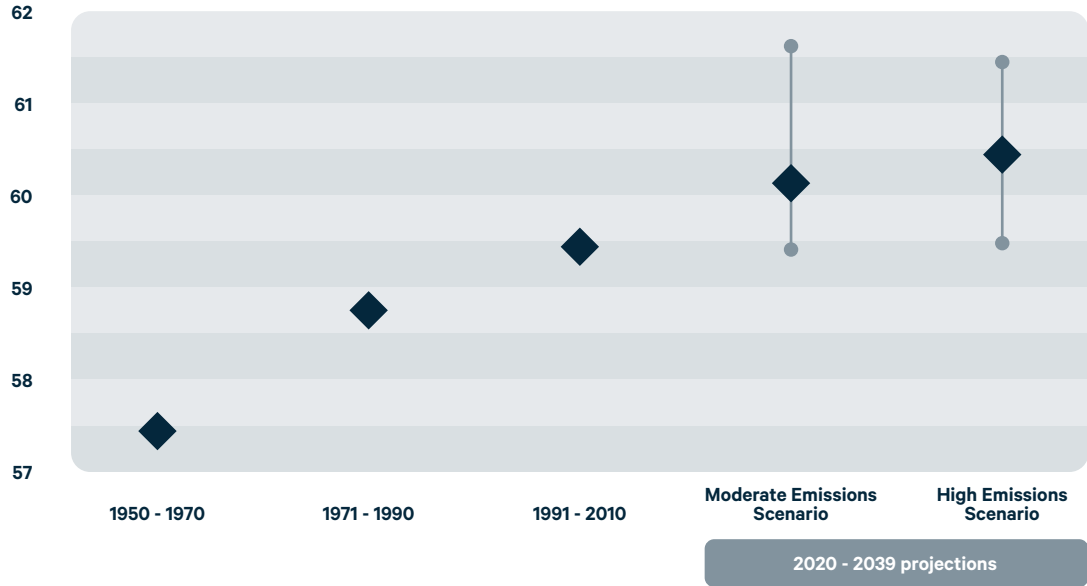
Note: Diamonds indicate median temperatures (for 1950-2010) and median temperature projections (for 2020 onwards). Grey dots show the 5th and 95th percentile range of projections between 2020 and 2039. "Moderate emissions scenario" and "High emissions scenario" refer to RCP 4.5 and RCP 8.5, respectively. See Appendix A for details. "Winter" refers to December, January, and February. Historical data from Southeast Regional Climate Center; projections from Climate Impact Lab.

References

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   http://www.impactlab.org/map/#usmeas=absolute&usyear=1981-2010&gmeas=absolute&gyear=1986-2005&tab=united-states (2019).

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Effects of Sea Level Rise in Florida

Overview

Climate change raises sea levels by increasing ocean temperatures (which causes water to expand) and by melting glaciers and ice sheets (which adds water to the oceans). Global sea levels have risen by an average of about 8–9 inches since 1880, and climate change is projected to further accelerate sea level rise.[1] Before land is permanently submerged, rising seas will lead to higher and more frequent coastal flooding.

Florida's long coastline and low-lying land make it particularly vulnerable to the damaging impacts of sea level rise. Every additional inch of sea level rise will increase the economic risks Florida faces from flooding, which will threaten more property and infrastructure. Rising seas will also reduce groundwater quality through saltwater intrusion.

The effects of higher sea levels are being felt today, with major implications for Florida communities. For example, a recent analysis by the Monroe County Sustainability Office highlights the large costs of raising public roadways to accommodate higher sea levels by 2045.[2] Because of these costs, it is unlikely that the county will be able to protect all roads in the Keys, suggesting that some roads and neighborhoods will need to be abandoned.[3]

This section examines the projected effects of sea level rise using three scenarios: a moderate scenario defined by 0.5 meters (1.6 feet) of additional[a] global sea level rise by

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a   In this section, additional sea level rise is relative to the average level between 1986 and 2005.

2100; a higher scenario defined by 1 meter (3.3 feet) by 2100; and an extreme scenario defined by 2.5 meters (8.2 feet) by 2100. For a more detailed description of these scenarios, and their likelihoods under different emissions pathways, see Appendix A.

Key Findings

- Globally, the median projection for additional sea level rise by 2040 is roughly 7 inches under the moderate scenario, 10 inches under the higher scenario, and 16 inches under the extreme scenario.[4]

- Because of wind and ocean circulation patterns, Florida has historically experienced higher rates of sea level rise than the global average.[5] This trend is expected to continue, with estimates varying for different locations along the Florida coast. By 2040, under the moderate scenario, median projections of sea level rise at different points along Florida's coastline range from 8–9 inches. Under the higher scenario, median projections are between 12 and 13 inches, and under the extreme scenario, median projections are approximately 24 inches.[4]

- There is uncertainty around these projections, even under a given scenario. For example, by 2040 at St. Petersburg, there is a two-thirds probability of sea level rise between 7 and 11 inches under the moderate scenario, 11 and 15 inches under the higher scenario, and 17 and 26 inches under the extreme scenario. There is a one-third probability that sea level rise will be either lower or higher than these ranges under a given scenario. Projections for other coastal locations include similar ranges of uncertainty.[4]

Florida's long coastline and low-lying land make it particularly **vulnerable to the damaging impacts of sea level rise.**

Every additional inch of sea level rise will increase the economic risks Florida faces from flooding, which **will threaten more property and infrastructure.**

Table 1

Annual Risk in 2040 of Flooding 3 Feet Above the High-water Mark[8,9]

Location	Sea Leve Rise Scenario		
	Moderate	Higer	Extreme
Fernandina Beach	20%	57%	100%
Vaca Key	2%	4%	97%
St. Petersburg	17%	28%	100%
Pensacola	17%	28%	100%
Apalachicola	37%	53%	100%

Note: These figures represent the median estimates and do not include uncertainty ranges.

- By 2100, averaging across coastal locations in Florida, scientists expect to see additional sea level rise of roughly 2, 4, and 10 feet under moderate, higher, and extreme sea level rise scenarios.[4] Four feet of sea level rise could submerge up to 2,400 square miles of land in Florida, including large portions of densely populated coastal regions.

- Several major tourist attractions, including the Everglades, Biscayne National Park, and Miami Beach, are largely situated on land less than three feet above the high-water mark[b] and may become permanently submerged by the end of

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b   In this section, "high-water mark" refers to the mean higher high water measurement from 1983 to 2001. "Mean higher high water mark" represents the average of the highest water mark during each tidal day over the reference period.[6]

Table 2

Annual Risk in 2040 of Flooding 5 Feet Above the High-water Mark[8,9]

Location	Sea Leve Rise Scenario		
	Moderate	Higer	Extreme
Fernandina Beach	0%	0%	5%
Vaca Key	0%	0%	1%
St. Petersburg	2%	3%	9%
Pensacola	3%	4%	9%
Apalachicola	10%	12%	24%

Note: These figures represent the median estimates and do not include uncertainty ranges.

the century. In the coming decades, they are particularly at risk from flooding and saltwater intrusion.

➤ Before land is permanently submerged, higher sea levels will bring more frequent and higher floods through the direct effects of tidal inundation and storm surge. Higher sea levels can also indirectly increase the severity of flooding by raising the groundwater level. This phenomenon decreases the capacity of the soil to help with drainage, resulting in floodwaters remaining higher for longer periods of time.[7]

➤ All along Florida's coast, the annual risk of flooding is projected to increase substantially. Extreme flooding that previously would have been expected to occur just once every 100 years (a "100-year" flood), with waters reaching 2–3

feet above the high-water mark depending on the specific location, will become more frequent (Table 1).

- This level of flooding would cause large damages. Statewide, roughly 490,000 people live on land less than 3 feet above the high-water mark, with over 300,000 homes and an estimated $145 billion in property value. Over 2,500 miles of roads, 372 hazardous waste sites, 30 schools, and 4 hospitals could be subjected to flooding. The counties with the largest number of people facing this risk are Miami-Dade, Broward, Pinellas, Monroe, and Hillsborough.[10,11]

- Through 2040, the risk for even higher flooding is greatest on the western side of Florida, from the Tampa Bay area through the Panhandle (Table 2). In future decades, as sea levels rise further, other parts of the state with greater populations, such as southeast Florida, will also face higher risks of flooding.

- From Tampa Bay through the Panhandle, the area most at risk by 2040, there are roughly 290,000 people living on land less than 5 feet above the high-water mark, with over 200,000 homes.[10]

- As sea levels rise, ocean water will continue to move farther inland into freshwater aquifers in a process known as saltwater intrusion, posing a contamination threat to drinking water and agriculture. Particularly at risk is the Biscayne aquifer, located under Miami-Dade County, which provides drinking water to around 4.5 million people.[12]

- Saltwater intrusion also poses a unique threat to inland ecosystems such as forests and freshwater wetlands, which are not accustomed to higher levels of salinity.[13]

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Understanding Sea Level Rise in Florida, 2040

Global sea level rise scenarios reveal an uncertain future

Future sea level depends on greenhouse gas emissions and atmospheric / oceanic processes. Moderate and higher scenarios represent a plausible range, while the extreme scenario is very unlikely, but still possible (<1% likelihood).

