



**Atlantic Council**

MILLENNIUM LEADERSHIP  
PROGRAM

# Flood Management Infrastructure in a Changing Climate

A Comparative Analysis of London,  
Rotterdam, New York, and Miami

Salem Afeworki, Kate Judson,  
Sadya Ndoko, and Axum Teferra



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Cover photo: New Jersey National Guard. Aerial views of the damage caused by Hurricane Sandy to the New Jersey, October 2012.

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# KEY FINDINGS

- Cities are playing a major role in climate adaptation planning and implementation. Recent major natural disasters (e.g., Hurricane Sandy in New York) and regularly occurring flooding in many regions (e.g., Thames River in London) underscore the urgency and necessity for city governments to take a leadership role in adaptation activities and in increasing climate literacy and citizen engagement. Strong leadership by elected officials along with the engagement of local communities and commitment from the private sector and civil society are needed to successfully develop effective climate adaptation policies, programs, and projects.<sup>1</sup>
- Immediate action is vital. Many early interventions to increase cities' adaptive capacities and improve quality of life can be implemented at a lower cost and with fewer disruptive consequences now rather than after climate disruptions.
- Climate adaptation policy development and planning in large cities often requires coordination between adjacent municipalities across the jurisdictional boundaries of individual cities.<sup>2</sup>
- International and national metropolitan networks—such as ICLEI-Local Governments for Sustainability (ICLEI), C40 Cities Climate Leadership Group (C40), the Global Covenant of Mayors for Climate and Energy, and the Rockefeller Foundation's 100 Resilient Cities network—offer a platform for cities to exchange knowledge, mobilize support, identify innovative sources for financing, and strengthen their leadership in sustainability and climate change.
- Decreasing vulnerability to climate change and enhancing resilience can be a catalyst for more livable and sustainable cities. As a result, cities are looking for indirect benefits of climate policies relevant to poverty alleviation, regional economic development, and livability. This approach can also help cities overcome financial and institutional barriers to climate change adaptation.
- Project implementation can be challenging, as both the institutional and physical contexts of each city are unique, complex, fragmented, and bounded by uncertainty. Integrating climate change adaptation in traditional policy sectors, such as housing, transportation, and economic development, can help bridge the gap between planning and implementation.
- Flood management is shifting from a traditional safety approach to a more risk-based and adaptive approach. Rather than solely relying on large-scale infrastructure projects to mitigate flooding, cities that are adapting to climate change are considering more malleable and modular options and technologies, while seeking to ensure stakeholders' inclusion and engagement in the process.

1 The New Climate Economy, *Seizing the Global Opportunity: Partnerships for Better Growth and a Better Climate*, 2015, <http://newclimateeconomy.report/2015/>.

2 Organisation for Economic Co-operation and Development, *Cities and Climate Change: National Governments Enabling Local Action*, Policy Perspectives, 2014, <https://www.oecd.org/env/cc/Cities-and-climate-change-2014-Policy-Perspectives-Final-web.pdf>.

# INTRODUCTION

Cities are already experiencing the negative impacts of climate change, including increasingly severe storm events, intense flooding, and frequent heat waves. To respond to these impacts and prepare for a changing climate, cities must identify their exposure to climate effects, assess their risks, reduce their vulnerability, and enhance their resilience. In short, cities are at the forefront of climate adaptation.

Adaptation requires planning for current and future climate threats to reduce the potential impacts on people, infrastructure, and the built environment. The estimated investment costs for adaptation measures are generally high, as many involve new or upgraded infrastructure. For example, the World Bank estimates that by 2050, adaptation might cost the United States between \$70-100 billion per year.<sup>3</sup> However, there is also a cost to not investing in adaptation, which is why cities around the world are already investing in adaptation measures to protect municipal assets and operations. In addition, international networks—such as ICLEI, C40, the Global Covenant of Mayors for Climate and Energy, and the Rockefeller Foundation’s

100 Resilient Cities network—bring local and regional leaders together for peer-to-peer learning and to share best practices.

Recognizing that climate change adaptation is a broad and multifaceted topic, this paper focuses on climate adaptation policies, programs, and projects for flood management infrastructure in four cities: London, Rotterdam, New York, and Miami.

This paper

- provides a comparative analysis of four cities embracing climate adaptation;
- identifies best practices and success stories on the benefits of adaptation investments; and
- identifies and develops local policy and planning recommendations that can assist municipal governments in enhancing their adaptation strategies for flood management.

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<sup>3</sup> World Bank, “Economics of Adaptation to Climate Change,” June 6, 2011, <http://www.worldbank.org/en/news/feature/2011/06/06/economics-adaptation-climate-change>.

# METHODOLOGY

Cities with flood risk and similar population sizes were selected as case studies, including two cities in the United States (New York and Miami) and two in Europe (London and Rotterdam) to provide a transatlantic comparison. New York and London have similar population sizes, as do Miami and Rotterdam. New York and Miami were also selected as the two US city case studies as they are located in states with dissimilar political support for climate change policy. All four case study cities face significant water infrastructure stresses due to flooding.

For each case study, a comprehensive literature review was conducted. A large volume of information was gathered from city government websites, where official adaptation plans and policies can be found. In addition, local city newspapers, scholarly articles, the websites of international climate change networks, and research materials developed by international think tanks were consulted. When reviewing these sources, special attention was given to social and climate equity in order to fully consider the human dimension of adaptation planning.

The research for this study is guided by the following questions:

- To what extent can cities drive their own policy agendas on climate adaptation?
- What role do stakeholders have in climate adaptation planning in each city?
- How do these cities leverage other stakeholders/resources to move their climate adaptation agendas forward?

Each case study seeks to answer these questions for a specific city and with a focus on water-related infrastructure (section III). The case studies provide information on climate threats and vulnerabilities, local climate adaptation frameworks, coordination and advancement of adaptation, social equity in adaptation planning, and collaboration with non-city stakeholders. In addition, the comparative analysis of the four cities (section IV) explores commonalities and differences in their planning and implementation of climate change adaptation programs and policies and projects, and seeks to identify best practices that can be replicated across borders.

# CASE STUDIES

## London

### Background

London, the capital of the United Kingdom (UK), is a bustling and growing city with over 8.5 million residents. The Thames River, a tidal river, runs through London and has played a major role in the development of the city. London's climate is temperate and warm; however, according to the United Kingdom Climate Projections (UKCP09), the city is facing hotter, drier summers and warmer winters with increased precipitation. The city is also facing more extreme weather events including increased flooding from storms and more frequent heat waves.

### Climate Threats and Vulnerabilities

London's greatest climate threats are flooding, drought, and excessive heat. As a dense, topographically low-lying urban center, London is more vulnerable to climate impacts than areas outside the city. In particular, London is prone to tidal flooding from the North Sea, fluvial flooding from the Thames River and its tributaries, and surface water flooding from heavy rain events.<sup>4</sup> To protect against these risks, London's primary defenses are floodwalls, gates, and the city's large storm surge barrier, the Thames Barrier. The city is well protected against tidal flooding, but is more vulnerable to fluvial and surface water flooding. Over eight hundred thousand properties are at risk of surface water flooding and this number will continue to grow as the city's population increases.<sup>5</sup>

London's critical infrastructure, including its public transport system, is at considerable risk from heavy

downpours and flooding.<sup>6</sup> A recent study found that eighty-five sites on the London Underground, including some of the city's busiest stations, are at increasingly high risk of flooding.<sup>7</sup> London's other major infrastructure, including electricity grid sites and the Immingham Container Terminal, are also vulnerable to flooding.

While too much water is a problem, so is too little. Drought is another recurring threat. The majority of London's water supply comes from the Thames River<sup>8</sup> and after just two dry consecutive winters, such as in 2004-06 and 2010-12, London's water supplies ran scarce. With London's population growing, the demands on water will only increase. The local water utility, Thames Water, predicts that without any changes, London's water supply will face a deficit of 133 million liters a day by 2020.<sup>9</sup>

### Local Climate Adaptation Framework

London, the first city in the world to develop a climate adaptation plan, is an international leader in climate adaptation policies and planning.<sup>10</sup> In addition to municipal-level efforts, the United Kingdom was the first country in the world to adopt climate change legislation, the Climate Change Act of 2008, requiring mandatory long-term targets for reducing greenhouse gas emissions. The act requires the national government to publish a climate risk assessment report every five years that analyzes the main climate-related risks and opportunities for the country and aids cities with adaptation planning.

