Playbook 1.0:
How Cities Are Paying for Climate Resilience

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Table of Contents

A Tale of Eight Cities

Miami Beach has tripled its stormwater utility rates to pay for $650 million in drainage system and roadway improvements to fend off rising seas for the next 10 years. The city's voters also approved, in 2018, a $198-million general obligation bond that included $117 million for improving the "below ground" resiliency of neighborhoods and public infrastructure.

In 2018 San Francisco voters approved a $425-million general obligation bond to pay for Phase I of a $5-billion plan to prepare its seawall for climate change and seismic risks. Two years earlier, voters in the city and nine-county San Francisco Bay Area approved a $12-a-year tax on land parcels in the region, raising $500 million over 20 years to fund nature-based flood protection through wetlands, habitat restoration, and pollution-removal projects.

Charleston, South Carolina, has a $500-million-plus plan to prevent flooding from rivers and sea level rise, and hopes the state legislature will let it use part of a 2% local accommodations fee for tourism-related projects to pay for some of the plan, which is also supported by increased stormwater rates.

Hoboken, New Jersey, parts of which were devastated by Hurricane Sandy in 2012, has spent $500 million from a variety of local and state funds, and federal post-disaster programs, as well as private and philanthropic capital, to pay for roughly the first half of its comprehensive plan to cope with high-intensity rainfall events.

The experiences of these and other US cities that have begun to pay for large-scale climate-resilience projects, mostly to address sea level rise and flooding, amount to an initial approach—Playbook 1.0—for deciding who will pay for what and how city governments will generate the needed revenue. The Playbook contains eight distinct strategies. But it is not the final answer for cities; it is the foundation of an emerging financial capacity that cities are building in response to climate change. Some cities are already experimenting with strategies that could become part of Playbook 2.0.

Playbook 1.0's Eight Strategies that Cities are Using

1. **Generate Local Revenue.** Produce revenue for government climate-resilience public infrastructure by taxing local property owners and charging utility ratepayers.
2. **Impose Land-Use Costs.** Adopt land-use and building regulations and policies that place undetermined future resilience-building costs on property owners and developers, rather than on government.
3. **Embed Resilience Standards into Future Infrastructure Investments.** Ensure that *all* future capital spending for public infrastructure will be designed to strengthen climate resilience as much as possible.
4. **Leverage Development Opportunities.** Link resilience-building projects with real estate development opportunities to generate public-private partnerships that invest in both public infrastructure and private development.
5. **Exploit Federal Funding Niches.** Identify resilience-friendly federal funding streams and develop projects that fit pre- and post-disaster program requirements.
6. **Tap State Government.** Mine existing state programs, or seek to modify them, to obtain funds for local climate-resilience efforts.
7. **Develop Financial Innovations.** Explore the use of innovative mechanisms for generating public and private revenue for climate-resilience projects, including district-scale financial structures.

8. **Pursue Equity in Resilience.** Factor social and economic equity into funding and financing actions by serving economic development, housing, and other needs while investing in climate resilience.

Playbook 1.0 is based on a close look at how eight US cities in seven states have been organizing the funding needed to implement their ambitious climate-resilience plans. They are among a small number of cities that have gotten this far. It turns out they are all coastal cities dealing with the increasingly pressing realities and daunting risks of sea level rise—chronic inundation and storm-driven shocks—as well as increased precipitation.

Cities in the Study					
City	**Population**	**Median Household Income (2016)**	**% Home Owners (2016)**	**% Residents Below Poverty Line (2016)**	**Form of Government**
Boston, MA	672,000	$63,621	35%	21.0%	Mayor-Council
Charleston, SC	134,000	$61,367	54%	14.5%	Mayor-Council
Hoboken, NJ	55,000	$118,479	32%	10.5%	Mayor-Council
Miami, FL	463,000	$34,901	32%	24.9%	Mayor-Commission
Miami Beach, FL	93,000	$53,531	37%	16.7%	Commission-Manager-Ceremonial Mayor
New York, NY	8,600,000	$58,856	32%	18.9%	Mayor-Council
Norfolk, VA	247,000	$46,467	41%	19.9%	Mayor-Council
San Francisco, CA	884,000	$103,801	43%	10.1%	Mayor-Council

Although some of the cities have substantial local wealth—household income and property value—none could absorb the cost of their resilience plans in their existing budgets. Even New York, which obtained $20 billion from the federal government to recover from Hurricane Sandy and has made some climate-resilient infrastructure investments out of its usual annual capital budget, needed rate increases by non-municipal utilities. And the city does not know how it would pay for its recently unveiled $10-billion proposed project to build new land out into the water—as much as 500 feet wide and 20 feet above sea level—to protect lower Manhattan.

Each of these cities has had to find its own way to public and private financial resources, because there is no system in place for solving the problem of how to pay for climate resilience—no cost-sharing arrangements, for instance, for resilience infrastructure across local, state, and federal levels of government. The cities are involuntary pioneers faced with growing climate hazards and exposure that require more money for resilience.

Examining these cities' pathways revealed common strategies that, while only reflecting the leading-edge of urban climate-resilience financing practices, quite likely foreshadow what other cities already or may do. These strategies form the content of Playbook 1.0. But the pathways also suggest the limits of what cities are able to do, with important implications for the continuing evolution of the urban playbook for climate-resilience finance.

Profiles of each of the eight city's situations and efforts appear in the appendix.

The INC Urban Climate-Resilience Series of Reports

This is the fourth report that the Innovation Network for Communities and its partners have produced, with support of the Summit Foundation, about the challenges of city climate resilience.

- The first, "Essential Capacities for Urban Climate Adaptation," examines cities' planning and implementation processes and identifies key capacities, including finance, that cities are building to strengthen their climate resilience.
- The second, "Toward a Climate Resilience Finance System for US Cities," offers a framework for a comprehensive financing system to pay for the many billions of dollars of infrastructure investments that cities, especially coastal cities, will need to protect themselves from future climate disasters. (Also supported by a grant from the Kresge Foundation.)
- The third, "Can It Happen Here? – Improving the Prospects for Managed Retreat by US Cities," analyzes the politically difficult choices presented by the potential need to retreat from parts of a city that will not be defended from climate risks.

Challenges of Paying for Urban Climate Resilience

"How will we pay for this?"

Sooner or later, city officials contemplating a plan to increase their community's climate resilience ask this question. The financial amounts involved may be quite large—tens or hundreds of millions of dollars, even billions. Price tags like that can make even big, wealthy cities pause. Just as sobering is the fact that America's governments at all levels have grossly underinvested in public infrastructure for decades and this sort of investment is precisely what is needed for much of resilience building. Plus, climate impacts increase demands on social safety nets, which adds to financial strains in cities.

A small number of cities have been coming up with answers to the question. The eight cities in our study have assessed their climate vulnerabilities and risks and developed climate-resilience plans to protect infrastructure, property, lives, businesses, and urban functions, at least for the next 10 to 20 years. This planning put them at the leading edge of dealing with a problem no US city had until just a few years ago: how to pay for the climate-resilience plans they have developed to protect their residents, private property, public infrastructure, and economies, at least for the next 10 to 20 years. Bottomline: they have to obtain more money from somewhere.

Eight Cities Studied
• Boston, Massachusetts
• Charleston, South Carolina
• Hoboken, New Jersey
• Miami, Florida
• Miami Beach, Florida
• New York, New York
• Norfolk, Virginia
• San Francisco, California

The difficulties involved in solving the climate-resilience financial puzzle are becoming well documented.

- **New costs are substantial.** The eight cities in this study have a total estimated capital need approaching $50 billion for public infrastructure during the next decade or so (with as much as $30 billion for New York alone). Although there are no authoritative studies that project the cost of resilience strengthening for US cities, some analyses suggest the large investment that may be needed. A June 2019 study estimated that building seawalls and other barriers around the contiguous US to protect public infrastructure from sea level rise could cost $400 billion.[1] The 2016 "Adaptation Finance Gap Report," produced by UN Environment, projected the annual *global* cost of adaptation by 2030 could range from $140 billion to $300 billion, and up to $500 billion a year by 2050.

- **Time horizons are mismatched.** The plans the cities are paying for do not extend protection beyond the next few decades, even though sea level rise and other climate changes are expected to worsen. Indeed, few players in the finance and funding realm consider investments in the longer time frames that climate change requires. Moreover, the uncertainty of climate impacts in future years makes planning and paying for resilience improvements more complicated for cities and investors.

- **Most investment does not have a return-on-investment that can attract private capital.** Unlike greenhouse gas mitigation, which is heavily centered on transforming energy markets and attracts more than $300 billion a year globally in

[1] https://cleantechnica.com/2019/06/20/retreat-abandonment-the-400-billion-problem-confronting-us-coastal-communities/.

private investment in clean-energy production,[2] much of the investment in climate resilience is for public infrastructure that has to be paid for from government revenue.

- **No federal/state framework exists to support city resilience.** Cities cannot turn to the federal government or, in most cases, to state governments for significant financial assistance for resilience building unless they have already suffered a climate disaster. The federal government has no framework for addressing climate changes, much less supporting urban resilience building. Funding from existing federal programs—Federal Emergency Management Agency, US Department of Housing and Urban Development, etc.—and special one-time appropriations (for New Orleans, New York City, and Houston, for example) is almost exclusively tied to post-disaster recovery and rebuilding.

"Plug and Play" Funding

Much urban infrastructure is funded from multiple public sources—a "plug and play" matrix of local, state, and federal programs. Knowing which pots can be used for particular projects and how to access them is an important local government competence.

An example of using the existing plug-and-play funding system is the Massachusetts Bay Transportation Authority (MBTA), which serves 175 cities and towns and provides 1.3 million passenger trips on an average business day. MBTA has a five-year, $7.4 billion Capital Investment Plan to modernize, expand, and improve its system. In April 2018, the Authority projected this funding would be obtained from a blend of 16 existing funding streams—grants, loans, bonds, and fees. A little more than half of the capital would come from at least six federal sources.[3]

- **Climate risks increase investor risks.** The financial capacity of cities—specifically, their ability to borrow long-term capital from private financial markets—is at risk due to climate change. Municipal bond rating agencies have begun to incorporate cities' climate risks into bond ratings. BlackRock, the world's largest financial manager, noted that climate changes can drive economic losses. Its 2019 assessment found that 58 percent of US metropolitan areas would likely see Gross Domestic Product losses of up to 1 percent or more. These losses, plus the costs of recovering after climate disasters and a potential decline in property values due to climate damage, could impair cities' ability to repay money they borrowed.[4] Cities also face the prospect of large-scale losses in the value of property that they tax. The 2018 "Fourth National Climate Assessment" estimated that about $1 trillion in coastal real estate is threated by rising seas in combination with storms, floods, and erosion.

- **Innovations are still in early stages of development.** Although a number of promising innovations in climate-resilience finance are underway, none, except perhaps green bonding, has yet become a widescale, reliable source of capital.

- **There is demand for equitable solutions.** As cities develop climate-resilience plans, they are being pressed to address long-standing and potential social and economic

[2] https://about.bnef.com/clean-energy-investment/

[3] Massachusetts Bay Transportation Authority, "MBTA – Moving Forward With Sustainability," presentation at Climate Adaptation Forum, April 13, 2018.

[4] https://www.cbsnews.com/news/climate-change-could-deliver-a-4-trillion-hit-to-the-financial-system/

inequities, and this concern extends to the financial burdens and benefits of capitalizing the implementation of plans.

The search for resources that cities that can use is the basis for Playbook 1.0's eight strategies. At its core, the Playbook answers these questions:

- **Who pays?** Which financial costs are being borne by the public sector, which by the private sector? More specifically, which by city government taxpayers, utility-service customers, businesses, or private property owners/developers in the city?

- **Which financial mechanisms?** Which financial mechanisms will city government use to obtain or leverage the needed public funding and private financing and what does the city have to do—e.g., win voter approval, mandate private property resilience standards—to use them?

The Eight Strategies of Playbook 1.0

#1: Generate Local Revenue

Cities have generated hundreds of millions of dollars in *local* revenue for public climate-resilience infrastructure by issuing general obligation (GO) bonds backed by property tax revenues and by charging their stormwater and electricity utility ratepayers. Using these two traditional financial mechanisms acknowledges that some investment costs, mainly for infrastructure, will be borne as a citywide responsibility—by private property owners and customers of city-serving utilities. It spreads the cost across a large base of payers, which helps to keep down per-payer costs. These costs may be perceived by the public as a fair way to allocate the burden because "everyone" pays.

City	Local Revenue Generating Mechanisms for Resilience Investment
Boston	TBD
Charleston	Stormwater Fees
Hoboken	GO Bond, Park District Budget, County Open Space Tax Trust Funds
Miami	GO Bond ($198 million)
Miami Beach	GO Bond ($117 million), Stormwater Fees
New York	Electricity Utility Fees (rate case)
Norfolk	Property tax Increase ($1.8 million/year)
San Francisco	GO Bond ($425 million), Regional Parcel Tax ($500 million)

In addition, cities have used other tactics to win local support for revenue raising. When they have had to ask voters to approve GO bonds, cities have designed the propositions to increase their popularity. They have tried to avoid increasing property taxes to back the bond issue and packaged climate resilience with investments in other, perhaps more appreciated, city improvements. And they point out that because interest rates on bonds are extremely low, this is one of the least expensive ways of acquiring money.

During the 2017 bond-approval campaign in **Miami**, for instance, the city stressed to voters that borrowing under the bond would only occur after the debt from a 2001-issued bond had been paid off. This meant that the property taxes needed to repay the new bond would simply replace the property taxes on the expiring bond—so property owners would not be paying any more than they already were. At the same time, city officials lowered the city's overall property tax rate. As a result, advocates of the Miami Forever bond noted at the time, the average homeowner "will actually pay $55 less next year" if the new bond was approved. They also pointed out that with approval of the bond, the city would take advantage of low interest rates in the market and the city's best bond rating in 30 years.

Miami packaged resilience investments into a $400-million bond proposal, with nearly half of the funds committed to non-resilience improvements: roadways, affordable housing, public safety, parks, and cultural facilities.

The debt on **San Francisco**'s $425-million bond, subject to voter approval in November 2018, was also designed to be paid by existing property taxes from the retirement of older bonds. The bond will pay for the first phase of improving the city's 100-year-old sea wall to address sea level rise, flooding, and seismic risks. About 60 percent of the longer-term $5-billion price tag for the seawall is for seismic retrofitting. A January 2018 survey by the Port of San Francisco found that just one in three residents was aware that the wall, which protects an estimated $100 billion worth of private and public assets, is a crucial backbone of the city's waterfront. Nonetheless, 80 percent of the voters voted for the bond proposal.

Two years earlier, voters in **San Francisco** and the nine-county San Francisco Bay Area were asked to approve a $12-a-year parcel tax to raise an estimated $500 million over 20 years to restore the bay's wetlands—an action that would help buffer against rising seas. Measure AA's language, designed with the help of polling data to appeal to local love for the Bay, was cast much more broadly than climate resilience. "The purpose," it stated, "is to protect and restore San Francisco Bay to benefit future generations by reducing trash, pollution, and harmful toxins, improving water quality, restoring habitat for fish, birds, and wildlife, protecting communities from flood and increasing shoreline public access and recreational areas." The money would be used for "the restoration, enhancement, protection, and enjoyment of wetlands and wildlife habitats in the San Francisco Bay and along its shoreline." The measure was approved by 77 percent of voters in the city and a total of 69 percent of the region's voters.

