VULNERABLE POPULATIONS: CLIMATE CHANGE AND EXTREME WEATHER THREATS FACING URBAN COMMUNITIES

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This article explores increasing extreme weather threats facing American cities due to global climate change, including hurricanes, floods, heat waves, and wildfires. After explanation of such threats, the paper delves into case studies of the response and resiliency measures being undertaken by three preeminent coastal American cities to prepare for weather disasters: New York, Miami, and San Francisco. The paper concludes by providing guidance and recommendations for urban policymakers seeking to develop resiliency measures in the face of long-term effects and short-term emergencies created by climate and weather extremes. Such recommendations include how to initiate and fund development of climate resiliency measures as well as examples and best practices for developing resiliency and mitigation tools for different extreme weather threats.

INTRODUCTION

Global climate change poses various threats to built and natural urban systems, including through floods, hurricanes, extreme heat, and wildfires. Such events can result in debilitating damage to ecosystems, vast financial losses stemming from property damage and business disruptions, and harmful effects on human health and quality of life. While climate change impacts may strike anywhere, they are most felt in highly populated and densely built cities, even more so in coastal communities.

Caused and exacerbated by rising carbon dioxide (CO_2), methane (CO_4), and nitrous oxide (N_2O) levels in the atmosphere, climate change is not expected to abate in the short term.[1] CO_2 levels continue to rise worldwide

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[1] *See* Michael Burger et al., *The Law and Science of Climate Change Attribution*, 45 COLUM. J. ENV'T L. 57, 80 (2020); Cynthia Rosenzweig & William Solecki, *New York City Panel on Climate Change 2019 Report Chapter 1: Introduction*, 1439 ANNALS N.Y. ACAD. SCI. 22, 26 (2019).

and, due to the longevity of CO_2 in the atmosphere, its effects will last for decades, if not centuries.[2] Thus, urban communities must anticipate, plan for, and mitigate expected climate change impacts.

This article will first explore the harmful effects of climate change on urban communities, with a focus on flooding and heat events, and then review case studies of the preparation and mitigation efforts of three large, coastal cities in America: New York, Miami, and San Francisco. Each of these cities is a member of the Rockefeller Foundation's 100 Resilient Cities, a network of communities seeking to develop urban resilience.[3] Based on the hurdles and successes demonstrated by these case studies, this article will present recommendations for proactive steps urban areas can undertake to develop climate resilience and mitigation tools in the face of more frequent and severe adverse weather events caused by climate change.

I. CLIMATE ISSUES

Global climate change has led to more frequent weather events that pose extensive threats to natural and built systems as well as human health and quality of life. The United Nations Intergovernmental Panel on Climate Change (IPCC) determined that the hottest period of the last 1,400 years in the Northern hemisphere was between 1983 and 2012.[4] The United Nations (UN) predicts the continuation of this global heating trend.[5] Recently, the National Aeronautics and Space Administration's (NASA) Goddard Institute for Space Studies found surface temperatures in 2018 to be 1.42°F higher than the average temperatures of the twentieth century, with nineteen of the hottest years on record having occurred since 2000.[6] This research comports with the findings of several other agencies, including the National Oceanic

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[2] Rosenzweig & Solecki, *supra* note 1, at 22.

[3] *Urban Resilience*, RESILIENT CITIES NETWORK, https://resilientcitiesnetwork.org/urban-resilience/ [https://perma.cc/UTF7-R3ZP] (defining "urban resilience" as "the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience").

[4] INT'L PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2014: SYNTHESIS REPORT 2 (Nov. 28, 2014) [https://perma.cc/TN6L-A8SU].

[5] *Id.*; *see also* Rosenzweig & Solecki, *supra* note 1, at 25.

[6] *Global Climate Change: Vital Signs of the Planet – Global Temperature*, NAT'L AERONAUTICS & SPACE ADMIN., https://climate.nasa.gov/vital-signs/global-temperature/ [https://perma.cc/7L8H-HL3Z]; Burger et al., *supra*, note 1, at 83; VIVIEN GORNITZ, NASA GODDARD INST. FOR SPACE STUDIES, RISING SEA LEVELS, FREQUENT FLOODS: EFFECTS ON NEW YORK CITY NEIGHBORHOODS (Sept. 2019).

and Atmospheric Administration (NOAA).[7] Such rising global temperatures have caused, and are anticipated to continue to cause, more frequent and severe droughts, wildfires, floods, and hurricanes; rising sea levels; and extreme heat events.[8]

Longer and more extreme heat waves have adverse health effects on humans, wildlife, and ecosystems.[9] Prolonged higher temperatures, paired with drought conditions, also create a greater chance for ignition and spread of wildfires—by drying vegetation and lowering the humidity, heat waves create the ideal conditions for wildfires.[10] Not surprisingly, the increased frequency, duration, and intensity of heat waves has coincided with significantly greater acreage of American lands burned during wildfire events.[11]

Global warming trends are not limited to land. The upper seventy-five meters of the ocean surface have experienced a mean warming increase of approximately 0.5°C over the last forty years.[12] Increased ocean temperatures have melted glaciers and polar ice caps, which in turn releases fresh water into the ocean.[13] This melting causes approximately two-thirds of annual worldwide sea-level rise and disrupts polar ecosystems (as the size of glaciers decrease) and aquatic ecosystems (by decreasing ocean salinity).[14]

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[7] *2018 Fourth Warmest Year in Continued Warming Trend, According to NASA, NOAA*, NAT'L AERONAUTICS & SPACE ADMIN. (Feb. 6, 2019), https://climate.nasa.gov/news/2841/2018-fourth-warmest-year-in-continued-warming-trend-according-to-nasa-noaa/ [https://perma.cc/MV29-DN4Z].

[8] Rosenzweig & Solecki, *supra* note 1, at 76; Jessica Merzdorf & Sara Blumberg, *A Drier Future Sets the Stage for More Wildfires*, NAT'L AERONAUTIC & SPACE ADMIN. (Jul. 9, 2019), https://www.giss.nasa.gov/research/news/20190709/ [https://perma.cc/R47P-ZPZ5].

[9] San Francisco State University, *Potential Impacts of Future Heat Waves on Humans and Wildlife*, SCIENCEDAILY (Mar. 12, 2019), https://www.sciencedaily.com/releases/2019/03/190312170757.htm [https://perma.cc/C94E-KXQR]; *Climate Change Indicators: Heat-Related Deaths*, U.S. ENV'T PROT. AGENCY (Aug. 2016), https://www.epa.gov/climate-indicators/climate-change-indicators-heat-related-deaths [https://perma.cc/UK5W-GBXU].

[10] Brian Dunbar, *NASA Maps Heat Wave Fueling Wildfires in the Rockies*, NAT'L AERONAUTIC & SPACE ADMIN. (Jun. 29, 2012), www.nasa.gov/mission_pages/fires/main/usa/20120629-westernUS.html [https://perma.cc/ZJ64-B9YU]; Merzdorf & Blumberg, *supra* note 8.

[11] *Climate Change Indicators: Wildfires*, U.S. ENV'T PROT. AGENCY (Aug. 2016), https://www.epa.gov/climate-indicators/climate-change-indicators-wildfires [https://perma.cc/7CPK-VB2G].

[12] INT'L PANEL ON CLIMATE CHANGE, *supra* note 4, at 40.

[13] *Ten Signs of a Warming World*, NAT'L OCEANIC & ATMOSPHERIC ADMIN., https://cpo.noaa.gov/warmingworld/global_sea_level.html [https://perma.cc/U6M2-9H8V].

[14] Rosenzweig & Solecki, *supra* note 1, at 77; Maria-José Canseco Viñas & Carol Rasmussen, *Warming Seas and Melting Ice Sheets*, NAT'L AERONAUTIC & SPACE ADMIN.

As sea levels rise, so does the threat of storm surges and coastal flooding.[15] Studies of New York's coastal areas indicate that inland flooding has increased over the last century.[16] Tidal intrusions between 1900 and 1993 ranged between 0.04 and 0.08 inches per year.[17] Between 1993 and 2017, tidal intrusions increased to an average of 0.12 inches per year.[18] Similar studies indicate that sea levels along the New York shoreline will rise by at least another foot and potentially as much as two and a half feet over the next thirty years.[19] These predictions for the New York coastline align with NASA's findings in the Global Climate Change Project and the *National Climate Assessment*, which reported exponential worldwide increases in sea levels during the last twenty years and anticipates continuing sea level rise.[20]

Warmer oceans also lead to more frequent and stronger hurricanes.[21] When these hurricanes strike land, they can damage or destroy infrastructure and ecosystems, resulting in extensive financial losses, loss of wildlife habitat, harm to human health, and reduction in quality of life.[22] Seven of the ten costliest weather events in U.S. history were due to hurricane damage.[23]

(Aug. 26, 2015), https://www.nasa.gov/feature/goddard/warming-seas-and-melting-ice-sheets [https://perma.cc/BWH3-9UQK].

[15] Brian A. Colle et al., *New York City's Vulnerability to Coastal Flooding*, 89 AM. METEOROLOGICAL SOC'Y 829, 830 (Jun. 2008).

[16] *Id.* at 840.

[17] Rosenzweig & Solecki, *supra* note 1, at 25.

[18] *Id.* at 27.

[19] *Id.* at 28.

[20] U.S. GLOB. CHANGE RSCH. PROGRAM, THIRD NATIONAL CLIMATE ASSESSMENT: CLIMATE CHANGE IMPACTS IN THE UNITED STATES, https://nca2014.globalchange.gov [https://perma.cc/P9E2-6WC3]; *Vital Signs of the Planet: Sea Level*, NAT'L AERONAUTIC & SPACE ADMIN., http://climate.nasa.gov/vital-signs/sea-level/ [https://perma.cc/G84Y-DFN5].

[21] Kazuyoshi Oouchi et al., *Tropical Cyclone Climatology in a Global-Warming Climate as Simulated in a 20 km Mesh Global Atmospheric Model: Frequency and Wind Intensity,* 84 J. METEOR. SOC. JAPAN 259, 260 (2006).

[22] Dianne Lowe et al., *Factors Increasing Vulnerability to Health Effects Before, During and After Floods*, 10 INT. J. ENV'T RSCH. PUB. HEALTH 7015, 7018 (Dec. 2013); Samiul Hasan & Greg Foliente, *Modeling Infrastructure System Interdependencies and Socioeconomic Impacts of Failure in Extreme Events: Emerging R&D Challenges*, NAT. HAZARDS (May 2015); Raffaele Marchigiani et al., *Wind Disasters: A Comprehensive Review of Current Management Strategies*, INT'L. J. CRITICAL ILLNESS & INJ. SCI. 130, 131 (Apr. 2013).

[23] David Muhlbaum & Michael Korsh, *The Most Expensive Natural Disasters in U.S. History*, KIPLINGER (Jul. 1, 2021), https://www.kiplinger.com/slideshow/business/t019-s001-most-expensive-natural-disasters-in-u-s-history/index.html [https://perma.cc/8837-93WU]; *Hurricane Costs*, NAT'L OCEANIC & ATMOSPHERIC ADMIN., OFF. COASTAL MGMT., https://coast.noaa.gov/states/fast-facts/hurricane-costs.html [https://perma.cc/UB8N-E7ZH].