EXTREME SCENARIO 16"

HIGHER SCENARIO 10"

MODERATE SCENARIO 7"

CURRENT SEA LEVEL

2040 Global sea level rise
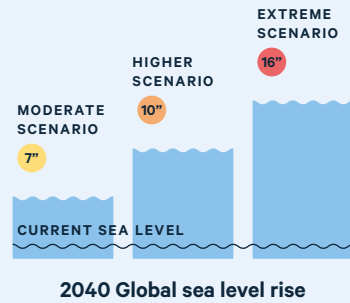
Sea levels are projected to rise faster in Florida than the global average

By 2100, large swaths of coastal land in Florida will be permanently submerged. In the shorter term, rising seas will increase the frequency and severity of coastal flooding. Statewide, three feet of flooding puts at risk:

- 490,000 People
- 300,000 Homes
- 2,500 Miles of Road
- 372 Waste Sites
- 30 Schools
- 4 Hospitals

Map Legend

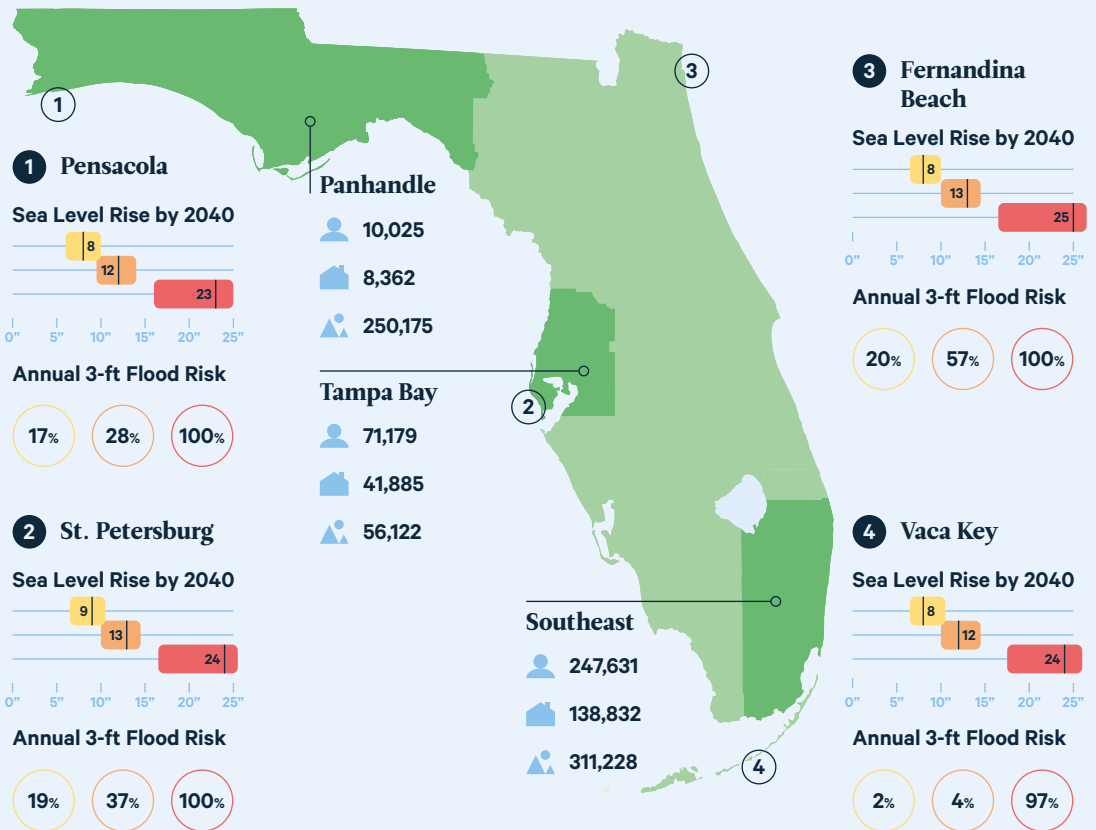### Sea level rise and annual flood risk by 2040 (in inches and %)

For sea level rise, projection ranges are depicted with the median value shown.

- 🟡 MODERATE SCENARIO
- 🟠 HIGHER SCENARIO
- 🔴 EXTREME SCENARIO

Areas at risk below 3ft

For the darker sections on the map, the following risk areas have been calculated:

- PEOPLE
- HOMES
- LAND (ACRES)

1 Pensacola

Sea Level Rise by 2040
8 | 12 | 23
0" 5" 10" 15" 20" 25"

Annual 3-ft Flood Risk
17% | 28% | 100%

2 St. Petersburg

Sea Level Rise by 2040
9 | 13 | 24
0" 5" 10" 15" 20" 25"

Annual 3-ft Flood Risk
19% | 37% | 100%

Panhandle

- 10,025
- 8,362
- 250,175

Tampa Bay

- 71,179
- 41,885
- 56,122

Southeast

- 247,631
- 138,832
- 311,228

3 Fernandina Beach

Sea Level Rise by 2040
8 | 13 | 25
0" 5" 10" 15" 20" 25"

Annual 3-ft Flood Risk
20% | 57% | 100%

4 Vaca Key

Sea Level Rise by 2040
8 | 12 | 24
0" 5" 10" 15" 20" 25"

Annual 3-ft Flood Risk
2% | 4% | 97%

Saltwater Intrusion

Higher sea levels lead to greater salt water intrusion, posing a contamination threat to drinking water and agriculture, as well as natural landscapes.

Flooding

Higher sea levels indirectly increase the severity of flooding by raising the groundwater level and decreasing the capacity of soil to help with drainage, resulting in flood waters remaining higher for longer periods of time.

⚠ AREA AT RISK OF FLOODING

FLOODLINE

FUTURE SEA LEVEL

PRESENT DAY SEA LEVEL

- ▲ FUTURE WATER TABLE (LESS DRAINAGE)
- ▲ PRESENT DAY WATER TABLE (MORE DRAINAGE)
- — PRESENT DAY SALT WATER INTRUSION
- ┄ FUTURE SALT WATER INTRUSION
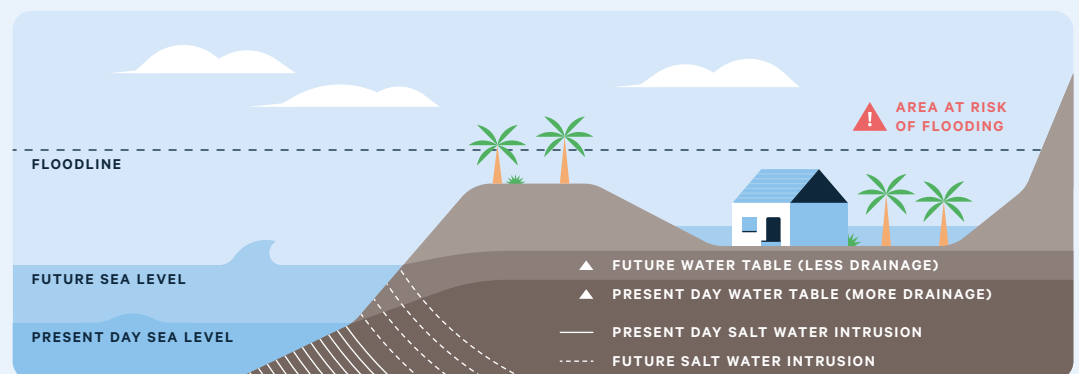
Effects of Climate Change on Storms in Florida

Overview

More than any other US state, Florida is susceptible to damages from tropical storms, and climate change is projected to increase these risks. Over the last 1,000 years, periods with higher global temperatures have corresponded with a larger number of intense hurricanes making landfall in the state,[1] and higher future air and water temperatures are projected to increase the severity of tropical storms, leading to higher storm surges (the rise in water levels above normal tides due to storms), faster wind speeds, and greater volumes of precipitation.[2]

The most severe property damage from tropical storms is typically caused by storm surges. Damages from a single hurricane can total tens of billions of dollars from storm surge alone, putting unprotected areas at particularly high risk.[3] Although many communities have prepared for a certain level of surge, small increases above that preplanned level can lead to a large increase in damages, with a disproportionate increase in flooded buildings, as well as disruption of evacuation routes.[4]

More severe storms not only pose risks to human lives and prosperity, they also reduce regional economic output over the short and long term.[5]

Key Findings

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▶ Miami is one of the most at-risk cities in the world from the damages caused by coastal flooding and storms. By one measure, it faces the largest risk of any major coastal city in the world, with more than $400 billion in assets at risk as of 2005.[6]

▶ Under a moderate emissions scenario,[a] by 2100, the combined effects of sea level rise and greater storm intensity are projected to increase the height of storm surges in Florida by 25–47 percent compared with storm surges from hurricanes between 1984 and 2013. High-end estimates show storm surges rising 40–70 percent above historic levels.[7]

▶ Adaptation measures include beach nourishment, wetlands restoration, "hard" protective barriers, and elevation of structures. However, projections through the year 2100 suggest that in some parts of Florida, such as East Tampa Bay, sea level rise combined with the effects of storm surges will make such protections very expensive. Modeling suggests that in such cases, the most economically viable option will be to abandon substantial areas of currently inhabited land.[8]

▶ Florida cities are investing to protect against these risks, such as Miami Beach's $500 million effort to protect buildings, roads, and water systems. Such investments can dramatically reduce the damages to property and risks to human life from sea level rise and storm surges.[8,9]

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a Note: "Moderate emissions scenario" refers to RCP 4.5. "High-end projections" refers to the 95th percentile of modeled scenarios. See Appendix A for details.

Miami is one of the most at-risk cities in the world from the damages caused by coastal flooding and storms.

By one measure, it faces the largest risk of any major coastal city in the world, **with more than $400 billion in assets at risk as of 2005.**

■▶ Warmer ocean temperatures are projected to contribute to higher hurricane windspeeds. One study estimates that damages from these higher windspeeds alone would result in roughly $200 million in additional annual storm damages for buildings in Miami-Dade County by 2035.[10]

■▶ Other types of severe weather, such as severe thunderstorms that produce damaging hail or tornadoes, may also become more harmful as a result of climate change. However, there is substantial uncertainty surrounding this issue, and researchers are currently working to better understand the topic.[11]

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Adaptation measures include **beach nourishment, wetlands restoration, "hard" protective barriers, and elevation of structures.**

However, projections through the year 2100 suggest that in some parts of Florida... **sea level rise combined with the effects of storm surges will make such protections very expensive.**
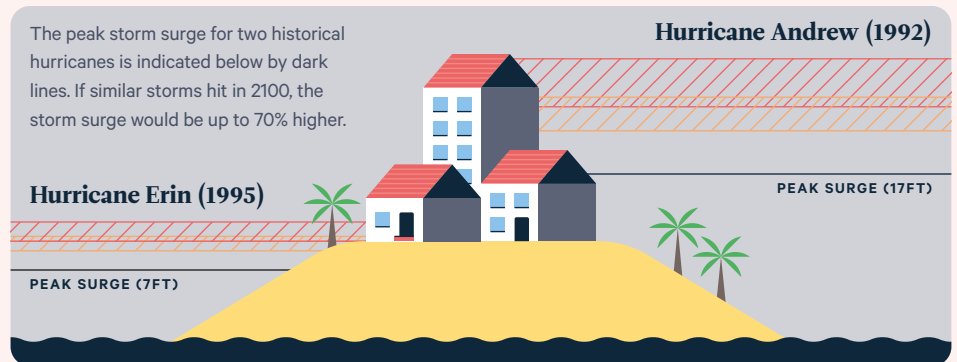
Effects of Climate Change on Storms in Florida

More than any other US state, Florida is susceptible to damages from tropical storms

By 2100, rising seas and more intense storms will increase storm surge by 25-47% under a moderate emissions scenario, and by 40-70% under a higher emissions scenario.
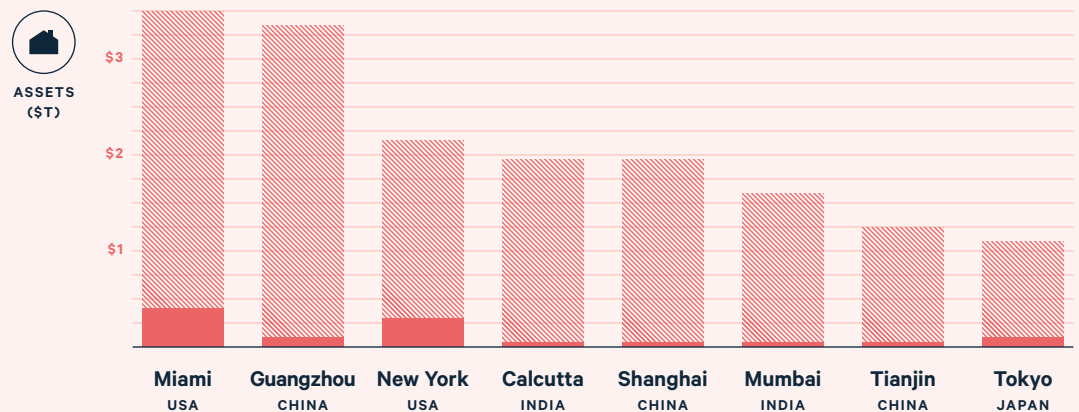
MODERATE SCENARIO

HIGHER SCENARIO

The peak storm surge for two historical hurricanes is indicated below by dark lines. If similar storms hit in 2100, the storm surge would be up to 70% higher.