% of City Voters Approving GO Bonds that Included Resilience Investment	
Miami	56%
San Francisco	80%
Miami Beach	70%
San Francisco (AA)	77%

When **Miami Beach** voters approved a $439-million bond, half of the funding was designated for improvement of public safety, city parks, and recreational and cultural facilities, as well as below-ground infrastructure. About 20 percent of the money was targeted for "above-ground aesthetics"—landscape, lighting, and other improvements—that would alleviate property owners' concerns about harmonizing with elevated roadways. The city also planned to use $100 million generated by a Tax Increment Financing (TIF) district that is set to sunset in 2022 to fund underground stormwater projects, thus reducing the need to further increase stormwater rates.

Hoboken, catalyzed in part by federal funds streaming in post-Hurricane Sandy, has used a blend of existing local funding sources, including a county-level open space trust fund,[5] a municipal government-issued bond, and local government budgets to further its resilience investments. Park district and sewage authority funds have been a part of resilience project funding, which has totaled more than $500 million to date.

Post Hurricane-Sandy, **New York** engaged in two energy-utility rate cases that produced funding for resilience efforts in the city and larger metropolitan region. The 2013 Con Edison rate case resulted in that utility investing $1 billion in flood risk mitigation for electric, gas, and steam facilities and other assets. The 2016 National Grid rate case produced about $250 million annually to help modernize pipeline infrastructure and customer information technology systems.

Norfolk adopted a property tax increase of $.01 per $100 assessed value that is dedicated for resilience efforts—it's called "the resilience penny." The tax generates about $1.8 million a year and could be used as the repayment source for a bond issue of up to $20 million repaid over 20 years.

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[5] The Hudson County Open Space Trust Fund was established in 2003 by a 2:1 majority of county voters to acquire land for conservation, open space purposes, recreational facility enhancements, and farmland and historic preservation, and assesses up to 1 mil on property. It has provided more than $44 million for projects since 2005.

Essentially, these cities turned to traditional revenue generating mechanisms—property taxes (for municipal bonds and TIFs) and utility rates—to generate some of the revenue they need to implement climate-resilience plans. But these mechanisms may have limited use in other cities.

One barrier may be the city's ability to repay the debt on a bond issue. Some cities may be at or near a state ceiling on how much debt they can have at any one time. Or cities may be at or near bond investor limits on the city's debt load due to concerns about the city's ability to repay what it borrows. Either condition would limit the city's borrowing capacity. At the same time, whatever a city's remaining borrowing capacity, there will usually be competing demands for the money that can be raised using the mechanism.

A second barrier: cities that are not experiencing significant growth of property values will not be able to generate much, if any, funding using tax-increment financing mechanisms.

Thirdly, concerns about a city's affordability may pose a barrier for using mechanisms that increase the cost of living in the city across the board—on private property owners or all utility customers. Many cities, including some in the study, already face substantial shortages of affordable housing or charge rates for drinking water and sewer services that are considered to be unaffordable for low-income households (stormwater rates are not part of this calculation).[6] Affordability issues may raise policy and political concerns. Some cities have been redesigning their utility-service rates to reduce financial burdens on low-income customers. But affordability is a slippery term. As Manuel Teodoro explains in a 2017 paper, "Measuring Water and Sewer Utility Affordability, "No metric, however well-conceived and executed, can in itself define what is 'affordable;' there is no scientific answer to a philosophical question. Just as incomes and essential expenditures vary from one community to another, so can social and political values—what one community considers affordable may not be considered affordable elsewhere."[7] In cities where voters must approve bond proposals or elected officials must approve utility rate increases, local affordability concerns can be a barrier to generating additional revenue. Even if these concerns are overcome, unaffordability in the city may increase.

[6] For a thorough analysis of water and sewer rates in the US largest 25 cities see Manuel P. Teodoro, "Measuring Water and Sewer Utility Affordability," Texas A&M University, August 2017, http://mannyteodoro.com/wp-content/uploads/2017/08/MTeodoro_Affordability-Method-Working-Paper-Aug2017.pdf.

[7] Manuel P. Teodoro, "Measuring Water and Sewer Utility Affordability," Texas A&M University, August 2017, 24, http://mannyteodoro.com/wp-content/uploads/2017/08/MTeodoro_Affordability-Method-Working-Paper-Aug2017.pdf.

#2: Impose Land-Use Costs

Nearly every city government in the study has adopted land-use and building regulations and policies that place an undetermined amount of the future cost of climate-resilience strengthening onto property owners and developers, rather than on government. These costs are for adapting private property to increase its resilience. They include the elevation of building sites and the design of sites and buildings to prevent flooding and reduce stormwater runoff. They are applied to the design of future development, including significant remodeling of existing development, but may also be applied to existing development.

Boston's updated Green Building Guidelines were accompanied by a Flood Hazard Area Map showing, on a parcel by parcel basis, flood risks from a 1% storm event with 40 inches of sea level rise. Proposed developments are required to demonstrate how their projects will be resilient to this level of future risk.

Charleston has increased the freeboard requirement for new or substantially improved structures to 2 feet above Base Flood Elevation for new and substantially improved structures. It is updating stormwater management standards.

Miami Beach also established a higher freeboard standard. In addition, it promulgated building code and land use requirements for new construction, including standards for first-floor elevations, setbacks, and water retention. It introduced prohibitions on underground parking, increased setbacks and open space requirements for single-family homes. It required that new construction or substantial reconstruction on private property must retain stormwater runoff from a 5-year/24-hour storm of 7.5 inches of rainfall. In 2016, the city required that seawalls for new construction be 5.7 feet NAVD (North American Vertical Datum) minimum elevation, or 4 feet NAVD for existing seawalls with the ability to accommodate an increase to 5.7 feet NAVD. The city is grappling with how to help private property owners pay to elevate sea walls in front of their properties. It is investigating various financing mechanisms to assist private property owners with these new costs.

Typical City Mandates for Private Property Climate-Resilience Measures
• Site and building elevation (new and existing buildings) • Site landscape design (e.g., setbacks) • On-site stormwater retention • Sea wall height • Building design (e.g., floodable first floor) • Historic district building retrofits • Below-grade space utilization • Elevated walkways

In 2018, **Norfolk** required all new or expanding development to meet minimum requirements for first-floor elevations 1.5-3 feet above flood level. The city required all new development to meet a "resilience quotient" based on a system that awards points for measures that builders use for climate-risk reduction, stormwater management, and energy resilience. "Norfolk's zoning ordinance creates policy through the lens of resilience," city documents explained. "It addresses factors with an innovative approach, guaranteeing that development will be more resilient, while still providing builders options and flexibility to achieve this." The city also required existing structures to comply with the 3-foot freeboard mandate if they had suffered two flood damage events, each totaling 25% or more of the structure's market value or if the building was structurally damaged. In addition, the city requires new buildings to capture at least the first 1.5 inches of rainfall on-site.

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These climate-resilience mandates determine which resilience-building costs should be borne by property owners and developers. They increase the cost of private development (although they may help to reduce the risk of damage and the cost of property insurance). The amount of this added cost is largely unknown, because it has not yet been widely applied and standardized into the calculation of development and construction activities. And, like other mandates, it is invisible to the public, unlike a bond issue or sewer rate increase that has a known and disclosed price tag.[8]

In some cities, these mandates may generate opposition from the development and business sectors. In Houston after Hurricane Harvey, for example, the Greater Houston Builders Association fought tougher elevation rules for new buildings, arguing that they could stifle development and increase housing costs.

Some cities are also beginning to pursue a "retreat" mandate: regulations and other changes that limit or prevent future development of highly at-risk areas. (See INC's "Can It Happen Here? – Improving the Prospects for Managed Retreat by US Cities," which analyzes the politically difficult choices presented by the potential need to retreat from parts of a city that will not be defended from climate risks.) **New York**, for instance, rezoned to limit future development in two areas highly vulnerable to sea level rise. **San Francisco** has been explicit that in the long term, sea level rise may force retreat of public infrastructure and privately owned structures from sea coast areas in the city. **Charleston** initiated efforts to purchase and demolish 50-60 houses that had repeatedly flooded, and **New York**'s post-Sandy voluntary buy-out program led to more than 1,000 property acquisitions.

Retreat can save a city from spending money on new or existing public infrastructure and on post-disaster emergency and relief services in high-risk areas. It affects the location of existing and future development in a city. This can become part of a larger trend in which cities use retreat-restrictions to channel development to less at-risk areas, while also increasing the cost of property ownership and development through policies and regulations, and through revenue-raising mechanisms mentioned in Strategy #1.

[8] Risk protection measures at the building and/or parcel level do not necessarily prevent the need for district-scale protection systems paid for by public sources of revenue. In many at-risk areas both forms of protection are needed and can be thought of as different "layers" of defense.

#3: Embed Resilience Standards into Future Infrastructure Investments

Cities also seek to ensure that *all* future capital spending for public infrastructure will be designed to also strengthen climate resilience as much as possible. They use anticipated investments in public infrastructure—repairs, maintenance, and new construction for roads, sewers, bridges, sidewalks, parks, and public buildings, for instance—as resilience-building opportunities.

This strategy comes with two types of actions. One is to require all capital projects to consider climate change scenarios and adapt design accordingly. **San Francisco** went in this direction in 2014, issuing instructions to all city departments to incorporate sea level rise as a factor in capital planning.

But cities are going beyond a blanket general requirement to consider climate resilience. They are designing specific resilience standards for various types of public infrastructure. **Boston**'s Smart Utility Standards, for example, requires the integration of green infrastructure design components into any developments in excess of 100,000 square feet, and also requires analysis of the feasibility of installing microgrids for energy resilience. The city's public works department has already developed resilient infrastructure standards to guide design and construction of elevated roadways, vegetated berms, elevated harbor walks, and deployable flood barriers. And it has begun to incorporate resilience considerations in the design or redesign of various parks along the waterfront.

Hoboken is developing design guidelines for resilient buildings, while **Miami**'s stormwater management plan will update design standards for developers and land use and the city building code.

New York's climate-resilience design guidelines are in their second public iteration, and in March 2019, the City released the latest version. These guidelines include practical information for incorporating projected data on intense precipitation, sea level rise, and storm surge into the design of buildings and infrastructure and include a benefit-cost analysis methodology that accounts for climate-related hazards.

In Boston, Charleston, and other cities there have also been efforts to produce resilience-design guidelines for historic buildings and sites. **Charleston**'s guidelines focus on retrofitting historic buildings by elevating sites, with considerations for streetscape, site design, foundation design, and architecture.

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The gradual emergence of design standards for public infrastructure and private development is a way to drive resilience deep into the physical elements of cities for the long term. The effort is supported by mounting evidence that investment in resilient infrastructure generates positive financial returns because it reduces future costs due to climate change.[9] At the same time, financial guidelines are emerging that recommend investors assess and reduce or avoid the physical impact of climate change on their assets.

[9] See https://www.nibs.org/news/381874/National-Institute-of-Building-Sciences-Issues-New-Report-on-the-Value-of-Mitigation.htm, Task Force on Climate-related Financial Disclosures | TCFD https://www.fsb-tcfd.org/ and https://www.nibs.org/page/mitigationsaves.

Design standards often start out as advisory and voluntary but may become part of the requirements embedded in government procurement and mandates for private development described in Strategy #2.

Design standards are often regarded as provisional or adaptive; they may not be sufficient for the longer term if actual or projected climate hazards, such as the level of rising seas, turn out to be worse than the standards address.

As more and more cities initiate resilience standards, they will create a hodge-podge of different standards. This has the potential to impede the integration of different types of public infrastructure and of public and private infrastructure. If, for instance, roadways are elevated to prevent flooding, will sidewalks also be elevated to connect to the roadways, and will roadside drainage systems be redesigned to take into account the changed stormwater flows? A jumble of unaligned standards among cities within the same region or state may also cause confusion and difficulties for development and building sectors that have to meet the standards.

#4: Leverage Development Opportunities

Cities sometimes link resilience-building projects with real estate development opportunities to generate public-private partnerships that invest in both public infrastructure and private development. As part of permitting specific building projects, they may negotiate resilience requirements for a building and site. More ambitiously, they use resilience strengthening as a way to redesign the function and fabric of large-scale sites and entire districts.

In 2018, **San Francisco**'s "Resilient By Design: Bay Area Challenge" unveiled nine final design concepts, including Islais Hyper-Creek, which would restore a watershed-turned-industrial district that hosts shipping centers, the city's wholesale produce market, a wastewater treatment plant that treats 80% of San Francisco's sewage, and many other supporting businesses in construction, manufacturing, and crafts—with 22,000 jobs. The redesign would create a large park with a restored tidal creek system and soft shoreline with maritime functions, light manufacturing, and logistics that have formed the area's economic backbone for decades. This would address coastal and stormwater flooding risks. The park would retain, convey, and clean water, protecting the surrounding neighborhoods while providing amenities and benefits to the community. Present-day industrial functions would be consolidated in a smaller area. The design is described as "a holistic, district-wide plan" that weaves "together natural, industrial, and social ecosystems" into a "dense, connective, and accessible area: a resilience model for the entire Bay Area."[10]

Hoboken includes several redevelopment projects in its resilience plans, with a focus on linking green infrastructure with housing development. For example, the 7th and Jackson Stormwater Project/Resiliency Park project includes a deal with a developer, Bijou, to provide the community benefits of a new two-acre park, public gymnasium, affordable housing, and flood resiliency measures. The park will manage the 10-year storm event, detaining nearly 470,000 gallons of stormwater to help address flooding issues in the area. The project includes construction, by Bijou, of a $20 million mixed-use residential building with 424 rental residential units (10% of them affordable units) and 30,000-square feet of retail space, and an on-site parking garage. The project won a Smart Growth Award from New Jersey Future in recognition of the project's resiliency efforts.

Norfolk has reimagined the entire city through the lens of climate resilience. Its 2015 visioning exercise, "Norfolk Resilient City," provided a new framework for thinking about the city's development patterns that divides the city into four color-coded zones. Green and purple represent relatively safe areas where the city should focus future development and improve existing neighborhoods. The red zone—mostly downtown and the Naval base—are areas of dense development that need protection. The yellow zone represents areas where the city can't afford to build expensive flood protection but must instead rely on some combination of adaptation and retreat.

Within this framework the city is initiating redevelopment projects, including the Ohio Creek Watershed Project. The project involves a resilience park that connects two predominantly African-American neighborhoods that experience tidal and rainfall flooding. It includes a flood berm, a restored tidal creek and wetland, and a multi-use sports field and places for community gatherings. The neighborhoods include 400 houses on the Historic National Register and 300 units of public housing. One of the only two roads connecting the area to the rest of the city

[10] Resilient By Design, "Islais Hyper-Creek," http://www.resilientbayarea.org/islais-hyper-creek.

becomes impassable during nuisance flooding. Shoreline erosion is preventing recreational activity. Resilience strategies aim to create smart investments by providing solutions with multiple benefits. A grassy area near the neighborhood's elementary school will be redesigned to hold water during storm events while also improving playing fields, upgrading playgrounds and adding a walking path. Streetscape improvements consider stormwater as well as access, with enhanced sidewalks increasing connectivity for pedestrians and cyclists. An existing pedestrian walkway to a light rail station will be widened and improved to define a safer, more accessible route in and out of the neighborhood. The city says that the approach in this project demonstrates methods that could be expanded citywide. Norfolk obtained a $112 million grant from US HUD for the project and has designated the area a federal Opportunity Zone to attract private investment in economic development.