Hurricane-caused infrastructure disruption also inhibits the ability to maintain daily activities such as business, education, and government activities. Human health and welfare are jeopardized when emergency services and health/safety systems, such as first responders and waste and sewage facilities, become overtaxed and unable to function. Beach erosion resulting from hurricanes waves can have long lasting effects on the natural functioning, beauty, and value of beach-front properties.[24]

II. WHY URBAN AREAS ARE UNIQUELY SITUATED TO BE HARMED BY CLIMATE CHANGE

In the United States, 80% of the population (approximately 250 million people) live in urban communities.[25] Due to their dense infrastructure and large populations, urban communities are uniquely situated to suffer disparate harm from climate events. Further, many cities were developed in coastal areas due to the historical use of water bodies as trade routes. The proximity of such cities to coastal and inland shorelines makes them particularly susceptible to rising sea levels, stronger tropical storms and hurricanes, and greater flooding.[26] Many of these coastal cities—such as Miami, Boston, New York, and San Francisco—are major metropolises with more than one million residents in the city core and surrounding metropolitan area.

The dense nature of development patterns and populations of urban areas facilitates a much greater loss of life and property: one hurricane or flood event can damage thousands of homes and businesses. Such storms can also disrupt infrastructure, government and law enforcement services, and medical facilities, rendering urban communities unable to provide sufficient emergency services to thousands of residents following a climate event.[27] In addition, expanses of impervious surfaces in urban areas prevent flood waters from naturally percolating into the ground, worsening flooding.[28]

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[24] Rosenzweig & Solecki, *supra* note 1, at 77.
[25] *2010 Census: Urban Area Facts*, U.S. CENSUS BUREAU, https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural/ua-facts.html [https://perma.cc/SS9U-28Q9]; Merrill Singer et al., "*I Feel Suffocated:" Understandings of Climate Change in an Inner City Heat Island*, 35:6 MED. ANTHROPOLOGY 453 (2016).
[26] Rosenzweig & Solecki, *supra* note 1, at 101.
[27] *Emergency Information*, FLA. DIV. EMERGENCY MGMT., https://www.floridadisaster.org/info/ [https://perma.cc/GH6D-GWLW]; Tatyana Deryugina, *The Fiscal Cost of Hurricanes: Disaster Aid Versus Social Insurance*, 9 AM. ECON. J. 168, 173-74 (2017).
[28] *Hurricane Costs*, *supra* note 23; Lynne Carter et al., *2018: Southeast*, *in Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*, 2 U.S. GLOBAL CHANGE RSCH. PROGRAM 743, 760 (2018).

In addition to extensive harm from hurricanes and floods, cities are also uniquely susceptible to rising heat, winds, and other climate extremes. Urban areas usually include a high ratio of impervious paved and built surfaces to pervious natural systems.[29] Thus, the mitigating benefits of natural cooling shade from trees, natural water retention from green spaces, and other weather mitigation of natural spaces have been lost or highly compromised through urban development patterns.[30] Urban "heat islands" are a direct result of such building patterns: extensive paved surfaces reflect solar heat at ground level while tall buildings block cooling winds, the combined result being higher temperatures in urban communities than in nearby suburban or rural areas.[31]

The heat island effect can result in urban temperatures ranging anywhere from 1°F to 6°F higher than neighboring areas.[32] This phenomenon is particularly concerning for southern communities, which are already expected to regularly experience dangerously hot days as annual global temperatures rise.[33] Extreme heat poses grave health risks to vulnerable populations such as the elderly, those with pre-existing health conditions, and those without access to adequate medical care.[34] Extreme heat can lead to dehydration, heat exhaustion, cramps, and strokes, as well as increases in respiratory, cerebrovascular, cardiovascular, and kidney disorders.[35]

In addition to the pressure of protecting citizens from climate change impacts, cities are often destinations for displaced residents of other areas that have been struck by extreme weather events.[36] Damaging events such as hurricanes and floods, sea-level rise, wildfires, and intolerable heat conditions can lead residents of one geographic area to leave their homes for temporary or permanent housing elsewhere.[37] The terms coined for these

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[29] *Reduce Urban Heat Island Effect*, U.S. ENV'T PROT. AGENCY, https://www.epa.gov/green-infrastructure/reduce-urban-heat-island-effect [https://perma.cc/78U5-5NHZ].
[30] *Id.*
[31] *Id.*
[32] Singer et al., *supra* note 25.
[33] Carter et al., *supra* note 28, at 749.
[34] Singer et al., *supra* note 25.
[35] *Id.*
[36] Daniel C. Vock, *Climate Migrants Are on the Move*, APA PLAN. MAG. (Jan. 1, 2021), https://www.planning.org/planning/2021/winter/climate-migrants-are-on-the-move/ [https://perma.cc/GSA6-7NW7].
[37] RANDALL ABATE, CLIMATE CHANGE AND THE VOICELESS: PROTECTING FUTURE GENERATIONS, WILDLIFE, AND NATURAL RESOURCES (Cambridge University Press 2020).

displaced persons are "climate migrants" or "climate refugees."[38] One recent example of this phenomenon was the influx of more than 150,000 Puerto Rican residents to cities in Florida following Hurricane Maria (with another 250,000 migrating to other cities throughout the United States).[39]

In fact, the Director of Sustainability of Orlando, Florida explained that environmental refugees are one of the most significant climate change challenges the city faces.[40] Orlando hosted thousands of refugees in the weeks after Hurricane Maria decimated Puerto Rico, many of whom became permanent residents of the city.[41] Estimates indicate that by 2050, the number of global climate migrants could range from twenty-five million to one billion people.[42]

Climate migrants require the same necessities and comforts of their prior home: safe shelter, employment, social services, and family or friends of similar cultural backgrounds. Urban communities, which are likely to receive many climate migrants, must develop plans enabling them to quickly supply necessities during a sudden population influx caused by a climate event. Analysts predict that states such as Florida, New York, New Jersey, Massachusetts, Louisiana, Texas, California, and Hawaii will be some of the most impacted by climate change weather events due to their coastal proximity and location of major urban centers in low-lying areas.[43] Thus, cities in these and adjoining states must be prepared not just for weather impacts on their existing residents, but also for likely population influxes when extreme weather events strike nearby cities.

In addition to the damage weather events inflict upon manmade structures and human populations, extreme weather also endangers urban-located ecosystems such as coastlines, wetlands, and forests. Sea level rise, flooding,

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[38] Thea Philip, *Climate Change Displacement and Migration: An Analysis of the Current International Legal Regime's Deficiencies, Proposed Solutions and a Way Forward*, 19 MELB. J. INTL. L. 639 (2018).

[39] Martin Echenique & Luis Melgar, *Mapping Puerto Rico's Hurricane Migration with Mobile Phone Data*, CITY LAB (May 11, 2018), https://www.bloomberg.com/news/articles/2018-05-11/where-puerto-rico-s-residents-migrated-since-maria [https://perma.cc/C8KZ-NZBD].

[40] Telephone Interview by Michael Camareno with Christopher Castro, Director of Sustainability, City of Orlando (June 10, 2020).

[41] Philip, *supra* note 38.

[42] *From Migration to Mobility*, 9 NATURE CLIMATE CHANGE 895 (Nov. 2019).

[43] Jim Dobson, *Shocking New Maps Show How Sea Level Rise Will Destroy Coastal Cities By 2050*, FORBES (Oct. 30, 2019, 3:55pm), https://www.forbes.com/sites/jimdobson/2019/10/30/shocking-new-maps-show-how-sea-level-rise-will-destroy-coastal-cities-by-2050/ [https://perma.cc/3QGB-GHUX].

and tidal intrusions can cause beach erosion and saltwater intrusion into brackish and freshwater systems.[44] Ground and surface water systems, including lagoons, marshes, estuaries, and underground aquifers, are especially susceptible to such saline intrusions, which can harm aquatic species and reduce freshwater drinking supplies.[45] Both hurricanes and extreme heat events pose significant danger to wildlife health and habitat.[46] As the case studies below will indicate, protection of natural systems serves the dual purposes of protecting wildlife and habitat as well as mitigating the impact of weather events on man-made structures and infrastructure.

III. WHAT URBAN POLICY-MAKERS CAN DO TO MITIGATE CLIMATE CHANGE

Many cities have already developed policies and regulations to address climate change impacts. Some are retroactive, responding to weather events that have already caused damage, while others are proactive in anticipating more frequent and severe climate events that will affect their communities. As with many problems, an ounce of prevention is worth a pound of cure. Thus, urban communities that acknowledge, study, and plan for the likely impacts of climate change will be better equipped to mitigate and respond to these events.

Examples of climate-readiness efforts in New York, Miami, and San Francisco are discussed below. These cities have each studied the climate threats facing their geographic areas, the natural and man-made components of their regions, and the socioeconomic and economic forces within their communities, to develop climate resilient regulations, infrastructure, and plans. It is this author's hope that urban communities seeking to develop climate resilience efforts use the mature efforts of these cities as guidance. However, it is important to note that climate change will affect different geographic areas in different ways, and thus urban policymakers must study the unique threats facing their communities to implement appropriate resilience tools that are tailored to their community.

"Resilience" is the oft-used terminology for community efforts to prepare for and mitigate a variety of adverse events facing modern society, such as

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[44] MIAMI-DADE CNTY. SEA LEVEL RISE TASK FORCE, REPORT ON FLOODING & SALT WATER INTRUSION (Sept. 2016), https://www.miamidade.gov/green/library/sea-level-rise-flooding-saltwater-intrusion.pdf [https://perma.cc/BL9F-9NXC].

[45] *See* Rosenzweig & Solecki, *supra* note 1; *From Migration to Mobility*, *supra* note 42.

[46] *Extreme Weather*, NAT'L WILDLIFE FOUND., https://www.nwf.org/Educational-Resources/Wildlife-Guide/Threats-to-Wildlife/Climate-Change/Extreme-Weather [https://perma.cc/G5J4-YVPN].

cyber-attacks, health pandemics, and warfare.[47] The term is also employed when planning for the adverse effects of climate change.[48] Climate resilience encompasses efforts to plan for, mitigate, withstand, and quickly recover from the effects of adverse climate events.[49] The following are case studies of three American cities that have tackled the challenge of developing climate change resilience head-on.

A. Case Study: New York, New York

Located along the Atlantic seaboard, New York City is home to more than eight million people.[50] Its built structures and infrastructure, including streets, water treatment facilities, power plants, high-rises, airports, rail lines, and shipping ports, line 520 miles of coastline.[51] The shoreline is expected to experience sea level rise of one or two feet during the next fifty years, resulting in extensive tidal intrusions, greater beach erosion, and more damaging hurricanes.[52] These adverse effects will impact both built and natural systems of this highly dense and populated area. Thirty-three square miles of the city, and approximately 220,000 residents, lie within the Federal Emergency Management Agency's (FEMA) estimates of the 100-year floodplain (areas that have a one percent chance of flooding in any given year).[53] This includes businesses, homes, hospitals, airports, roads, power facilities, and other significant infrastructure.[54] As underscored in 2012, when Hurricane Sandy struck the area and caused $19 billion in property damage and forty-three deaths, New York City is highly vulnerable to hurricanes and sea-level rise.[55] In addition, the city faces more and more dangerously hot days—currently the leading cause of climate-related mortality in the nation.[56]

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[47] EDMOND J. SAFRA, CENTRE FOR ETHICS, HARVARD UNIVERSITY, ROADMAP TO PANDEMIC RESILIENCE (2020); *Cyber Resilience Review*, U.S. DEPT. HOMELAND SECURITY, https://www.cisa.gov/uscert/sites/default/files/c3vp/crr-fact-sheet.pdf [https://perma.cc/L6Z2-9CH8].