Hurricane Andrew (1992)

PEAK SURGE (17FT)

Hurricane Erin (1995)

PEAK SURGE (7FT)

Miami is one of the world's most at-risk cities from coastal flooding

By one measure, it faces the largest risk of any major coastal city, with $400 billion in assets at risk as of 2005, growing to $3.5 trillion by the 2070s.

ASSETS ($T)

Legend

CURRENTLY EXPOSED (2005)

FUTURE EXPOSURE (2070s)

	$3	$2	$1	

Miami USA — Guangzhou CHINA — New York USA — Calcutta INDIA — Shanghai CHINA — Mumbai INDIA — Tianjin CHINA — Tokyo JAPAN

Florida cities are investing to protect against the risks ahead

1 Beach Nourishment

Fortifying existing beaches can help protect low-lying coastal property.

2 Building Protective Barriers

In some cases, hard barriers such as sea walls may be needed.

3 Raising Infrastructure

Some buildings, roads, and other infrastructure will need to be raised.

4 Restoring Natural Habitats

Wetlands and other coastal ecosystems provide natural protection.
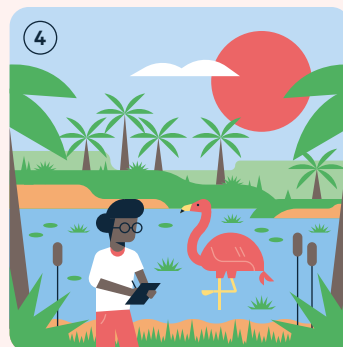
These protections won't prevent all damages

Population displacement

The high cost of protection in some areas, like parts of Tampa Bay, suggest the most economically rational option will be to abandon substantial areas of inhabited land.

Other severe weather

Scientists are currently unsure whether climate change will increase the frequency or severity of storms that produce damaging hail or tornadoes.

Effects of Climate Change on Human Mortality in Florida

Overview

As the climate changes, shifts in temperature, precipitation, sea levels, and other physical drivers have the potential to affect human health in a variety of ways. Extreme temperatures can directly affect mortality rates when the physiological response to heat or cold (e.g., increased heart rate) endangers well-being, particularly through cardiovascular, cerebrovascular, and respiratory pathways.[1]

Studies consistently find that increased exposure to extreme heat or cold is associated with higher rates of cardiovascular-related mortality. Climate change is also likely to indirectly affect human health through changing patterns of disease vectors (i.e., mosquitoes and other organisms that can transmit diseases), extreme weather, human conflict, and other environmental or socioeconomic pathways.

Because Florida is warmer than most US states, its residents already experience risks from heat and—compared with the rest of the US—relatively little risk associated with cold. This dynamic will be enhanced as average temperatures increase as a result of climate change. Because the average age in Florida is higher than in most other states,[2] its population is particularly vulnerable to these risks.[3]

Key Findings

▶ Within the next 15–20 years, the median estimates under moderate and high emissions scenarios[a] project respective increases in the rate of mortality of 3.8 and 5.6 per 100,000 Florida residents per year.[5] These estimates translate to roughly 1,000 and 1,400 additional deaths annually by 2035 and would mostly affect those older than 65.

▶ There is substantial uncertainty surrounding these median estimates. Low- and high-end statewide estimates in 2035 range from a decrease of 2.1 to an increase of 12.8 deaths per 100,000 residents per year.[5] This is equal to between 540 fewer deaths and 3,200 additional deaths in Florida in the year 2035. Decreased mortality is possible because of reduced exposure to cold temperatures.

▶ Charlotte, Martin, Monroe, Palm Beach, and Hernando Counties face the greatest risk. Under a moderate emissions scenario, the central estimate for these counties is an increase in annual mortality rates of more than 6 deaths per 100,000 residents. Under a high emissions scenario, the central estimate for Hernando and Charlotte Counties is greater than 9 additional deaths per 100,000 residents annually.[5]

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a The estimate of additional deaths in 2035 is based on population projections[4] for the year 2035 and assumes no demographic changes from 2012 to 2035. "Moderate emissions scenario" refers to RCP 4.5, and "high emissions scenario" refers to RCP 8.5. "Low- and high-end estimates" refers to the 5th and 95th percentile estimates from Hsiang et al.[5] under both RCP 4.5 and RCP 8.5 scenarios.

Moderate and high emissions scenarios project respective increases in the rate of mortality of **3.8 and 5.6 per 100,000 Florida residents per year.**

These estimates translate to roughly **1,000 and 1,400 additional deaths annually by 2035.**

- In absolute terms, the largest number of excess deaths is projected to occur in heavily populated southeastern counties. Under moderate and high emissions scenarios, the median estimates for annual excess deaths in 2035 are respectively 175 and 191 for Miami-Dade, 110 and 128 for Broward, and 99 and 119 for Palm Beach Counties.[5]

- More modest effects are projected for northern Florida. However, median estimates project increased mortality due to temperature change in every Florida county. Under a moderate emissions scenario, the smallest risks are seen in Liberty, Bay, and Gulf Counties, though median estimates show mortality rates increasing by more than 0.5 per 100,000 residents in these counties.[5]

- There is a substantial range of uncertainty for all counties. For example, low- and high-end estimates for Miami-Dade County range from 65 fewer deaths to 420 additional deaths per year by 2035.[5] Fewer deaths could occur because of reduced exposure to cold temperatures.

- Disease risk from mosquito-borne viruses (particularly *Aedes aegypti*, which can spread dengue, chikungunya, and Zika) is projected to become a year-round phenomenon in southern Florida.[6] Florida residents are already at risk of exposure to West Nile virus, a trend that is projected to persist under climate change.[7]

- Recent peer-reviewed studies have examined other factors that may increase mortality in Florida. Quantitative estimates for these effects are not available for Florida specifically, but the findings suggest increased risks from energy supply disruptions,[8] storm-related flooding,[6] suicide,[9] and wildfire.[6]

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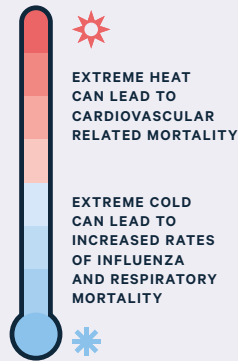
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Effects of Climate Change on Human Mortality in Florida

Extreme heat and cold are both factors that can directly increase mortality

Extreme temperatures lead to physiological responses (e.g., increased heart rate) that can endanger well-being through cardiovascular, cerebrovascular, and respiratory pathways. Studies consistently find higher mortality rates at very high and very low temperatures.

EXTREME HEAT CAN LEAD TO CARDIOVASCULAR RELATED MORTALITY

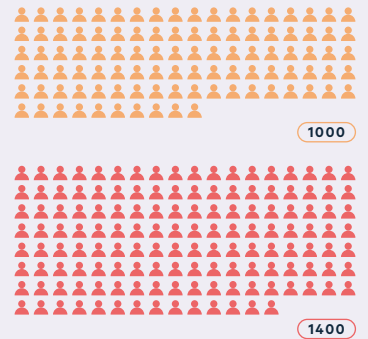EXTREME COLD CAN LEAD TO INCREASED RATES OF INFLUENZA AND RESPIRATORY MORTALITY

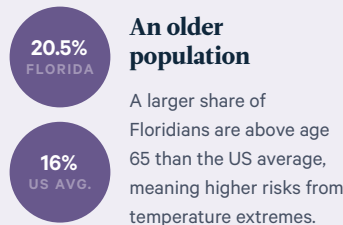## Climate change is projected to increase mortality across Florida

By 2035, median estimates under moderate and high emissions scenarios are an increase in statewide mortality of 1,000 and 1,400, respectively, mostly affecting those older than 65.

Annual Additional Deaths by 2035

1000

1400

REPRESENTS 10 PEOPLE

MODERATE SCENARIO

HIGHER SCENARIO

Other factors are likely to increase mortality risk in Florida

20.5% FLORIDA

16% US AVG.

An older population

A larger share of Floridians are above age 65 than the US average, meaning higher risks from temperature extremes.

Disease risks will increase

Risks of chikungunya, dengue, and Zika will become greater as mosquitos become active for more of the year.