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Large-scale resilience projects can create the need and opportunity for the redesign of urban districts, and this creates the possibility of blending public and private investment within the framework of a resilience-based redevelopment project. These types of projects start with clarity about what is required for resilience-strengthening of an area, such as restoring a creek-watershed function in San Francisco or managing stormwater in Hoboken. Then the project considers what the linked redevelopment opportunities might be and how they might attract private investment.

In New York in 2019, the city concluded that a low-lying portion of Manhattan (the Seaport and Financial District) could not be protected from sea level rise and storm surges without extending the shoreline into the East River as a land barrier. Estimated cost of the project is $10 billion, with $6 billion for construction and $4 billion for drainage infrastructure. But just how the new land would be developed—as a park, as residential and commercial sites, or something else—and how much private capital might come into play has not been determined.

#5: Exploit Federal Funding Niches

Cities have identified some resilience-friendly federal funding streams and developed projects that fit program requirements, despite the fact that resilience-building funding from Washington is scarce.

New York worked with the Federal Emergency Management Agency to repurpose cost savings from FEMA funds initially allocated to the city's Rockaway Boardwalk reconstruction project after Hurricane Sandy. The city used these savings to create resilience projects in the Rockaway vicinity through FEMA's 428 alternative to public assistance program.[11] New York's public housing authority received $3 billion in federal grants for resiliency investments to move forward the design and implementation of measures across its 33 impacted developments. The city and the Health and Hospitals Corporation secured $1.8 billion from FEMA for resiliency investments at four hospitals and care centers.

Norfolk obtained planning assistance from the US Army Corps of Engineers as part of a larger post-Sandy effort that identified "hot spots" vulnerable to sea level rise along the North Atlantic coast of the US. The three-year study, with a projected cost of $3 million, assessed the feasibility of implementing solutions for systemwide and site-specific flood risk management. The completed study recommended a $1.4 billion project, including storm-surge barriers, nearly eight miles of floodwall, one mile of levee, 11 tide gates, and seven pump and power stations.

The city also obtained a $112 million grant from HUD's National Disaster Resilience Competition for its Ohio Creek Watershed Project, which involves a resilience park that connects two predominantly African-American neighborhoods and includes a flood berm, a restored tidal creek and wetland, and a multi-use sports field and places for community gatherings.

In 2018, the US Army Corps initiated a study of coastal protection for **San Francisco**. The Corps reported that its "South Pacific Division considers the San Francisco waterfront, protected by a seawall more than a century old and deemed likely to falter during a major storm surge or earthquake, to be the highest priority for new federal dollars, or what is known as new start investigations. The structure provides flood protection for downtown neighborhoods and if it fails, the city estimates water damage to property and business could run as high as $35 billion."[12]

Hoboken benefited from the US Department of Housing and Urban Development's "Rebuild by Design" competition, from which it obtained, with two other New Jersey cities, a $230 million award to reduce coastal and rainfall flooding. The funding from HUD's Community Development Block Grants-Disaster Recovery (CDBG-DR) program was released in 2017.

Charleston applied for FEMA funding to support the buyout of 51 repeated-flood properties. Most of the structures would be demolished to restore natural function in floodplains.

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[11] FEMA, "Following Alternative Procedures," https://www.fema.gov/alternative-procedures.
[12] USACE, "Reducing Flood Risk: San Francisco District Tackles Multiple Bay Area Flood Challenges," https://www.spn.usace.army.mil/Media/News-Stories/Article/1583363/reducing-flood-risk-san-francisco-district-tackles-multiple-bay-area-flood-chal/.

Federal policy has focused on short-term post-disaster relief and recovery and has provided incentives in the form of subsidized insurance for development in floodplains. It has been slow to incorporate climate change projections and resilience-building approaches into programs and funding.

Yet, as cities are showing, there have been some opportunities in federal programs to obtain capital for investment in resilience. For example, in 2018 HUD allocated $16 billion for states to use on disaster mitigation, paying for revamping stormwater drainage systems, raising homes and roads, building levees and seawalls, and other improvements. However, HUD has not yet issued any rules to guide applications for the funding. As of Fiscal Year 2018, FEMA can use 6% of its Disaster Relief Fund on pre-disaster mitigation. That year it had approximately $500 million in pre-disaster mitigation grants available through both pre-disaster mitigation and flood mitigation assistance. In the previous fiscal year, FEMA spent $429.1 million on Hazard Mitigation Assistance Programs.

These amounts are small fractions of all federal disaster spending and they hardly address the enormous investment needed for resilience. But as climate hazards worsen and post-disaster costs mount—for government and private insurers—it seems likely that demand for resilience-building federal funds will grow.

The challenge for cities, then, will not be just to identify and take advantage of whatever niched federal funding there is, but to help shape the quantity and rules of future federal spending on resilience.

#6: Tap State Government

Cities mine existing state programs, or seek to modify them, to obtain funds for local climate-resilience efforts. They contend that building resilience is not just a local government responsibility: cities contain large portions of states' populations and generate substantial amounts of economic activity in states.

Charleston elected officials are working with the South Carolina state legislature to obtain the ability to use more funding from the Accommodations Tax that supports tourism for flooding and drainage projects. This is not an increase in the tax; it's an expansion of what types of projects would be eligible for use of the funds (e.g., seawall improvement).

Hoboken tapped several New Jersey funding programs to support its resilience-building plans: a Clean Water Revolving Loan Fund, the New Jersey Green Acres program, and the New Jersey Infrastructure Trust.

Norfolk anticipates seeking state funding support for the state/local matching dollars (35% of the total) that would be needed should the federal government invest in the US Army Corps of Engineers' $1.4 billion plan for coastal stormwater protection of the city.

When **San Francisco**'s Seawall Finance Work Group identified strategies for funding the $5-billion project, it listed two state sources among primary recommendations, both of which would require state legislation: State Property Tax Increment Revenue generated from Infrastructure Finance Districts on Port of San Francisco property and a State Resilience General Obligation Bond. It gave lower priority to trying to tap other state programs, including the state's Cap and Trade program (on carbon emissions).

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State governments, like their federal counterparts, don't provide much resilience-building investment for their cities. Because states have been a center of funding for stormwater management infrastructure and many states have invested in open space acquisition and environmental protection, their existing investment programs may be usable for urban resilience building. But these are limited pots of money and they usually have not been sufficient to meet demand for traditional uses.

Several states have begun to allocate funding for resilience. California and Massachusetts have advanced substantial state investments in resilience, which could provide capital for **San Francisco** and **Boston**. California's Proposition 68, approved by 56% of state voters in 2018, will raise $4 billion for state and local parks, environmental protection and restoration projects, water infrastructure projects, and flood protection projects. In 2018, Massachusetts state government authorized over $2.4 billion in capital allocations for investments in safeguarding residents, municipalities and businesses from the impacts of climate change, and protecting environmental resources and improving recreational opportunities. About $501 million is earmarked for responding to and preparing for extreme weather, sea level rise, inland flooding and other climate impacts.

#7: Develop Financial Innovations

Cities explore the use of a range of innovative mechanisms for generating public and private revenue for climate-resilience projects, including district-scale financial structures. "Explore" means cities are considering, learning about, or participating in the design of innovations, but haven't started to use them in most cases. For now, they have mostly used traditional mechanisms to take care of near-term investment needs.

Boston's 2018 comprehensive analysis of resilience-financing possibilities included a discussion of "district-level financing" that would "capture value from a targeted district that benefits from publicly financed infrastructure. The funding could be generated by a special assessment on property taxes or a resilience fee based on a surcharge on water and sewer bills."[13]

Toward a Climate Resilience Financial System for US Cities

INC's 2018 report on climate-resilience finance identified six goal-categories in which more than 30 innovations were underway to generate public and private climate-resilience investment:

- Generating public revenues
- Managing financial risk
- Balancing burdens and benefits
- Aligning public policies
- Leveraging/catalyzing private investment
- Revising governance jurisdictions

Hoboken is looking at several possibilities: leveraging the insurance savings of property owners that could result from reduced flooding risks due to improved stormwater management; establishing a nonprofit "Friends of Hoboken" to raise donations for maintenance of green infrastructure in parks; creating a stormwater park associated with a public housing authority.

Miami Beach has considered establishing a special taxing district to support future beach re-nourishment projects. It considered insuring against the loss of tourism spending and related local tax revenue—making up 15% of the city's budget—due to storms of a pre-specified magnitude and other stresses.

Norfolk is contemplating how special districts might be created for neighborhoods willing to pay more in taxes for climate-risk reduction and is leveraging Opportunity Zones for resilience projects.

New York is considering use of resilience zones—business improvement districts—to raise funds. After Sandy, the Metropolitan Transit Authority, which serves the city, entered into a parametric-based catastrophe bond based on actual recorded storm surge heights in a number of zones around New York City. The insurance is for $200 million, with the annual premium set at 4.5% of that amount ($10 million). Immediately after Sandy, more than 20,500 donors contributed more than $58 million to the Mayor's Fund for hurricane relief, support which has aided recovery on many fronts, including $10 million toward repairing homes and more than $16 million for loans and grants to nonprofits and small businesses.

San Francisco's 450-acre development for as many as 8,000 homes on Treasure Island in San Francisco Bay would have buildings and streets elevated 3 feet above current 100-year flood elevations, with development setbacks, and drainage improvements. The city plans to use a

[13] David Levy, "Financing Climate Resilience: Mobilizing Resources and Incentives to Protect Boston from Climate Risks," Sustainable Solutions Lab, UMass Boston, April 2018, 21.

special-district model, a Community Facilities District, to collect taxes to pay for future sea level rise adaptation.

In a different innovative approach to obtaining capital for resilience, **San Francisco** and **New York** are participants in lawsuits against the five largest fossil fuel companies—BP, Chevron, ConocoPhillips, Exxon Mobil, and Royal Dutch Shell to recover the billions needed to fund climate change resiliency measures required to protect the city, city property, and residents from the ongoing and increasingly severe impacts of climate change. This includes physical infrastructure like coastal protections, upgraded water and sewer infrastructure, and heat mitigation measures, but also public health campaigns such as education programs to help protect residents from the effects of extreme heat. A US District Court dismissed the California cities' suit in late 2018, but cities asked an appeals court to reinstate it.

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The search for new ways to generate more *local* revenue seems likely to focus on the use of district-scale financial mechanisms:

- Resilience Districts. The use of special assessment/taxing districts to generate funds for resilience investments that entirely or mostly benefit property owners, businesses, and residents within the area that is being protected. Special districts are a known financial mechanism, typically authorized by state governments but implemented by cities. Some only tax increases in property value or economic activity, but others have broader powers including adding surcharges to utility bills. The authorizing statutes for various types of special districts may need to be amended to allow for certain types of resilience investments or to allow the district to borrow money against future revenues. Creation of special districts usually requires formal approval—by petition or vote—of property owners/residents within the district. It also requires a city to have a rationale for why certain resilience measures should be paid for by a targeted district rather than by a citywide source of revenue.

In this mechanism, the city attaches a revenue-capturing mechanism to specific people who are benefiting, through targeted risk reduction or reduced insurance costs, from specific resilience investments the city would be making.

#8: Pursue Equity in Resilience

Cities factor social and economic equity into funding and financing actions by serving economic development, housing, and other needs while investing in climate resilience. This is a relatively new practice, arising with broader urban concerns about the availability of affordable housing and historical patterns of racial discrimination in public and private investment as well as the disproportionate impacts of extreme events on lower resourced communities.

As cities employ the other strategies for investing in resilience building, their commitment to "equity in resilience" appears so far to focus on (1) investing in the resilience of low-income neighborhoods, involving them in planning (2) maintaining the affordability of public services and some housing and (3) ensuring that residential neighborhoods are designed for mixed-income occupancy.

Norfolk's Ohio Creek Watershed resilience-development project focused on investing in two low-income, predominantly African-American neighborhoods. The project signals the use of district-scale resilience redesign to incorporate equity into the city's resilience-strengthening plans, by investing in low-income areas. In some cities, plans of this sort raise concerns among residents of the neighborhoods that resilience investments will make the area more attractive for development of more expensive housing, leading to displacement of current residents.

Hoboken's Jackson Street green-infrastructure redevelopment project with Bijou developers required 10% of new residential units be affordable with a 40-year deed restriction. **Miami**'s general obligation bond that included funds for resilience, also contained funding for low-income housing in the city. **San Francisco**'s Islais Hyper-Creek design project noted the economic development opportunities that may be created through district-scale redesign for resilience. **New York City** dedicated HUD funding to resilience investments in lower resource communities.

In a related development, California's $4-billion resilience-oriented bond, approved in 2018, dedicated up to 20% of the funds to projects in communities with median household incomes less than 60 percent of the statewide average ($39,980 in 2016). The largest amount of bond revenue—$725 million—was earmarked for parks in park-poor neighborhoods.

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In June 2019, Earth Economics released an analysis of the potential environmental, social, and economic-displacement costs of a proposed 17-acre development in **Miami**'s low-income Little Haiti neighborhood. "As the impacts of sea-level rise intensify and developers look to higher ground to build new projects," the study noted, "Miami's low-income communities of color are at risk of displacement, particularly to climate-vulnerable neighborhoods."[14] It cited the loss of urban vegetation and its stormwater management and heat reduction benefits, the potential for reduced air quality, and the negative impacts of increased traffic congestion in the neighborhood. It calculated the cost of displacement as $22,000 over 10 years for each low-income household—in relocation, commuting, and flood-related costs—and noted that local businesses would lose customers, social networks would be fragmented, and costs to local

[14] Earth Economics, "Magic City Innovation District: A Snapshot of Potential Environmental and Social Costs of the Proposed Little Haiti Development," 2019, https://static1.squarespace.com/static/561dcdc6e4b039470e9afc00/t/5d02759f1e38b30001a4c9d4/1560442275234/CJP-LittleHaiti_FactSheet_0619-2.pdf.

government would increase. In short, the development project "runs the risk of perpetuating economic and racial inequities [and] contributing to unsustainable development practices that threaten Miami's log-term resilience."

This analytic examination of the effects of development on resilience, poverty, and urban design—who wins, who loses, who pays?—is an emerging feature of cities' development and political dynamics. When cities take social and economic equity into account, their investments in resilience take on new elements. They target the use of public investments and infrastructure differently. They see ways to use the construction of resilience-building green infrastructure to improve the quality of low-income neighborhoods. They look for ways to tie to resilience investments the development of economic opportunities for low-income people.

Mostly these pioneering practices serve to modify public resilience investments, rather than increase the amount of money available for resilience strengthening in the city. Sometimes they can be maladaptive, if, for example, cities perpetuate historic land use decisions by building new affordable housing in high-climate risk areas. Generally, cities pursuing equity in resilience have engaged equity at the project scale, rather than through citywide policies. In addition, some cities have found that residents in low-income districts fear that the main result of resilience investments in their neighborhood will be to attract private investment in development and more affluent residents, displacing current residents.