[48] Carl-Friedrich Schleussner et al., *Pathways of Climate Resilience Over the 21st Century*, 16 ENV'T. RSCH. LETTERS 2 (May 2021).

[49] Robin Leichenko, *Climate Change and Urban Resilience*, 3 SCIENCEDIRECT 164 (2011).

[50] *Quick Facts: New York City*, U.S. CENSUS BUREAU, https://www.census.gov/quickfacts/fact/table/newyorkcitynewyork,NY [https://perma.cc/VK64-EVQF].

[51] PLANYC, A STRONGER, MORE RESILIENT NEW YORK 40 (June 2013), http://s-media.nyc.gov/agencies/sirr/SIRR_spreads_Hi_Res.pdf [https://perma.cc/N498-EANC].

[52] Colle et al., *supra* note 15.

[53] PLANYC, *supra* note 51, at 13.

[54] *Id.*

[55] GORNITZ, *supra* note 6.

[56] ONENYC 2050, 7 A LIVABLE CLIMATE 6 (Apr. 2019), http://1w3f31pzvdm485dou3dppkcq.wpengine.netdna-cdn.com/wp-content/uploads/2019/11/OneNYC-2050-A-Livable-Climate-11.7.pdf [https://perma.cc/BJL9-T7CV].

New York City is undertaking significant efforts to study, plan, and develop resilience for the unavoidable reality of increasing climate change-based weather events. In the same year as Hurricane Sandy, the City appointed an advisory team of academic and private-sector experts to serve on the New York City Panel on Climate Change (NYCPCC).[57] The purpose of the NYCPCC is "to provide an authoritative source of actionable information on future climate change and its potential impacts to support City decision-making . . . through climate analysis and integrated, transdisciplinary assessment."[58] This group has produced a number of reports and recommendations relating to New York's present and future risks of sea-level rise, flooding, heat increases, heavy precipitation, and drought.[59] Some recommendations have already been enacted, such as installing flood walls and berms, raising existing seawalls and bulkheads, and constructing levees.[60] There are also plans to construct streets that can be raised in areas vulnerable to intense flooding.[61]

The City also developed a "New Green Deal" as part of *OneNYC 2050*, an aspirational plan to make a variety of improvements to the built and natural environments and quality of life for residents of New York City.[62] The New Green Deal includes steps to develop resilience to the climate crisis" facing the City, defining "resilience" as having effective weather defenses, weather event mitigation, and quick recoveries.[63] The *OneNYC 2050* plan is based on expectations that the city will reach certain significant thresholds by 2050, including:

- a population of nine million residents;
- an 11% increase in average annual precipitation;
- a 5% increase in average annual temperatures, more days exceeding 90^{O}, and longer heatwaves;
- sea-level increases between eleven and thirty inches; and
- more frequent "100-year floods" with greater flood water heights.[64]

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[57] PLANYC, *supra* note 51, at 1.
[58] NYC MAYOR'S OFFICE OF RESILIENCY, NPCC CALL FOR NOMINATIONS 1 (2021)
[59] *Advancing Tools and Methods for Flexible Adaptation Pathways and Science Policy Integration*, 1439 N.Y. ACAD. OF SCIENCES (Cynthia Rosenzweig & William Solecki, eds., March 2019).
[60] GORNITZ, *supra* note 6.
[61] *Id*.
[62] ONENYC 2050, *supra* note 56, at 7.
[63] *Id.*
[64] *Id.*

The City has also taken steps to limit its contribution to climate change. Its policies have reduced the city's greenhouse gas (GHG) emissions by 17% below 2005 levels and increased reliance on clean-sourced electricity by 27%.[65] The city government has funded retrofits of 1,600 municipal buildings for energy efficiency.[66] The Retrofit Accelerator and Community Retrofit NYC programs have resulted in five thousand private buildings undergoing energy efficiency retrofits.[67] Additionally, the city has provided economic incentives to install solar power facilities that supply electricity to approximately fifty thousand households and has implemented programs to reduce reliance on gas-powered vehicles.[68] While these efforts may offset the effects of worldwide global warming, only resilience policies (i.e. mitigation policies) will directly prepare the city to withstand adverse climate impacts.

New York City is not undertaking its resilience efforts in an *ad hoc* manner. Rather, the City has created a detailed index of planned efforts to enhance climate resiliency, which includes biennial self-assessments of progress made toward such goals.[69] While the COVID-19 pandemic slowed release of the 2020 self-assessment, the 2018-2019 progress report outlines approximately fifty objectives designed to "strengthen communities, buildings, infrastructure, and the waterfront to be more resilient"; the report "indicates steady progress toward commencement or completion of each."[70] There are several large-scale infrastructure projects planned or underway, ranging from stormwater and wastewater facility improvements, to wetland and forest restoration and acquisition, shorelines enhancements, and neighborhood-scale flood mitigation projects.[71]

The City has already completed projects to enhance wetlands by removing invasive plants and introducing native plants; implemented pilot projects for wetland mitigation banking; installed natural plantings on coastal berms to limit erosion; and revamped its evacuation plans to address the needs of vulnerable populations.[72] The City is planning additional natural mitigation, such as preserving and enhancing natural wetlands, forests, and

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[65] ONENYC 2050, *supra* note 56, at 5.
[66] *Id.* at 7.
[67] *Id.*
[68] *Id*.
[69] ONENYC 2050, PROGRESS REPORT (2019) [https://perma.cc/9BY2-GWRH] [hereinafter PROGRESS REPORT].
[70] ONENYC 2050, *supra* note 56, at 3.
[71] *Id.* at 23.
[72] *Id.*

sand dunes, and planting urban shade trees, which will both reduce the heat island effects and mitigate the effects of flooding.[73]

Projects are also underway to install armor stone shoreline protection along Coney Island and Staten Island; raise bulkheads in low-lying areas of the city; install backwater valves that limit drainage pipe flooding; and enhance emergency shelters to be more accessible to those with disabilities.[74] In addition, the City has developed temporary flood mitigation structures that can be rolled out when storms approach. One example is specialized fabric covers that seal subway entrances against undulation from flood waters.[75]

Several projects have been completed or are underway in partnership with the U.S. Army Corps of Engineers, such as improvements to sand dunes and natural protection systems, installation of berms, and installations of flood walls on the Rockaway Peninsula, Newtown Creek, and Gowns Canal.[76] The city sought proactive assistance from FEMA to implement a mitigation banking system for private developments that incorporate resiliency measures.[77] However, limited support from FEMA has led the City to explore other options for expanding mitigation credits.[78]

One area of the city that is particularly threatened by sea-level rise, and thus at risk of tidal flooding and storm surges, is the financial district of Lower Manhattan. Lower Manhattan is one of the city's, and America's, most important economic hubs.[79] To mitigate such threats, the City has invested $500 million in flood mitigation efforts in the Manhattan Two Bridges, Battery, and Battery Park neighborhoods (which account for approximately 70% of the Lower Manhattan shoreline).[80] Along the remaining Lower

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[73] *See generally id.*
[74] ONENYC 2050, *supra* note 56, at 7.
[75] Joel Rose, *To Flood-Proof Subways, N.Y. Looks at Everything from Plugs to Sheets*, NAT'L PUB. RADIO (Oct. 8, 2015) https://www.npr.org/2015/10/08/446600221/to-flood-proof-subways-n-y-looks-at-everything-from-plugs-to-sheets [https://perma.cc/TP9Z-Z3ME].
[76] ONENYC 2050, *supra* note 56, at 23; *see Progress Report*, *supra* note 69.
[77] PROGRESS REPORT, *supra* note 69, at 47, 60-63 (noting that the City intended to create mitigation banks for a variety of resiliency measures, such as wetland preserves, installation of building resiliency measures, and improvements to both transportation and energy infrastructure from which mitigation credits could be sold and profits invested in further mitigation strategies).
[78] *Id*.
[79] ONENYC 2050, *supra* note 56, at 22.
[80] *Id.*; Leslie Brody, *New York City Plans Expansion of Lower Manhattan Shoreline to Prevent Flooding*, WALL STREET J. (March 14, 2019), https://www.wsj.com/articles/new-york-city-plans-expansion-of-lower-manhattan-shoreline-to-prevent-flooding-11552600839 [https://perma.cc/RJG3-A4HA].

Manhattan shoreline, including Seaport, Two Bridges, and the Financial District, the City is also implementing flood protection measures. One auspicious project is the extension of the shoreline into the East River to create a land buffer twenty feet above sea level, at an estimated cost of $10 billion.[81] Other flood mitigation projects are planned for Red Hook, Rockaways, Jamaica Bay, and the East Shore of Staten Island.[82] Funds are also earmarked for projects that limit coastal erosion in Sea Gate, Staten Island, and the Rockaway Peninsula.[83]

In addition to large scale government projects, the City is encouraging, incentivizing, and assisting resilience and mitigation efforts on private property. For example, the *NYC CoolRoofs Program* funds the installation of solar reflective roof coatings in the city's most heat-vulnerable communities to lessen the risk of heat-related health impacts and conserve energy.[84] Targeted communities are those in which a significant percentage of the population lacks air conditioning, such as Brownsville, Brooklyn, where approximately 30% of residents lack air conditioning.[85] Similarly, the *Green Infrastructure Grant Program* provides funding assistance for privately-owned buildings to design and install (or retrofit) green roofs to enhance stormwater management.[86] The City has also explored retrofitting private structures (particularly residential and medical buildings) with flood-mitigation measures, such as dry and wet flood-proofing, which can limit the extent of structural damage caused by floodwaters.[87]

In particular, the City has focused on increasing the sustainability of public housing, including weatherizing almost one thousand apartments, improving on-site stormwater management, installing green infrastructure (including an innovative sunken basketball court that doubles as a stormwater retention facility), and implementing pilot projects to install solar electricity generation on small buildings.[88]

New York City has recognized that rising sea levels and hurricanes pose an immediate threat to its infrastructure, buildings, and natural areas. The City has further recognized that such weather events, along with rising heat levels, pose dramatic health threats to its residents. Thus, the City appointed

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[81] ONENYC 2050, *supra* note 56, at 22.
[82] *Id.* at 24.
[83] *Id.* at 23.
[84] *Id.* at 26.
[85] *Id*.
[86] Green Infrastructure Grant Program, N.Y. CITY STAT. § 48-01 (2020).
[87] PLANYC, *supra* note 53, at 72.
[88] PROGRESS REPORT, *supra* note 69, at 21, 39, 56.

the NYCPCC to study and recommend actions to enhance the city's climate resilience. Such actions include far-reaching infrastructure improvements, resilience-based construction standards, improvements to natural areas, and funding to lower income communities to assist with resiliency retrofits. While funding the planned resiliency projects is expensive, the City partnered with the federal government to fund improvements necessary to protect this preeminent American city. These efforts are employed by the City at the regional, neighborhood, and site-specific levels, developing several layers of climate resiliency.