New research highlights new risks

Climate change may also increase mortality risk from energy disruptions, storm-related flooding, suicide, and wildfire.
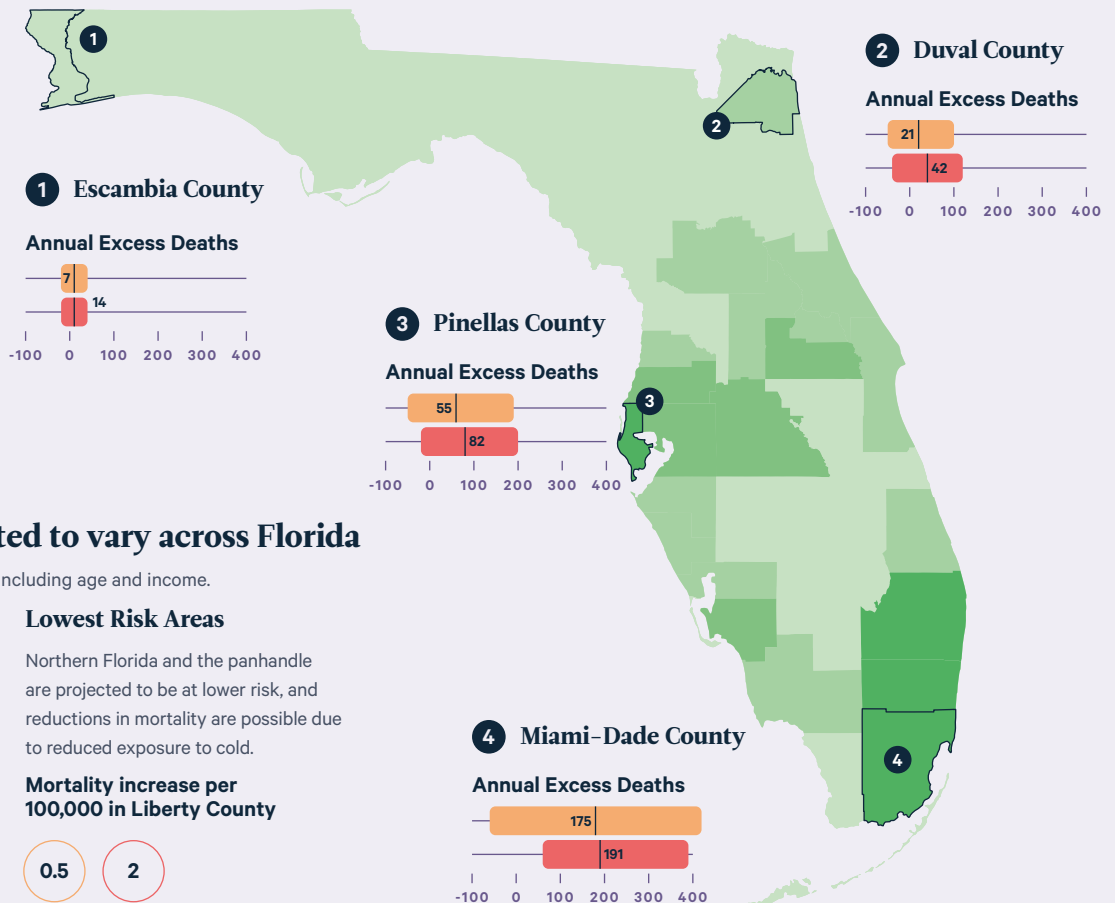
Map Legend

Annual Mortality Estimates by 2035

Bars show 90% confidence range, while numbers show the median estimate.

MODERATE SCENARIO

HIGHER SCENARIO

Per County within Moderate Scenario

0-10

11-30

31-50

50+

1 Escambia County

Annual Excess Deaths

7

14

-100 0 100 200 300 400

2 Duval County

Annual Excess Deaths

21

42

-100 0 100 200 300 400

3 Pinellas County

Annual Excess Deaths

55

82

-100 0 100 200 300 400

4 Miami-Dade County

Annual Excess Deaths

175

191

-100 0 100 200 300 400

Mortality risk is projected to vary across Florida

A variety of factors affect mortality risk, including age and income.

Highest Risk Areas

Southern Florida is projected to be most at-risk. Martin, Palm Beach, and several other counties face a similar increase in mortality risk.

Mortality increase per 100,000 in Charlotte County

7   9

Lowest Risk Areas

Northern Florida and the panhandle are projected to be at lower risk, and reductions in mortality are possible due to reduced exposure to cold.

Mortality increase per 100,000 in Liberty County

0.5   2

Effects of Climate Change on Agriculture in Florida

Overview

Climate change will have varying effects on Florida's agricultural sector. Some of the state's most valuable agricultural products will be at increased risk of damages due to climate change, while some of its less important crops may benefit somewhat from a changing climate and atmosphere.

Florida's most valuable agricultural products include fruits—particularly citrus—and vegetables; livestock and dairy; and a variety of greenhouse, nursery, and mushroom products.[1] Florida farmers produce more than half of all the oranges and grapefruits grown in the United States.[2] However, these crops have recently come under threat from "citrus greening" (also known as Huanglongbing, or HLB), a disease that reduces a tree's ability to absorb nutrients, decreasing yields and typically leading to tree death within several years.[3]

Although Florida is a major producer of certain agricultural products, the overall sector accounted for just 0.6 percent of state gross domestic product in 2017, down from 1.2 percent in 2000.[1] The sector is not a major employer in the state, with just 0.2 percent of Florida's workforce employed in farming, fishing, and forestry. Workers in this sector are paid approximately $25,000 per year on average, well below the average statewide wage of $46,000 for all sectors.[4]

The relatively small role of agriculture in Florida's economy suggests that any impacts are unlikely to have major economic consequences for the state as a whole. However, individual farmers, farmworkers, communities supported by farming, and others may face more acute effects.

Key Findings

- Quantitative estimates of the impacts of climate change on Florida's agriculture sector are limited: they cover fewer than half of the state's counties and only include cotton, soy, and grains (which are small contributors to the state's agricultural output). Under moderate and high emissions scenarios,[a] median estimates show increased yields of 5–6 percent for cotton and soy, and decreased yields of 1.5–3 percent for grains (including corn). However, substantial uncertainty exists, with low- and high-end estimates of −1 to +12 percent for cotton, −1 to +11 percent for soy, and −8 to +5 percent for grains.[5] Yield increases could occur in part due to the benefits of higher CO_2 concentrations in the atmosphere.

- Climate change will affect the risks of citrus greening, which threatens Florida's valuable citrus crops. Citrus greening transmission can occur between 61°F and 91°F, with optimal disease transmission at 77°F.[6] Climate change will increase the risks of disease transmission during the winter, as average temperatures are projected to rise from 59°F to above 60°F by 2035 under a moderate emissions scenario. However, an increase in the number of summer days with temperatures exceeding 91°F will reduce transmission risk during the summer (average summer lows currently exceed 61°F across most of the state).[7]

- Cattle, other livestock, and dairy sales generated 24 percent of Florida's farm cash receipts in 2017.[1] But as the climate changes, higher temperatures are likely

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a "Moderate emissions scenario" refers to RCP 4.5, and "high emissions scenario" refers to RCP 8.5. "Low- and high-end estimates" refers to the 5th and 95th percentile estimates from Hsiang et al.5 under both scenarios.

Cattle, other livestock, and dairy sales **generated 24% of Florida's farm cash** receipts in 2017.

As the climate changes, **higher temperatures are likely to increase heat stress on livestock,** reducing productivity.

to increase heat stress on livestock, reducing productivity. Climate change is also projected to reduce breeding productivity in livestock.[8]

- Outdoor farmworkers in Florida face challenging working conditions due to exposure to high levels of heat, humidity, and disease vectors (e.g., mosquitoes or other animals that can transmit diseases).[5] Under a moderate emissions scenario, labor productivity for such outdoor workers is projected to decrease by approximately 17 percent per worker, but there is substantial uncertainty surrounding this estimate. A high-end (more damaging) estimate projects a productivity decrease of 64 percent, while a low-end (less damaging) estimate projects an *increase* in productivity of 11 percent.[5] Labor productivity increases are possible because of reduced exposure to cold temperatures.

- Climate change is projected to increase the frequency and severity of droughts in the southeastern United States, including Florida. It is also projected to increase the severity of extreme rainfall events. Climate models project drier summers and wetter falls in the southeastern United States, including in parts of Florida. These changing trends may create new challenges for Florida's farmers.[9]

- Increased frequency and severity of drought will likely exacerbate competition for Florida's water resources. In 2015, the state's farms consumed 3.2 billion gallons of fresh water per day—and this figure is projected to rise by 17 percent through 2035.[10] In 2017, roughly 75 percent of Florida's planted cropland was irrigated mechanically (i.e., not rain-fed).[11] As droughts intensify, crop irrigation may become more costly.

- Saltwater intrusion is projected to increasingly affect freshwater aquifers in Florida, damaging crops for farmers relying on irrigation from groundwater near the coasts.[12] However, quantitative estimates for these damages are not currently available.

Climate change is projected to increase the severity of tropical storms making landfall in Florida, leading to higher windspeeds, storm surges, and volumes of precipitation during these events.[13] These more severe storms are likely to increase disruptions to the agricultural sector.

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2 Florida Department of Agriculture and Consumer Services. *Florida Agriculture Overview and Statistics.* **https://www.freshfromflorida.com/ Agriculture-Industry/Florida-Agriculture-Overview-and-Statistics** (2019).

3 United States Department of Agriculture, Animal and Plant Health Inspection Service. *Citrus Greening.* **https://www.aphis.usda.gov/aphis/ resources/pests-diseases/hungry-pests/the-threat/citrus-greening/ citrus-greening-hp** (2019).

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Effects of Climate Change on Agriculture in Florida
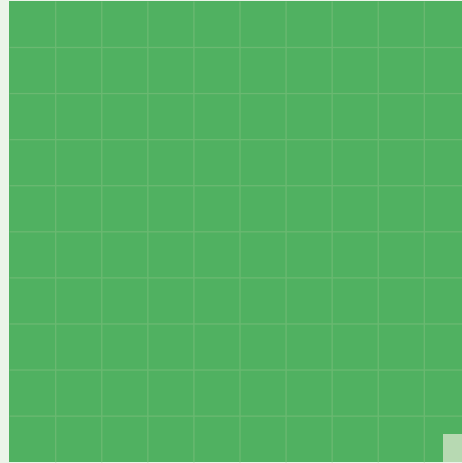
Florida is a major citrus producer, but agriculture is a small part of the state's economy

Florida produces more than half of all US oranges and grapefruits, but agriculture accounts for just 0.6 percent of state GDP in 2017.

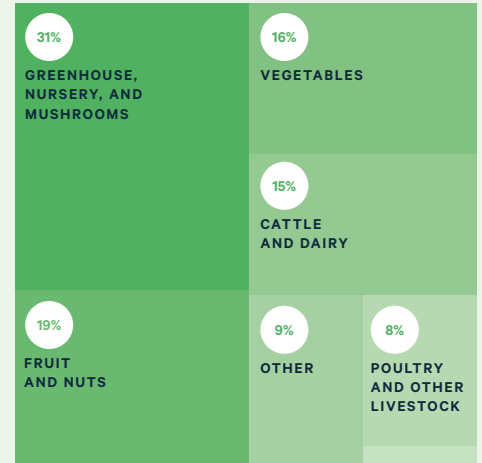**0.2%** The sector employs just a small percent of Florida's workforce.