Toward Playbook 2.0

When San Francisco's Seawall Finance Work Group looked for funding sources to pay for what may amount to a more than $5-billion infrastructure project, it identified 48 possible sources. But when it scored the options' revenue-generating potential, timing, administrative complexity, political feasibility, and cost burden, it recommended nine primary and secondary strategies, six of them local, two involving the state, and one federal.

It's no surprise that a blend of sources from multiple levels of government will be needed for a city's large-scale resilience projects. But the San Francisco list of recommendations was not a catalog of known, already funded "plug-and-play" pots of money with clear rules for eligibility, access, and prioritization. Most of the items on the list were somewhat speculative. Three were scored by the work group as only "somewhat feasible" politically, five as "somewhat complex" or "complex" administratively. More detailed analysis revealed significant weaknesses for each strategy. Some would have to compete with other uses for the money, or need approval of the state legislature, or take years to establish.

These uncertainties reflect the newness and insufficiency of Playbook 1.0. It has emerged mostly from the efforts of individual cities that moved sooner and further than most other cities to grapple with grave, unavoidable climate risks and started to answer the "how-will-we-pay-for-it" question. Cities can use the strategies to patch things together for now, but Playbook 1.0 does not amount to the robust, sustainable system for urban climate resilience finance that is needed. It hints at, but does not establish, major elements of such a system: mechanisms for local revenue generation; mandates for private property resilience; standards for resilience-designed infrastructure; frameworks for state and federal government policies, regulations, programs, and funds to support urban resilience; development of financial innovations and ways to ensure equitable investment in resilience. Nor does it address the equally important question of who will actually design, build and manage resilience investments. What institution, or combination of institutions, will build the technical and project management capabilities to undertake these complicated projects and manage the work across multiple affected stakeholders?

Playbook 1.0 amounts to an initial attempt by some cities to address some of these elements. But there is much it does not do, with important questions it does not answer.

- **How will less affluent cities be able to pay for resilience building?**

The cities in the study tend to be well-heeled communities with access to substantial financial and technical resources. Six of the eight cities had median household incomes above or near the US median ($57,617 in 2016). Four of the eight (Boston, Miami, New York, and San Francisco) ranked in the top 10 US cities by total value of residential housing, a prime source of property tax revenue. Norfolk, a less affluent city, had access to financial, network, and consultant resources through the 100 Resilient Cities project pioneered by the Rockefeller Foundation (as did the other cities in the study except Hoboken).

Not all US cities have access to these levels of local financial assets to generate local revenue for resilience. Less affluent cities may also find it difficult to maintain the affordability of housing and utility services if they raise property taxes and utility rates to pay for resilience investments. Those that share a metropolitan area with more affluent cities may be unable to keep up with resilience-building investments that would keep their community attractive within the region for residents, development, and other private investment.

- **As increases in climate hazards drive up demand for urban-resilience investment, how will supply grow enough to meet the need?**

Demand for urban resilience investment will grow. The eight cities in the study are predominantly dealing with only some of the threats that climate change poses for cities—sea level rise combined with increased precipitation—and they are only dealing with the risks posed during the next several decades. But other cities face other climate risks—extreme heat, wildfire and river flooding, for instance—that also require substantial investment in resilience. Moreover, it is likely that actual climate hazards and potential risks will get worse over the longer run and will require more difficult and costly solutions. It's also safe to assume that demand for resilience investment will increase as more cities undertake and complete climate vulnerability assessments and resilience planning.

Where will the volume of resilience capital that will be needed, but that cities cannot produce, come from if not mostly from federal and state governments? This is not just a matter of quantity. When state and federal levels of government start to allocate more funding for resilience, what rules will determine eligibility, uses, matching requirements, and other conditions? Which resilience-financial innovations can and should gain traction?

- **How will private investment markets—municipal bond buyers, insurers, real estate developers, private property owners, and businesses—respond to increasing climate disasters and risks and rising urban costs for resilience strengthening?**

As private-investment markets assess the growing amount of information about climate risks faced by corporations, real estate owners, municipal governments, and other entities and sectors, they may decide to increase the price of capital, stop making certain new investments, and/or withdraw existing investments. All of these actions have already occurred, although they are not widespread, as we noted in a previous report, "Can It Happen Here? – Improving the Prospects for Managed Retreat by US Cities." Will it become more difficult to obtain private financing when high climate risks are involved? What will it take in incentives for government programs to leverage private capital for resilience building? Will, as BlackRock's recent analysis suggests,[15] the climate-driven economic vulnerability of cities affect their ability to borrow money from markets?

The availability and pricing of private capital in light of climate risks may also affect development patterns in cities, with the potential that favored projects and locations would exacerbate social and economic inequities.

Even if cities do identify adequate revenue sources for resilience investments, who will do the actual work of designing, permitting, building, and maintaining these investments?

These questions mean there is a great deal to be determined about Playbook 2.0. But in anticipation of a continuing evolution in climate-resilience finance, cities could take two steps:

- ***Prepare for and seek to influence state and federal decisions about funding climate resilience***. Cities should be ready when state and federal governments act, by having "shovel-ready" high-priority resilience projects based on thorough, comprehensive resilience assessments, plans, and designs. They should, if possible, build

[15] https://www.cbsnews.com/news/climate-change-could-deliver-a-4-trillion-hit-to-the-financial-system/

local funds that may be needed to leverage state and federal resources. When it comes to influencing the design of state and federal resilience-building funds, cities should advocate for rules that support equitable projects and regional collaborations of cities rather than competitions. Along with state and federal decisions about funds, cities will need greater clarity, uniformity, and authority about resilience standards and funding mechanisms.

- ***Prepare for and seek to influence private investment market responses to climate risks.*** Cities should consider what private capital for development is likely to require of the city in terms of resilience strengthening and determine what they will require of and do for private investment. This is best done in the context of a revisioning of the city's future in the climate-change era, much as Norfolk undertook, and in the design of district-scale resilience and development. It should incorporate design standards for resilience of buildings and infrastructure, equity standards for the benefits and burdens of resilience building, and clarity about how the costs of resilience will be shared by the public and private sectors.

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The US has previously assembled systems for massive, national-scale public and private investment in vital infrastructure and operations—resulting in large and sustained outlays made by multiple levels of government.

- Between 2000 and 2014, for instance, local, state, and federal governments invested about $500 billion in water and wastewater infrastructure. Local and state governments supplied more than 90% of the capital spending.[16]

- Between the mid-1950s and early-1990s, federal and state governments invested more than $500 billion (inflation adjusted) to construct the US Interstate Highway system. The federal government provided 90% of those funds.

Major investment systems like these require robust political consensus about the need to provide such investment, such as national security (highways) and environmental damage (water pollution); agreement among levels of government over who, including the private sector, will contribute how much of the funding and what type of funding (grants, loans, etc.); and the design and implementation of revenue-generating mechanisms, such as gas taxes, that can be targeted for specific purposes.

At best, US governments are at an early stage of meeting these conditions when it comes to public investment in urban-climate resilience. As climate changes and disasters increase, awareness is dawning among political leaders at all levels that climate-resilience building is necessary. But as of yet there is little serious discussion, much less negotiation, about what funding role different levels of government should play, where private capital fits, and how they would all be coordinated into a "plug and play" system. Nor is there discussion about which costs to allocate to the public and private sectors and what financial mechanisms can be revised or invented to enable revenue generation.

[16] CBO data cited in Shadi Eskaf, "Four Trends in Government Spending on Water and Wastewater Utilities Since 1956," Environment Finance Center, University of North Carolina, September 9, 2015, http://efc.web.unc.edu/2015/09/09/four-trends-government-spending-water/.

What's evident, then, is an evolutionary process that is barely a decade old, much as planning and implementing climate-resilience projects is becoming a new (and challenging) aspect of city planning and design. The process has been too slow and remains incoherent. But with a small number of cities driving much of the early momentum, Playbook 1.0 shows the leading edge of what is now possible and what still needs to be figured out.

Appendix: Climate-Resilience Financial Profiles of the 8 Cities in Study

The information in the following profiles is based on the research team's examination of public records and interviews with city officials. It was last up dated on June 1, 2019. The cities have not endorsed the information or guaranteed the accuracy of the information.

Boston

Overview

Boston is a high-density city of 672,000 residents on 48.4 square miles of land (plus 41 square miles of water). The median household income in 2016 was $63,621 (about 10% above the national level), about 35% of households are homeowners, and 21% of residents lived below the poverty line. The city has a strong mayor-council form of government.

The city is located mostly on low-lying land along a sheltered harbor off the Atlantic Ocean and is traversed by three rivers. Much of the harbor area was built on fill just above high tide.

Local sea level rise was about 9 inches in the 20th century. Between 1958 and 2010, the city (and region) experienced a 70% increase in precipitation that fell on the days of heaviest precipitation. Stormwater flooding occurs throughout Boston, as the city's drainage system struggles to manage intense rain events, rising sea levels, and less permeable ground surface that would slow and absorb stormwater. Common areas for stormwater flooding are along the coast, where outfalls may be unable to discharge; transportation corridors with impervious surfaces where water cannot percolate; and designed drainage areas whose capacities are exceeded.

The city's analysis projected sea level rise of about 8 inches by 2030, a three-fold increase in the pace. By 2050, levels may be as much as 1.5-feet higher than in 2000, and by 2070 they may be as much as 3-feet higher. Under a high-GHG emissions scenario, sea level could rise 7-10 feet by 2100. At the same time, an increase in extreme precipitation is expected to continue.

Rising seas will bring severely damaging floods on a monthly basis. There is a 1% chance that 5% of the city will be inundated in any given year. By midcentury, such a flood will be 10 times more likely and by the late 21st century it will occur at least once a month. Between 10- 20% of certain coastal districts of the city will face high-tide flooding even when there is no storm. Because of increasing precipitation, as soon as the 2050s, 7% of the total land area in the city could be exposed to frequent stormwater flooding from 10-year, 24-hour rain events.

Climate Resilience Plans and Projects

The city's "Climate Ready Boston" report divided the city into eight areas with significant coastal and riverine flooding risks. The city began detailed planning for four of these areas—Charleston, East Boston, South Boston and Downtown (with planning for a fifth area, Dorchester, set for late 2019)—and more general planning for coastal areas and Boston Harbor. When these neighborhood plans are completed, the city will have a fairly complete assessment of the long-term capital investments that will be required to protect the city from sea level rise and coastal flooding between now and the end of the century. These neighborhoods represent approximately 85% of the city's risk to sea level rise. Total implementation costs over the next couple of decades could range from $1.5- $2.5 billion.

East Boston & Charleston

The completed plans recommended short, medium, and long-term solutions to protect these two Boston communities. Total cost of all the recommended projects was estimated at between $154-262 million.

- The East Boston Greenway deployable floodwall was included in the City's FY19 capital budget and installed in July 2018.

- The Boston Planning and Development Agency issued a follow-up RFP for a consultant study on financing options for specific resilience projects in East Boston. The study was expected to be completed by April 1, 2019. The proposed infrastructure solutions were designed to protect from sea-level-rise enhanced storm surge and tidal inundation, as well as provide open space and neighborhood waterfront access opportunities. According to the plan, the measures could cost between $120-$200 million to construct for all waterfront areas of East Boston and $24-$39 million for the Border Street alignment projects.

South Boston

The neighborhood resilience plan recommends a detailed set of resilience investments in five different areas of South Boston. It is expected that the total cost of the proposed investments will be in the range of $513 million to $1 billion.

The "Climate Ready South Boston" report, released in March 2019, recommended completion by 2025 or 2030 of 10 resilience infrastructure projects in the Seaport Boulevard and Fort Point Channel areas of South Boston. The total estimated cost for the projects ranged from $106-196 million. Three projects—south end of Fort Point Channel and Seaport Boulevard near-term and intermediate-term—accounted for about 70% of the total cost.

Boston Harbor

In June 2018, the city issued an RFP seeking a consultant to produce design concepts for a harbor-wide resilient coastline, with more detailed concepts for key areas that present opportunities for new or improved resilient open spaces (which might include Long Wharf/Sargent's Wharf/Christopher Columbus Park, Charlestown Navy Yard, Moakley Park/Harbor Point, and Tenean Beach/Port Norfolk/Neponset Circle).

The Moakley Park Vision Plan is underway, led by the Boston Parks and Recreation Department in partnership with the city's Environment Department. This community engagement process will result in a conceptual design and implementation roadmap for a resilient, 60-acre waterfront park. It is scheduled to be completed in 2019.

In October 2018, Mayor Martin Walsh released his Resilient Boston Harbor vision that integrates a resilience vision for the full 42 miles of the City's shore line. As part of this release, the City committed to invest 10% of its annual capital budget on resilience projects.

The Boston Green Ribbon Commission commissioned a feasibility study of a harbor-wide barrier system by the University of Massachusetts—Boston. The report, published in May 2018, examined the potential impacts of a harbor barrier on sea level rise, storm surge protection, operation of the Boston harbor and waterfront, environmental quality and recreational use. The

study focused on barrier concepts that would maintain the viability of commercial shipping and protect the improvements to water quality and the marine environment that have been achieved in recent decades. The analysis found a barrier strategy to be operationally impractical and less effective, dollar for dollar, than continued investment in shore-based coastal protection solutions such as those described in the City's Climate Ready Boston plans. It recommended no short-term action on a harbor barrier, but a revisiting of the issue sometime in the next two decades.

Non-Infrastructure Measures

The Boston Planning and Development Agency (BPDA) and other parts of city government have begun the process of integrating resilience requirements into the city's planning and development structures. Some of the important developments include:

- The BPDA released an updated Climate Change and Resilience Preparedness Checklist under its Article 37 Green Building Guidelines. This was accompanied by a Flood Hazard Area Map showing, on a parcel by parcel basis, flood risks from a 1% storm event with 40 inches of sea level rise. Proposed developments are required to demonstrate how their projects will be resilient to this level of future risk.

- The BPDA also received a grant from Coastal Zone Management to begin development of a zoning Flood Resiliency Overlay District for the City. A consultant has been hired to support this project, with an expected completion date of June 2019. The overlay district will be based on the 40-inch sea level rise map.

- The BPDA adopted a Smart Utilities Policy for Article 80 Development Review that requires certain resilience standards for new utility investments in the City. For instance, they require the integration of green infrastructure design components into any developments in excess of 100,000 square feet, and also require analysis of the feasibility of installing microgrids for energy resilience

- The City is in the process of developing an implementation plan for the Infrastructure Coordination Committee (ICC) to develop resilience design guidelines for transportation, power, water, sewer and other infrastructure investments in the City. The ICC has not yet been formally launched. (To initiate this process internally, the Boston Public Works Department has developed resilient infrastructure standards to guide design and construction of elevated roadways, vegetated berms, elevated Harborwalks, and deployable flood barriers across the City.)

- The Environment Department has developed guidelines for resilience retrofits of historic properties, that will be shared through the Landmarks Commission website in the coming month.

- The City has also begun to incorporate resilience considerations in the design or redesign of various parks along the waterfront, including Moakley Park, Martin's Park, and Langone Park.

Funding and Financing Resilience Plans

An initial examination of potential approaches to funding Boston's sea level rise resilience needs roughly put the cost at $1-$2.4 billion and stated that "it is not realistic for the City of Boston to finance 100% of its resilience needs from existing general tax revenues and capital budgets."

The city does not have an overall plan for funding the emerging plans. For the South Boston projects, a process is underway to develop funding options, which could set a pattern for other areas and the overall city approach.