B. Case Study: Greater Miami, Florida

Located on the southeastern coast of Florida, Miami-Dade County, along with its largest municipality, the city of Miami, is also positioned to be adversely affected by rising sea levels, storm surges, flooding, hurricanes, and dangerous heat levels. This area has a regional population of nearly three million residents and measures eighty-four coastal miles.[89] Much of this population resides in densely built communities along the Atlantic coast, primarily Biscayne Bay, and inland waterways such as the Miami River, where threats of floods and hurricanes are acute.[90] It is also one of America's southernmost cities and therefore faces increasing numbers of extreme heat days and lengthier heat waves as global temperatures rise.[91]

Hurricanes are an especially significant threat to Miami. Thirty-four percent of hurricanes that made landfall in the United States between 1851 and 2014 hit the Florida coastline, including Hurricane Andrew and the Great Miami Storm, which both struck the city of Miami directly.[92] As global warming leads to rising temperatures in the Atlantic Ocean, threats of

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[89] *Miami-Dade County Municipalities*, MIAMI-DADE CNTY., https://www.miamidade.gov/global/management/municipalities.page [https://perma.cc/6425-FZS5]; *Quick Facts: Miami-Dade County, Florida*, U.S. CENSUS BUREAU, https://www.census.gov/quickfacts/fact/table/miamidadecounty florida/POP060210 [https://perma.cc/SH3T-KRA2].

[90] S.E. FLA. REGIONAL CLIMATE CHANGE COMPACT'S SEA LEVEL RISE AD HOC WORK GROUP, UNIFIED SEA LEVEL RISE PROJECTION SOUTHEAST FLORIDA (2019); Leonard Berry et al., *Climate Change Impacts in the United States: Southeast and the Caribbean*, NAT'L CLIMATE ASSESSMENT, https://nca2014.globalchange.gov/report/regions/southeast [https://perma.cc/RHZ8-E987]; *Global Climate Change: Vital Signs of the Planet – Sea Level*, NAT'L AERONAUTICS & SPACE ADMIN., https://climate.nasa.gov/vital-signs/sea-level/ [https://perma.cc/33XQ-JWK4].

[91] Berry et al., *supra* note 90.

[92] Muhlbaum & Korsh, *supra* note 23; Eliot Kleinberg, *Florida History: The Biggest Hurricanes to Hit Florida, Part One*, PALM BEACH POST (May 30, 2019) https://www.palmbeachpost.com/news/20190530/florida-history-biggest-hurricanes-to-hit-florida-part-one [https://perma.cc/MZ6W-GCH8].

increasing frequency and strength of hurricanes are a major concern for this community.

Continuous sea-level rise further increases the threats posed by hurricanes, flooding, and storm surges. Studies indicate that coastal sea levels in and around Miami have risen four inches over the past fifty years.[93] The Southeast Florida Regional Climate Change Compact's *Unified Sea Level Rise Project for Southeast Florida* study predicts sea levels around Miami-Dade to rise another six to ten inches by 2030 and fourteen to sixteen inches in the decades thereafter.[94] These studies have been illustrated in a 3-D modeling simulator, *Sea Level Rise Building Impact 3-D Modeling,* which demonstrates the dramatic and far-reaching consequences of predicted inland flooding on Miami-Dade's built and natural coastal, riverbank, and other riparian environments.[95] The model also indicates that thousands of buildings, dozens of roads, and vital infrastructure facilities will be temporarily or permanently submerged as sea-level rise, storm surges, and flooding worsens.[96] These studies enable Miami-Dade and its municipalities to identify a variety of threats posed by water intrusions and the areas most vulnerable to coastal erosion, storm surge damage, tidal floods, saltwater intrusion into fresh drinking water supplies, and flooding of septic systems.[97] Armed with the knowledge of where damage is most likely to be felt with each incremental increase in sea level rise, Miami-Dade has planned in a targeted and proactive manner.

There are several long-standing city and county regulations and programs that can be appropriated to mitigate climate change impacts. For example, the Miami-Dade County government has well-developed tree protection regulations that include elevated protections for mangrove trees. In general, trees protect inland areas from erosion due to their extensive root systems, which hold soil in place and provide shade that offsets rising heat levels.[98] Mangrove trees are of particular value in coastal areas because of their ability

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[93] Berry et al., *supra* note 90; *Global Climate Change: Vital Signs of the Planet – Sea Level*, *supra* note 90.

[94] S.E. FLA. REGIONAL COMPACT, UNIFIED SEA LEVEL RISE PROJECTION FOR SOUTHEAST FLORIDA: 2019 UPDATE (2019).

[95] This virtual modeling can be accessed at *Sea Level Rise (SLR) Building Impacts*, MIAMI-DADE CNTY., https://mdc.maps.arcgis.com/apps/webappviewer3d/index.html?id=b92a9fa4ff8847bf97f3e628a195a398 [https://perma.cc/JP9J-TA4U].

[96] *Id.*

[97] *Sea Level Rise and Flooding*, MIAMI-DADE CNTY., https://www.miamidade.gov/global/economy/resilience/sea-level-rise-flooding.page [https://perma.cc/78PH-XJJY].

[98] Mary L. Duryea & Eliana Kampf, *Wind and Trees: Lessons Learned from Hurricanes*, IFAS EXTENSION AT UNIV. OF FLA. (2021).

to reduce the energy impacts of storm surges and hurricane-enhanced waves.[99] One study of the beneficial impact of mangroves after Hurricane Wilma indicated a 20% offset to wave energy for every three hundred feet of mangrove forest.[100]

Miami-Dade's tree regulations are highly detailed and descriptive in their requirements to protect its tree stocks. It is illegal to undertake any tree removal work or to "effectively destroy" any understory in a natural forest community without a permit.[101] When trees are authorized for removal, specified replacement trees must be planted in accordance with codified standards, including that any natural forest community understory tree be replaced by native pine land species.[102] Further, if a permit is granted to remove understory trees, the regulations require that the permit holder wait fifteen days before removal to allow third parties to salvage native plant materials.[103] Replacement standards also restrict planting any listed "controlled plants" within 500 feet of native plant communities.[104] Mangrove trees have additional protections from cutting, pruning, and other forms of alteration absent a permit.[105]

In addition to tree protections, Miami-Dade has regulations that protect wetlands and flood-prone forests. Among these are prohibitions against dredging or filling of any tidal waters, submerged bay land, wetlands, or any other action which would result in "harmful obstruction or alteration of the natural flow of surface waters" without obtaining a permit.[106]

Supplementing its regulations, Miami-Dade also has several programs to encourage and fund the protection of vegetation and forests. The Environmentally Endangered Lands (EEL) and Area of Critical Environmental Concern (ACEC) programs are designed to preserve shoreline vegetation through the acquisition, preservation, and management of

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[99] Siddharth Narayan et al., *Valuing the Flood Risk Reduction Benefits of Florida's Mangroves*, THE NATURE CONSERVANCY 5 (2019).
[100] *Id.*; MIAMI-DADE CNTY., EXECUTIVE SUMMARY, MAYOR'S RESPONSE TO COUNTY COMMISSION'S RESOLUTIONS IN SEA LEVEL RISE 6 (Sept. 2016), https://www.miamidade.gov/green/library/sea-level-rise-executive-summary.pdf [https://perma.cc/6TUC-ATVZ] [hereinafter MAYOR'S RESPONSE].
[101] MIAMI-DADE CNTY., FLA., CODE OF ORDINANCES Art. IV, Div. 2, § 24-49 (2021).
[102] *Id.* § 24-49.4 (b).
[103] *Id.* § 24-49.2 (b).
[104] *Id.* § 24-49.9 (b).
[105] *Id.* §§ 24-48, 24-48.16.
[106] *Id.* § 24-48.

ecologically important lands.[107] The programs are funded by the Florida Water and Land Conservation Initiative; revenue was sufficient to fund the Acquisition Trust Fund for both state- and county-owned lands in Miami-Dade.[108]

The EEL program and its associated financial trust were established to acquire, restore, and preserve "natural forest or wetland communities, native plant communities, rare and endangered flora, and fauna, endemic species, endangered species habitat, a diversity of species, or outstanding geologic or other natural features, or that land which functions as an integral and sustaining components of an existing ecosystem."[109] While climate change resilience is not specifically listed as a purpose of the EEL program, the associated funds have been used to purchase more than 24,000 acres of environmentally endangered land–one of the goals of Miami-Dade's resiliency efforts.[110] In fact, in recent years Miami-Dade has focused EEL funding on maintaining contiguity of mangrove forests.[111]

The ACEC program also seeks to preserve valuable natural lands.[112] Like the EEL program, climate change mitigation is not mentioned specifically as a reason for such preservation efforts. However, the ACEC program is designed to protect current and future residents' health, safety, and welfare; thus, it can and has been used to address climate change impacts affecting Miami-Dade residents.

The ACEC program has been especially active regarding Florida Everglades restoration. The easternmost portion of the Everglades is located within the jurisdictional boundaries of Miami-Dade and has been designated as an ACEC.[113] This designation is based in part upon the need to maintain and preserve the Everglades flood storage capacity, which serves to limit flooding within other areas of the county during hurricanes and floods.[114] Additionally, the Everglades watershed protects freshwater sources from saltwater intrusion during ocean flooding events.[115] Finally, the water flow

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[107] *Environmentally Endangered Lands Program*, MIAMI-DADE CNTY., https://www.miamidade.gov/environment/endangered-lands.asp [https://perma.cc/6J6D-QYXB]; MIAMI-DADE COUNTY, FLA., CODE OF ORDINANCES § B-13 (2021).
[108] FLA. CONST. Art. X, § 28.
[109] MIAMI-DADE CNTY., FLA., CODE OF ORDINANCES, §§ 24.50.1-.2, 24.50.5 (2021).
[110] MAYOR'S RESPONSE, *supra* note 100.
[111] *Id* at 7.
[112] MIAMI-DADE CNTY., FLA., CODE OF ORDINANCES § 33B (2021).
[113] *Id.* § 33B-12.
[114] *Id.* § 33B-13(c)(3).
[115] MIAMI-DADE CNTY. SEA LEVEL RISE TASK FORCE, *supra* note 44.

and water storage supported by a healthy Everglades ecosystem reduces the threat of wildfires in southeast Florida during drought and heat conditions.[116] As an ACEC, the Eastern Everglades is protected through a series of zoning and construction restrictions; local property owners obtain transferable development rights to other parts of Miami-Dade County.[117]

In addition to EEL and ACEC funding sources, natural coastal areas are protected through the Biscayne Bay Shoreline Development Review Program. The goals of this planning-based program do not specifically reference extreme weather mitigation.[118] However, the shoreline development review strives to protect coastal sand dunes, vegetation, and mangrove forests.[119] These natural ecosystems serve a beneficial role in protecting Miami-Dade from sea level rise, storm surge, and hurricane impacts.[120] Shoreline Development Action Review implements protective requirements, such as minimum shoreline setbacks for coastal development, including a setback of twenty-five feet for small buildings and thirty-five to seventy-five feet for large structures (as measured from bulkheads, seawalls, or the mean high water line).[121] These building setbacks ensure that sand dunes and coastal vegetation within the setbacks are undisturbed by construction activities and remain intact to offset storm surges, floods, and hurricanes.