$25k Workers are paid well below the state average of $46,000 per year.

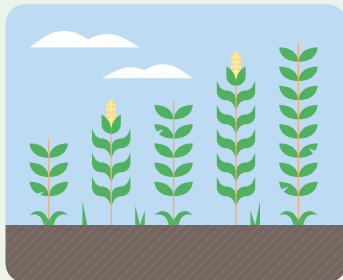### Florida's Economy

AGRICULTURE MAKES UP ONLY 0.6% ▲

Florida's Agricultural Economy

- **31%** GREENHOUSE, NURSERY, AND MUSHROOMS
- **16%** VEGETABLES
- **15%** CATTLE AND DAIRY
- **19%** FRUIT AND NUTS
- **9%** OTHER
- **8%** POULTRY AND OTHER LIVESTOCK

SUMS MAY NOT TOTAL DUE TO ROUNDING   GRAINS / 1% ▲

Four major impacts of climate change on Florida agriculture

Staple crops may benefit somewhat from climate change in Florida

Cotton and soy yields increase by 5–6 percent, and grains increase by 1.5–3 percent under moderate and high scenarios, but with large uncertainty.
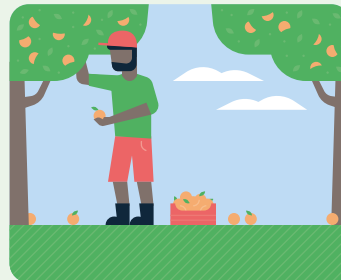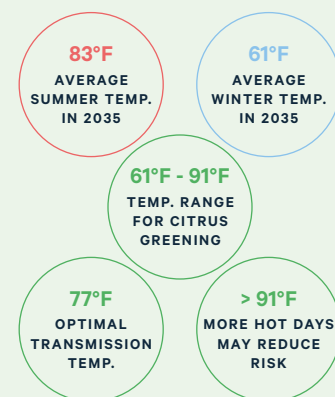
Projected effects of climate change on crop yields by 2035

CORN

SOY

COTTON

12%
8%
4%
0%
-4%
-8%

EMISSIONS SCENARIO
- MODERATE
- HIGH
- ◆ MEDIAN
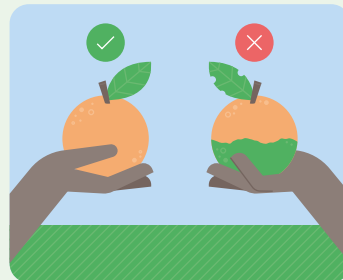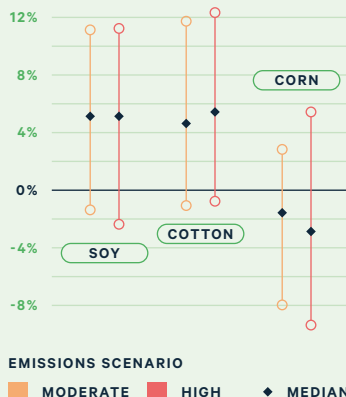
Citrus greening poses a threat to Florida's iconic agricultural products

Climate change will affect the risks of citrus greening, making transmission more likely in the winter but less likely during hot days in the summer.

Citrus greening transmission in a changing climate

- **83°F** AVERAGE SUMMER TEMP. IN 2035
- **61°F** AVERAGE WINTER TEMP. IN 2035
- **61°F - 91°F** TEMP. RANGE FOR CITRUS GREENING
- **77°F** OPTIMAL TRANSMISSION TEMP.
- **> 91°F** MORE HOT DAYS MAY REDUCE RISK

Outdoor farmworkers in Florida face challenging working conditions

Under a moderate emissions scenario, labor productivity for outdoor workers decreases by 17 percent per worker, but there is substantial uncertainty.

Climate impacts range from slightly positive to very negative

20%
0%
-20%
-40%
-60%

11
-17
-64

EMISSIONS SCENARIO
- LOW
- MODERATE
- HIGH
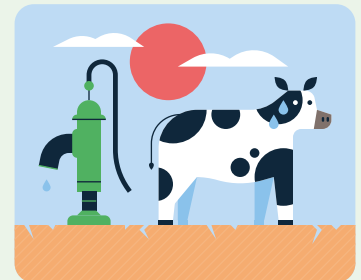
Increased heat and drought across Florida are projected to have negative effects

Increased frequency and severity of drought will exacerbate water stress. Higher temperatures will reduce livestock output and breeding productivity.

Florida agriculture relies heavily on irrigation

4B
3B
2B
1B

2015 **3.2B gallons per year**

2035 **3.7B gallons per year**
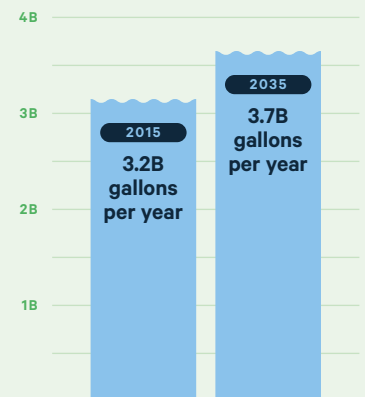
Impacts of National Climate Policies on Florida Households

Overview

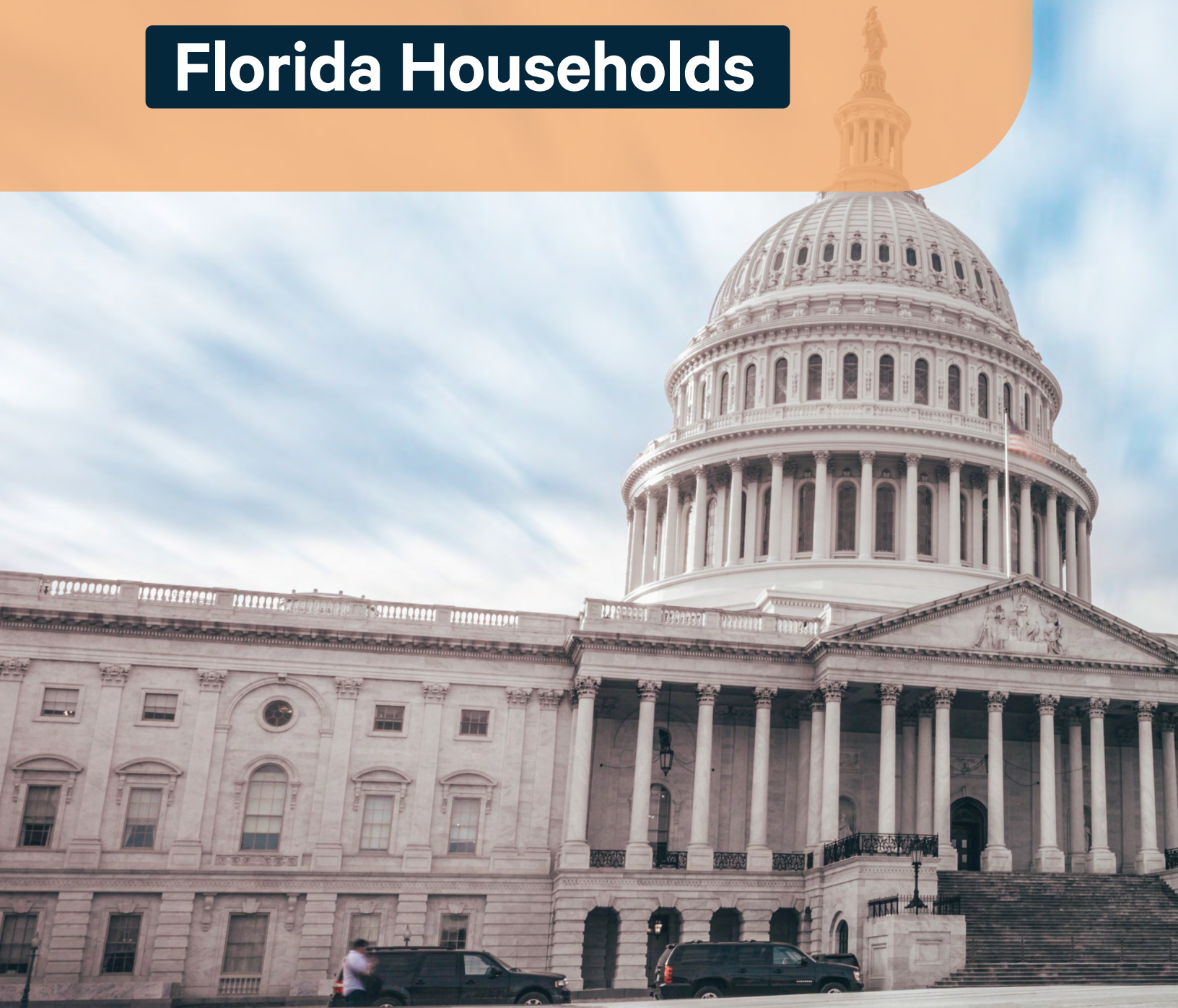**Momentum is growing in the US Congress** to address climate change, and many legislators are turning to carbon pricing policies to reduce greenhouse gas emissions quickly and efficiently. Carbon pricing policies, which charge emitters for the carbon dioxide (CO_2) they release into the atmosphere through the combustion of fossil fuels, have been implemented in numerous countries, regions, states, provinces, and cities around the world.

These policies can be designed in many different ways: major design factors include variations in stringency (the level of the price and how much it changes each year), coverage (which sectors of the economy are covered), and how revenues raised from carbon pricing are used.[1] Eight federal carbon pricing bills have been introduced in

<table>
<tr><td>Table 1</td></tr>
</table>

Proposed Bills and Revenue Use

Proposed Bill (Identified by Primary Sponsor)	Deutch	Whitehouse	Rooney	Coons	Lipinksi	Fitzpatrick	Larson	Van Hollen
Carbon Price in Year 1 ($/metric ton)	$15	$52	$29	$15	$44	$34	$52	$55
Carbon Price in 2035 ($/metric ton)	$165	$125	$58	$240	$64	$68	$125	$99
Major Revenue Use	Dividends	Dividends	Payroll Tax Cuts	Dividends	Payroll Tax Cuts	Infrastructure	Infrastructure	Dividends

Note: See Appendix B for additional policy details.

Congress in 2019, each with a unique policy design. Our analysis uses two models of the US economy built by RFF researchers to estimate the effects of these proposed policies on US and Florida households (see Appendix B for details, and explore the impacts in greater depth using RFF's interactive Carbon Pricing Calculator tool at **www.rff.org/cpc**).