Following an extensive outreach campaign, the Greater London Authority (GLA) published London's

4 Patricia McCarney, *City Indicators on Climate Change: Implications for Governance*, World Bank's 5th Urban Research Symposium - Cities and Climate Change, June 2009, <http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1256566800920/6505269-1268260567624/McCarney.pdf>.

5 Greater London Authority, *Managing Risks and Increasing Resilience: The Mayor's Climate Change Adaptation Strategy*, October 2011, [https://www.london.gov.uk/sites/default/files/gla\\_migrate\\_files\\_destination/Adaptation-oct11.pdf](https://www.london.gov.uk/sites/default/files/gla_migrate_files_destination/Adaptation-oct11.pdf).

6 London Assembly, *Come Rain or Shine: London's Adaptation to the Risks of Severe Weather*, March 2015, <https://www.london.gov.uk/sites/default/files/Come%20rain%20or%20shine%20report.pdf>.

7 Damian Carrington, "57 Tube Stations at High Risk of Flooding, Says London Underground Report," the *Guardian*, April 10, 2016, [www.theguardian.com/uk-news/2016/apr/10/57-tube-stations-high-risk-flooding-london-underground-report](http://www.theguardian.com/uk-news/2016/apr/10/57-tube-stations-high-risk-flooding-london-underground-report).

8 "London: Trends: Socio-economic, Climate Change," Connecting Delta Cities: A C40 Network, accessed March 29, 2017, <http://www.deltacities.com/cities/london/trends>.

9 London Assembly, *Come Rain or Shine: London's Adaptation to the Risks of Severe Weather*.

10 Sarfaraz Gani Adnan and Heidi Kreibich, "An Evaluation of Disaster Risk Reduction (DRR) Approaches for Coastal Delta Cities: A Comparative Analysis," *Natural Hazards*, May 27, 2016, <https://link.springer.com/article/10.1007/s11069-016-2388-8>.



Thames barrier—London’s major flood protection against storm surges and high tides. *Photo credit: Salem Afeworki.*

climate adaptation plan, the London Climate Change Adaptation Strategy (LCCAS), in October 2011.<sup>11</sup> Former Mayor Boris Johnson’s office solicited ideas from the public for inclusion in the strategy, including through a digital media campaign asking residents how they are adapting to a changing climate. The LCCAS is based on 2009 climate change projections from the UK’s official center for climate change research, the Met Office Hadley Centre.<sup>12</sup> Its scope includes identifying climate risks, assessing how best to manage these risks, and implementing actions to address the risks; it encourages leaders to take on adaptation activities despite the uncertainties and contemplate how to manage the residual risk. The LCCAS also outlines thirty-four initiatives to make the city more resilient.

In addition to the policy architecture, London has also implemented physical adaptation infrastructure. The Thames Barrier, operational since 1982, is one of the largest moveable flood barriers in the world.<sup>13</sup> The barrier was constructed following the North Sea Flood of 1953, which killed 307 people, damaged twenty-four thousand properties, and killed forty-six thousand livestock.<sup>14</sup> The barrier has been closed over one hundred times in order to protect London from flooding.<sup>15</sup> There are eight other flood barriers along the Thames that work together as a tidal defense system.

11 Greater London Authority, *Managing Risks and Increasing Resilience*.

12 Maria Gallucci, “6 of the World’s Most Extensive Climate Adaptation Plans,” *Inside Climate News*, June 20, 2013, <https://insideclimatenews.org/news/20130620/6-worlds-most-extensive-climate-adaptation-plans>.

13 Alexander Hall, “The Thames Barrier: London’s Moveable Flood Defense,” *Arcadia*, 2014, no. 15 via Environment & Society Portal, <http://www.environmentandsociety.org/arcadia/thames-barrier-londons-moveable-flood-defense>.

14 Alexander Hall, “The North Sea Flood of 1953,” *Arcadia*, 2013 via Environment & Society Portal, <http://www.environmentandsociety.org/arcadia/north-sea-flood-1953>.

15 London Climate Change Partnership, *A Summary of Climate Change Risks for London*, 2012, <http://climatelondon.org.uk/wp-content/uploads/2012/01/CCRA-London.pdf>.

### Coordinating and Advancing Adaptation

The Greater London Authority has the most critical role and responsibility with respect to climate adaptation in London.<sup>16</sup> The GLA is composed of the mayor of London and a separately elected London assembly. Responsibility for climate adaptation, mitigation, and energy strategies was granted to the mayor of London in the 2007 Greater London Authority Act,<sup>17</sup> charging the mayor with a “climate change duty” and responsibility for climate adaptation and mitigation strategies for the city.<sup>18</sup>

The London Climate Change Partnership (LCCP), a stakeholder group comprised of over thirty organizations representing developers, climate scientists, government departments, healthcare sector employees, and others, is charged with facilitating cooperation among London’s climate change stakeholders. The LCCP also plays an advocacy role by promoting the inclusion of climate change within city government plans and policies, and is responsible for commissioning climate adaptation research and conducting outreach.

The Drain London partnership, comprised of London’s thirty-three councils, the Environment Agency, Thames Water, and the GLA, is another key coordinating player.<sup>19</sup> The partnership was originally founded to facilitate cooperation to better understand flood risks and assess the condition of London’s drainage infrastructure to enable the GLA and the boroughs to reduce flooding. The group has evolved over time and has created surface water flood risk maps and management plans as well as overseen several pilot projects.

In addition to the LCCAS, London has incorporated climate adaptation planning into its citywide spatial development strategy, the London Plan. The London Plan references the LCCAS and incorporates the plan’s policies into development guidelines. The London Plan includes adaptation strategies ranging from flood defenses to sustainable storm water management via the creation of a “sustainable drainage hierarchy” policy.

“London, the first city in the world to develop a climate adaptation plan, is an international leader in climate adaptation policies and planning.”

The Thames Estuary 2100 (TE2100) project is another example of climate adaptation planning in London. The United Kingdom’s Environment Agency developed this plan to manage tidal flood risk in London and the Thames Estuary in the twenty-first century.<sup>20</sup> The plan includes flexible options or pathways that assess the thresholds for responding to different degrees of sea level rise.<sup>21</sup>

### Social Equity in Adaptation Planning

London has many vulnerable communities that will be disproportionately impacted by climate change. To deal with these impacts, the LCCP is part of the Climate Just project, an online visual information tool to enable “the equitable responses to climate change at the local level” and add an equity lens to climate adaptation planning.<sup>22</sup> This tool aids groups like LCCP by identifying where vulnerable populations live and how climate change impacts them disproportionately compared with other communities. LCCP has organized training and development programs to help public service providers better understand how to use the Climate Just project and incorporate it in their work.

### External Collaboration

London is an active member in several international climate change initiatives, including the C40 global initiative, the Compact of Mayors, the Delta Network, and the Rockefeller Foundation’s 100 Resilient Cities. London’s Mayor, Sadiq Khan, currently serves in a leadership role in the C40 Cities Climate Leadership Group.<sup>23</sup> Belonging to these international organizations

16 Greater London Authority, *Managing Risks and Increasing Resilience*.

17 “Greater London Authority Act 2007,” UK Legislation, accessed March 29, 2017, <https://www.legislation.gov.uk/ukpga/2007/24/contents>.

18 Simin Davoudi, Abid Mehmood, and Liz Brooks, *The London Climate Change Adaptation Strategy: Gap Analysis*, Electronic Working Paper No. 44, Global Urban Research Unit, 2011, <http://orca.cf.ac.uk/53010/1/ewp44.pdf>.

19 “Flood Risk Management,” London Councils, accessed March 29, 2017, <http://www.londoncouncils.gov.uk/node/1040>.

20 “Thames Estuary Asset Management 2100 Programme (TEAM2100),” Environment Agency of the United Kingdom, May 11, 2015, <https://www.gov.uk/government/news/thames-estuary-asset-management-2100-programme-team2100>.

21 UK Climate Projections, *UK Climate Projections Science Report: Marine and Coastal Projections*, 2009, <http://ukclimateprojections.metoffice.gov.uk/media.jsp?mediaid=87894&filetype=pdf>.

22 “About: Climate Just,” Climate Just, accessed March 29, 2017, <http://www.climatejust.org.uk/>.