The foregoing regulations and programs have been in place for many years and, although flexible enough to be used for climate change mitigation, were not originally enacted to address climate change or its impacts. To focus attention on climate resiliency, Miami-Dade created an Office of Resilience that oversees numerous climate initiatives, including Sea Level Rise programs.[122] The office collaborates with the cities of Miami and Miami-Beach on climate resiliency measures.[123]

In 2013, recognizing the need to plan for "unavoidable" rising sea levels, the Miami-Dade County Commission created the Sea Level Rise Task Force

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[116] MIAMI-DADE COUNTY, FLA., CODE OF ORDINANCES § 33B-13(d) (2021).
[117] *Id.* §§ 33B-43-45.
[118] *Id.* § 33D.
[119] *Id.*
[120] *Id.* § 33D-31.
[121] *Id.* § 33D-38.
[122] *Strengthening Resilience in Miami-Dade County*, MIAMI-DADE CNTY., https://www.miamidade.gov/global/economy/resilience/home.page [https://perma.cc/8TDE-EL4G].
[123] *Resilient305*, MIAMI-DADE CNTY., https://www.miamidade.gov/global/economy/resilience/resilient305.page [https://perma.cc/KT3Q-5L2U].

to explore and plan for the effects of sea-level rise on its built environment, natural environment, economy, and community.[124] The task force recommended a variety of policy actions, which were passed as seven resolutions by the County Commission in 2015.[125] The resolutions addressed numerous resilience actions to be undertaken by the County, including adaptation actions, flooding and saltwater intrusion prevention, protection of environmentally endangered lands, capital investments, and insurance and risk management.[126] These resolutions reflect the government's intent to foster the community's ability to "live with water" rather than continue to assume water bodies can be stabilized and contained.[127]

The state of Florida recommended that coastal communities create "Adaptation Areas" for communities at risk of floods, storm surges, and other sea-level rise impacts.[128] Miami-Dade's resolutions to prepare for stronger storms and rising sea levels contemplates utilizing managed natural systems and improvements to man-made infrastructure. Government staff have proposed various adaptive measures that can be scaled to the regional, neighborhood, block, and site levels.[129] The first adaptive measures were simple monitoring and operational changes designed to reduce flooding and saltwater intrusion.[130] Longer-term adaptive strategies are based on setting anticipated hydrologic thresholds and planning for natural and infrastructure improvements to address the problems as these thresholds are met.[131]

Natural adaptive measures include preserving interconnected wetlands and native forests (particularly mangrove forests) to absorb and clean flood waters; preserving and restoring higher, wider, and interconnected sand dunes and sea grass beds to limit the extent of inland flooding and limit erosion; protecting coral reefs to limit the impact of storm surges; and executing beach renourishment projects.[132]

Planned regional structural adaptations include elevation of critical evacuation routes above anticipated flood levels; wide-scale closure of septic systems and increased connections to the sanitary sewer systems; enhanced

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[124] MAYOR'S RESPONSE, *supra* note 100; Bd. of Cnty. Comm'rs, R-44-15, R-47-15 (Miami-Dade Oct. 6, 2015).
[125] Bd. of Cnty. Comm'rs, *supra* note 124, at R-44-15, R-46-15, R-47-15, R-48-15.
[126] MAYOR'S RESPONSE, *supra* note 100.
[127] Telephone interview by Michael Camareno with Jim Murley, Chief Resilience Officer, Miami-Dade County (June 8, 2020).
[128] FLA. STAT. §163.3177 (2020).
[129] MIAMI-DADE CNTY. SEA LEVEL RISE TASK FORCE, *supra* note 44, at 34.
[130] *See id.*
[131] *Id.* at 11.
[132] *Id.* at 19, 41.

pump capacities; additional stormwater collection and impoundment systems; installation of backflow preventers to restrict seawater from entering stormwater systems; re-engineered canals; use of porous paving materials and elevated bulkheads; filling certain low-level areas; construction of flood barriers; and enhancement of pervious surfaces.[133]

Site-based structural adaptive measures include elevating parking facilities, mechanical systems, and buildings and/or finished floor areas; incorporating flood-proofing in critical facilities and in high-risk areas; using larger swales; and increasing on-site infiltration systems.[134] Some adaptive measures may incorporate both natural and structural elements, such as green or garden roofs, rain gardens, and dredge and fill activities to direct flood or storm surge waters.[135]

Miami-Dade anticipates forging intergovernmental and community partnerships to increase the impact of its adaptive actions, including with the South Florida Water Management District, the U.S. Army Corps of Engineers, the Nature Conservancy, other conservation organizations, and various universities. Through such partnerships, Miami-Dade has secured additional expertise, personnel, and funding. For example, the South Florida Water Management District (SFWMD), an independent state agency, has undertaken planning and construction activities related to flood containment and water supply planning within Miami-Dade.[136] The SFWMD built a series of canals, levees, water storage facilities, and pump stations to assist Miami-Dade with flooding and protecting fresh drinking water supplies.[137] The SFWMD has also installed forward pumps to drain flood waters near the Miami International Airport and a water impoundment reservoir in the western part of the county to drain highly urbanized areas.[138]

Miami-Dade has also partnered with the Urban Land Institute, Citymart, and the Knight Foundation to facilitate the Arch Creek Drainage Basin pilot project.[139] This nearly three thousand acre low-lying basin has been developed with residential, commercial, and institutional facilities, using virtually no impervious surface for drainage when waters overflow Biscayne

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[133] *See id.*
[134] *See id.*
[135] *See id.*
[136] FLA. STAT., Ch. 373 (2020).
[137] MIAMI-DADE CTY. SEA LEVEL RISE TASK FORCE, *supra* note 44, at 10.
[138] *Id.*
[139] *See* URBAN LAND INST., ARCH CREEK BASIN, MIAMI-DADE COUNTY, FLORIDA (May 2016).

Bay.[140] After an extensive study and bidding process, the County plans to implement sea level rise resilience and mitigation measures in the Arch Creek Basin. [141]

While many of the adaptive measures discussed are solely controlled by Miami-Dade or its institutional partners, there is also a need for partnerships with individual landowners, particularly to steer development to high ground and encourage greater preservation of natural areas.[142] For example, efforts to protect environmentally endangered lands are being implemented by acquiring coastal barrier islands, mangrove forests, shallow bays, estuaries, and wetlands to offset sea level rise impacts and protect fresh water supplies. These efforts require buying land–or at least easements–from private owners.[143] Similarly, making building improvements to offset flooding or storm surges require the property owner's approval (and often financial investment). These private partnerships might be formed voluntarily, arising from self-interest, or out of concern for the best interests of the community. However, achieving compliance by private actors will often require some level of government regulation or eminent domain to acquire necessary lands. For example, building codes are necessary to establish minimum elevations for new structures in flood prone areas, mandate flood-proofing construction techniques, or increase setbacks from water bodies.[144] Other private adaptive measures might be achieved through government incentives, such as tax breaks, expedited permitting, and allowing taller buildings.[145]

As a practical complement to its adaptive measures, Miami-Dade also resolved to provide capital funding for infrastructure improvements. The County has recognized that it is not financially or practically feasible to eliminate risk completely, but directs funding toward efforts to balance acceptable risk against cost of mitigation.[146] Categorizing potential climate-based risks as "Acceptable," "Tolerable," and "Unacceptable," initial capital

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[140] *Id. a*t 11.
[141] MIAMI-DADE CNTY., ARCH CREEK PARK MANAGEMENT PLAN (Sept. 2020).
[142] MIAMI-DADE CTY. SEA LEVEL RISE TASK FORCE, *supra* note 44, at 9.
[143] An emphasis has been placed on ensuring extensive, contiguous, and healthy mitigation areas, since the larger and healthy an ecosystem, the more benefits it provides to the County. MAYOR'S RESPONSE, *supra* note 100.
[144] MIAMI-DADE CTY. SEA LEVEL RISE TASK FORCE, *supra* note 44.
[145] However, due to Florida's Bert J. Harris Private Property Rights Act, local governments must tread carefully when applying new land use regulations to existing property entitlements, else they risk incurring the obligation to pay compensation to the affected property owner. FLA. STAT. Ch. 70 (2021).
[146] MAYOR'S RESPONSE, *supra* note 100, at 8.

expenditures have been directed to urgent vulnerabilities.[147] As noted by Jim Murley, the Chief Resilience Officer for Miami-Dade, a chief concern is protecting key government facilities.[148] Longer-term capital will be employed for less critical anticipated infrastructure threats. Pursuant to its Local Mitigation Strategy, the County has already spent $37 million on more than a dozen infrastructure projects and has more than twenty other projects planned at an anticipated cost of $35 million.[149] These investments are expected to save four dollars for every one dollar spent.[150] While these completed and near-term financial investments are significant, the Local Mitigation Strategy has identified more than one thousand known flood risk mitigation projects that still must be funded.[151]

In addition to facing climate-based physical and economic threats, Miami-Dade is also attempting to limit the adverse effects of "climate gentrification." Such gentrification occurs when wealthy climate migrants drive the indigenous residents of climate-resilient high ground communities out of their neighborhoods due to real estate demand and associated increased rents.[152] While climate gentrification may occur on the international, national, or state-level, it is also occurring at the local level in places like Miami-Dade.[153] Higher elevation, drier, and inland properties that are less vulnerable to flood and hurricane impacts, like Miami's Little Haiti (thirteen to thirty-two feet above sea level), are becoming attractive property investments.[154] Similarly, lands that are shaded by large mature trees and situated in areas with abundant cooling winds are increasingly sought after as extremely hot days become more frequent.[155]

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[147] *Id.*; MIAMI-DADE CNTY. SEA LEVEL RISK TASKFORCE, OFF. OF RESILIENCE, RECOMMENDATIONS FOR AN ENHANCED CAPITAL PLAN 9 (2016) [https://perma.cc/SFR4-CF72].

[148] Interview with Jim Murley, *supra* note 127.

[149] MIAMI-DADE CNTY. SEA LEVEL RISE TASK FORCE, *supra* note 44, at 34.

[150] *Id.*

[151] The most recently published list of Local Mitigation Strategy projects is available at MIAMI-DADE CNTY., WHOLE COMMUNITY HAZARD MITIGATION PART 2: THE PROJECTS (June 2018).

[152] Jesse M. Keenan et al., *Climate Gentrification: From Theory to Empiricism in Miami-Dade County, Florida,* 13 ENVTL. RES. LETT. (2018); Yvette Killian, *Climate Gentrification: How Extreme Weather is Displacing Low-Income Residents from Their Communities*, YAHOO! FINANCE (May 19, 2020), https://finance.yahoo.com/news/climate-gentrification-how-extreme-weather-is-displacing-lowincome-residents-from-their-communities-182206343.html [https://perma.cc/ZNE3-N2XB].

[153] Keenan et al., *supra* note 152.