The proposed federal policies would, if implemented, affect households by generating benefits and imposing costs. Households receive substantial long-term benefits from the mitigation of climate change. However, climate policies also impose substantial economic costs by making goods and services that depend on combustion of fossil fuels more expensive. While energy goods like motor gasoline and electricity typically experience the greatest increases in prices, any goods that are created or transported using fossil energy can be affected. The price impacts of climate policies can also reduce household income. Capital income, including dividends and interest, is most affected in the short run.[a] At the same time, carbon pricing generates substantial revenues that can significantly benefit households by, for example, distributing dividends (lump-sum payments to households) or reducing taxes. Depending on

the details of the policy design, these benefits may more than offset the negative economic effects, leaving many households better off.

The most important policy design choice that determines how households are affected is how the revenues from carbon pricing are used. Dividends, which can be distributed equally or targeted to certain types of households, tend to benefit households most. However, reducing payroll or other taxes can benefit many households and provide a greater increase in economic activity. Investing in infrastructure or clean energy technologies can provide an economic boost and accelerate decarbonization, but these approaches typically leave households worse off in the short term. The level of the carbon price is also important in determining how households are affected. Higher carbon prices have greater effects on prices of goods and income, but they also raise more revenues that can be returned to households.

Of the eight policy proposals we analyze, four use most revenues to return dividends to households, two to reduce payroll taxes, and two to invest in infrastructure. The policies have initial carbon prices ranging from \$15 to \$52 per ton of CO_2, rising at different rates over time.[b] Our analysis estimates the economic welfare impacts, a metric that describes how much better or worse off a household would be, as a result of each of the proposed policies.[c] This measure accounts for the effects of changes in prices, expenditures, and income due to each policy and the impacts of returning revenues to households. It does not account for the benefits of avoiding climate change or the benefits of investments in infrastructure and green technologies.

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a   Carbon pricing reduces capital income because it reduces the value of investments related to the combustion of fossil fuels, such as mutual funds that hold stocks in corporations that produce coal, oil, or natural gas.

b   See Appendix B for a table describing each proposed federal policy in detail.

c   See Appendix B for descriptions of the models used to produce estimates.

Key Findings

➤ The proposed policies are projected to have varying impacts on the prices of energy goods such as gasoline. For example, policies with the lowest carbon price ($15 per metric ton in their first year) would increase the cost of a gallon of gasoline by 4 cents, while policies with the highest carbon price ($52 per metric ton in their first year) would raise the cost by 16 cents per gallon.[d]

➤ The policies are expected to reduce economic welfare by varying amounts in Florida. The proposed policy with the least impact, the Van Hollen bill, would reduce welfare by $183 per Florida household in the first year of implementation. The policy with the most impact, the Larson bill, would reduce welfare by $1,360 per Florida household. Policies that use revenues for dividends and payroll tax cuts are expected to leave Florida households better off than policies that use revenues for infrastructure investments. These estimates do not account for the benefits of mitigating climate change and infrastructure investments.

➤ The average economic welfare impacts of the policies on households across the United States are expected to range between net benefits of $74 under the Van Hollen bill to net costs of $1,100 under the Larson bill. Florida households are likely to fare slightly worse than the average US household because Floridians on average earn more capital income relative to other states, and carbon pricing reduces capital income.

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d   These projections are based on a price of $2.60 per gallon of gasoline (the 2018 average price in Florida).[2]

The most important policy design choice that determines how households are affected is **how the revenues from carbon pricing are used.**

Dividends, which can be distributed equally or targeted to certain types of households, **tend to benefit households most.**

These average projections mask large differences in impacts felt by different types of households. For example, the Whitehouse and Van Hollen bills are expected to make low- and middle-income households (income quintiles 1–4) better off while making the highest-income households (quintile 5) worse off.[e] These bills raise large revenues through high carbon prices and use those revenues for dividends, which produce large net benefits for low- and middle-income households.

Policies with higher carbon prices that use revenues for infrastructure investments tend to have the worst outcomes for households in our modeling. However, our estimates do not account for the benefits that infrastructure spending could create or the benefits of greater climate change mitigation from a higher carbon price.

The highest-income households (quintile 5) are expected to be most negatively affected by these policies, with economic welfare losses of $862 to $5,005 per household across all proposals. This is primarily because high-income households earn more capital income than other households.

Low-income households spend the greatest share of their income on energy goods compared with higher-income households. However, when revenues are distributed to households in the form of dividends, they generally offset price impacts and make low-income households better off. Each of the four proposed policies that use most revenues for dividends are expected to make the lowest-income households (income quintiles 1 and 2) better off.

---

e   Florida households are grouped into five income quintiles, equally sized groups of households sorted by income. Quintile 1 contains the lowest-income households, and quintile 5 contains the highest-income households.

- The four proposed policies that use revenues for payroll tax cuts and infrastructure spending are expected to make the lowest-income households worse off. Payroll tax cuts have the largest negative impacts on the lowest-income households because these households pay little or no payroll taxes and thus receive little benefit from the tax cuts.

- Across all proposals examined here, the economic welfare impacts for the lowest-income Florida households (quintile 1) in the first year of policy implementation are expected to range from losses of $316 under the Lipinski bill to benefits of $1,037 per household under the Van Hollen bill.

- Rural households are expected to be more positively impacted than urban households under most of the proposed policies. While rural households consume more energy goods and are thus more affected by price changes, urban households tend to have higher income and are thus more affected by reductions in capital income.

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Low-income households spend the greatest share of their income on energy goods compared with higher-income households.

However, when revenues are distributed to households in the form of dividends, they generally offset price impacts and make low-income households better off.

Impacts of Federal Climate Policies on Florida Households

Legislators are turning to carbon pricing plans to reduce emissions quickly and efficiently

We analyzed eight proposed federal carbon pricing policies to understand their impact on Florida. The policies have initial carbon prices ranging from $15 to $52 per ton of CO_2 and have various means of revenue usage. The bills are labeled by their primary sponsor.

Payroll Tax Cuts

Two bills use most revenues to reduce payroll taxes.

- **REP. ROONEY**
- **REP. LIPINSKI**

Dividends

Four bills use most revenues to return dividends (direct payments) to households.

- **SEN. COONS**
- **SEN. WHITEHOUSE**
- **SEN. VAN HOLLEN**
- **REP. DEUTCH**

Infrastructure Spending

Two bills use most revenues to invest in infrastructure.

- **REP. FITZPATRICK**
- **REP. LARSON**

Impact Areas

Policy impacts are driven by changes in household expenditures and income.

- ⚡ **Energy Goods**
  e.g., gasoline and electricity
- 🔒 **Other Goods**
  e.g., healthcare and food
- 💲 **Sources of Income**
  e.g. wages and dividends
- ⚌ **Total Impact**

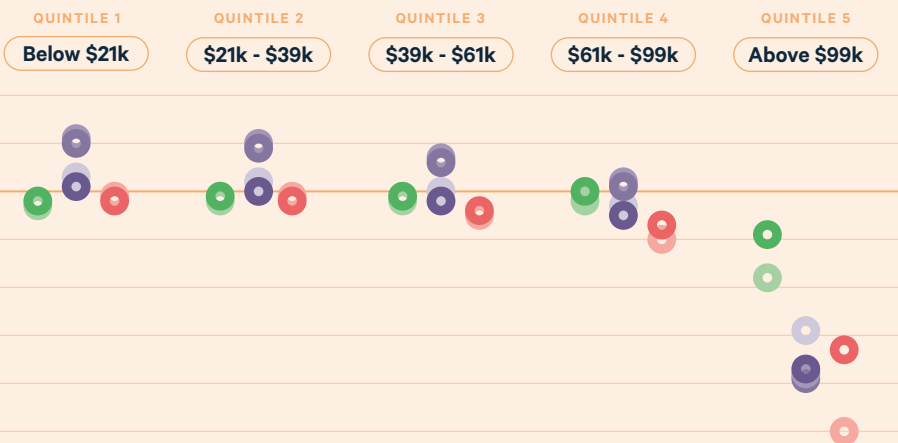### How will the policies affect Florida compared to the rest of the US?

US vs **Florida**
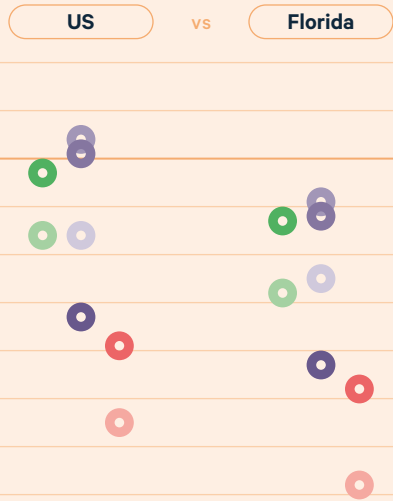
How will the policies affect urban and rural households in Florida differently?

Urban vs **Rural**
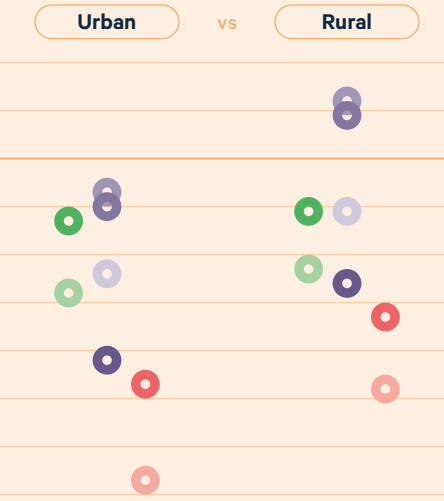
ECONOMIC WELFARE CHANGE* ($ PER HOUSEHOLD)

$400 / $200 / $0 / -$200 / -$400 / -$600 / -$800 / -$1000 / -$1200 / -$1400

How will the policies affect households in Florida at different income levels?

QUINTILE 1	QUINTILE 2	QUINTILE 3	QUINTILE 4	QUINTILE 5
Below $21k	$21k - $39k	$39k - $61k	$61k - $99k	Above $99k

$2000 / $1000 / $0 / -$1000 / -$2000 / -$3000 / -$4000 / -$5000

How will the policies affect income and spending?