South Boston

Among the next steps that are being taken is the development of funding scenarios. The Green Ribbon Commission received a grant from the Barr Foundation to do a detailed analysis on options for funding the resilience projects that need to be completed by 2030. This analysis will include:

- Development of a financial analysis model to provide a comparison of funding options to determine and narrow which option provides better financial benefit to customers, including:
    - Projection of capital financing costs for financing structures for each project scenario. This could include public debt, private debt, grant options, or a mix of these and other financing elements.
    - Projection of operation and maintenance (O&M) costs for each project scenario and other known, miscellaneous and/or administrative costs for each project scenario.
    - Total amount of revenue needed each year to be recovered from specific customers or customer groups (to be defined leveraging existing information).
    - Impact of revenue recovery on specific customers or customer groups, particularly in light of what they currently pay to the City for services. This would attempt to derive an estimated annual revenue amount that customers would be responsible for paying for implementation of the project scenarios.

- Analysis of pros and cons of the different financing structures with respect to the results of the financial analysis. This will look at the benefits and drawbacks to potential financing structures, particularly their impact on customers.

- Analysis of the pros and cons of potential revenue recovery options for the project scenarios evaluated in the financial analysis model. This will look at the pros and cons of potential revenue recovery options, such as taxes, fees, and a mix of revenue recovery between customers.

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Charleston

Overview

Charleston is a low-density city of 134,000 residents on 109 square miles of land (plus 18.5 square miles of water). The median household income in 2016 was $61,367 (about the US median), about 54% of households are homeowners, and 14.5% of residents lived below the poverty line. The city has a mayor-council form of government.

The city is located on low-lying land in a peninsula along Charleston Harbor, an inlet of the Atlantic Ocean formed by the confluence of the Ashley, Cooper, and Wando Rivers. Most of the city is at elevations between 12-39 feet (average of 19 feet). In more recent decades, the city expanded its boundary and development into wet, low-lying areas.

In the last 100 years, the local sea level has risen 1.07 feet. In the past few years Charleston has experienced a marked increase in the number of days of "minor coastal flooding" due to tides. Since October 2015, three major events have caused historic flooding in streets, businesses, and homes. In 2015 Hurricane Joaquin dropped 20 inches of rainfall and caused an 8.2-foot tide, the highest since 1989. Hurricane Matthew in 2016 delivered a peak storm tide of 9.29 feet and 9-10 inches of rain. Irma in 2017, arriving at high tide, produced a 9.9-foot tide and 7 inches of rain.

Given sea level rise projection scenarios (from low to extreme) of 2-11 feet by 2100, the city has adopted a 50-year planning horizon based on a 2-3-foot rise. The 2-foot increase is intended for less vulnerable infrastructure such as parking lots; the 3-foot increase is for more critical infrastructure. The city also noted that potential changes in precipitation trends—specifically, increased frequency of precipitation—may occur.

Climate Resilience Plans and Projects

After Hurricane Matthew, much of the city's stormwater infrastructure needed repair. In February 2019 Charleston issued a "Flooding and Sea Level Rise Strategy" that built upon its 2015 strategy (which used a lower projection for sea level rise). The 2019 strategy includes investment in infrastructure to protect the most critical and vulnerable areas and changes in land use to direct growth to high, dry, and connected areas, as well as adaptation and retreat in higher risk areas.

Among the non-public infrastructure initiatives:

- Increase freeboard to 2 feet above Base Flood Elevation for new and substantially improved structures
- Improve the city's Community Rating System rating from the National Flood Insurance Program to reduce flood-insurance premiums
- Strengthen stormwater management regulations, including updating design standards
- Create design guidelines for retrofitting historic buildings. The guidelines focused on elevating sites with considerations for streetscape, site design, foundation design, and architecture/preservation (https://www.charleston-sc.gov/DocumentCenter/View/20433).
- Establish road design standards for SLR resilience (partnering with county and state DOT)
- Acquisition of repeatedly flooded properties (40-50 structures)

The city has 12 major infrastructure projects underway or set to begin soon with an estimated total cost of $512 million. Several other projects are being planned and costed out. The bulk of the costs, $483 million, involve 4 projects:

- Calhoun West Drainage Improvement ($200 million) – 800 acres on the west side of the city. Deep tunnel and pump system are needed; check valve installation and drainage pipe replacement, cleaning, and maintenance are underway. Estimated end: 2030-2035. (https://www.charleston-sc.gov/index.aspx?NID=1676)

- Spring/Fishburne Drainage Improvement ($197 million) – 500 acres on the west side of the city, a tunnel and pump project involving 8,200 linear feet of deep tunnel, outfall into the Ashley River, surface collection and conveyance system, and new pump station. Estimated end: 2023-2024. (http://charleston-sc.maps.arcgis.com/apps/MapJournal/index.html?appid=ead1e4ba1fba4ba1b260520f654e9710#)

- Low Battery Seawall Improvements ($54 million) – Extensive reconstruction to replace and raise seawall to address next 100 years of sea level rise. Adjoining sidewalk will be raised, and there will be improvements to streetscape, upgrading utilities, curbing, and pavement. Estimated end: 2025-2027. (http://charleston-sc.maps.arcgis.com/apps/MapJournal/index.html?appid=ead1e4ba1fba4ba1b260520f654e9710#)

- Market Street Drainage Improvement ($32.6 million) – a tunnel and pump project involving updates to existing pump station, new surface collection and conveyance system, more than 4,000 linear feet of deep tunnel, an emergency outfall, improvement to sidewalks and streetscape. Estimated end: 2023-2024. (https://www.charleston-sc.gov/index.aspx?NID=591)

Note that three of the projects (excluding Calhoun), with a total cost of $283 million, are supposed to be completed by 2027. A fifth project, Church Creek, which involves 5,000 acres of marsh and phosphate mines that are now 80% developed, recently received a price tag of $40 million (not included in the $512 million total above).

Funding and Financing Resilience Plans

The 2019 strategy contains a section on "Resources":

- Federal Funds
  - FEMA funds from Hazard Mitigation Grant Program and Hazard Mitigation Assistance. FEMA awarded city funding after 2015 and 2016 floods. It has applied for grants to acquire 51 structures in the floodplain—which will be demolished to restore natural function—and to elevate 3 structures there.
  - City is investigating obtaining Mitigation funding from Community Development Block Grant Recovery Program.
- State Authorized Funds
  - City (mayor) is working with state legislature to obtain ability to use more funding from the Accommodations Tax (supporting tourism) for flooding and drainage projects. This is not an increase in the tax; it's an expansion of what types of projects would be eligible for use of the funds (e.g., seawall improvement).

- Local Funds
    - The city's main source of funding for stormwater projects has been stormwater fees, which were raised recently, but they don't produce enough revenue to cover the drainage program.
    - The city's property taxes are relatively low and produce about half of the city's operating revenue.

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Hoboken

Overview

Hoboken is a high-density city of 55,000 residents and 1.2 square miles of land (plus .73 square miles of water). The median household income in 2016 was $118,479 (nearly double the US median), about 32% of households were homeowners, and 10.5% of residents lived below the poverty line. The city has a mayor-council form of government.

The city is characterized by a low topography and a prevalence of impervious surfaces. About 80% of the city lies within the FEMA designated Special Flood Hazard Area and is susceptible to local flooding from rain events and coastal flooding. About 75% of the city is located in a FEMA A-Zone and the eastern coastline, along the Hudson River, is tidally influenced and categorized as a FEMA V-Zone. (Both A- and Z-Zones are considered to have a 1% chance of flooding on an annual basis). The city's combined sewer infrastructure (stormwater and wastewater) is antiquated, and the city has insufficient pumping capacity.

Hoboken was substantially flooded by Hurricanes Irene (2011) and Sandy (2012). Irene brought a 5-foot storm surge to the Hudson River and 10 inches of rain. Sandy, which occurred during a full moon, generated a 13-foot storm surge (but less than 1-inch of rain) that resulted in 8 feet of water entering the city from vulnerable points along the waterfront. The city's vulnerability is increased by the location of combined sewer outfalls below the high tide level. When heavy rain coincides with a high tide in the Hudson River, excess stormwater cannot be discharged into the river, resulting in flooding that backs up into basements and streets in the lowest-lying areas.

The city's risk from flooding is increasing due to projected rising sea levels (high/king tides and storm surges) and increased precipitation. Studies show that today there is a 20-25% chance of bulkheads in the New York Harbor area being overtopped during a storm surge. In the future, Hoboken's sewer system outfalls and other critical infrastructure will be closer to mean sea level and will be inundated more frequently during high tides. It will take less intense storm surges to inundate outflows and back up drainage systems.

Climate Resilience Plans and Projects

Since Sandy, Hoboken has undergone a set of planning processes (Hurricane Sandy Recovery Plan, Resilient Capital Improvement Plan, Hazard Mitigation Plan, Open Space, Recreation and Historic Preservation Plan, etc.) that sum to a comprehensive climate-resilience plan. A key resilience-design process initiated through the Rebuild by Design (RBD) initiative, called "Resist, Delay, Store, Discharge," developed the City's comprehensive water management strategy to reduce coastal and rainfall flooding. The Resist phase will cost $230 million, with full award to be made by 2022.

High-intensity rainfall events, not sea level rise, is the primary driver of resilience measures and spending so far. The city assumes that sea level rise and transit resiliency will be the focus of state government in the next few decades. New Jersey is developing a coastal management plan and a comprehensive statewide strategy for resilience.

Major elements of the various Hoboken plans include:

- Installation of wet-weather pumping stations, including:
    - H5 Pump Station for the city's northwest section ($11.5 million)

- H1 Pump Station ($17.6 million).

- Green infrastructure projects, including:
  - First Street. Three green infrastructure installations designed as part of a comprehensive streetscape revitalization project for First Street, completed in 2016, which spans 12 blocks and includes 4 right-of-way bioswales,15 new shade trees, and other streetscape amenities.
  - Southwest Resiliency Park. City acquired Block 12 in southwest section for proposed park with passive recreational space, green infrastructure (rain gardens, shade tree pits, porous pavers, a cistern for rainwater harvesting and reuse) and an underground detention system to store 200,000 gallons of stormwater and reduce localized flooding from the 10-year storm event. ($8.5 million, total project)
  - Northwest Park. City acquired BASF site to create park and underground floodwater detention system. ($50 million total, including $30 million for the acquisition)
  - City Hall cisterns, rain gardens, porous concrete, permeable pavement, trees – reducing city hall monthly runoff by 47%. Completed in 2016. ($300,000)

- Coastal flood hazard mitigation projects, including:
  - The Resist phase of "Resist, Delay, Store, Discharge including the Hoboken Cove Resiliency Center and Boat House, a new park space, waterfront access along the Hudson River, critical shoreline protection and added amenities for enhancing access and enjoyment of the City's waterfront. The new park and boat house create a dual-purpose levee with parks and recreational facilities incorporated into the design. (Part of $230 million Resist phase)

- Floodproofing of critical facilities. Wet floodproofing projects at three firehouses.

- City policies that provide design guidelines for resilient buildings, minimization of runoff, legalization of rain barrels, endorsement of redevelopment projects, etc.

- Redevelopment projects including:

  - 7th and Jackson Stormwater Project/Resiliency Park. The project includes a deal with Bijou (developer) to provide the community benefits of a new two-acre park, public gymnasium, affordable housing, and flood resiliency measures. The park will manage the 10-year storm event, detaining nearly 470,000 gallons of stormwater to help address flooding issues in the area. The project includes construction of a mixed-use residential with 424 rental residential units (10% of them affordable units) and 30,000-square feet of retail space, and an on-site parking garage. The project won a Smart Growth Award from New Jersey Future in recognition of the project's resiliency efforts.

Funding and Financing Resilience Plans

Hoboken developed a six-year capital spending plan in the first quarter of 2018, including spending by the electric and gas utility, Suez Water, and the North Hudson Sewage Authority. It contains all projects GIS mapped and a spread sheet with all expenses. This was to be presented to the city planning board in 2019 and was not yet public.

To date, the city has spent an estimated $500 million on implementing its climate resilience plans and is about half way to implementing the full RBD plan. It has drawn funding from a large variety of public, philanthropic, and private sector sources. Sources include:

- Federal government. Sandy Recovery Plan (US Housing and Urban Development)
- State government. Clean Water Revolving Loan Fund, New Jersey Green Acres program, New Jersey Infrastructure Trust
- Local government. Hudson County Open Space Trust Fund, municipal bond (without raising property taxes for additional debt service)
- Philanthropy. Rockefeller Foundation
- Private. Bijou developer (community benefits agreement)

Other financial mechanisms in various stages of consideration include:

- Leveraging insurance savings. Based on fewer losses due to the protection created by a using insurance savings to fund stormwater management
- Municipal stormwater utility fees.
- Green infrastructure. Establishing a "Friends of Hoboken" nonprofit to raise funds for annual maintenance of green infrastructure in parks.
- Use of public housing authority for green infrastructure. Establishing a stormwater park associated with a Housing authority parcel that abuts New Jersey transit land.

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Miami

Overview

Miami is a high-density city with 463,000 residents and 36 square miles land (plus 20 square miles of water), making it one of the smallest major US cities by land mass. The median household income in 2016 was $34,901, about 32% of households are homeowners, and 24.9% of residents lived below the poverty lines. The city has a mayor-commission form of government.

Miami is located on a broad plain between the Florida Everglades and Biscayne Bay. The area's elevation never rises above 40 feet and averages around 6 ft above mean sea level in most neighborhoods, especially near the coast. The main portion of the city lies on the shores of Biscayne Bay which contains several hundred natural and artificially created barrier islands. The surface bedrock under the Miami area is limestone. The Biscayne Aquifer beneath the city provides the city with drinking water. Because of the aquifer, it is not possible to dig more than 15 to 20 ft beneath the city without hitting water, which impedes underground construction. For this reason, mass transit systems in and around Miami are elevated or at grade.

With its high-water table, porous limestone bedrock, and low elevation, Miami is already susceptible to flooding. Between 1992 and 2012, sea level rose roughly three inches in the region, and in recent years flood-prone locations have seen around six tidal floods per year. Prolonged flooding from strong storms has become a frequent event.

Miami uses sea level rise projects adopted by the Southeast Florida Climate Compact:

- By 2030, a rise of 6-10 inches above the 1992 mean sea level
- By 2060, a rise of 14-34 inches above 1992 level

With more than 15 inches of additional sea level rise projected by mid-century, flood-prone locations in Miami-Dade County's coastal communities could face roughly 380 high-tide flood events per year, and the extent of tidal floods would expand to affect new low-lying locations, including many low-income communities with limited resources for preparedness measures Salt water intrusion through limestone will encroach on drinking water reservoirs and kill non-salt tolerant vegetation. More intense hurricanes will produce higher storm surges and more rainfall. Miami may see increased frequency of Category 4 and 5 storms.

Climate Resilience Plans and Projects

In April 2017, the Miami Sea Level Rise Committee recommended the city commission obtain outside expertise to recalibrate land-use plans and standards for increased resilience

Miami has acted to upgrade its stormwater system to reduce flooding. It has installed 13 pump stations to remove water from flooding. For instance, the $3 million upgraded Brickell Village pump station can move 29,000 gallons of water a minute off the street and into the Miami River.