[154] *Id.*; *Fighting for the Soul of Little Haiti*, GRIST (March 10, 2020) https://grist.org/Array/fighting-for-the-soul-of-little-haiti/ [https://perma.cc/DU95-S3GP].

[155] *Fighting for the Soul of Little Haiti*, *supra* note 154.

While moving populations inland to high-ground is wise in terms of climate readiness, the economic pressure of rising land values and rising rents can force out less-affluent indigenous communities.[156] At the same time, increases in adverse weather events lead to property maintenance and insurance costs that lower-income households cannot afford.[157] Unfortunately, Miami-Dade is already one of the nation's least-affordable housing markets and faces severe income inequality.[158] Indigenous residents of climate-gentrifying communities face significant financial hurdles to locate new housing.[159] While private housing sales and rents tend to be within the control of private parties, the County has attempted to ensure affordable housing is available for climate refugees. For example, the County recently required redevelopment interests in Little Haiti to fund $31 million to build affordable housing in another area of Little Haiti.[160]

Miami-Dade balances many economic, environmental, and societal factors while addressing climate change, such as by blending existing regulations for preservation of trees and ecological systems with targeted resilience measures. Recognizing that climate change weather impacts are inevitable and funding resilience projects is necessary to combat them, adaptation is the primary element of Miami-Dade's efforts.

C. Case Study: San Francisco, California

San Francisco is a consolidated city and county on America's west coast, adjoining the Pacific Ocean to the west and San Francisco Bay to the north and east. It is home to almost 900,000 residents and is expected to grow to include more than a million residents by 2040.[161] It faces climate-based challenges from sea-level rise and resultant storm surges and flooding, as well as more frequent heat waves, and impacts from California wildfires.[162] It was

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[156] Keenan et al., *supra* note 152.
[157] *Id.*
[158] URBAN LAND INST., *supra* note 139, at 9.
[159] CITY OF MIAMI PLAN. DEPT., THE CITY OF MIAMI IN THE CONTEXT OF CLIMATE CHANGE, POPULATION GROWTH, AND DEVELOPMENT PRESSURE: POLICY AND STRATEGY RECOMMENDATIONS (Nov. 2019).
[160] *Fighting for the Soul of Little Haiti*, *supra* note 154.
[161] CITY & CNTY. OF SAN FRANCISCO, RESILIENT SAN FRANCISCO: STRONGER TODAY, STRONGER TOMORROW (2016).
[162] Telephone interview by Michael Camareno with Shawn Rosenmoss, Senior Environmental Specialist, City of San Francisco (July 13, 2020) (on file with author). As throughout much of California, wildfires pose significant threats to property and human health. *Id.* The 2013 Rim Fire caused over $70 million in damages to regional cities and counties, including San Francisco. Even though wildfires are usually outside of City limits,

the first American city to develop a climate action plan.[163] San Francisco's efforts to develop resilience include preparation for climate-change weather events and earthquakes.[164]

San Francisco has assigned the responsibility of building resilience to several city agencies, including the Department of Environment, Planning Department, Public Works Department, Office of Resiliency and Recovery, and the Mayor's Office.[165] The City also participates in several interagency groups working on resilience measures, such as the Sea Level Rise Coordinating Community (SLRCC), which is composed of representatives from the local utility, transportation authority, international airport, and port authority.[166] These agencies seek to limit the city's contribution to climate change and strategize how and where to deploy local climate mitigation tools.[167] In addition to professional partnerships, San Francisco has created several citizen advisory groups to recommend actions for community improvements in their respective fields of study.[168]

The oldest tidal gauge in the Western Hemisphere, the Presidio Tide Gauge, has recorded sea levels near the San Francisco coast since 1854.[169] During the last century, the Presidio Tide Gauge reflected steady but limited annual tidal increases of approximately 0.1 inches per year.[170] However, these tidal increases have more than doubled between 2000 and 2020 to an

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the smoke and particle pollutants of these fires travel on wind currents to affect the health of City residents. *Id.*

[163] *Id.*

[164] San Francisco has already had to recover from the devastation of several major earthquakes, including the earthquake of 1906 and recent losses of over $1.3 billion from the 1989 Loma Prieta earthquake. *See id.*

[165] *See generally Departments*, CITY & CNTY. OF SAN FRANCISCO, https://sf.gov/departments [https://perma.cc/ZA3Z-DG8G].

[166] SAN FRANCISCO DEPT. OF PUBLIC HEALTH, SAN FRANCISCO'S COMMUTE AND HEALTH ADAPTATION FRAMEWORK (2017) [hereinafter HEALTH ADAPTATION].

[167] *Neighborhood Summary*, SAN FRANCISCO CLIMATE & HEALTH PROGRAM, http://sfclimatehealth.org/neighborhoods/ **[**https://perma.cc/Y249-CDD3].

[168] This includes advisory panels for Economic Prosperity, Jobs, and Environmental Justice; Gray to Green, Urban Greening & Climate Change; New Century Transportation, Moving the Future Forward; Energy Independence, Global Technologies & Local Solutions, and The Business Council. *Community Climate Action Advisory Panels*, SF ENVIRONMENT, https://sfenvironment.org/article/community-climate-action-advisory-panels [https://perma.cc/G8XZ-3EEZ].

[169] CITY & CNTY. OF SAN FRANCISCO, SEA LEVEL RISE COMM., GUIDANCE FOR INCORPORATING SEA LEVEL RISE INTO CAPITAL PLANNING: ASSESSING VULNERABILITY AND RISK TO SUPPORT ADAPTATION (Jan. 3, 2020) [hereinafter CAPITAL PLANNING].

[170] *Id.*

average of over 0.2 inches per year–and rising.[171] San Francisco anticipates that rising sea levels will increase water levels in the San Francisco Bay by nearly seven feet by 2099, which will result in temporary or permanent flooding of approximately four square miles of businesses, homes, and vital infrastructure, including the Port of San Francisco.[172]

These rising sea levels are expected to increase tides and storm surges by up to five feet by 2050 and nine feet by 2100, posing an even greater threat to infrastructure.[173] Of more imminent concern is the strength of "king tides," which occur annually when the gravitational pull of the sun and moon are aligned and result in extraordinarily high tidal influxes.[174] The city also faces more frequent storms and heavier precipitation, particularly during El Niño winter weather events.[175] In addition, climate change is expected to increase the amount of precipitation during storms, resulting in flooding from underground creeks, drainage basins, and stormwater facilities.[176]

In response to these threats, the City undertook a comprehensive analysis of sea-level threats and in 2020 released its *Sea Level Rise, Vulnerability and Consequences Assessment*, addressing local vulnerabilities facing transportation, water supply, wastewater capacity, electricity systems, public safety, parks, marinas, port facilities, shorelines, neighborhoods, and businesses.[177] The assessment evaluated risks at stepped thresholds of anticipated water rise, from an additional one to nine feet, and included consideration of ancillary flooding in the city's eight watersheds.[178] The effect of each incremental increase in sea level was assessed with regard to its direct adverse impact on residences, businesses, jobs, streets, and parks.[179]

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[171] *Id.*
[172] Sarah Cafasso, *Stanford Researchers Map How Sea-Level Rise Adaptation Strategies Impact Economies and Floodwaters*, STANFORD NEWS (Jul. 12, 2021), https://news.stanford.edu/2021/07/12/economic-impacts-combatting-sea-level-rise/ [https://perma.cc/W2LM-CACX].
[173] HEALTH ADAPTATION, *supra* note 166.
[174] CAPITAL PLANNING, *supra* note 169.
[175] *Id.*
[176] HEALTH ADAPTATION, *supra* note 166. Unfortunately, there are concerns in San Francisco that the reverse climate situation, extended periods of drought, will also be exacerbated by climate change. *See id.*
[177] CITY & CNTY. OF SAN FRANCISCO, SEA LEVEL RISE, VULNERABILITY, AND CONSEQUENCES ASSESSMENT, EXECUTIVE SUMMARY (Feb. 2020) [hereinafter EXECUTIVE SUMMARY].
[178] *Id.*
[179] *Id.*

As noted below, the City is also taking steps to mitigate the health impacts of increased flooding, including injury and waterborne illnesses.[180]

The City also studied the exposure, sensitivity, and adaptive capacity of significant infrastructure.[181] Exposure evaluations were based on the likelihood of temporary or permanent flooding or other climate impacts, at various magnitudes and durations, at the evaluated facilities.[182] The study further evaluated the sensitivity to climate threats of facilities that are likely to be exposed to climate events (for example, whether a flood wall would be damaged by a storm surge and how long it would take the facility to resume operations).[183] If the facility was found to be both exposed and sensitive to climate events, the additional study considered the ability of the facility to adapt to such events, as well as strategies or improvements that could be implemented to render the facility more adaptable.[184] In sum, the assessments evaluated the anticipated useful life of the facility vis-a-vis anticipated climate threats.[185]

Based on these quantitative assessments, the City has taken steps to design new structures and retrofit existing buildings and infrastructure to mitigate anticipated sea-level rise effects. In 2018, residents voted to approve a bond to reconstruct a significant portion of the surrounding sea wall.[186] Private development projects are also subject to greater requirements for climate resiliency. For example, a large redevelopment project in former military and an industrial area along the southern shoreline of the city, known as the Mission Rock Development, has incorporated elevated building pads to limit flooding impacts within the habitable areas of homes and businesses, as well as large, strategically located open spaces to capture and drain stormwater.[187] However, even these measures may not be enough to completely mitigate sea-level rise if climatic change occurs at faster or greater amounts than anticipated.[188]

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[180] HEALTH ADAPTATION, *supra* note 166.
[181] CAPITAL PLANNING, *supra* note 169.
[182] *Id.*
[183] *Id.*
[184] *Id.*
[185] *Id.*
[186] Interview with Shawn Rosenmoss, *supra* note 162; John King, *SF's Embarcadero Seawall Measure Wins Easily*, SAN FRANCISCO CHRONICLE (Nov. 6, 2018).
[187] EXECUTIVE SUMMARY, *supra* note 177.
[188] *Mission Rock*, ARCGIS STORY MAPS 5 (Dec. 30, 2021), https://storymaps.arcgis.com/stories/8ed5c4ecc93b4964a803d9ed519136fd [https://perma.cc/QMS8-DC3F].