23 Sadiq Khan, “Mayor of London, Sadiq Khan on His Climate Change Priorities,” C40 Blog, August 1, 2016, [http://www.c40.org/blog\\_](http://www.c40.org/blog_)

has helped London further its climate adaptation and mitigation goals. For instance, since London's government does not have the authority to mandate that owners and tenants install energy efficient technology in commercial buildings, the city worked with C40 to gather ideas from other cities in similar situations. As a result of this idea sharing, London set up an incentive program, the mayor's Business Energy Challenge, which attracted fifty-eight businesses, twenty-seven of which received awards for reducing their carbon emissions by 18 percent or more as well as using 181,892 fewer megawatt hours of energy.<sup>24</sup> This challenge is helping London meet its carbon mitigation goals.<sup>25</sup>

## Rotterdam

### Background

Rotterdam, also known as the Gateway to Europe, is a port city located in the Province of Zuid-Holland with over six hundred thousand inhabitants, making it the second-largest city in the Netherlands after Amsterdam.<sup>26</sup> It is situated near the North Sea and has one of the largest ports in the world, making it a hub city for both the Netherlands and Europe. The city has well-equipped port infrastructure, multi-modal accessibility, and high volumes of passengers and goods passing through.

Rotterdam is situated in the delta of the rivers Rhine and Meuse;<sup>27</sup> nearly 80 percent of the city lies below sea level. The city is shielded from the sea by a sophisticated system of dikes, closure dams, and storm surge barriers, which are also components of the

broader Dutch delta plan.<sup>28</sup> The seaward port extends out over a length of forty kilometers (km).

### Climate Threats and Vulnerabilities

Due to its location, Rotterdam is likely to be affected by sea level rise and projections show that extreme weather conditions will become more likely. It is predicted that the Netherlands will be subject to increasingly milder winters and hotter summers as a result of climate change.<sup>29</sup> "On average, winters will become wetter and rainfall increasingly extreme."<sup>30</sup> "During summers in particular, the frequency and severity of the rainfall will increase, although the total number of rainy summer days will decrease."<sup>31</sup>

The water in Rotterdam comes from four sources: the sea, the river, precipitation, and groundwater.<sup>32</sup> As a result, like many other delta cities, Rotterdam is vulnerable to increased flood risks due to the rise in sea levels. During periods of extreme rainfall, it is difficult for water to drain. Conversely, drought lowers water tables and river levels.<sup>33</sup>

Rotterdam's practice of evolving with natural changes dates far back to the very origins of the city; for centuries it has been protecting itself from the threat of the water from rivers and especially the sea.<sup>34</sup> For example, the city has taken steps to use dams and dikes for flood mitigation, and has even reclaimed lands that are prone to flooding.<sup>35</sup> Nevertheless, the city is still vulnerable to climate change. Some of the observed effects related to climate change include exacerbated flooding and erosion, freshwater shortage, loss of coastal ecosystems, levee breakthroughs, and sediment buildup, all of which affect water quality.

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posts/mayor-of-london-sadiq-khan-on-his-climate-change-priorities.

24 "London Businesses Urged to Step Up to the Business Energy Challenge," London Assembly, August 7, 2015, <https://www.london.gov.uk/press-releases/mayoral/business-energy-challenge-0>.

25 Matthew Pencharz, "10 Years of Results: Matthew Pencharz on Transforming London into a Greener, Healthier and Wealthier Place to Live," C40 Blog, September 23, 2015, [http://www.c40.org/blog\\_posts/10-years-of-results-matthew-pencharz-on-transforming-london-into-a-greener-healthier-and-wealthier-place-to-live](http://www.c40.org/blog_posts/10-years-of-results-matthew-pencharz-on-transforming-london-into-a-greener-healthier-and-wealthier-place-to-live).

26 C40, "Delta Cities, Programme Description: Rotterdam," accessed on March 28, 2017, <http://www.deltacities.com/cities/rotterdam/description>.

27 "Rhine-Meuse Delta," Delta Alliance, accessed March 28, 2017, <http://www.delta-alliance.org/deltas/rhine-meuse-delta>.

28 "The City of Rotterdam," Adaptation Futures, 2016 Practices and Solutions, accessed on March 28, 2017, <http://www.adaptationfutures2016.org/rotterdam/rotterdam>.

29 Joyeeta Gupta et al., *Assessing Dangerous Climate Change Impacts for the Netherlands*, Climate Change Scientific Assessment and Policy Analysis, November 2006, <http://www.pbl.nl/sites/default/files/cms/publicaties/500102007.pdf>.

30 Arnoud Molenaar, Jeroen Aerts, Piet Dircke, and Mandy Ikert, *Connecting Delta Cities II*, City of Rotterdam, 2015.

31 Rotterdam Climate Initiative, *Rotterdam Climate Proof Adaptation Programme 2010*, 2010, [http://www.rotterdamclimateinitiative.nl/documents/2015-en-ouder/RCP/English/RCP\\_ENG\\_def.pdf](http://www.rotterdamclimateinitiative.nl/documents/2015-en-ouder/RCP/English/RCP_ENG_def.pdf).

32 Ibid.; M. Van Koningsveld, J. P. M. Mulder, M. J. F. Stive, L. Van Der Valk, and A. W. Van Der Weck, "Living with Sea Level Rise and Climate Change: A Case Study of the Netherlands," *Journal of Coastal Research*: 367-379 (2008).

33 Rotterdam Climate Initiative, *Rotterdam Climate Change Adaptation Strategy*, 2013.

34 Ibid.

35 Ibid.

### Local Climate Adaptation Framework

Rotterdam is one of the most active Dutch cities when it comes to climate adaptation.<sup>36</sup> Like many cities, Rotterdam is facing not only increasing flooding threats, but also pressures from development demands and aging infrastructure.<sup>37</sup> Historically, policy and planning practices in the Netherlands focused on flood management and regulating the water levels to keep the city dry.<sup>38</sup>

The Rotterdam Climate Initiative (RCI) is Rotterdam's response to the challenges the region will face over the next few decades, and the economic opportunities this provides. RCI is a collaborative composed of the City of Rotterdam, Port of Rotterdam, Deltalinqs (as representative of the port and industrial companies), and DCMR Environmental Protection Agency Rijnmond.<sup>39</sup> These organizations joined forces to realize the objectives of the RCI, as it became clear that cross-sector cooperation would be required to meet their goals.<sup>40</sup> The RCI aims to reduce greenhouse gas emissions in different sectors while also preparing adaptation strategies for long-term climate-induced changes. The RCI developed Rotterdam Climate Proof, a climate adaptation program that aims to make the city 100 percent climate proof by 2025. The Rotterdam Climate Change Adaptation Strategy developed in 2013 sets a blueprint that will enable the city to adapt to a changing climate.<sup>41</sup>

### Coordinating and Advancing Adaptation

In the Netherlands, management and funding responsibilities for coastal flood defense are shared between national and subnational authorities.<sup>42</sup> At the national level, that includes the Ministry of Transport, Public Works, and Water Management and its executive

agency, the Directorate-General for Public Works and Water Management.<sup>43</sup> The ministry is responsible for setting the policy and legislative agenda.<sup>44</sup>

The Royal Netherlands Meteorological Institute is the country's key body researching climate change scenarios.<sup>45</sup> The Royal Netherlands Meteorological Institute's analyses inform national policy and operational changes. National climate policy is largely focused on land-use planning and flood-risk mitigation.<sup>46</sup>

Rotterdam is developing new orientations for flood management, retaining the water inside consolidated urban areas, and recovering new space for the river.<sup>47</sup> One example is the Green Roof Policy, which aims to reduce surface water flooding while enabling the development of ecosystem services and contributing to urban sustainability.<sup>48</sup> The municipality of Rotterdam was the first Dutch local authority to recognize the potential of green roofs for retaining increased rainfall in densely built city districts; green roofs are a primary focus of the Rotterdam Adaptation Strategy. In 2008, an incentive program for green roofs was introduced that provides a subsidy of €30 per square meter to commercial and non-commercial property owners covering roughly half of the installation costs.<sup>49</sup>

### Social Equity in Adaptation Planning

A cornerstone of Rotterdam's Adaptation Strategy is public engagement. The concept of community resilience is widespread in Rotterdam, with many educational campaigns and programs designed to draw participation from diverse groups of residents.<sup>50</sup> The city also leverages the use of innovative information technology for public engagement on flood control, making Rotterdam well recognized as an innovative

36 Heleen-Lydeke P. Mees and Peter P.J. Driessen, "Adaptation to Climate Change in Urban Areas: Climate-Greening London, Rotterdam, and Toronto," *Climate Law* 2, no. 2 (2011): 251-280.