When the city proposed a nearly $200-million bond for resilience in 2017, which was approved by voters, it did not specify the projects that would be funded, because a new stormwater management plan was to be developed, taking sea level rise projections into account. It was expected that the first tranche of projects supported by the bond would focus on low-cost, high-

result investments such s tidal backflow prevention values and additional capacity at existing pump stations.

In 2019 the city is updating its comprehensive Stormwater Master Plan and coastal infrastructure plan to address flooding risks for the next 40-50 years. The stormwater plan update will provide:

- Comprehensive assessment of the city's roads, drainage infrastructure, and water management features
- Recommendations on infrastructure improvements that will reduce the frequency, severity, duration, and impact of flooding events
- Informed recommendations for multiple sea level rise scenarios
- Cost benefit analysis to prioritize the City's investments and inform Capital Improvements Plan
- Updated design standards for developers and land use and building code recommendations

In 2019, the first tranche of spending from the bond, the city advanced six resilience-oriented projects—design, bidding, planning, or construction—for a total of $11.1 million, with about $5.4 million for two of the projects from other sources.

- Alice Wainwright Park Seawall, $2.65 million
- Installation of Backflow Valves for Flood Control, $2.45 million
- Improved Drainage Outside of Priority Drainage Basins, $2.3 million
- Planning for Brickell Bay Drive Design, $1 million
- Jose Marti Park Flood Mitigation Study, $940,000
- Fairview Flood Mitigation, $1.8 million

The city considers these to be demonstration projects that will help the City's professional staff learn the effectiveness of water outfall back-flow valves; understand how to best address bayside and river waterfront storm surge and sea-level rise; explore drainage solutions outside major drainage basins; install a traditional pump station and drainage systems in a low-lying neighborhood; and use an advanced road design to provide enhanced mobility and meet resiliency requirements.

In March 2019 the city broke ground on the Fairview project in a low-lying neighborhood. Phase I of the project consists of the construction of a centralized and interconnected drainage collection system, raising existing roadways in the neighborhood, and constructing new driveway approaches and concrete curbs. Phase II will include construction of a stormwater pump station, drainage wells and design of a force main outfall to replace the existing gravity outfall. The pump station will include a backup generator to power it in the event of an electrical outage.

The planning for the Brickell Bay Drive project has larger implications for city resilience efforts. The city plans to release as RFQ for design and permitting of a new linear park that will also inform an update to city-wide waterfront standards that will maximize green infrastructure, enhance multi-modal connectivity and provide strengthen flood protection.

For the Marti Park project, the city is soliciting proposals for adaptive, resilient redesign of the park.

Funding and Financing Resilience Plans

In November 2017, Miami voters approved a $400 million general obligation bond, known as "Miami Forever," that contained $192 million dedicated to infrastructure for addressing sea level rise: to minimize flooding frequency, severity, duration, and impact and protect critical infrastructure and high-use areas, reducing financial and economic vulnerability. The bond was to fund storm drain upgrades, flood pumps and sea walls to curb flooding that has worsened in recent years and begin to fund an estimated $900 million - $1 billion in projects needed to brace the city against rising seas.

The bond was approved by 56% of voters. The bond's other funds were for roadways, affordable housing, public safety, parks and cultural facilities.

Key to the campaign was the city's decision not to raise taxes to pay for the bond. Instead, borrowing will only occur after debt from a 2001-issued bond is paid off. At the same time, city officials lowered the city's property tax rate. As a result, advocates of the Miami Forever bond noted, the average homeowner "will actually pay $55 less next year." They also pointed out that with approval of the bond, the city would take advantage of low interest rates in the market and the city's best bond rating in 30 years.

The outgoing and popular mayor (21 years in office) led the bond campaign. The incoming mayor (elected with 82% of the vote) was somewhat critical of the bond, noting that some stormwater projects specified had been conceived in 2012 stormwater plan before substantial SLR was taken into account.

After the bond was approved, Moody's Investors Service upgraded the city's primary bond rating from A1 to Aa2, citing the city's improved financial position, average debt burden and large, strong diversified economy, and the positive nature of the Miami Forever Bond Program. It noted that city resiliency was important to continue to grow tourism, population growth, and downtown development. The improved rating means a lower interest rate on the Miami Forever bonds.

The city established a Citizens' Bond Oversight Board to ensure the bond program has "transparent and accountable internal project management and progress reporting." The Board advises the mayor, city commission, and city administration.

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Miami Beach

Overview

Miami Beach is a high-density city of 93,000 residents on 7.1 square miles of land (plus 7.5 square miles of water). The median household income in 2016 was $53,531 (below the US median), about 37% of households are homeowners, and 16.7% of residents lived below the poverty line. The city has a commission-manager form of government with a ceremonial mayor.

The city is located on flat islands with an average elevation of 4 feet, a porous substrate, and a high groundwater table. 93% of buildings are in the FEMA Special Flood Hazard Area category. Nearly 30% of property in the city is within historic districts—2/3 of these properties are partially or fully at an elevation lower than 3.7 feet NAVD. The City has separate sewer and stormwater systems, both of which it is modernizing.

The city has experienced king tides, rainfall flooding, and groundwater flooding. Major storms have degraded the sand beaches. In the last decade there has been an increase in tidal elevations of approximately 1 foot and a marked increase in sunny day flooding due to king tides. The city has not had a disaster declaration in many years (and thus is not the recipient of federal disaster funds). The city's risk from flooding are increasing due to projected rising sea levels (high/king tides and storm surges), warming gulf waters and increased precipitation. Its tide monitors are showing elevations greater than those anticipated by sea level rise scenario models.

Miami Beach has used the sea level rise scenarios of the Southeast Florida Regional Climate Change Compact:

- A rise of 6-10 inches by 2030 (above 1992 sea level).
- A rise of 14-34 inches by 2060.
- A rise of 31-81 inches by 2100.

Climate Resilience Plans and Projects

Miami Beach created a 30-year planning horizon that accounted for a 12-inch projected increase in sea level, arriving at a base elevation of 2.7 feet NAVD. The city's plans for physical protection, which will need an estimated 15 years to be implemented, focus on:

- Improving drainage systems
- Elevating roads and public seawalls
- Installing pumps to replace gravity-based stormwater pipes that will drain about 7.5 inches of water in 24 hours and have a capacity of up to 30,000 gallons per minute
- Replacing aging water and wastewater pipes
- Renourishing beaches
- An integrated engineering plan (just started) for grey/green/blue infrastructure

As of 2018, the city is approximately 15% through implementation of this plan.

A key challenge in street elevations has been both the frustration of residents inconvenienced by road construction and concerns from property owners about the harmonization of private property with the elevated streets. In both cases, adding aesthetic improvements to the outcomes of roadway construction, communicating clearly with residents, and applying a

consistent approach while addressing street harmonization with individual concerned residents has helped.

The city is also grappling with how to help private property owners pay to elevate sea walls in front of their properties, a city requirement based on 2014 and 2015 resolutions that requires seawalls to be designed to reach 5.7 feet NAVD with an interim condition of 4.0 feet NAVD in consideration of existing homes. In addition to "leading by example" by installing various types of sea barriers and natural infrastructure on public property, the city is investigating various financing mechanisms to assist private property owners with their sea wall elevation costs.

Main infrastructure projects include:

- Pump infrastructure. Pumps, which are being built with backup generators, prevent sea water incursion onto land, a common occurrence given Miami Beach's porous substrate.

- Road elevation. In 2013, the city committed to raise roads to a 3.7-foot NAVD crown of road and back of sidewalk. The plan projected that nearly 60 percent of Miami Beach–owned roads will be elevated to meet the elevation goal.

- Groundwater monitoring. Miami Beach is installing 42 monitoring wells in nested sets of three at 14 different locations throughout the city to develop a comprehensive groundwater program. This plan accounts for groundwater as a key component of flooding in the stormwater management master plan and considers its direct interaction with surface waters and sea-level-rise effects.

- Coastal protection. In partnership with the Florida Department of Transportation, the city is currently upgrading the stormwater system and elevating Indian Creek Drive. This project will protect a hurricane evacuation route from tidal flooding and improve water quality going into the adjacent Indian Creek Waterway, which is part of the Biscayne Bay aquatic preserve. To enhance this project, the city is proposing the first in-water hybrid shoreline that includes a mangrove planter waterward of a new elevated seawall. Farther north, the Brittany Bay Park shoreline project has been redesigned to incorporate mangrove and wetland species by pulling the seawall into the park to create a living shoreline inside the existing park footprint. This project includes a walkway and waterway overlooks to connect the public with the natural environment. The Muss Park Seawall Enhancement project included the construction of a seawall, designed strategically to protect existing mangroves that had naturally recruited along the shoreline. This project pulled the seawall back into the park around the mangrove and created additional space to plant more red mangroves.

In addition, Miami Beach's policy actions (non-public infrastructure) include:

- Promulgating building code and land use requirements for new construction including standards for first-floor elevations, setbacks and water retention
- Establishing a freeboard above Federal Emergency Management Agency (FEMA) base flood elevation
- Introducing additional commercial building height standards
- Increasing setbacks and open space for single-family homes
- Requiring that new construction or substantial reconstruction on private property shall retain storm water runoff from the 5 year/24-hour storm of 7.5 inches of rainfall
- Requiring sea-level rise review criteria for land use.

Funding and Financing Resilience Plans

The initial estimated cost for drainage work, made about four years ago, was $400 million. This has increased to $650 million to include a number of revisions: expansion of the area to be protected; adding backup generators for pumps; increasing street sweeping and vacuum extraction of the pump apparatus to keep discharge clean; designing for a 10-year storm instead of a 5-year storm; more green infrastructure in neighborhoods. The city has spent $100 million so far.

Miami Beach is paying for this infrastructure work through three local revenue sources, stormwater fees, existing tax increment funds and General Obligation Funds:

- Stormwater fees. The city has tripled stormwater fees since 2009. In 2014 they were raised 84% to cover a $100M bond used to install pumps and raise roads. In 2016 they were raised 34% to cover the second $100 million in bonds. Stormwater fees are currently $22.67 a month.

- Existing Tax Increment Funds. The city plans to use $100 million generated by a Tax Increment Financing (TIF) district that is set to sunset in 2022. The money will be used for underground stormwater projects, thus decreasing the need to further increase stormwater rates.

- General obligation bond. City voters approved a $439 million bond in 2018 (70% yes vote) that included $198 million for improving neighborhoods and infrastructure ($117 million for "below ground" resiliency; $85 million for "above ground" aesthetics: sidewalks, lighting, landscaping, etc.). This was the first increase in property taxes in 20 years and indicated to the City that, in spite of residential frustration about the inconvenience of sea level rise mitigation, a majority was willing to pay to continue efforts to protect and enhance the city.

- Parametric insurance. The city considered insuring against loss of resort taxes--15% of Miami Beach's budget revenue--which can suffer in the event of shocks and stresses that decrease tourist visits and spending, including from coastal storms (but also e.g. due to other uncontrollable impacts on tourism like a zika outbreak or an economic downturn). The city investigated the viability of a trigger-based parametric insurance policy to pay out in place of resort taxes in the event of e.g. a storm of a certain magnitude or a zika outbreak of a certain size. But financial calculations showed that a better alternative to the insurance policy was to increase the resort tax in the event of a shock or stress decreasing tourist spending.

- Other. The city is also contemplating the creation of a special taxing district to support future beach renourishment. (The state/county pay for beach renourishment following storms.)

Currently, the city is working with consultants to derive a cost-benefit analysis for its current and future spending on sea level rise and stormwater management projects.

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New York

Overview

New York is the densest city in the US, with 8.6 million residents on 302 square miles of land (plus 165 square miles of water). The median household income in 2016 was $58,856 (below the US median), about 32% of households are homeowners, and 18.9% of residents lived below the poverty line. (The city has the highest number of billionaires of any city in the world, 103, and the highest number of millionaires per capita of major US cities.) The city has a mayor-council form of government.

The city is located on a natural harbor and there has been considerable land reclamation, especially in lower Manhattan, on the East Shore of Staten Island, and in the neighborhoods surrounding Jamaica Bay. New York has 520 miles of coastline. The city's average elevation is 33 feet, with the highest point, 409 feet above sea level, on Staten Island. According to the city comptroller, in 2014, $129.1 billion of property in the city was located within the 100-year floodplain. (FEMA has updated floodplain maps, but these were appealed by the city because of technical errors in the mapping. The city is currently working with FEMA on their New York/New Jersey Coastal Flood Study as a result of the appeal. In addition, the City will be working with FEMA on future-looking flood maps that take sea level rise sea level rise projections for the 2050s and beyond into account.)

Sea level rise in New York City has averaged 1.2 inches per decade (a total of 1.1 feet) since 1900, nearly twice the observed global rate over a similar period. In 2012, Hurricane Sandy flooded 50.6 square miles of the city—17 percent of the land mass—and in many areas the depth of floodwaters was unprecedented. Parts of the city have experienced king tides, while the frequency of heavy downpours is increasing.

Projected mid-range sea level rise for the city is 11-21 inches by the 2050s, 18-39 inches by the 2080s, and as much as 6 feet at the highest projection by 2100. Rising levels would increase the frequency and intensity of coastal flooding, leading to between a doubling and a 10-15-fold increase in the frequency of the current 100-year coastal flood by the 2080s. For the 100-year flood, the affected area would roughly double by 2100 compared to FEMA 2013 Preliminary Flood Insurance Rate Maps. For the 500-year flood, sea level rise would increase the affected area by 50%.

Also projected is an increase in mean annual precipitation of 4-11% by the 2050s and 5-13% by the 2080s and an increase in the number of days with extreme precipitation by the 2080s. It is expected that the number of most intense hurricanes will increase in the North Atlantic Basin, along with extreme winds and intense precipitation associated with these storms.

Climate-Resilience Plans and Projects

The City's coastal resiliency projects are focused on reinforcing coastlines and managing storm surge in certain low-lying neighborhoods to mitigate the impacts of sea level rise and erosion. In addition to infrastructure system upgrades and policies, this includes the development of berms, levees, raised shorelines, wetlands restoration, and other potential measures developed to mitigate existing or future flood risks from storm or other events.

In the aftermath of Hurricane Sandy, the Special Initiative for Rebuilding and Resiliency ("SIRR") Report, "A Stronger, More Resilient New York," made recommendations for the reconstruction and fortification of New York City shorelines to provide city-wide protection from future flooding caused by elevated sea levels. The city's 520 miles of coastline were mapped and optimized to determine what sea level rise strategies were most appropriate and cost beneficial, an analysis that underpins the Raise Shoreline program. (USACE is also analyzing coastal flood risk regionwide as part of the New York-New Jersey Harbor and Tributaries study). The Raise Shoreline program builds off of the SIRR analysis to address the vulnerability of New York City shorelines exposed to sea level rise and erosion by increasing the height of coastal edges and/or reinforcing the shoreline. The first phase of the Raise Shorelines program includes several low-lying neighborhoods in Queens, Staten Island, and Brooklyn.

A key resilience-design process was initiated through the Rebuild By Design (RBD) initiative, a competition of President Obama's Hurricane Sandy Rebuilding Task Force and the U.S. Department of Housing and Urban Development (HUD), with support from the Rockefeller Foundation. The most prominent of the submissions to this competition, known as the "Big U" concept, entailed protecting all of Lower Manhattan with stand-alone neighborhood compartments comprised of a mix of berms and deployable walls (land-based, onshore coastal protection). The RBD competition resulted in seven funded projects in the region, three of them in the city (two to be implemented by the city and one by the state). HUD awarded the city with $335 million to implement a compartment of the Big U concept, known as the East Side Coastal Resiliency project.