City zoning and construction codes also require climate mitigation efforts in private developments and redevelopments. This includes requirements to plant twenty-four-inch box trees along every twenty feet of street frontage development; that new roofs include 15% solar panels or 30% living vegetation; that at least 50% of new front yards remain permeable; and to install and maintain natural stormwater management systems by incorporating green infrastructure.[189]

In partnership with the U.S. Department of Energy's *Sunshot Initiative* and the *Solar Market Pathways Program*, San Francisco is developing an emergency power system reliant on solar power generation and on-site solar power storage facilities.[190] This back-up electricity can be used in an emergency to provide critical facilities, such as city buildings, with operational power.[191]

More frequent extreme heat days and heat waves are also a major concern for a city that was built in anticipation of temperate, not hot, weather. In a recent publication by the city's Department of Public Health, temperature increases were deemed the greatest climate-based health risk facing San Francisco neighborhoods.[192] The assessment found that annual temperatures in the City were expected to increase approximately 4-6^{O}F by 2100.[193] Similarly, the study noted that San Francisco was likely to experience up to thirty-five more days per year of dangerous heat by 2050 and up to ninety more days of dangerous heat by 2100.[194] More frequent and lengthier heat waves are also expected during the same study period.[195]

Increased heat is particularly difficult to mitigate because the city has been developed with buildings and infrastructure designed for its historically cool climate.[196] Unmitigated increased heat can cause more incidences of heat stroke, dehydration, heart disease, diabetes, and renal disease, as well as increased air pollution leading to respiratory illness, asthma, and allergies.[197] Increased heat has also been linked to increased behavioral problems.[198]

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[189] Public Works Code, Art. 16, §806(d); Environmental Code, Ch. 26; Planning Code, Art. 1.2, § 132, Board of Supervisors Resolution 107-18.
[190] RESILIENT SAN FRANCISCO, *supra* note 161.
[191] *Id.*
[192] HEALTH ADAPTATION, *supra* note 166.
[193] *Id.* at 41.
[194] *Id.* at 8.
[195] *Id.* at 8.
[196] *Id.* at 17.
[197] *Id.* at 10.
[198] *Id.* at 10.

To address health impacts posed by climate change, such as increased heat waves, impacts of flooding, and smoke from wildfires, the Department of Public Health created its Climate and Health Program to engage in research and community outreach and education. The work of this program has determined that communities in lower socioeconomic brackets are most vulnerable to climate change impacts, as residents and businesses are less able to obtain air conditioning and install flood mitigation, and face a greater risk of job loss due to weather events.[199] Beyond socioeconomic factors, demographics such as age, race, and pre-existing health conditions were also found to increase vulnerabilities.[200] Not surprisingly, geography also increases vulnerability, especially in flood-prone communities, areas susceptible to the urban heat effect (in which extensive concrete and limited tree shade raise temperatures above surrounding areas), and communities lacking sufficient emergency infrastructure.[201] To mitigate the potential health effects of climate change in vulnerable areas, the program recommended a variety of approaches, such as providing virtual medical resources, extending the reach of weather-related warnings, giving financial assistance toward installation of home insulation and/or air conditioning and air filtration systems, and funding green space initiatives.[202]

The City has also taken steps to ensure residents can access cooling centers during heat waves. All public facilities have functional air conditioning, and some are designated as "cooling centers" where residents can take respite during extreme heat events.[203] The City has also modified its electric grid to include microgrids in areas that experience high power demand during heat events to limit black- or brown-outs so that air conditioning units remain functional.[204]

San Francisco faces a variety of threats due to climate change, including rising sea levels and storm surges, rising heat levels, and impacts of wildfires.[205] The City has undertaken studies to determine the best methods to protect vulnerable infrastructure and communities to keep its population

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[199] *Id.* at 17.
[200] *Id. at 17.*
[201] *Id.* at 14. Communities which were identified as especially vulnerable include the Downtown/Civic Center area, Chinatown, Bayview, Hunters Point, South of Market, and Mission Bay.
[202] *Id.* at 15.
[203] Interview with Shawn Rosenmoss, *supra* note 162; *CCSF Cooling Centers*, CITY & CNTY. OF SAN FRANCISCO, DEPT. OF EMERGENCY MGMT. (Sept. 2, 2017), https://sfdem.org/article/ccsf-cooling-centers-english-chinese-spanish [https://perma.cc/G5YK-CAQB].
[204] Interview with Rosenmoss, *supra* note 162.
[205] *Id.*

safe. Its efforts have taken various forms, including new development requirements for coastal development, capital funding to increase adaptability of climate-exposed facilities and infrastructure, and assistance programs to enhance resiliency within vulnerable populations.

CONCLUSION

Current events demonstrate that climate change fuels extraordinarily destructive weather events throughout the United States. In 2020, repeated hurricanes disabled cities along the Gulf coast; wildfires raging throughout the western states endangered human health and property in cities throughout California, Oregon, and Washington; prolonged heat waves endangered residents throughout the southeast; and rising sea levels flooded cities located along seacoasts and riverbanks.[206] It may be beyond the ability of urban governments to halt climate change or prevent this ever-increasing pandemic of extreme weather. Yet, as this article has demonstrated, cities can do many things to anticipate, prepare for, and mitigate the effects of weather extremes. In doing so, cities also develop community resiliency and the ability to recover quickly from weather disasters.

The first step for urban policymakers developing location-appropriate climate resilience is to study and assess the most likely climate risks and vulnerabilities facing their communities, with a recognition that such events are likely to increase in frequency and impact as global climate change accelerates.[207] Policymakers should study the complex interrelations between the specific climate threats facing their communities and the unique characteristics and needs of their communities, such as the location and quality of critical infrastructure, the location and resources of vulnerable populations, at-risk geographic areas and facilities, strengths and weaknesses in available emergency response, and the health, strength, and extent of natural buffers.[208]

Such studies require a high level of expertise in several fields, including emergency management, ecosystem management, hydrology, planning, and

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[206] The entire city of Calistoga California was evacuated due to the 2020 wildfires. Jason Hanna & Hollie Silverman, *The California City of Calistoga is Evacuated as the Glass Fire Closes In*, CNN (Sept. 29, 2020), https://www.cnn.com/2020/09/29/us/california-wildfires-zogg-glass-emergency-declaration-tuesday/index.html [https://perma.cc/YA5Z-UTSA]; Stacey Plaisance & Rebecca Santana, *Busy 2020 Hurricane Season Has Louisiana Bracing a 6th Time*, ABC NEWS (Oct. 7, 2020), https://abcnews.go.com/US/wireStory/busy-2020-hurricane-season-louisiana-bracing-6th-time-73481220 [https://perma.cc/P5GU-PKRG]

[207] Carter et al., *supra* note 28, at 2.

[208] Leichenko, *supra* note 49, at 166.

engineering. Many urban communities, particularly smaller cities and towns, do not have staff with all types of expertise. However, there are many institutes and universities with the necessary expertise and willingness to partner with cities. For example, interactive 3D GIS sea-level rise modeling for Miami-Dade County was developed through a partnership between the NOAA Office for Coastal Management and the South Florida Water Management District.[209] The partnership provided Miami-Dade with the necessary expertise and technology to create cutting-edge sea-level modeling from which it could plan policy and infrastructure improvements and educate the city's populace as to why such measures were necessary. Similarly, New York partnered with NOAA to study ongoing and increasing climate risks facing urban communities in the northeast.[210]

Once extreme weather threats and impacts have been carefully studied, urban governments should develop and implement plans to prepare for and mitigate these impacts at the regional, neighborhood, and site-based levels. This planning stage includes many considerations such as infrastructure improvements, ecosystem enhancements, building retrofits, emergency energy supply, capital financing, and regulatory needs for planning and construction activities. Proper planning is the crux of extreme weather planning but can be daunting. While much of this planning activity must be conducted by city policymakers (who best know the community's needs and assets), there are also partnerships available to assist cities with planning resilience projects. For example, Miami-Dade partnered with the U.S. Army Corps of Engineers to implement the Biscayne Bay Coastal Wetlands residency project.[211] Similarly, New York partnered with the Corps to install natural and manmade flood mitigation facilities along its coastline.[212] San Francisco partnered with the U.S. Department of Energy to develop solar-based emergency power systems to keep electricity running after an

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[209] Miami-Dade Cnty., *Sea Level Rise (SLF) Building Impacts*, ARCGIS MAPS, https://mdc.maps.arcgis.com/apps/webappviewer3d/index.html?id=b92a9fa4ff8847bf97f3e628a195a398 [https://perma.cc/3CBK-82WD].

[210] Earth Institute, *New York City Panel on Climate Change Releases 2019 Report*, COLUMBIA CLIMATE SCH. STATE OF THE PLANET (March 15, 2019) https://news.climate.columbia.edu/2019/03/15/npcc-report-2019-climate-change-nyc/ [https://perma.cc/8AZH-JNM3]; ONENYC 2050, *supra* note 56; PROGRESS REPORT, *supra* note 69.

[211] *Corps Awards $7.7 Million Contract for Biscayne Bay Coastal Wetlands Project*, U.S. ARMY CORPS OF ENG'RS (May 15, 2020), https://www.usace.army.mil/Media/News-Releases/News-Release-Article-View/Article/2188626/corps-awards-77-million-contract-for-biscayne-bay-coastal-wetlands-project/ [https://perma.cc/9JAE-2B6V].

[212] Earth Institute, *supra* note 210; ONENYC, *supra* note 56, at 23; PROGRESS REPORT, *supra* note 69, at 59.

emergency.[213] Many of these partnerships can also be supplemented by grants from federal agencies and public interest groups. Local governments seeking to develop resiliency measures should communicate with potential partners and explore grant opportunities that would provide financial and technical assistance to completing complex and expensive resiliency projects.

A vital and ongoing part of the planning process is the need to raise capital to fund climate-change readiness expenditures. Individual improvements, particularly land acquisition and infrastructure improvements, often require millions of dollars in investment. For most cities, multiple projects and expenditures are needed to create holistic weather resiliency. New York anticipates it will need $20 billion in capital expenditures to develop wide-scale weather resiliency measures.[214] It has already allocated more than $500 million for flood mitigation improvements along the Lower Manhattan shoreline alone.[215] Similar costs are anticipated in Miami-Dade, where a recent report by the bipartisan Southeast Florida Regional Compact estimates that metro communities in southeast Florida will need to spend more than $18 billion to implement community-wide adaptation measures.[216] In San Francisco, the Embarcadero Seawall Program, a high-priority infrastructure project to limit flooding and earthquake impacts along the shoreline, is projected to cost $5 billion.[217] While the expense of resiliency projects may be daunting to policymakers, the financial and social damages wreaked upon an unprepared community by extreme weather can be far greater.[218]

Funding for resiliency measures can be generated by dedicated sources such as taxes, bonds, or impact fees. Taxes are a reliable source of dedicated funding and can be tailored to link the taxed item to resiliency projects. For example, taxes on carbon emitting sources, comparable to a tax on gasoline, can be dedicated toward capital funding of infrastructure to mitigate sea-level

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[213] RESILIENT SAN FRANCISCO, *supra* note 161, at 79.
[214] ONENYC, *supra* note 56, at 28.
[215] *Id.* at 22.
[216] *Regional Business Case for Resilience Demonstrates Compelling Need for Adaptation Investment Today*, SE FLA. REGIONAL COMPACT (Oct. 2020) https://southeastfloridaclimatecompact.org/uncategorized/regional-business-case-for-resilience-demonstrates-compelling-need-for-adaptation-investment-today/ [https://perma.cc/A4ZY-RDUV].
[217] *Embarcadero Seawall Program*, PORT OF SAN FRANCISCO, https://sfport.com/wrp/embarcadero-seawall-program [https://perma.cc/P7DC-DNRC].
[218] The Southeast Florida Regional Compact created a nationwide map of anticipated climate-impacts costs on a county-by-county basis. *See Map: How Much Climate Change Will Cost Each U.S. County*, SE FLA. REGIONAL COMPACT, https://southeastfloridaclimatecompact.org/news/map-much-climate-change-will-cost-u-s-county/ [https://perma.cc/X4MF-7LFZ].

rise. Impact fees can also be an effective and tailored method to link capital fundraising to development projects that pose additional burdens upon facilities and infrastructure.[219] For example, impact fees could be imposed upon new development projects within flood zones to fund evacuation route improvements. And various grants are available to local governments as they develop resiliency measures, such as those from the Rockefeller Foundation, the World Bank, and the federal government.[220]

The unique threats, needs, and funding availability of a particular city will guide the resiliency efforts within that community, though certain capital improvements are universally necessary to face specific climate threats. The expansion and improvement of emergency shelters should be a priority in every jurisdiction seeking to develop community resiliency. These facilities should be evaluated for sufficient levels of safety and comfort, including assurance of sufficient electricity, water, bedding, food preparation facilities, sanitation facilities, medical facilities, and even pet needs. As weather events grow in frequency and strength, emergency shelters must be able to accommodate larger populations for longer periods of time.