QUINTILES 1 - 4	QUINTILE 5
Household income under $99k	Household income over $99k

$2,000 / $1,000 / $0 / -$1,000 / -$2,000 / -$3,000 / -$4,000 / -$5,000
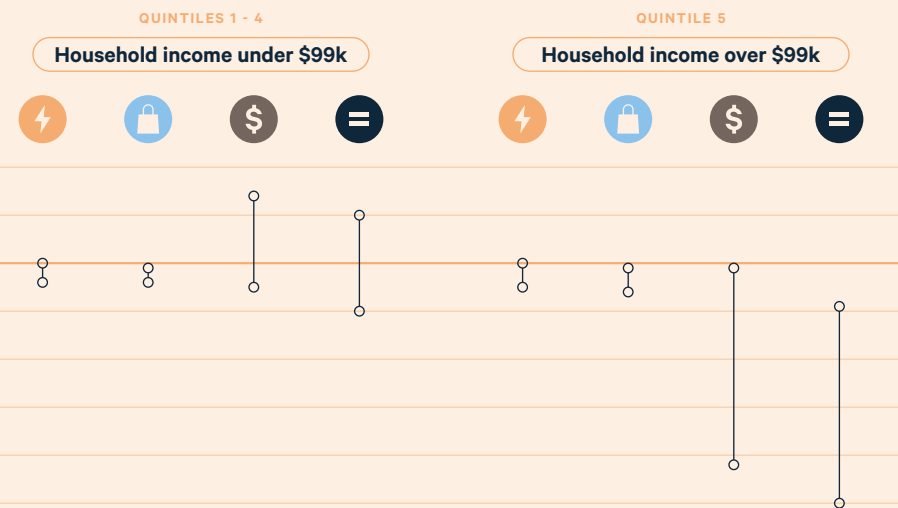
Does not include benefits of infrastructure investment or environmental benefits from mitigating climate change.

Scenarios, Projections, and Uncertainty

Projections of the effects of climate change on the topics discussed in this project are subject to significant uncertainty. Such uncertainty stems from underlying uncertainty in the drivers of physical impacts—such as changes in temperature, precipitation, and sea level rise—and is present even over a relatively short time frame, such as 15 or 20 years.

Uncertainty in these physical drivers is due to two main factors. The first is related to human activities—namely, that the future levels of greenhouse gas emissions are uncertain and will depend on government policies, technological development, and other factors. The second is related to the state of scientific understanding of geophysical, atmospheric, and other Earth system dynamics. Put simply, there is uncertainty regarding Earth's physical response to any given level of emissions.

Modeling the Global and Regional Effects of Greenhouse Gas Emissions

Dozens of groups of experts—consisting of hundreds of researchers from around the world—have developed computer models of Earth's climate system to estimate the potential future effects of the greenhouse gas emissions currently accumulating in the atmosphere and oceans. Such models have improved over time and have for the most part successfully characterized historical changes in global average temperatures.[1]

Climate modeling teams work together regularly to compare the results of their projections in a recurring exercise known as the Coupled Model Intercomparison Project (CMIP). The most recent of these exercises, CMIP5, provided a range of global projections based on the output of 20 modeling groups.[2]

Until recently, the results of these intercomparisons have generally been reported as a range of outcomes, without estimating their relative *likelihood* of occurrence. Recent work from US climate scientists, however, used the CMIP5 studies to estimate the likelihood of different outcomes, providing a probabilistic set of projections for temperature and precipitation for all US counties under different emissions scenarios.[3] In the preceding sections, we relied on the results of this probabilistic work, accessed through a simplified version of the data made available by the Climate Impact Lab,[4] a multidisciplinary group of researchers estimating the effects of climate change in the United States and globally.

We focused on the median results of this work, which estimates that under a high emissions scenario (discussed in further detail below), by 2040, average annual summer temperatures in Florida will increase by 2.0°F above their 1981–2010 average. At the low end, this work estimates a 5 percent chance that summer temperatures will increase by just 0.6°F or less. At the high end, it estimates a 5 percent chance that average summer temperatures will increase by 2.7°F or more by 2040. We provide more information on these probabilities below in the section on "Uncertainty within scenarios."

Scenario Choice

The use of scenarios in climate modeling (and for other purposes) allows researchers to produce results that can be readily compared with one another. At the request of the Intergovernmental Panel on Climate Change, experts from a variety of disciplines have worked to develop scenarios that capture a range of potential futures for global emissions and the resulting atmospheric concentrations of greenhouse gases. These scenarios, known as Representative Concentration Pathways (RCPs), provide four scenarios of global greenhouse gas emissions and concentrations (along with other air emissions and land use changes) spanning the range of estimates found in the peer-reviewed literature at the time the RCPs were developed.[5]

Figure 1

Historical and Projected Annual Carbon Emissions
from Fossil Fuel Use and Industry (Gigatons of Carbon)
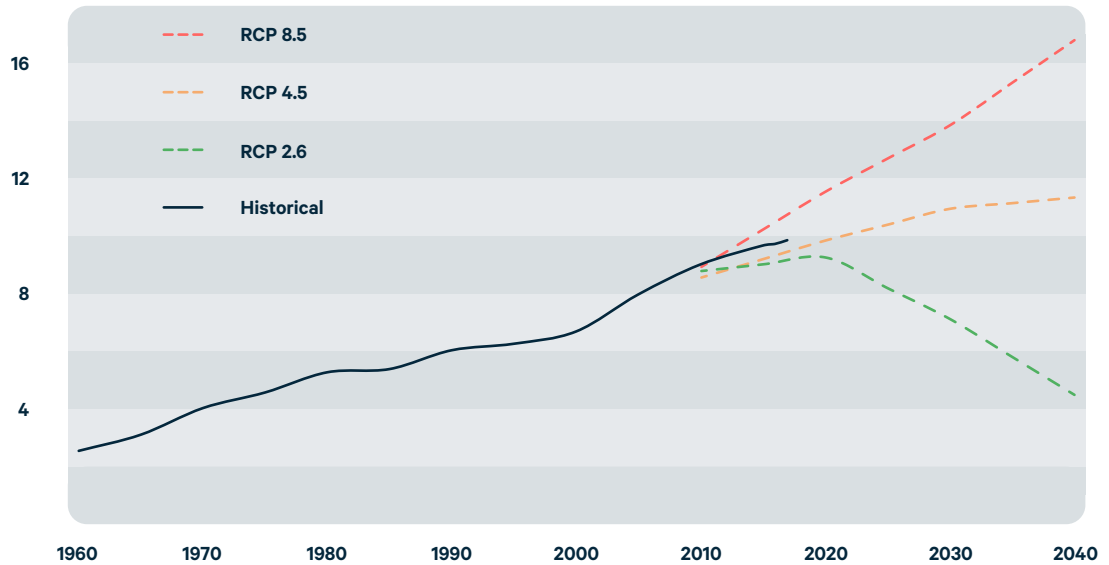
Data sources: Global Carbon Project[8] and IIASA RCP database.[9]

The RCPs lead to radiative forcing (a measure of the additional energy reaching Earth's surface from the atmosphere) in the year 2100 of 2.6, 4.5, 6.0, and 8.5 watts per square meter and are thus referred to as RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5. Climate modelers and others can then use these scenarios as inputs into their models, producing estimates for global mean temperature rise, global mean sea level rise, and other physical outcomes based on a given RCP. In general, greater levels of radiative forcing result in greater warming of surface temperatures. The surface warming resulting from any given level of emissions/concentrations, however, is also subject to uncertainty, as we discuss in the next section.

In the preceding sections, we refer to two emissions scenarios: a moderate emissions scenario (RCP 4.5) and a high emissions scenario (RCP 8.5). We chose these two scenarios because, over

the time frame considered (today through 2035 or 2040), both scenarios appear plausible based on recent emissions trends. A lower emissions pathway (e.g., RCP 2.6) is also possible, but we do not include it in our analysis because numerous recent publications[6,7] have shown that existing and announced public policies such as national pledges included in the 2015 Paris agreement are not consistent with a pathway such as RCP 2.6 (see Figure 1). Because of the slow-changing nature of the global energy system, and given the relevant time frame of analysis, our assessment of the data is that it is appropriate to refer to RCP 4.5 as a moderate emissions scenario and RCP 8.5 as a high emissions scenario.

Uncertainty within Scenarios

Uncertainty does not end with the choice of a scenario. Because the physical response of Earth's natural systems to a given level of CO_2 and other greenhouse gases in the atmosphere is also uncertain, a range of climatic outcomes are possible under any given emissions scenario such as RCP 4.5 or RCP 8.5.

Uncertainty in Temperature Projections

One useful metric for evaluating this uncertainty is equilibrium climate sensitivity (ECS), defined as the long-term change in global average temperatures resulting from a doubling of atmospheric concentrations of CO_2. Before the industrial revolution, CO_2 made up 280 parts per million of the atmosphere (which is mostly composed of nitrogen and oxygen[10]). ECS therefore measures the long-term change in global average temperatures resulting from an atmospheric doubling of CO_2, stabilizing at roughly 560 parts per million.

In the late 19th century, Swedish scientist Svante Arrhenius estimated that such a doubling would lead to a global average temperature increase of 9°F to 11°F (5°C to 6°C).[11] In the decades that followed, significant effort has gone into refining this estimate, and the IPCC's

most recent (AR5) report estimates that ECS is "likely" (66 percent probability) to be in the range of 2.7°F to 8°F (1.5°C to 4.5°C) and "very unlikely" (less than 10 percent probability) to be higher than 11°F (6°C).[12]

Importantly, the damages associated with long-term global mean temperature rise of 11°F or more are highly uncertain and could be catastrophic (e.g., widespread crop failures, human health effects, and long-term sea level rise of hundreds of feet). It is therefore important to consider the unlikely—but still possible—scenarios under which a moderate emissions scenario such as RCP 4.5 could lead to very high levels of warming, resulting in disastrous impacts to human and natural systems.[13] These levels of warming are not relevant over the time frame of analysis here (15 to 20 years), but they are highly relevant to any consideration of the longer-term impacts of climate change. In particular, public policy decisions made over the next several decades will play a major role in determining whether future generations might face these extreme impacts.

Because of the uncertainties surrounding ECS for any given RCP, we reported a range of results in this analysis. For both the moderate and high emissions scenarios (RCPs 4.5 and 8.5), we provided a central estimate (50 percent likelihood) along with low end (5 percent likelihood) and high end (5 percent likelihood) estimates in all cases for which the underlying research allowed us to do so. For cases in which the underlying research does not provide the range or likelihood of a given outcome, we presented central estimates from the underlying study.