37 Michael Thomas Mitchell, *Adaptations within Dutch Architecture and Urban Planning Practices in Response to a Changing Climate* (dissertation, University of Michigan, 2012).

38 Ibid.

39 Rotterdam Climate Initiative, *Rotterdam Climate Change Adaptation Strategy*.

40 Rotterdam Climate Initiative, *Rotterdam CCS Cluster Project: Case Study on 'Lessons Learnt,'* April 18, 2012.

41 Rotterdam Climate Initiative, *Rotterdam Climate Change Adaptation Strategy*.

42 European Commission, *The Economics of Climate Change Adaptation in EU Coastal Areas* (Luxembourg: European Communities, 2009), Chapter 21.

43 Ibid.

44 Ibid.

45 Ibid.

46 Ibid.

47 Rotterdam Climate Initiative, *Rotterdam Climate Proof Adaptation Programme 2010*.

48 Erica Oberndorfer, Jeremy Lundholm, Brad Bass, Reid R. Coffman, Hitesh Doshi, Nigel Dunnett, Stuart Gaffin, Manfred Köhler, Karen K. Y. Liu, and Bradley Rowe, "Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services," *BioScience* 57, no. 10 (2007): 823-83.

49 Rotterdam Climate Initiative, *Rotterdam Climate Proof Adaptation Programme 2010*.

50 Arnoud Molenaar, Jeroen Aerts, Piet Dircke, and Mandy Ikert, *Connecting Delta Cities* (City of Rotterdam, 2013).



Watersquare Bethemplein in Rotterdam—the world first combined water retention and public square designed by De Urbanisten. *Photo credit: Kate Judson.*

hub for water management.<sup>51</sup> Many smart climate adaptation tools have been produced, including the Rotterdam Climate Atlas, the Adaptation Design Toolkit, the Rotterdam Climate Societal Cost Benefit Analysis, and the Rotterdam Climate Game.<sup>52</sup>

### External Collaboration

Rotterdam is an active participant in global conversations on climate change. The RCI participates in C40, surging as a leader in the climate change approach of port cities; it also closely collaborates with cities such as New York, Shanghai, Singapore, Jakarta, Hong Kong, London, and New Orleans on adaptation and mitigation strategies.<sup>53</sup> As part of the Rotterdam Climate Proof initiative, seven low-lying metro areas

participate in the Connecting Delta Cities network,<sup>54</sup> which creates a platform for member cities to share knowledge and exchange best practices on climate adaptation.<sup>55</sup>

In April 2016, Rotterdam released its resilience strategy as part of the Rockefeller Foundation’s 100 Resilient Cities network.<sup>56</sup> Some of the biggest challenges and transitions addressed in the strategy include “a changing economy driven more by sharing and technological innovation; a different climate resulting from predicted climate change; and changes in society and democracy driven by a move away from top-down hierarchy to a bottom-up approach with greater levels of community and citizen involvement.”<sup>57</sup>

51 Ibid.

52 Ibid.

53 Divya Sharma, “Mainstreaming Climate Resilience,” presentation, TERI-APN Training Program on Building Urban Climate Change Resilience, January 22-23, 2015.

54 City of Rotterdam, *Rotterdam World Story*, 2009.

55 Ibid.

56 100 Resilient Cities, *Rotterdam Resilience Strategy*, 2016.

57 Ibid.

# New York

## Background

With 8.5 million inhabitants living in 790 square km,<sup>58</sup> New York is the most populous city in the United States.<sup>59</sup> An additional three hundred thousand inhabitants are expected by 2030.<sup>60</sup> It is also a vibrant, cosmopolitan, and wealthy city, with a gross domestic product (GDP) of \$778 billion. However, as a waterfront city, New York is particularly vulnerable to the effects of climate change; the World Bank ranks the city third globally on its list of places with the greatest risk of costly damages from storm surge and flooding.<sup>61</sup>

## Climate Threats and Vulnerabilities

Global climate models project an increase in temperatures within the city ranging from 4.0 degrees Fahrenheit (°F) to 6.6°F<sup>62</sup> by 2050, as well as increases in total annual precipitation. By mid-century, heat waves as well as extreme winter conditions are also projected, and coastal flooding is likely to increase in frequency, extent, and height due to rising sea levels.<sup>63</sup>

In October 2012, Hurricane Sandy wrecked the eastern coast of the United States and caused severe damage in New York and the surrounding area, amounting to at least \$19 billion in damages and forty-three deaths.<sup>64</sup> The hurricane's associated storm surge flooded streets, tunnels, and subway lines, and caused power outages. While it is not possible to directly attribute Hurricane Sandy to climate change, sea level rise over the past several decades in the New York area increased the extent and magnitude of coastal flooding that occurred during the storm.<sup>65</sup>

## Local Climate Adaptation Framework

In 2007, during the tenure of former mayor of New York Michael Bloomberg (2002–13),<sup>66</sup> the city prioritized and released its strategic development plan, PlaNYC.<sup>67</sup> PlaNYC aimed to improve environmental sustainability by 2030, while also positioning New York as a world leader in sustainability and in addressing climate change mitigation and adaptation.<sup>68</sup> Despite early efforts in city planning and infrastructure investment in New York on climate change adaptation, Hurricane Sandy was a milestone that reaffirmed the relevance of PlaNYC and highlighted its importance and the urgency to implement it. Six months after the hurricane, building on PlaNYC, the city released its Special Initiative for Rebuilding and Resiliency: A Stronger, More Resilient New York (SIRR).<sup>69</sup> The SIRR specifically addresses issues related to resilience and climate change adaptation. It strives to be location-specific, by providing information on particular neighborhoods impacted by Sandy.<sup>70</sup> Sustainability and climate change are also high on the political agenda of Mayor Bill de Blasio who revised PlaNYC to include a poverty reduction dimension. He also renamed it One New York City: The Plan for a Strong and Just City (OneNYC).<sup>71</sup>

## Coordinating and Advancing Adaptation

A panel of experts was convened in 2008 to advise the city authorities on climate change and adaptation issues related to critical infrastructure, including communications, energy, transportation, water, and waste systems. The New York City Panel on Climate Change consists of academic experts covering a broad range of disciplines, including physical climatology, geology, oceanography, and social science and economics, as well as private sector experts

58 "Quick Facts New York City, New York," United States Census Bureau, <https://www.census.gov/quickfacts/NY>.

59 "New York City Population Projections by Age/Sex & Borough, 2010-2040," City of New York, [https://www1.nyc.gov/assets/planning/download/pdf/data-maps/nyc-population/projections\\_briefing\\_booklet\\_2010\\_2040.pdf](https://www1.nyc.gov/assets/planning/download/pdf/data-maps/nyc-population/projections_briefing_booklet_2010_2040.pdf).

60 Ibid.

61 "Home," New York City Environmental Justice Alliance, <http://nyc-eja.org/>.

62 Temperature and precipitation changes are expressed relative to the baseline period 1971–2000. Source: New York City Panel on Climate Change, *Building the Knowledge Base for Climate Resiliency*, 2015.

63 Ibid.

64 "New York City – A Stronger, More Resilient New York," C40, <http://www.c40.org/awards/2013-awards/profiles/7>.

65 New York City Panel on Climate Change, *Climate Risk Information 2013*, 2013.

66 Michael Bloomberg has since been appointed special envoy for cities and climate change of the United Nations Secretary-General.

67 PLaNYC was updated in 2011 to reflect the importance of meeting the needs of a growing population.

68 This is reflected in two of the plan's four pillars. Pillar 3 - New York City will be the most sustainable big city in the world and a global leader in the fight against climate change; and Pillar 4 - Neighborhoods, Economy, and Public Services will be ready to withstand and emerge stronger from the impact of climate change and other 21st-century threats. Through implementing this plan and the subsequent one (OneNYC), New York also aims to reduce its greenhouse gas emissions by 80 percent by 2050.

69 "NYC Special Initiative for Rebuilding and Resiliency," City of New York, 2013.

70 "Building Climate Resiliency in New York City," Presentation delivered by Adam Freed for the University Corporation for Atmospheric Research, accessed on March 20, 2017, <https://www.ucar.edu/governance/meetings/oct09/followup/freed.pdf>.