In 2018-19, the city announced a major revision to the East Side Coastal Resiliency (ESCR) project, changing the design for a segment of the project. In this area, East River Park will be elevated, allowing for flood protection to begin at the water's edge. The previous design had the flood protection alignment farther west, in the park adjacent to the FDR Drive. The revised design addresses constructability issues and will allow flood protection to be secured one hurricane season sooner.

Additionally, the City recently announced a comprehensive strategy to increase the resiliency of Lower Manhattan (LMCR) by investing approximately $500 million in projects in Battery Park City, The Battery, and the Two Bridges neighborhood. As part of this announcement, the City also unveiled plans to extend a portion of the city's shoreline into the East River to protect the low-lying and highly constrained Seaport and Financial District area, with a roughly estimated cost of $10 billion ($6 billion for construction, $4 billion for drainage infrastructure). Once completed, the LMCR projects—together with the adjacent ESCR project—will provide 4.7 miles of continuous coastal protection for the u-shaped area stretching from the north boundary of Battery Park City on the west side to East 25th Street on the east side.

Although the city has numerous infrastructure projects for resilience building, the main projects include:

- East Side Coastal Resiliency project (ESCR). The project spans from Montgomery at the south to the E25th Street to the north. Once constructed, the flood barrier would protect 110,000 residents from a concurrent rain and Sandy-like storm surge with a mix of flood walls, roller gates, swings gates, and improved drainage capacity. The total cost of the project is $1.45 billion, which includes $338 million of HUD funding and other city capital funding. (https://www1.nyc.gov/site/escr/index.page)

- Lower Manhattan Coastal Resiliency. The Battery Park City Authority (BPCA), with $134 million in city bonds, will develop coastal protection projects to adapt to new climate conditions. In The Battery, the City will elevate the waterfront esplanade and integrate a grassy berm at the back of the park. This design will preserve the look and feel of the existing park while protecting it and the neighborhood from a 100-year storm surge in the 2050s. In the Two Bridges neighborhood, the City will install a combination of flood walls and deployable flip-up barriers to protect the neighborhood from a 100-year storm surge in the 2050s, while also maintaining access to the waterfront.

- Lower Manhattan Coastal Resiliency - Financial District and South Street Seaport Resilience Master Plan. An analysis concluded that there were no feasible on-land projects in the Financial District and Seaport. For this area, the city will study and advance plans for a shoreline extension project that reduces risk for these neighborhoods. This $10-billion proposal needs various approvals from the US Army Corps of Engineers and the New York State Department of Environmental Conservation. The City will procure a team of engineers and designers by issuing a Request for Proposals. A "master planning process" for the project will be completed in 2021 and will identify the first phase of the project.

- Red Hook Integrated Flood Protection System. The City and State have committed $100 million to the study, design, and construction of an integrated flood protection system in Red Hook, Brooklyn. The project aims to make the waterfront community more resilient and better protected from future storms. (https://www.nycedc.com/project/red-hook-integrated-flood-protection-system)

- USACE East Shore of Staten Island Coastal Storm Reduction Project. A 5.3-mile, $615-million seawall will function as both a barrier during major flooding events, and a recreational space with a boardwalk, bike paths, beach access, and other public spaces. This project has been designed to leverage and enhance the City's Bluebelt program (a green-grey drainage plan, initiated in the 1990s, that is restoring freshwater wetlands to serve as stormwater conveyance). When the project is completed, Bluebelts on the East Shore will function as both stormwater conveyance for rainfall events and interior drainage for detention of rainfall and overtopping during surge events.

- USACE East Rockaway to Rockaway Inlet Reformulation. The City is partnering with USACE to construct an approximately $550 million system of flood-risk reduction measures on the Rockaway Peninsula. USACE will construct a reinforced dune and new tapered groinfield on Rockaway Beach as well as a mix of berms, floodwalls, and nature-based features in Bayfront neighborhoods.

- Public Housing Resilience. The city's public housing authority received $3 billion in federal grants for resiliency investments to move forward the design and implementation of this program across its 33 impacted developments.

- Hospital Resilience. The City and Health and Hospitals Corporation secured $1.8 billion from FEMA for resiliency investments at Bellevue Hospital Center, Coney Island Hospital, Coler Rehabilitation and Nursing Care Center, and Metropolitan Hospital.

- Wastewater Resiliency Plan. The city's 2013 plan evaluated flood vulnerabilities, likelihoods and impacts of failures, and appropriate adaptation strategies for much of the City's wastewater infrastructure. Nine projects covering 21 locations have been initiated

as part of a $161 million portfolio to floodproof critical equipment at treatment facilities by implementing a combination of the following adaptation strategies: installing permanent and/or temporary barriers, sealing buildings, elevating or floodproofing critical equipment, and installing backup power systems.

- Cloudburst Resiliency/Green Infrastructure. The city's Department of Environmental Protection has been working with partners at the Department of Transportation, the Department of Design and Construction, and the New York City Housing Authority to initiate design of two pilot "cloudburst" resiliency projects leveraging a partnership with the City of Copenhagen. These pilots build off of the city's Green Infrastructure Program to reduce stormwater runoff into the sewer. The cloudburst projects will help manage extreme rainfall events in St. Albans and the South Jamaica Houses by capturing up to 2.3 inches of rainfall per hour. The project provides a proof-of-concept for using green infrastructure to mitigate the effects of cloudbursts and will help reduce nuisance flooding in Southeast Queens while enhancing the local landscape. (https://www1.nyc.gov/html/dep/html/stormwater/using_green_infra_to_manage_stormwater.shtml)

- Bluebelts. Approximately a third of Staten Island's land area is served by its Bluebelts, which are composed of networks of streams, wetlands, and other natural features to filter and help manage storm water before it reaches the harbor. For more than 20 years, the Department of Environmental Protection has built Bluebelts throughout south Staten Island to improve drainage. In the South Richmond and mid-island areas, the city has purchased approximately 400 acres to install the Bluebelt systems that support better drainage and wetland preservation. The Bluebelts also provide important open spaces and serve as a habitat for diverse wildlife. There are over 70 Bluebelt features currently installed on Staten Island, with additional sites in planning and currently in construction. In 2017, DEP completed the largest ever expansion of the Bluebelt system with the addition of the Sweet Brook Bluebelt, serving the Woodrow area with improved infrastructure to help better manage precipitation and reduce localized flooding.

In addition to these infrastructure projects, the city has undertaken a number of policy/regulatory steps to boost climate resilience, including:

- Climate Resiliency Design Guidelines. In March 2019, the City released the latest version of the Climate Resiliency Design Guidelines (CRDG), to ensure both new construction and retrofit capital projects, are designed to withstand hazards in a changing climate. These guidelines include practical information for incorporating projected data on extreme heat, intense precipitation, sea level rise, and storm surge into the design of buildings and infrastructure. CRDG also includes a methodology for how to conduct a benefit-cost analysis that accounts for climate-related hazards and resilient design investments. (https://www1.nyc.gov/assets/orr/pdf/NYC_Climate_Resiliency_Design_Guidelines_v2-0.pdf)

- Building Code. The city made 16 improvements to its building code to address new climate threats and issued a guide to retrofitting residential buildings for flood risk.

- Development Restriction. Establishing a Hamilton Beach and broad channel special coastal risk district and rezoning to limit future development in two areas highly vulnerable to sea level rise.

Funding and Financing Resilience Plans

In 2013, the US Congress allocated more than $50 billion to fund recovery efforts for Hurricane Sandy, with nearly $17 billion earmarked for projects in New York City. The city administers over $14 billion in federal grants for Sandy recovery and resiliency projects. FEMA-Public Assistance provided $9.6 billion, HUD's CDBG-Disaster Recovery, $4.2 billion, and several other programs the rest. At the same time, the federal government administers more than $2.4 billion in Sandy recovery projects, including US Army Corps of Engineers, $840 million; FEMA-Individual Assistance, $595 million; and about $1 billion from three other agencies.
At the time of its release, the city's SIRR implementation plan has a $19.5-billion, 10-year budget that includes $14 billion for capital expenditures and study costs, and $5.5 billion for housing, business, city agency recovery and resiliency costs. Project budgets and funding have changed since the plan's release as costs and funding sources have developed These funds come from a mix of sources:[17]

- Federal Funding. Sandy-related federal aid (from US Housing and Urban Development, FEMA and some US Army Corps of Engineers projects), with some city capital budget funding, some of it as part of a required match to federal funds (but none driving new taxes) amounts to $10 billion. This total includes about $145 million from FEMA's 428 Alternate Resiliency Projects, for 7 resilience projects at the Rockaway sites. The funding was made available through the capture and repurposing of the City's cost savings from the $480 million Rockaway Boardwalk reconstruction.

- City Funding. The city's capital program will provide $5 billion, with some federal funding (HUD, USACE) mixed in. Funding for the estimated $5-10-billion South Seaport-Financial District project has not yet been identified.

- Other. The balance of $4.5 billion for the SIRR may include the use of "resilience zones" (business improvement districts) as well as other city funds.

In addition:

- Utilities. Two energy-utility rate cases have resulted in funding for resilience efforts. The 2013 Con Edison rate case resulted in that utility investing $1 billion in flood risk mitigation for electric, gas, and steam facilities and other assets and created a city/utility collaboration for storm hardening. In the 2016 National Grid rate case, about $250 million was raised annually to help modernize pipeline infrastructure and customer information technology systems, and also created a City/utility collaborative effort to prioritize future storm hardening investments. (https://www.nationalgridus.com/Our-Company/Rate-Case-2016-LI)

- Federal Transit Funds. The Metropolitan Transit Authority, a state agency that serves the 12-county New York metro area, created a Climate Adaptation Task Force and received $10.5 billion in emergency relief from the Federal Transit Administration. Half of that amount is being spent on resilience projects including repairing and sealing

[17] The Sandy Funding Tracker site tracks the city's response to Hurricane Sandy, including over $14 billion in federal funding supporting numerous city recovery and resiliency programs and project sites. While the federal government ultimately finances these grants, in practice the City pays upfront for costs associated with grant-funded activities and is later reimbursed. https://www1.nyc.gov/content/sandytracker/pages/

tunnels, making substation assets more resistant, and elevating critical equipment and sealing vents and station doors during a storm, and sealing signal and communication rooms and equipment at vulnerable stations.

- Parametric Insurance. After Sandy, the Metropolitan Transit Authority decided to expand its risk transfer protection and entered into a parametric-based catastrophe bond based on actual recorded storm surge heights in a number of zones around New York City. The insurance is for $200 million, with the annual premium set at 4.5% of that amount ($10 million).

- Donations. Immediately after Sandy, more than 20,500 donors contributed more than $58 million to the Mayor's Fund for hurricane relief, support which has aided recovery on many fronts, including $10 million toward repairing homes and more than $16 million for loans and grants to nonprofits and small businesses.

- Emissions Lawsuit. In January 2018, New York City filed a lawsuit against the five largest fossil fuel companies—BP, Chevron, ConocoPhillips, Exxon Mobil, and Royal Dutch Shell to recover the billions needed to fund climate change resiliency measures required to protect the city, City property, and residents from the ongoing and increasingly severe impacts of climate change. This includes physical infrastructure like coastal protections, upgraded water and sewer infrastructure, and heat mitigation measures, but also public health campaigns such as education programs to help protect residents from the effects of extreme heat.

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Norfolk

Overview

Norfolk is a medium-density city of 247,000 residents on 54 square miles land (plus 42 square miles of water). The median household income in 2016 was $46,467, about 41% of households are homeowners, and 19.9% of residents lived below the poverty line. The city has a mayor-council form of government.

The city is on a low-lying, subsiding land with the Elizabeth River to the west and the Atlantic Ocean to the north and east. With 144 miles of shoreline, it is particularly vulnerable to sea level rise, which is occurring at twice the global average and at the highest rate along the Atlantic coast, according to the U.S. Geological Survey.

The city is 97% developed. Its infrastructure is aging, with many community facilities more than 50 years old, including 9 of 14 fire stations and 25 public schools. The city needs new transportation and utility infrastructure to support higher densities in designated areas. It is estimated that extension of light rail within city might cost $1 billion.

Some areas of Norfolk already flood regularly at high tide. Ten times a year, the US Naval Station in Norfolk, the world's largest navy base, floods: the entry road swamps; connecting roads become impassable; crossing from one side of the base to the other becomes impossible, and at dockside, floodwaters overtop the concrete piers, shorting power hookups to docked ships.

Seas are projected to rise as much as 1.5 feet by 2050—and the rate of rise has been increasing. Scientists at the Virginia Institute of Marine Science estimated in 2013 that if current trends hold, the sea in Norfolk will rise by 5.5 feet or more by the end of this century. Some projections are for 6.5 feet or more by 2100—a scenario that would inundate nearly 40% of the city at least twice a month, according to an analysis by the Union for Concerned Scientists.

Climate Resilience Plans and Projects

Norfolk has undertaken a number of planning efforts, with major studies including a 2014 coastal resilience strategy, which recommended elevating new construction; a 2015 resilience-visioning effort supported by 100 Resilient Cities, and a 2017 coastal stormwater management feasibility study by the US Army Corps of Engineers. The city's comprehensive plan, "plaNorfolk2030," encourages planners to consider the effects of sea level rise on all development activities.

The 2015 visioning exercise, "Norfolk Resilient City," yielded a strategy with three goals for the city:

- Design a coastal community capable of dealing with the increased risk of flooding
- Create economic opportunity by advancing efforts to grow existing and new industry sectors
- Advance initiatives to connect communities, deconcentrate poverty, and strengthen neighborhoods

The study provided a new framework for thinking about the city's development patterns but did not lay out specific projects. The framework divides the city into four color-coded zones. Green

and purple represent relatively safe areas where the city should focus future development and improve existing neighborhoods. The red zone—mostly downtown and the Naval base—are areas of dense development that need protection. The yellow zone represents areas where the city can't afford to build expensive flood protection but must instead rely on some combination of adaptation and retreat.

In 2017, the Army Corps recommended more than $1.4 billion in structural upgrades to protect Norfolk from flooding, including four storm-surge barriers, nearly eight miles of floodwall, one mile of levee, 11 tide gates, and seven pump and power stations. Four areas of the city were identified as most vulnerable. The plan identifies structural and non-structural solutions citywide and within specific districts of the city. For example, it calls for extending the existing downtown floodwall north into West Ghent and east to Harbor Park and creating four new storm-surge barriers:

- Across the Lafayette River, from Norfolk International Terminal to the Lambert's Point golf course
- Across Broad Creek, south of Interstate 264
- Across Pretty Lake, around Shore Drive in East Ocean View
- Across the entrance of the Hague

Norfolk has also blended resilience building with redevelopment of low-income neighborhoods that experience tidal and rainfall flooding. The Ohio Creek Watershed Project involves a resilience park that connects two predominantly African-American neighborhoods and includes a flood berm, a restored tidal creek and wetland, and a multi-use sports field and places for community gatherings. The neighborhoods include 400 houses on the Historic National Register and 300 units of public housing. One of the only two roads connecting the area to the rest of the city becomes impassable during nuisance flooding. Shoreline erosion is preventing recreational activity. Resilience strategies aim to create smart investments by providing solutions with multiple benefits. A grassy area near the neighborhood's elementary school will be redesigned to hold water during storm events while also improving playing fields, upgrading playgrounds and adding a walking path. Streetscape improvements consider stormwater as well as access, with enhanced sidewalks increasing connectivity for pedestrians and cyclists. An existing pedestrian walkway to a light rail station will be widened and improved to define a safer, more accessible route in and out of the neighborhood. The city says that the approach in this project demonstrates methods that could be expanded citywide. The city obtained a $112 million grant from US HUD for the project and has designated the area a federal Opportunity Zone to attract private investment in economic development.