Uncertainty in Sea Level Rise Projections

Projections of sea level rise (SLR) under different emissions scenarios are made using complex computer models of Earth's physical systems that model thermal expansion (the process by which ocean water expands as it warms) and ice melt (water added to

the oceans from melting ice on land). The median projection for global mean sea level (GMSL) in 2100 is 0.53 meters (21 inches) and 0.74 meters (29 inches) for RCP 4.5 and RCP 8.5, respectively. The 5 – 95 percent uncertainty range for these estimates in the year 2100 are 0.32 – 0.63 meters (13 – 25 inches) for RCP 4.5 and 0.52 – 0.98 meters (20 – 39 inches) for RCP 8.5.[14]

Importantly, sea levels will continue to rise in the centuries to come, as the response of oceans and glaciers to warming occurs over decades to centuries. For example, melting of the Greenland and Antarctic Ice Sheets may become irreversible by the latter half of the 21st century if emissions are not reduced. Under a high emissions scenario, sea levels could rise by more than 25 feet by 2200[15] and potentially more than 50 feet over thousands of years.[16] While experts believe these levels of SLR are unlikely, they are physically plausible, particularly under the high emissions scenario and if ECS is at the higher end of current estimates.

To translate from global SLR projections to Florida-specific SLR projections, additional factors need to be accounted for in the computer models, such as ocean circulation, gravitational field changes, and vertical land shift. Such regional projections were necessary for the purpose of the National Climate Assessment (NCA), and a joint federal government task force was established to carry out this modelling effort.[a]

This federal research group created projections of regional sea level rise based on six different global scenarios. These scenarios span a range of plausible GMSL and correspond with SLR of 0.3, 0.5, 1.0, 1.5, 2.0, and 2.5 meters in 2100 (roughly 1 to 8 feet).

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a   The Federal Interagency Sea Level Rise and Coastal Flood Hazard Scenarios and Tools Task Force, a joint task force of the National Ocean Council (NOC) and the US Global Change Research Program (USGCRP).

For each of these scenarios, regional SLR is modeled probabilistically for points along the entire US coastline.[17]

Although we used RCPs as scenarios in the sections, it is difficult to directly connect each RCP with the available *regional* SLR scenarios developed for the NCA. While the six NCA scenarios span the plausible range for GMSL under the RCPs, they do not directly correspond with different emissions scenarios. For example, the median GMSL for RCP 4.5 (0.53 meters) is similar to the second NCA scenario (0.5m GMSL in 2100), but the median for RCP 8.5 (0.74 meters) falls squarely between the second and third NCA scenarios.

As a result, our section on sea level rise used the second and third NCA scenarios as moderate SLR and higher SLR scenarios and also reports the sixth scenario (0.41 meters GMSL by 2040) as an extreme SLR scenario. The first two are our best attempts to represent the central ranges of SLR projections for RCP 4.5 and RCP 8.5, acknowledging that this is not a direct mapping. Under RCP 4.5, there is a 73 percent chance of exceeding the moderate SLR scenario, and under RCP 8.5 there is a 17 percent chance of exceeding the higher SLR scenario. The extreme SLR scenario represents an upper bound (0.05 percent chance of exceeding under RCP 4.5, and 0.1 percent chance of exceeding under RCP 8.5) and includes less likely, but still possible, extreme climate responses such as rapid ice sheet melt in Greenland and Antarctica.

Modeling Climate Policy Impacts

Model Description

Our analysis of the impacts of climate policy on Florida households draws on two models developed by researchers at Resources for the Future (RFF). The Goulder-Hafstead Energy-Environment-Economy (E3) Model is an economy-wide computable general equilibrium model of the United States that is used to project the nationwide impacts of a carbon price, including CO_2 emissions, consumer expenditures, and personal income.[18] The model has been featured in a book published by Columbia University Press (*Confronting the Climate Challenge: US Policy Options*), four peer-reviewed journal publications, and Stanford's Energy Modeling Forum (EMF) 32: Inter-model Comparison of US Greenhouse Gas Reduction Policy Options.[19–24] Our analysis draws on E3 model results published online in RFF's Carbon Pricing Calculator.[18]
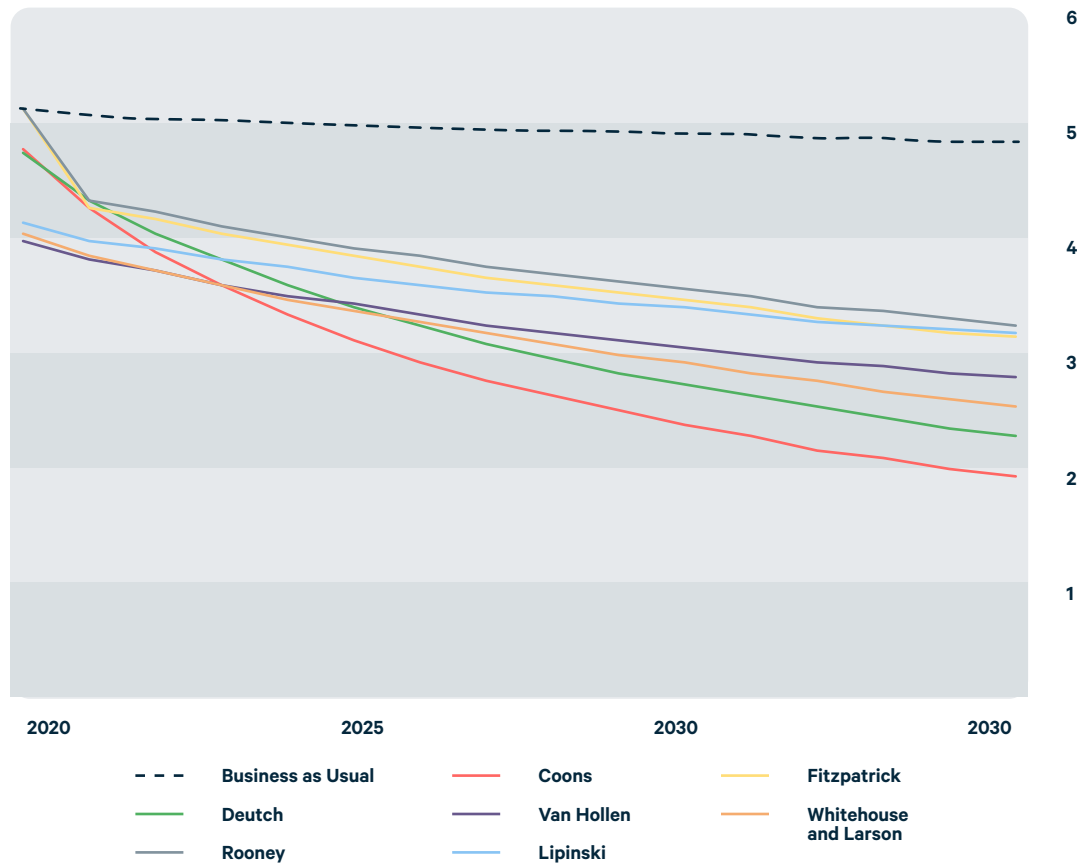
The distributional impacts of the carbon price in the first year of the policy are derived from the RFF Incidence Model, which uses inputs from the E3 model to determine the average change in household economic welfare by quintile in the first year of policy implementation. The Incidence Model takes estimates of nationwide changes in expenditure and income and uses detailed data on US households to estimate the impacts of aggregate change on specific household types distinguished by income, geography and demographic information. The Incidence Model has been featured in two peer-reviewed publications.[25,26]

Uncertainty

Projections are not firm predictions or forecasts about the future. Rather, projections depend on important assumptions, including values for a number of variables whose future values are inherently uncertain (such as future economic growth, technological innovation, and much more).

Figure B1

Projected Annual US CO_2 Emissions Under Recent Carbon Pricing Proposals (Billion Metric Tons)

Legend:
- Business as Usual
- Deutch
- Rooney
- Coons
- Van Hollen
- Lipinski
- Fitzpatrick
- Whitehouse and Larson

Source: Goulder-Hafstead E3 Model.

Projections in the E3 model represent central estimates of future outcomes conditional on a large number of parameter and model assumptions, and changes to any single assumption may alter the projection results. Key sources of uncertainty include both baseline forecasts and price elasticities. Chen, Goulder, and Hafstead (2018) evaluate the sensitivity of E3's projected emissions to baseline forecasts such as fossil fuel prices, economic growth, and the rate of energy efficiency improvements in nonenergy sectors.[22]

Table B1 (on the next page) provides key policy elements and other information for the scenarios modeled in the preceding sections. Figure B1 (left) illustrates projected annual US CO_2 emissions for the modeled scenarios.

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Projected Annual US CO$_2$ Emissions Under Recent Carbon Pricing Proposals (Billion Metric Tons)

Bill (Sponsor and Cosponsors)	Energy Innovation and Carbon Dividend Act Ted Deutch and 58 cosponsors	American Opportunity Carbon Fee Act Sheldon Whitehouse, Brian Schatz, Martin Heinrich, Kirsten Gillibrand	Stemming Warming and Augmenting Pay Act Francis Rooney, Dan Lipinski
Political Coalition	Bipartisan	Democratic	Bipartisan
Starting Year	2020	2020	2021
Carbon Price Path	$15 rising annually by $10 + inflation	$52 rising annually by 6% + inflation	$30 rising annually by 5% + inflation
Reductions below Business as Usual in 2035	53%	47%	33%
Revenue Use	Carbon Dividends	Tax credits, social security beneficiary payments, state block grants ($10 billion)	**70%:** Payroll tax cuts **10%:** Social security payments **10%:** Block grants for low-income assistance **10%:** Adaptation, energy efficiency and advanced research and development

Climate Action Rebate Act	Raise Wages, Cut Carbon Act	MARKET CHOICE Act	America Wins Act	Healthy Climate and Family Security Act
Chris Coons, Dianne Feinstein	Dan Lipinski, Francis Rooney	Brian Fitzpatrick	John Larson	Chris Van Hollen, Don Beyer
Democratic	Bipartisan	Bipartisan	Democratic	Democratic
2020	2020	2021	2020	2020
$15 rising annually by $15 + inflation	$44 rising annually by 2.5% + inflation	$35 rising annually by 5% + inflation	$52 rising annually by 6% + inflation	Emissions cap of 80% below 2005 levels by 2040
60%	34%	35%	47%	42%
70%: Carbon dividends for low- and middle-income households **20%:** Infrastructure **5%:** Research and development **5%:** Transitional assistance	**94%:** Payroll tax cuts and increases to social security benefits **5%:** Low-income home energy **1%:** Weatherization assistance	**70%:** Highway Trust Fund **10%:** State grants for low-income households **4%:** Coastal flooding infrastructure **3%:** Transitional assistance **1%:** Misc. spending and R&D	**54%:** Infrastructure spending **43%:** Consumer tax refunds to low-income households **3%:** Transitional assistance	Carbon dividends

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