71 OneNYC aims to lift eight hundred thousand people out of poverty by 2025. See "Home," OneNYC, accessed March 2017, <http://onenyc.cityofnewyork.us>.

representing the fields of law, insurance, and risk management.<sup>72</sup> The mayor's Office of Sustainability and Office of Recovery & Resiliency provide overall strategic guidance and oversight on OneNYC and SIRR, respectively,<sup>73</sup> foster interagency collaboration, and monitor progress. The New York City Climate Change Adaptation Task Force (CCATF) was established to support the implementation of PlaNYC<sup>74</sup> and has been revived to support the implementation of OneNYC. The CCATF<sup>75</sup> aims to identify critical infrastructure that could be at risk from the effects of climate change; facilitate knowledge sharing; develop coordinated adaptation strategies to secure assets;<sup>76</sup> and make recommendations, including on issues relating to equity and interconnectedness. Members of the CCTAF include stakeholders at the city, state, and federal level, as well as in the private sector.<sup>77</sup>

Building on the work of the CCATF, a special task force was established to prepare the SIRR, drawing on consultations with state and national agencies, as well as elected officials, community groups, and over one thousand city residents who participated in public workshops. The CCATF and the special task force interact with the city's departments and agencies in their areas of competency and encourage the integration of climate change adaptation and resilience into their work.<sup>78</sup> For example, they work closely with the Department of Environmental Protection, which traditionally manages sanitation and drinking water systems.<sup>79</sup>

From the PlaNYC/OneNYC and SIRR, several programs and projects have been identified and prioritized for implementation to climate proof future water-related investments. A green infrastructure program was initiated with an investment of over \$900 million over a ten-year period in projects like curbside gardens, green roofs, and storm water green streets. At the end of 2016, 500 green infrastructure projects had been completed and an additional 2,900 were under construction; the city has also been repairing 148,000 storm water runoff catch basins on a three-year cycle since 2010.<sup>80</sup> Over the next decade, New York is planning to invest \$2.4 billion in critical sewer infrastructure to expand sewer capacity and networks and repair and replace old pipes.<sup>81</sup> The city is also piloting new technologies, programs, and analytical tools to improve operations and maintenance systems.<sup>82</sup>

To date, more than \$100 million has been committed to the city's \$3.7 billion coastal protection plan, and additional funding is being sought through feasibility studies of several investment opportunities and by applying for National Disaster Resilience Competition funds.<sup>83</sup> New York is also continuously reviewing long-term coastal protection measures, such as a multipurpose levee in Lower Manhattan, particularly in places where investments could strengthen communities. In addition, New York intends to repair critical infrastructure systems damaged or destroyed by Hurricane Sandy, while mitigating future climate risks through billions of dollars in funding, in particular from the Federal Emergency Management Agency's Public Assistance grant program. Since Hurricane

72 C. Rosenzweig, D.W. Solecki, R. Blake, M. Bowman et al., "Developing Coastal Adaptation to Climate Change in the New York City Infrastructure-Shed: Process, Approach, Tools and Strategies," *Climatic Change*, 106, 2011: 93-127.

73 The mayor's Office of Sustainability was created after the merging of the mayor's Office of Long-Term Planning and Sustainability, established in 2006, and the mayor's Office of Environmental Coordination. The mayor's Office of Recovery and Resiliency was established in 2014.

74 The CCATF was established in 2008.

75 The CCATF's objectives are codified in Local Law 42.

76 Brian J. McLaughlin, Scott D. Murrell, and Susanne DesRoches, "Case Study: Assessment of the Vulnerability of Port Authority of NY & NJ Facilities to the Impacts of Climate Change," Transportation and Development Institute Congress, 2011.

77 The CCTAF includes twelve city agencies, five regional public authorities, six state agencies, two federal agencies, and fifteen private companies.

78 C. Rosenzweig and D.W. Solecki, *Introduction to Climate Change Adaptation in New York City: Building a Risk Management Response*, New York Academy of Sciences, ISSN 0077-8923, 2010, 14-17.

79 For water supply, the Department of Environmental Protection collaborates closely with the state-managed Board of Water Supply, which manages water from the Catskill/Delaware River basin, the primary source of potable water in New York City. Source: Annals of the New York Academy of Sciences, *Responding to Climate Change in New York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation in New York State*, Final Report, December 2011.

80 City of New York, *One New York: The Plan for a Strong and Just City*, 2013, <http://www.nyc.gov/html/onenyc/downloads/pdf/publications/OneNYC.pdf>.

81 City of New York, *One NYC Plan Progress Report 2016*, "Water and Waste Water," Chapter 12, 2016, <http://www1.nyc.gov/html/onenyc/downloads/pdf/.../OneNYC-2016-Progress-Report.pdf>.

82 City of New York, *Green Infrastructure Plan: A Sustainability Strategy for Clean Waterways*, 2016.

83 The following projects and policies are being implemented: (i) storm surge barriers on specific creeks and waterways; (ii) armored levees on certain beachfronts; (iii) mandate for big buildings to undertake flood retrofits; (iv) rebuilding damaged housing stock; (v) reduced flood insurance rates for different resiliency measures; (vi) frequent upgrades of the waterfront management tools; (vii) funding of citywide inspections to assess and better manage assets.

“To date, more than \$100 million has been committed to [New York’s] \$3.7 billion coastal protection plan.”

Sandy, New York has received \$15.4 billion of federal funding, of which \$13 billion is directly administered by the city.<sup>84</sup> Despite these efforts, as OneNYC reports, significant coastal protection strategies have yet to be funded.<sup>85</sup> It remains to be seen whether New York will continue to receive the same level of public support with a new presidential administration that is skeptical of climate change.

### Social Equity in Adaptation Planning

Lower-income populations, including those located on industrial waterfront areas, are highly vulnerable to climate change impacts,<sup>86</sup> and are disproportionately affected by infrastructure and service failures in the aftermath of extreme weather events. Highly dependent on public transportation and living far from work, the poorest segment of the New York population struggled, for instance, to reach their workplaces after Hurricane Sandy, and experienced losses of income.<sup>87</sup>

New York recognizes that unsustainable practices and economic disparities must be addressed simultaneously and that equity is a crosscutting issue and a guiding principle of PlaNYC and then OneNYC. Despite these efforts, some gaps and limitations have been reported, including the absence of a mechanism to support on-the-ground efforts to fully engage local communities<sup>88</sup> and to consider existing community resilience and

adaptation plans. In addition, in preparing the SIRR, not all New York departments were involved in the process. For instance, the Department for the Aging, which serves a vulnerable segment of the population, could have assisted in improving emergency preparedness and planning. Additionally, low-income communities, including those located on industrial waterfront areas, which have historically been disproportionately burdened by various environmental impacts, have not received the same level of resiliency investment as wealthier areas,<sup>89</sup> and there is a noticeable difference in the level of investment in Lower Manhattan, a wealthy neighborhood associated with corporate business sectors (e.g., Wall Street) and government offices, versus lower-income neighborhoods.

### External Collaboration

For Bill de Blasio, the current mayor of New York, climate change is a priority and intercity coordination is expected to increase.<sup>90</sup> This continues the work under former Mayor Michael Bloomberg, who declared that cities, including New York, will continue to enact climate policies regardless of federal action or inaction.<sup>91</sup> New York is part of several global city networks, including C40, and has established city-to-city exchanges and collaborations with cities like Copenhagen. Such international engagement reinforces New York’s determination to keep its global status as a sustainable and influential city on climate change.<sup>92</sup>

In past years, the city has worked very closely with state and federal entities to secure additional funding and enact relevant legislation for climate change adaptation and resilience. It is hoped that even in a more resource-constrained context, consideration of equity will remain high and the above-mentioned equity gaps will be fully addressed.

84 For example, in 2014 it received \$335 million through the national contest Rebuild by Design. In 2016, the city was awarded \$176 million for flood protection through another national contest. The Federal Emergency Management Agency also provided \$595 million in assistance to individuals and businesses in New York that suffered losses from Hurricane Sandy (New York City Federal Funding Companion page). Source: “Welcome to the Sandy Funding Tracker,” New York City Sandy Funding Tracker, accessed on August 9, 2017, <http://www1.nyc.gov/sandytracker/>.

85 New York City Environmental Justice Alliance, *NYC Climate Justice Agenda: Strengthening the Mayor’s OneNYC Plan*, 2016, [http://www.nyceja.org/public/publications/NYC\\_ClimateJusticeAgenda.pdf](http://www.nyceja.org/public/publications/NYC_ClimateJusticeAgenda.pdf).