Norfolk has adopted a number of resilience-oriented policies affecting development:

- All new construction must have a 3-foot freeboard above FEMA's base flood elevation, a 2-foot increase in existing requirements.
- Existing structures must comply with the 3-foot freeboard requirement if two flood damage events occurred—each totaling 25 percent or more of the market value of the structure—or if the building was structurally damaged or altered.
- New buildings must capture at least the first 1.5 inches of rainfall on-site.

In addition to elevation of buildings, the USACE feasibility study identified a number of "non-structural" measures for the city to use, including protection of water treatment plants, stormwater storage improvement, wetlands development, and acquisition or relocation of highly at-risk buildings.

Funding and Financing Resilience Plans

Norfolk has been budgeting for capital outlays to address street flooding throughout the city. Its Capital Improvement Plan for 2012-2016 contained $4.5 million and $6.5 million for a beach stabilization and erosion control initiative.

The USACE report said 65% of the projected $1.4-billion cost for stormwater management would be paid by the federal government. That requires a congressional authorization for projects and then appropriations for project construction. The balance would be funded by unspecified state or local sources. In 2019, the Commanding General of the U.S. Army Corps of Engineers approved the project. A congressional decision may occur as early as 2020, with construction beginning by 2026. In the meantime,

The city adopted a property tax increase of $.01 per $100 assessed value that is dedicated for resilience efforts—it's called "the resilience penny." The tax generates about $1.8 million a year and can be used as the repayment source for a bond issue of up to $20 million repaid over 20 years. These funds could provide some of the local/state match for federal funds. Norfolk may also seek state funding support for the match.

The city is considering other ways to generate local funds for resilience: increasing stormwater rates, creating special districts for neighborhoods willing to pay more in taxes for climate-risk reduction.

The city has also attracted funding for resilience efforts linked to redevelopment of neighborhoods. It obtained a $112 million grant from US HUD for its Ohio Creek Watershed Project and has designated the area a federal Opportunity Zone as a way to attract private investment for economic development.

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San Francisco

Overview

San Francisco is a high-density city with 884,000 residents on 47 square miles of land (plus 185 square miles of water). The median household income in 2016 was $103,801, about 43% of households are homeowners, and 10.1% of residents lived below the poverty line. The city has a mayor-council form of government.

The city is on a peninsula, its western shoreline on the Pacific Ocean and the rest of the urban coast along San Francisco Bay. Although the city faces a variety of climate risks, the condition of its 100-year old seawall has attracted substantial attention and there is a plan to upgrade it and a cost estimate. The seawall protects downtown San Francisco with its numerous jobs and transit passengers. The seawall also supports the area's numerous parks and open spaces, with recreation, as well as restaurants, food vendors, businesses, commercial fishing, tourism, transportation, and the natural environment. Residents from lower socioeconomic backgrounds rely on the utility and transportation networks that would be disrupted should the seawall fail during a seismic or flooding event. A 2017 study concluded that there is between $24.6 billion and $102.1 billion at risk depending on the size of a seismic event and assumptions made on the level of sea level rise.

Sea level rise projections from the state Ocean Protection Council were increased recently to a maximum of 122 inches by 2100 from a maximum of 66 inches. The projection includes both sea level rise, which will account for 11 to 24 inches by 2050, and coastal erosion and shoreline flooding. In San Francisco, preliminary findings suggest that between 17 and 84 miles of streets, 242 to 704 acres of open space, 335 acres to 1,203 acres of public land, and 2 to 20 schools will be affected by flooding between 2030 and 2100. The assessment found that roughly 6 percent of land area along San Francisco's coastal areas is vulnerable to sea level rise. Land subsidence is also a concern.

Climate Resilience Plans and Projects

In 2016, San Francisco completed a number of reports that examined the city's climate vulnerabilities. "Resilient San Francisco" called for the city to "complete a disaster-resilient waterfront by 2040."

Also in 2016 the Port of San Francisco completed a study that concluded that the northeastern waterfront is highly susceptible to earthquake damage because the city's seawall was built prior to the development of engineering techniques that account for seismic risks and land liquefaction. In addition, the waterfront is vulnerable to sea level rise.

As city planning took sea level rise into account, a mix of approaches were considered in different areas, among them:

- Ocean Beach, along the Pacific Ocean, recommended a retreat strategy with rerouting of a major highway, protection for a wastewater tunnel, and improvements of natural infrastructure on the shoreline.
- Pier 70/Port of San Francisco would be reconstructing major portions of the shoreline for flexible recreation and habitat uses, as well as strategic site grading to allow the Bay to reclaim portions of the site.

- Treasure Island, a low-lying 450-acre development in San Francisco Bay, would have buildings and streets elevated 3 feet above current 100-year flood elevations, with development setbacks, and drainage improvements.
- San Francisco International Airport, which has already protected much of its 8-mile shoreline, would undertake additional protection measures where there are remaining flood risks.

In 2017 the city also initiated a Resilient By Design challenge for the Bay Area, with financial support from the Rockefeller Foundation. The challenge's premise was "to connect internationally-renowned experts with local communities to inspire innovation and catalyze designs, ideas and collaboration toward a more resilient future."[18] Nine design teams assembled, conducted research, engaged with local advisory groups, and submitted design proposals in May 2018.

Funding and Financing Resilience Plans

Capital Planning Guidance re SLR

In September 2014 the SF City and County Capital Planning Committee (CPC) issued instructions to all departments for incorporating SLR into capital planning. The CPC makes recommendations to the Mayor and Board of Supervisors on all city capital plans. It is chaired by the City Administrator and includes all capital-intensive department heads, chair of the Board, the Planning Director, Controller, and Mayor's Budget Director. Each year the CPC reviews and approves the city's Capital Budget and any issuance of long-term debt for infrastructure projects. It also approves the city's 10-Year Capital Plan, which is sent to the Mayor and Board for final adoption.

The Guidance was to be revisited four years from publication in order to allow incorporation of new science after two capital planning cycles have been completed. Revision of the Guidance sooner than this will occur if new information comes to light requiring significant adjustment of sea level rise projections or other elements of the Guidance.

The Guidance requires (1) SLR science review, (2) Vulnerability assessment, (3) Risk assessment, and (4) Adaptation planning.

$500 million SF Bay Clean Water, Pollution Prevention and Habitat Restoration Tax (2016)

In June 2016, voters in a 9-county area, including SF, approved Measure AA by more than the state-required 65%--a regionwide local tax to fund nature-based flood protection through wetlands, habitat restoration, and pollution-removal projects. Although no specific projects were part of the tax proposal, it was claimed that the impact of projects would nearly double the 40,000 acres of tidal marsh that remain in the Bay.

The special parcel tax, a kind of property tax, of $12 a year per taxable parcel, would last 20 years. It taxes each parcel equally and is expected to raise $500 million in total.

From Measure AA Text:

[18] http://www.resilientbayarea.org/about

> "The purpose ... is to protect and restore San Francisco Bay to benefit future generations by reducing trash, pollution, and harmful toxins, improving water quality, restoring habitat for fish, birds, and wildlife, protecting communities from flood and increasing shoreline public access and recreational areas. ...
>
> "3. Integrated Flood Protection Program - The purpose of this program to be funded under the Measure is to use natural habitats to protect communities along the Bay's shoreline from the risks of severe coastal flooding caused by storms and high water levels."

Funds will be managed by the SF Bay Restoration Authority, established by state law in 2008, "to raise and allocate resources for the restoration, enhancement, protection, and enjoyment of wetlands and wildlife habitats in the San Francisco Bay and along its shoreline." The Authority's allocation of funds is governed by several provisions in the Measure, including

- It must give priority to projects that meet the selection criteria of the Coastal Conservancy's San Francisco Bay Area Conservancy Program and are consistent with the San Francisco Bay Conservation and Development Commission's coastal management program and with the San Francisco Bay Joint Venture's implementation strategy.
- It shall ensure that 50% of the total net revenue generated during the 20-year term of the Special Tax is allocated to the four Bay Area regions, defined as the North Bay (Sonoma, Marin, Napa and Solano Counties), East Bay (Alameda and Contra Costa Counties), West Bay (City and County of San Francisco and San Mateo County) and South Bay (Santa Clara County) in proportion to each region's share of the Bay Area's population, as determined in the 2010 census, and consistent with the priorities set forth in this section. As a result, each region will receive the following minimum percentage of total net revenue generated during the 20-year term of the Special Tax: North Bay: 9%, East Bay: 18%, West Bay: 11%, South Bay: 12%. The remaining revenue shall be allocated consistent with all other provisions of this Measure.

Seawall Funding

In 2017 San Francisco's Seawall Finance Work Group looked for funding sources that could pay for what may amount to a more than $5-billion project, and identified 48 possible strategies. But when it scored the revenue generating potential, timing, administrative complexity, political feasibility, and cost burden of the options, it recommended nine primary and secondary strategies, six of them local, two involving the state, and one federal:

Primary recommendations:

1. General Obligation (G.O.) Bonds, specifically the $350 million Seawall Fortification Bond proposed in the City's 10-Year Capital Plan.
2. A Community Facilities District (CFD) to fund sea-level rise adaptations and seismic mitigation measures on the Seawall.
3. Local Property Tax Increment Revenue generated from Infrastructure Finance Districts (IFDs) over development areas on Port property.
4. State Property Tax Increment Revenue generated from IFDs on Port property, to be pursued through legislation at the State level.
5. State Resilience General Obligation (G.O.) Bond funding pursued through legislation at the State level.

6. U.S. Army Corps of Engineers Funding at the federal level through the CAP 103 Program and a General Investigation.

Secondary recommendations that could also produce meaningful proceeds for the Project:

7. Port Capital Contribution – specifically $6-9 million in planned funding and resources over the next 10 years.
8. Sales Tax Increase Revenue pursued through a citywide Sales Tax Increase.
9. Tourism & Hotel Funding Sources that could take the form of a Hotel Assessment District or a general Transient Occupancy Tax (TOT) dedicated to support the Project.

$425 million Embarcadero Seawall Bond (2018)

Proposition A was approved by 82% of voters (206,000+) in November 2018. Based on a 2016 study by the Port of SF Commission, the proposition was put on ballot by the SF Board of Supervisors (unanimously). Funds will be used for first phases of seismic and sea level rise/flooding improvements as part of an estimated $5 billion project, about $3 billion for seismic retrofitting. Specific projects were not identified in the bond proposal.

The seawall stretches from Fisherman's Wharf to Mission Creek. It's essentially the foundation that keeps the waterfront in place and protects from the threat of potential daily flooding. Constructed between 1879 and 1916, the Seawall made possible the transformation of three miles of shallow tide lands.

There was no organized resistance to Prop. A. More than $1.3 million was raised for the Yes on A campaign, much of it from developers and local businesses, including Dignity Health, Facebook and Salesforce. A January 2018 survey by the Port of SF found that 73 percent of San Francisco residents would back a measure paying for seawall upgrades even though just one in three residents were aware that the wall is a crucial backbone of the city's waterfront.

The bond debt will be paid by existing parcel taxes, as older bonds retire. A's bond will fund most of Phase 1 of the Port of San Francisco's seawall facelift. Work planned through 2026 will reduce seismic risk, potentially beginning around the Ferry Building, where some of the oldest sections of the wall are cracking. The bond measure will cover 85 percent of the $500 million needed for the first of three repair and construction phases for the seawall.

Resilient By Design: Bay Area Challenge - Projects (2018)

The nine final design concepts unveiled in May 2018 are in different parts of the Bay Area and address various climate issues. One project is in the City of San Francisco. This is detailed below but there is no cost estimate yet.

Islais Hyper-Creek (Big + ONE + Sherwood) – Restoration of underlying watershed in SE San Francisco

From the RBD design project overview:

- Today, the basin of Islais Creek–an historic watershed-turned-industrial district in San Francisco, built on rubble from a 1906 earthquake–is at risk from coastal and stormwater flooding, as well as liquefaction.

- Islais Hyper-Creek is a vision for the area where ecology and industry co-exist in harmony. A large park with a restored tidal creek system and soft shoreline shares the area with maritime functions, light manufacturing, and logistics that have formed the area's economic backbone for decades. This park plays an important role in building physical and social resilience: it retains, conveys and cleans water, protecting the surrounding neighborhoods while providing amenities and benefits to the community. Present-day industrial functions are consolidated in a smaller area, clustered with complementary programs. This increases their efficiency and provides new economic opportunities.
- The present-day Islais Creek is more channel than creek, though its low-lying surroundings were once marshland, now filled in with debris and at risk of liquefaction. The area also faces the risks of stormwater and sewage flooding along with repeat coastal flooding. It functions as important infrastructural hub for the entire city, host to shipping centers, the city's wholesale produce market, a wastewater treatment plant which treats 80% of San Francisco's sewage, and many other supporting businesses in construction, manufacturing, and crafts. The area currently provides 22,000 jobs. If it were to come to a standstill because of catastrophic shock, the City of San Francisco would stop functioning.
- The central element of Islais Hyper-Creek is a naturalized creek, its restored watershed absorbing millions of gallons of stormwater annually while providing multi-level ecosystem benefits. Public spaces along the swimmable riparian corridor offer recreational amenities, reconnecting the area to its historic waterfront.
- Beyond the creek itself, Islais Hyper-Creek is a holistic, district-wide plan. Existing industrial operations in the nearby districts are clustered, consolidated, and intensified, creating a vital job and logistics hub dependent on the industrial economy. Infrastructure, including logistical and port functions, is strengthened and adapted to be both flood and earthquake-resistant. Weaving together natural, industrial, and social ecosystems, the creek becomes a dense, connective, and accessible area: a resilience model for the entire Bay Area.
- Subject to king tides, repeat flooding, and sea level rise, the neighborhoods surrounding the present-day industrialized creek house an increasingly vulnerable hub of vital infrastructure for the City of San Francisco, as well as constituent jobs and cultural assets. At the same time, residents and local workers raise the issues of environmental justice and equitable access to training and jobs.
- With Islais Hyper-Creek, the team proposes a strategy integrating protective and adaptive measures on the shoreline with ecological restoration and economic growth extending throughout the creek basin, while also fostering social resiliency and training programs further upland.

The design project highlighted six potential pilot projects to advance toward the long-term vision for a resilient Islais Hyper-Creek.

US Army Corps of Engineers Study (2018)

In June 2018 USACE announced a tentative work plan for the year that included studying San Francisco's seawall and helping look for ways to reduce the local flood risk. Then-House Minority Leader Nancy Pelosi called the Army Corps' announcement "a crucial first step" that could lead to "significant federal funding to repair and upgrade the seawall to withstand the next major earthquake and provide vital flood protection from sea level rise.

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