Similarly, municipalities must improve evacuation routes in the face of extreme weather by assuring evacuation procedures can be conducted safely and efficiently. Where financially feasible, significant transportation infrastructure improvements, such as elevating evacuation roadways above expected floodwaters, may be necessary to ensure safe evacuations. However, even where finances are constrained, low-cost transportation improvements can be made to improve evacuations, such as reorienting streets from two-direction traffic flow to one-way during emergencies, waiving tolls during emergencies, and utilizing emergency directional signage.

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[219] ELIZABETH KNEEBONE ET AL., RESIDENTIAL IMPACT FEES IN CALIFORNIA: CURRENT PRACTICES AND POLICY CONSIDERATIONS TO IMPROVE IMPLEMENTATION OF FEES GOVERNED BY THE MITIGATION FEE ACT, TERNER CENTER (Aug. 5, 2019), [https://perma.cc/ALP5-FS3A].

[220] *See generally* Press Release, The Rockefeller Foundation, The Rockefeller Foundation Launches New Climate and Resilience Initiative; Commits an Initial $8 Million to Continue Supporting Global Network of Cities and Chief Resilience Officers (July 8, 2019) https://www.rockefellerfoundation.org/news/rockefeller-foundation-launches-new-climate-resilience-initiative-commits-initial-8-million-continue-supporting-global-network-cities-chief-resilience-officers/ [https://perma.cc/PK3Q-NSJY]; *Resilient Cities*, WORLD BANK (Oct. 7, 2019), https://www.worldbank.org/en/topic/urbandevelopment/brief/resilient-cities-program [https://perma.cc/D3KV-FTXC]; *Federal Disaster Policy: Toward a More Resilient Future*, U.S. DEPT. OF HOUSING & URBAN DEV., OFFICE OF POLICY DEV. & RSCH. (2015), https://www.huduser.gov/portal/periodicals/em/winter15/highlight1.html [https://perma.cc/8BYW-WJN5].

As funding allows, urban communities should also upgrade their power facilities. Communities should construct and/or retrofit transmission lines and other power infrastructure to be climate-resilient, such as by burying power lines underground so that floods or storm winds do not destroy connectivity. Critical facilities, such as emergency shelters, hospitals, and government facilities, should connect to on-site solar generators, such as is done in New York, to ensure that power remains fully functional. And, where possible, other buildings should be retrofitted with on-site and grid-independent solar facilities to ensure continued electricity even when the electric grid is disrupted.

Flood mitigation infrastructure should be installed in communities facing threats of hurricanes, storm surges, or flooding. Sea walls and natural berms have been demonstrated as successful tools to prevent floods and storm surges, or where full prevention is not feasible, mitigate impacts.[221]

As also seen in New York and Miami-Dade, resilience planning must include conserving large natural areas, particularly along coast lines and wetlands. Natural ecosystems operate as pervious natural buffers that can absorb flood waters and destructive winds during hurricanes.[222] Green preserves also offset the effect of urban heat islands by providing shade and reducing the extent of heat-reflective concrete.[223] As an ancillary benefit, nature preserves add natural beauty to the urban community, provide opportunities for recreation and tourism, and enhance the value of nearby properties.[224] Cities that are too highly developed to preserve large nature preserves should instead focus on developing smaller "pocket" parks throughout flood-sensitive areas that can serve as natural water retention facilities for floodwaters.[225] In addition, cities should launch campaigns to

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[221] *See* Umair Irfan, *New $1.1B Sea Wall Protects New Orleans Against Major Storms but May Cultivate Complacency*, E&E NEWS (May 15, 2014), https://subscriber.politicopro.com/article/eenews/1059999621 [https://perma.cc/2HHP-3UF3].

[222] *See From Gray to Green: Advancing the Science of Nature-Based Infrastructure: Hearing Before the H. Science, Space, and Technology Subcomm. on Environment*, 117th Cong. (2022) (statement of Steven Thur, Director, National Centers for Coastal Ocean Science, National Oceanic and Atmospheric Administration); *see also* LYNNE CARTER ET AL., FOURTH NATIONAL CLIMATE ASSESSMENT VOL. II, U.S. GLOB. CHANGE RSCH. PROGRAM 743 (2018) [hereinafter FOURTH NATIONAL CLIMATE ASSESSMENT VOL. II].

[223] Daniel Cusick, *Scientists to Use NYC's Central Park as Climate Laboratory*, CLIMATEWIRE (Jan. 19, 2022), https://advance.lexis.com/api/document?collection=news&id=urn:contentItem:64T2-5MT1-F0YC-P111-00000-00&context=1516831.

[224] Carter et al., *supra* note 28, at 757.

[225] *Id.*

plant trees and encourage the development of green roofs to further offset rising heat levels.

The foregoing recommendations have focused on government-funded weather mitigation efforts. However, private investment is also necessary to shoulder some of the burden of developing weather resiliency.[226] When property within urban areas is privately-owned, the inclusion of private property owners is typically necessary to implement improvements and conservation strategies on their land. Furthermore, resiliency measures are costly. While governments may be able to obtain funding for community-wide or neighborhood-scale resiliency measures, private property owners will often need to fund site-specific improvements. Urban governments should encourage and–where necessary–mandate that private property owners take climate resiliency measures. Examples include retrofitting existing buildings with wet or dry flood proofing; elevating buildings and associated infrastructure in flood prone areas; using weather-resilient building materials such as high-wind load roof shingles; installing built-in generators (preferably solar powered to offset potential fuel shortages); and enhancing on-site wastewater storage facilities. In addition to encouraging or mandating such building improvements, policymakers should limit or prohibit new development in low-lying coastal areas or other areas that are expected to experience regular flooding caused by rising sea levels.[227] New development in flood-prone areas should incorporate water sensitive urban design.[228]

Policymakers should determine which resiliency measures to incentivize and which to mandate. One tool San Francisco uses is mandating appropriate weather mitigation for new development, such as the Mission Rock project or redevelopment projects.[229] This strategy, sometimes known as "pay to play," places the impetus on private developers who wish to reap the benefits from government-issued development approvals to, in turn, agree to exactions upon that development that develops climate resiliency. That approach can be used to require conservation reserves, resilient building materials, installation of sea walls, and the like.

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[226] *See* John W. Allman, *Building Against the Odds*, THE TAMPA TRIBUNE (Feb. 20, 2006).
[227] *Id.*
[228] Alexander Kane et al., *Can Integrated Green Spaces and Storage Facilities Absorb the Increased Risk of Flooding Due to Climate Change in Developed Urban Environments?*, 579 J. HYDROLOGY 1, 1 (2019).
[229] EXECUTIVE SUMMARY, *supra* note 177.

New York City, on the other hand, has sought private support for resiliency measures through a different approach: providing financial assistance to private property owners who voluntarily undertake climate resiliency initiatives.[230] Financial assistance can be particularly effective in smaller-scale projects such as installing air conditioning units, rooftop solar panels, wind-load resistant roofs, and emergency generators.[231]

Voluntary site-by-site improvements on private property may not be sufficient to develop holistic climate readiness. Thus, cities must consider enacting legislation to prepare for extreme weather events. Such legislation may take a variety of forms, depending on community needs. For example, cities prone to heat waves and wildfires should consider legislation to prevent use of recreational incendiary activities, such as using fire pits and fireworks, during dry seasons. Cities prone to hurricanes and flooding should mandate wind and water-resistant building materials and construction techniques, such as wind-rated roofing shingles, concrete walls, and stilt construction. Urban planners should also enact zoning restrictions to limit construction or expansion of structures in areas vulnerable to weather events.[232] Governments may consider directing residents away from high-risk areas through mandatory disclosure of weather dangers during the sales process or potential government buy-outs.

To gain support for regulatory efforts, cities should engage in public education campaigns. Cities could follow the lead of Miami-Dade in developing and publishing interactive models which demonstrate pending threats.[233] These models are effective at building public support for funding and regulating climate resiliency. Cities that faced recent weather emergencies, like New York after Hurricane Sandy, can heighten public support for resiliency measures immediately following destructive weather events to enact regulatory and funding measures.

Reaching beyond community boundaries, cities should also consider interlocal aid agreements, particularly with cities located close enough to

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[230] *See* EQUAL HOUSING OPPORTUNITY, NEW YORK CITY BUILD IT BACK: SINGLE-FAMILY POLICY MANUAL (Dec. 31, 2021); Press Release, New York City, Mayor's Announcement Program to Help Curb Effects of Extreme Summer Heat (June 14, 2017); NYC DEPT. OF HOUSING PRES. & DEV., *Mayor Bloomberg Announces First Multi-Family Buildings to Receive NYC Build It Back Funding to Repair Storm Damage and Improve Resiliency*, STATE NEWS SERV. (Oct. 30, 2013).

[231] *See* NYC DEPT. OF HOUSING PRES. & DEV., *supra* note 230.

[232] D.J. Wrathall et al., *Meeting the Looming Policy Challenge of Sea-Level Change and Human Migration*, NATURE CLIMATE CHANGE 9, 898 (2019).

[233] *Sea Level Rise (SLR) Building Impacts*, *supra* note 95.

respond to a call for aid within 24 hours of a weather event but far enough away to not be hampered by the same weather event. Interlocal agreements may be tailored to provide immediate aid in a specific weather event, such as shared law enforcement and other emergency response after a hurricane. Such agreements may also address longer-term needs, such as shared resources to restore vital infrastructure or provide human necessities in the weeks following a climate event. By having such interlocal aid agreements in place, emergency support can be rallied before, during, and immediately after a weather event, minimizing the time it takes for citizens to regain power, transportation, and medical services.

Urban communities facing climate threats must engage in careful study, physical and financial planning, infrastructure improvements, enacting regulations, and developing intergovernmental cooperation to maximize community resiliency. As noted by Jim Murley, Chief Resilience Officer of Miami-Dade, one of the main hurdles blocking cities from pursuing climate mitigation strategies is hesitancy to recognize that climate change impacts will become more frequent and devastating over the next several decades.[234] Yet, to properly meet and mitigate such climate change, urban policymakers must face these challenges today. Cities like New York, Miami, and San Francisco have already planned for and implemented extensive climate resilience measures to keep their people and places safe in the face of climate change. Other urban communities can model the tools and strategies used by these cities as guidance for their own climate resilience planning.

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[234] Interview with Jim Murley, *supra* note 127.