86 New York City Panel on Climate Change, *Building the Knowledge Base for Climate Resiliency*, 2015.

87 “Coastal Zones: Equity and Justice in Vulnerability and Adaptation” in Karen O’Brian and E. Selboa, *The Adaptive Challenge of Climate Change*, 2015, 106-113.

88 “Home,” New York City Environmental Justice Alliance, accessed August 9, 2017, <http://nyc-eja.org>.

89 Ibid.

90 Edward Wong, “Bloomberg Says Cities Will Fight Climate Change, With or Without Trump,” *New York Times*, November 23, 2016, [https://www.nytimes.com/2016/11/23/us/politics/mike-bloomberg-donald-trump-climate-change.html?\\_r=1](https://www.nytimes.com/2016/11/23/us/politics/mike-bloomberg-donald-trump-climate-change.html?_r=1).

91 Ibid.

92 “Home,” OneNYC, <http://onenyc.cityofnewyork.us>.

# Miami

## Background

Miami is a coastal city along the Atlantic Ocean on the Florida peninsula. It has a population of nearly 400,000 within the city proper and more than 5.5 million inhabitants in the metro region (covering 92.4 square km), making Miami the eighth-most populous metro area in the United States.<sup>93</sup> The city is known as a popular tourist destination, with tourism driving a significant portion of the local economy, alongside financial services, real estate, and trade.

The greatest climate threats for Florida are increasing temperatures, stronger tropical storms and hurricanes, and sea level rise.<sup>94</sup> Over the last century, Florida has already experienced 1°F of warming, and is experiencing more than two centimeters of sea level rise annually.<sup>95</sup> Among cities across the world, Miami has the fourth-largest population vulnerable to sea level rise.<sup>96</sup> Miami's total value of assets exposed to flooding exceeds \$400 billion, making it the most asset-exposed city in the world.<sup>97</sup>

## Climate Threats and Vulnerabilities

By 2030, sea levels are projected to rise by up to twenty-five centimeters (cm) in Miami.<sup>98</sup> By 2060, this is expected to increase up to 66 cm, and by 2100 approximately 150 cm beyond the 1992 mean sea level.<sup>99</sup> The rate of sea level rise in south Florida is expected to outpace the global average due to fluctuations in Florida's currents and the Gulf Stream.

By 2050, it is projected that 380 high-tide flood events will occur per year (compared with six times per year today), and the geographic span of tidal floods will grow larger over time).<sup>100</sup>

Historically, Miami has been hit by highly damaging tropical storms and hurricanes, though in the last decade the city has experienced a period of quiet.<sup>101</sup> Projections are unclear on whether storm frequency will increase, but they do indicate that storms are expected to become stronger. Across the southeastern United States, precipitation during heavy rainstorms has increased by 27 percent since 1958.<sup>102</sup>

The most prevalent of Miami's climate vulnerabilities is the threat of sea level rise, which is already creating an increase in flooding from high tide and storm surges. As sea level rise worsens, flooding from high tide, precipitation, and storms will be exacerbated.<sup>103</sup> Miami's topography and low elevation and Florida's porous limestone make it highly susceptible to damaging flooding. The limestone presents a unique challenge because as sea levels rise, seawater may infiltrate the freshwater aquifers located underground, which the population relies on for drinking water.<sup>104</sup> The state's freshwater sources are close to the surface, and thus are particularly vulnerable to saltwater intrusion.<sup>105</sup> During a storm event, Miami's underlying porous limestone also makes it difficult for storm water to recede, and much of the region already depends on drainage and pumping infrastructure to mitigate flooding and saltwater intrusion. With 7 to 23 cm of sea level rise expected by around 2020, it is projected that

93 Bureau of Economic Analysis, *Miami-Fort Lauderdale-West Palm Beach, FL*, 2016, <https://www.bea.gov/regional/bearfacts/pdf.cfm?fips=33100&areatype=MSA&geotype=4>.

94 United States Environmental Protection Agency, *What Climate Change Means for Florida*, September 2016, <http://www.southeastfloridaclimatecompact.org/wp-content/uploads/2016/09/climate-change-FL.pdf>.

95 Ibid.

96 World Resources Institute, "Sea-Level Rise and Its Impact on Miami-Dade County Fact Sheet," 2014, [https://www.wri.org/sites/default/files/sealevelrise\\_miami\\_florida\\_factsheet\\_final.pdf](https://www.wri.org/sites/default/files/sealevelrise_miami_florida_factsheet_final.pdf).

97 Stan Cox and Paul Cox, "A Rising Tide," *New Republic*, November 8, 2015, <https://newrepublic.com/article/123216/miami-sinking-beneath-sea-not-without-fight>.

98 Sea Level Rise Work Group, *Unified Sea Level Rise Projection: Southeast Florida*, Southeast Florida Regional Climate Change Compact, October 2015, <http://www.southeastfloridaclimatecompact.org/wp-content/uploads/2015/10/2015-Compact-Unified-Sea-Level-Rise-Projection.pdf>.

99 Ibid.

100 Union of Concerned Scientists, *Encroaching Tides in Miami-Dade County, Florida: Investing in Preparedness to Manage the Impacts of Rising Seas*, April 2016, <http://www.ucsusa.org/sites/default/files/attach/2016/04/miami-dade-sea-level-rise-tidal-flooding-fact-sheet.pdf>.

101 United States Environmental Protection Agency, *What Climate Change Means for Florida*, September 2016, <http://www.southeastfloridaclimatecompact.org/wp-content/uploads/2016/09/climate-change-FL.pdf>.

102 Ibid.

103 World Resources Institute, "Sea-Level Rise and Its Impact on Miami-Dade County Fact Sheet."

104 Ibid.

105 Abt Associates, *Climate Adaptation: The State of Practice in US Communities*, December 2016, <http://www.southeastfloridaclimatecompact.org/wp-content/uploads/2016/12/climate-adaptation-the-state-of-practice-in-us-communities-full-report.pdf>.

## Flood Management Infrastructure in a Changing Climate

southeast Florida's flood control infrastructure could be at 70 percent capacity.<sup>106</sup>

### Local Climate Adaptation Framework

In Miami, climate change work is largely collaborative and integrated across the municipality, the county government, and a four-county collective in southeast Florida. In 2006, Miami-Dade County created a Climate Change Advisory Task Force to guide the county's climate mitigation and adaptation work.<sup>107</sup> By 2008, the City of Miami published its Climate Action Plan addressing both mitigation and adaptation, positioning the city as a launch pad for institutionalizing climate planning and policies at the municipal level.<sup>108</sup> In 2009, the county co-founded the Southeast Florida Regional Climate Change Compact, and a regional climate action plan was developed for the four participating county governments.<sup>109</sup> In 2013, the county approved integrating climate change considerations into its Comprehensive Development Master Plan (CDMP) and established a Sea Level Rise Task Force to assess sea level rise threats and adaptation opportunities.<sup>110</sup> The CDMP states that county government should enhance coordination with state and municipal governments, and that regional sea level rise projections should be taken into consideration for the design, location, and development of infrastructure and public facilities in their jurisdiction.<sup>111</sup>

### Coordinating and Advancing Adaptation

The City of Miami's Sea Level Rise Committee has met monthly since 2015 to study the effects of sea level rise and recommend local policies to advance adaptation.<sup>112</sup> Local strategies for mainstreaming adaptation practices include making upgrades and modifications to building codes and zoning regulations, as well as working with the county and other levels of government to make broader infrastructure upgrades.

The County of Miami-Dade's Sea Level Rise Task Force aims to synthesize existing sea level rise analyses and make recommendations that enhance resilience in infrastructure, facilities, and real estate at the regional scale. At the county level, Miami Dade's Department of Regulatory and Economic Resources and Water and Sewer Department have taken steps to implement adaptation programs. The South Florida Water Management District (SFWMD) oversees a vast and complex water management system of canals, levees, water storage areas, pump stations, and other water controls equipment.<sup>113</sup> Thus far, the SFWMD has put in place two forward water pumps by the Miami International Airport and created a reservoir in parts of its jurisdiction to mitigate flooding in high-impervious urban areas.

The Water Management Division of the Regulatory and Economic Resources Department administers a countywide storm water master plan that is complementary to its Comprehensive Development Master Plan, emergency preparedness planning, and infrastructure upgrades that mitigate storm water and sea level rise.<sup>114</sup> Additionally, Miami-Dade County participates in the Southeast Florida Regional Climate Change Compact with three other adjacent county governments.<sup>115</sup> This regional collective of county governments aims to strengthen cross-county collaboration on climate mitigation and adaptation, and together advocates for climate policies and funding at the state and federal levels.

One of the region's greatest challenges is funding the infrastructure upgrades that need to be phased in over time. Significant portions of the city's and county's revenue streams rely on property taxes. As climate change threatens properties and causes devaluation or abandonment, that may mean reduced tax revenue for the city and county, and thus less money for climate

<sup>106</sup> World Resources Institute, "Sea-Level Rise and Its Impact on Miami-Dade County Fact Sheet."

<sup>107</sup> "Climate Change Advisory Taskforce," Miami-Dade County, 2016, <http://www.miamidade.gov/environment/boards/climate-change-task-force.asp>.

<sup>108</sup> Miami-Dade County, *Climate Change Action Plan*, [https://www.miamidade.gov/greenprint/pdf/climate\\_action\\_plan.pdf](https://www.miamidade.gov/greenprint/pdf/climate_action_plan.pdf).

<sup>109</sup> "Home," Southeast Florida Regional Climate Change Compact, accessed March 20, 2017, <http://www.southeastfloridaclimatecompact.org/>.

<sup>110</sup> Miami-Dade County, *Miami-Dade (Florida) Sea Level Rise Task Force Report and Recommendations*, 2014, <http://www.adaptationclearinghouse.org/resources/miami-dade-florida-sea-level-rise-task-force-report-and-recommendations>.

<sup>111</sup> Abt Associates, *Climate Adaptation: The State of Practice in US Communities*.

<sup>112</sup> Miami, Florida Code of Ordinances, "Chapter 2, Article XI, Division 18, Sec. 2-1271," [https://library.municode.com/FL/miami/codes/code\\_of\\_ordinances?nodid=PTIITHCO\\_CH2AD\\_ARTXIBOCOCO\\_DIV18SELERICO](https://library.municode.com/FL/miami/codes/code_of_ordinances?nodid=PTIITHCO_CH2AD_ARTXIBOCOCO_DIV18SELERICO).

<sup>113</sup> South Florida Water Management District, *Strategic Plan 2012-2017*, [https://www.sfwmd.gov/sites/default/files/documents/2012\\_strategic\\_plan.pdf](https://www.sfwmd.gov/sites/default/files/documents/2012_strategic_plan.pdf).

<sup>114</sup> Miami Sea Level Rise Task Force, *Final Status Reports in Response to Multiple Resolutions Pertaining to Recommendations by the Sea Level Task Force*, 2016, <http://www.miamidade.gov/mayor/library/memos-and-reports/2016/09/09.2116-Final-Status-Report-Response-Multiple-Resolutions-Pertaining-to-Recommendations-Sea-Level-Task-Force.pdf>.

<sup>115</sup> "Home," Southeast Florida Regional Climate Change Compact, accessed March 20, 2017, <http://www.southeastfloridaclimatecompact.org/>.



Miami cityscape. *Photo credit:* Ryan Parker.

adaptation investments. Private developers are taking a leadership role in making buildings more resilient, but the success of their investments also relies on other public infrastructure systems being adaptive and able to serve residents and businesses. Additionally, those private developers building with adaptation in mind tend to be high-end developers, reinforcing the line that divides those with and without adaptive capacity, with the potential to exacerbate socioeconomic inequalities.

Until now, many local and regional climate adaptation projects have been funded by federal and foundation grants, with some support from the state or universities. Miami-Dade County does not see those investments as reliable over the long term, especially as climate risks become greater and more capital is needed. Municipalities and the county are exploring the appropriateness of supplemental funding mechanisms, such as ad valorem taxes and municipal service taxing units, special assessments and municipal service benefit units, development taxes, storm water

and drainage fees, bonds, special districts, local government infrastructure surtaxes, and charter county and regional transportation system surtaxes.<sup>116</sup>

### **Social Equity in Adaptation**

Resilient Miami is a community-driven, foundation-funded initiative that mobilizes residents around climate planning, and builds capacity for community climate leaders and organizers. This program aims to enhance community resilience, create a better framework for community engagement on climate projects, and strengthen communication and collaboration among neighborhoods, the government, and the private sector.

Climate adaptation planning at the county level is also important for creating just solutions because in many multicounty metro areas marginalized populations are often spatially segregated from affluent communities. In Miami-Dade County, more than 20 percent of families with children live below the poverty line, making it challenging for these families to be resilient in the face

<sup>116</sup> Miami Sea Level Rise Task Force, *Final Status Reports in Response to Multiple Resolutions Pertaining to Recommendations by the Sea Level Task Force*.

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of climate shocks. In the Miami area, there is currently debate about whether the US Army Corps of Engineers should raise freshwater levels in the Everglades in order to increase flow eastward, thus creating a water force against intruding salt water of the Atlantic. If this were to happen, however, Sweetwater (west of Miami), a small low-income and predominately Latino suburban community, would be flooded out because it is low-lying and sits above the subterranean freshwater flow that runs eastward.<sup>117</sup> Many small low-income communities are located on high-risk land and must have a seat at the table in climate planning processes because just as with Sweetwater, positive-seeming flood mitigation strategies in one location could have catastrophic implications elsewhere.

### External Collaboration

Miami-Dade County participates in the US federal government's National Flood Insurance Program's

Community Rating System, which requires the country to take numerous flood mitigation actions to minimize flood insurance premiums for its residents.<sup>118</sup>

The City of Miami and Miami-Dade County are both participants of the Rockefeller Foundation's 100 Resilient Cities network.<sup>119</sup> In 2016, Miami appointed a chief resilience officer (CRO) to work in coordination with the CROs of Miami Beach and Miami-Dade County to create the region's first comprehensive Resilience Strategy Plan.

While Miami is not a participant in the global C40 program or the US Conference of Mayors' Climate Protection Agreement, Miami-Dade County is committed to the US Cool Counties Climate Stabilization Declaration and<sup>120</sup> the US Conference of Mayors' Climate Protection Agreement,<sup>121</sup> and is a member of ICLEI.

117 Natalie Delgadillo, "The Realities of Sea-Level Rise in Miami's Low-Income Communities," CityLab, October 23, 2014, <http://www.citylab.com/weather/2016/10/sea-level-rise-is-affecting-miami-low-income-communities/505109/>.

118 "Flood Insurance," Miami-Dade County, accessed March 24, 2017, <http://www.miamidade.gov/environment/flood-insurance.asp>.

119 "Greater Miami and the Beaches' Resilience Challenge," 100 Resilient Cities, accessed March 24, 2017, <http://www.100resilientcities.org/cities/greater-miami-and-the-beaches/>.

120 The US Cool Counties Climate Stabilization Declaration commits counties to reducing greenhouse gas emissions from public and private sources by 80 percent by 2050.

121 The US Conference of Mayors' Climate Protection Agreement commits cities to meeting or surpassing Kyoto Protocol targets in their

# COMPARATIVE ANALYSIS

The four cities analyzed in this paper provide a firsthand account of how addressing climate change is part of a larger equation in which complex political, social, economic, and environmental systems interact and shape prospects for sustainable development.<sup>122</sup>

Extreme weather conditions such as Hurricane Sandy in New York, inherent vulnerabilities in Rotterdam where the land is mostly below sea level, and frequent flooding from high tide, precipitation, and storm surges have increased awareness of climate change and its impacts. In turn, this has provided political leaders with the support to actively respond to the threats of climate change and increase buy-in from diverse segments of the population.

A multilevel governance of various types supports climate change adaptation in these cities.<sup>123</sup> Of the cities, Rotterdam is the only one that follows a vertical approach in which national, subnational, and regulatory frameworks directly influence the city's decisions on adaptation. In the two European case studies, high-level national vision, political mandates, and national adaptation plans and strategies provide a framework for accelerating adaptation in cities. At the same time, Rotterdam is a good illustration of the critical role that local governments play in scaling up community adaptation efforts. Across the Atlantic, the US federal government has a much smaller role in the development of the cities' climate visions and strategies. In Miami, efforts to address climate change are primarily undertaken by the county, with the city itself having limited jurisdiction and responsibilities. Conversely, New York makes relatively autonomous decisions, with limited involvement from the state and federal government.

This analysis shows that regardless of the governance structure, the political clout necessary for comprehensive adaptation planning and implementation is first enabled by strong mayoral leadership on climate change issues, commitment to

integrating climate change adaptation in the city's broader development framework strategies, and the sphere of influence outside the city's boundaries. Figure 1 presents the mayoral powers of the four cities.<sup>124</sup> The degree of political engagement of the city government will also determine the involvement and buy-in of the private sector, including utility providers and small and medium-sized enterprises. The same applies to the local community.<sup>125</sup>

At the operational level, cities have also modified their institutional structures to better address emerging issues such as sustainable development, technological advances, and climate change. In the past ten years, climate change institutional arrangements have been established in local authorities, building on existing ones and acting as coordination mechanisms. They are composed of a spearheading committee, which provides political guidance, and a multiagency technical committee. In addition to addressing the immediate risks associated with infrastructure, a robust coordination mechanism will also help identify trade-offs, synergies, and co-benefits, e.g., between adaptation and mitigation.

In all four case studies, strong scientific input is essential for decision making, addressing urgent, medium- and long-term adaptation needs, and setting ambitious mitigation targets. In this respect, global cities, such as London, New York, and Miami, are clearly at an advantage as they can tap into a pool of world-class experts and institutions, covering a broad range of environmental- and social science-related disciplines. Rotterdam also benefits from hosting a high-caliber climate research program in coastal protection.

However, while data and models have good near-term precision, they are less accurate over planning horizons longer than thirty to fifty years. The three cities and one county (Miami-Dade) realized the necessity of planning for adaptation, even when the best data were not available. Despite limited access to cutting-edge

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cities and taking steps to urge state and federal governments to enact climate policies.

122 "Home," Meridian Institute, <http://www.merid.org>.

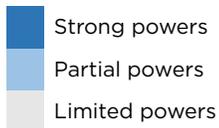
123 "Home," Connecting Delta Cities, <http://www.deltacities.com>.

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Figure 1. Mayoral powers on areas relating to flood management infrastructure

LONDON				
Finance and economy	Partial powers	Strong powers	Strong powers	Strong powers
Water	Limited powers	Partial powers	Partial powers	Partial powers
Urban and land use	Partial powers	Partial powers	Partial powers	Partial powers
ROTTERDAM				
Finance and economy	Partial powers	Limited powers	Limited powers	Limited powers
Water	Limited powers	Partial powers	Partial powers	Partial powers
Urban and land use	Limited powers	Limited powers	Limited powers	Limited powers
NEW YORK				
Finance and economy	Strong powers	Strong powers	Strong powers	Strong powers
Water	Strong powers	Strong powers	Strong powers	Strong powers
Urban and land use	Strong powers	Strong powers	Strong powers	Strong powers
MIAMI CITY				
Finance and economy	Partial powers	Partial powers	Strong powers	Strong powers
Water	Strong powers	Partial powers	Partial powers	Partial powers
Urban and land use	Partial powers	Partial powers	Partial powers	Partial powers



Source: Adapted from the C40 website, available at <http://www.c40.org/cities>, and complemented by the findings of this paper, in particular for the case of Miami, which is not a member of the C40.

information, the four locations were in agreement that they would have started planning for adaptation regardless, focusing on no-regrets options. They have adopted risk management approaches with respective degrees of flexibility to make room for necessary adjustments as the understanding of climate change and its impacts improves over time. More specifically, New York, London, and Rotterdam have developed adaptation pathways as a tool to explore and

sequence possible adaptation decisions and actions over time. This entails a dynamic sequence of analysis and action followed by evaluation, further analysis, and refinement.<sup>126</sup> In all cities, planning for flood management takes into consideration the interface between the cities’ administrative boundaries and the adjacent areas. New York also proposes tailored climate responses for each of its areas/boroughs.

<sup>126</sup> Rosenzweig, Solecki, Blake, Bowman, et al., “Developing Coastal Adaptation to Climate Change in the New York City Infrastructure-Shed.”

Figure 2. Climate risks and actions taken by cities

	London	Rotterdam	New York	Miami City/ Miami-Dade County
Flood (river, flash, and/or permanent inundations)	■■■	■■■	■■	■■■
Coastal flood	■■■■	■■■■	■■	■■
Storm (rain storm and/or severe wind)	■	■■■■	■■■	■■■
Water scarcity	■■■	■	■	■

- Recognized, but not currently being implemented
- Currently in effect and being piloted
- Currently in effect at a significant scale across most of the city
- Currently in effect city-wide

Source: Adopted from the C40 website, available at <http://www.c40.org/cities>, and complemented by the findings of this paper, in particular for the case of Miami, which is not a member of the C40.

Adaptation measures for flood mitigation include a mix of hard engineering solutions (e.g., storm surge barriers, flood defenses, draining and pumping infrastructure), green infrastructure (e.g., green roofs), and policy measures (changes in building codes and zoning). Measures also include the development of innovative tools to further enhance climate-proofing assets.<sup>127</sup> Several of these measures are in the process of implementation or have already been implemented across the case study cities. Figure 2 provides an overview of the progress made by each city in addressing some of the climate risks affecting flood mitigation infrastructure.

Our analysis indicates that reframing the adaptation discourse can prove to be useful for identifying opportunities to mobilize adaptation funding. In fact, as cities and regional governments take on primary adaptation roles and responsibilities, there is a need for added capital at these levels. Both in the United States and in Europe, many local and regional governments rely heavily on property tax revenue, but if property values depreciate because of increasing flooding risks, or if properties that have increasing flood insurance premiums cannot be sold or have to be abandoned due to sea level rise, city and regional governments could see decreased tax revenue. Decreased tax revenue could mean less availability of funds for adaptation investments. And, although private developers are seeing benefits in creating and marketing new developments such as resilient buildings, the longevity and success of these developments depend on broader municipal and public infrastructure systems being resilient too, in order to truly create adaptive and

resilient communities. The case of Miami is particularly compelling and demonstrates that policy makers should see climate change adaptation as protecting not only people and properties, but also sources of funding for continued adaptation investment.

Initial findings also tend to show that when major national political shifts are likely to affect subnational levels, such as the climate-skeptic federal administration of the United States led by President Donald Trump, cities may have to explore innovative ways to communicate their climate adaptation needs to national-level decision makers. If subnational governments are to protect existing federal support and continue to mobilize the national government funding necessary for large-scale infrastructure investments, climate projects may need to be framed in the context of their other beneficial effects, such as providing poverty reduction, job creation, improved health outcomes, and disaster risk reduction to overcome national-level resistance to climate change-themed projects.

The case studies in this report also highlight the importance of engaging city stakeholders at various stages of the planning and implementation phases. Most of these stakeholders are associated with long-existing public, private, and community networks and organizations. They can also represent more recently founded networks, in particular those whose primary mission is to combat climate change, such as the London Climate Change Partnership. Careful consideration needs to be given to the engaged organizations and networks to ensure that the needs

<sup>127</sup> "Home," Connecting Delta Cities, <http://www.deltacities.com/>.

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of the most vulnerable segments of the population are fully taken on board. Similarly, the engagement should go beyond simple consultations to sustain public participation. While all cities recognize the added threat to vulnerable low-income populations, the majority of flood protection infrastructure investments are going to wealthier neighborhoods, creating protections for high-end coastal properties that bring in higher tax revenue and exacerbating inequality. By placing its inhabitants at the center of its adaptation strategy, Rotterdam offers practices that can be replicated in other cities.

Cities are increasingly engaged in international climate change forums. Leaders of cities such as New York, London, and Rotterdam have been instrumental in raising awareness of the role and responsibility of local governments in the fight against climate change. Cities' leadership roles are fostered through national and international city networks like the C40 and

ICLEI, which provide platforms for sharing lessons learned and best practices, forging partnerships, and bringing cities into the formal international discourse on climate change. The Paris Agreement gives visibility to subnational leadership;<sup>128</sup> the adoption and entry into force of the agreement has provided additional momentum and empowerment to cities as they continue to scale up their adaptation and mitigation action.

Against this backdrop and regardless of the supranational and national political contexts, cities with relatively high GDP, like the case studies, are unlikely to stop their climate efforts.<sup>129</sup> On the contrary, with sustained political leadership at the city/county level and strengthened international partnerships, these cities are likely to continue to enact progressive climate change policies and will strive to address, at the very least, their urgent adaptation needs.

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<sup>128</sup> United Nations, *Report of the Conference of the Parties on Its Twenty-First Session, Held in Paris from 30 November to 13 December 2015*, "Addendum: Part Two: Action Taken by the Conference of the Parties at Its Twenty-First session," January 29, 2016, <https://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf>.

<sup>129</sup> Wong, "Bloomberg Says Cities Will Fight Climate Change, with or without Trump."

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