Resilient by Design:
New York City's Climate Policies and Design Guidelines for Sea Level Rise, Urban Heat Island, and Stormwater Management

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Derrick Seegars

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Thesis Advisor: Sumeeta Srinivasan

Thesis Reader: Christine Cousineau

Abstract

This thesis examines New York City's climate resilience strategies, focusing on sea level rise, urban heat islands (UHI), and stormwater management. It evaluates the effectiveness of current policies, building codes, and design innovations in mitigating these interconnected challenges. The research addresses two central questions: (1) What design innovations and materials can enhance climate-resilient buildings in NYC? (2) How can LEED and other rating systems promote such innovations? Using mixed methods, including literature reviews, policy analysis, case studies of LEED and Passive House buildings, and interviews with experts, the study identifies gaps in NYC's reactive approach and proposes proactive solutions. Key findings highlight the inadequacy of outdated flood maps, the disproportionate impact of UHI on marginalized communities, and the need for integrated green infrastructure. The thesis recommends centralized governance, equitable resource allocation, and advanced materials like mass timber and phase-change materials to improve resilience. By aligning policy with future climate projections, NYC can safeguard its infrastructure and communities while setting a global standard for urban climate adaptation.

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Chapter 1. Introduction and Background

1.1 Research Topic

This thesis investigates three pivotal dimensions of climate change, sea level rise, urban heat islands (UHI), and stormwater management, within the context of New York City. By examining the city's existing policies, strategies, and building design methods addressing these challenges, the study aims to provide a holistic understanding of the vulnerabilities faced by NYC in the face of a changing climate. Through a combination of data analysis, policy evaluation, and stakeholder interviews, this research seeks to identify gaps and opportunities within current approaches, focusing on how innovative building design and renewable materials can mitigate climate risks more effectively. Ultimately, the goal is to develop evidence-based strategies and practical recommendations to bolster the city's resilience, reduce risks, and ensure sustainable adaptation for its communities, infrastructure, and ecosystems. By integrating scientific insights with urban planning and policy frameworks, this thesis aspires to contribute to a more robust and forward-thinking climate resilience agenda for New York City with a strong emphasis on the role of building design and policy adjustments as critical tools for climate adaptation measures.

New York City (NYC), one of the world's most populous and dynamic urban centers, faces unprecedented climate change challenges. Rising global temperatures, increasing frequency of extreme weather events, and accelerating sea level rise threaten the city's infrastructure and ecosystems, as well as the well-being of its residents. This analysis explores the gaps in NYC's building codes, the economic, social, and environmental costs of inaction, and how recent research fills a critical gap in policy and practice. By integrating these interconnected topics, this research aims to contribute to mandating climate-resilient design and construction standards for all new buildings and significant renovations in NYC, ensuring they can withstand climate-related risks while promoting sustainability and innovation.

New York City's building codes have evolved significantly, particularly in response to major climate events such as Hurricane Sandy. However, these codes remain largely reactive, focusing on mitigating immediate hazards rather than proactively addressing long-term, cumulative climate risks. For example, while the city has introduced flood-resistant construction standards and updated zoning regulations to reduce vulnerability to storm surges, these measures are often grounded in historical data rather than forward-looking climate projections.

This approach risks underestimating future challenges, as climate change is expected to exacerbate sea level rise, accelerate storm frequency, and increase the severity of urban heat islands (UHI).

According to the *U.S. Climate Resilience Toolkit* (n.d.), buildings and infrastructure must be designed with future climate scenarios in mind to ensure long-term resilience. While a step in the right direction, NYC's current codes do not fully account for the accelerating pace of climate change. For instance, flood maps and construction standards are based on past flood events, which may not accurately reflect future conditions due to rising sea levels and more frequent extreme weather events. Similarly, while energy efficiency standards have been incorporated to reduce greenhouse gas emissions, they often fall short of addressing the broader impacts of UHI, such as increased cooling demands and public health risks during heat waves.

NYC's building codes could integrate predictive modeling and climate adaptation strategies that align with future projections to enhance resilience. This could include elevating structures beyond current floodplain requirements, incorporating green infrastructure to manage stormwater more effectively, and mandating reflective materials or green roofs to mitigate UHI effects. By shifting from a reactive to a proactive framework, the city can better prepare for the compounding impacts of climate change, safeguarding its residents, infrastructure, and economy for decades to come.

1.2 Sea Level Rise and Coastal Flooding

Sea level rise (SLR) is one of the most pressing threats to NYC's future. The city's extensive coastline of 520 miles, population of over 8.5 million people, high building density, and concentration of critical infrastructure make it particularly vulnerable to coastal flooding. Climate change, driven by global warming and the melting of polar ice caps, is causing sea levels to rise at an accelerating rate. Current building codes in NYC are based on FEMA's Flood Insurance Rate Maps (FIRMs), which are outdated and do not account for future sea-level rise. In the NYC region, sea levels have risen by approximately 1.1 feet since 1900, and projections indicate an additional increase of 2.5 feet by mid-century and up to 6 feet by 2100 under high-emission scenarios (Horton et al., 2015). Such increases would exacerbate the frequency and severity of flooding events, disrupting transportation networks, energy systems, and wastewater treatment facilities (Solecki, 2012). The impact of SLR is not uniform; low-lying neighborhoods such as Red Hook, Battery Park City (BPC), and Broad Channel are at heightened risk, with

disproportionate effects on socio-economically disadvantaged communities. This thesis assesses the vulnerability of NYC's critical infrastructure to SLR and coastal flooding, using recently compiled predictive modeling data and geospatial analysis to identify high-risk zones and how to mitigate climate change issues using design metrics effectively.

Red Hook, a coastal neighborhood on the western edge of Brooklyn, might be the most vulnerable dense urban area within the city limits because it is surrounded by water on three sides (Figure 1).

During Hurricane Sandy in 2012, the neighborhood was most susceptible when it experienced catastrophic flooding, with water levels cresting over 10 feet in some locations. Resilience efforts were further complicated by the unique variation of residential areas mixed in with industrial warehouses. Many of these spaces were often housed in older and inadequately supported structures. Consequently, the storm surge from the hurricane inundated local businesses, displaced many residents, particularly in low-income and marginalized areas, and destroyed critical infrastructure. Nearly all scientists and climate change experts agree that Red Hook's exposure to storm surge and SLR will continue to increase for the rest of this century. Probabilistic study modeling of flood risks done by Aerts et al. (2013) and Karamouz et al. (2014), predicted that projected increases in extreme sea levels under different climate change scenarios could lead to a 25-48% rise in the magnitude of flooding for Red Hook.

Figure 1: Map of Red Hook, NYC

Another highly susceptible community in NYC to SLR and storm surge is a newer community, Battery Park City (BPC) (Figure 2). It was developed from reclaimed landfill from the original World Trade Center excavation in the 1970s and 1980s, and was already prone to flooding.

Hurricane Sandy demonstrated the severe vulnerabilities of Battery Park City due to its proximity to the massive Hudson River. A report that came out in 2019 (New York City Panel on Climate Change, 2019) demonstrated that SLR has consistently risen in Battery Park City at a rate of 0.11 inches per year since 1850 and with temperatures estimated to increase in NYC at an average of 5.7 degrees by 2050, BPC will need to adopt significant measures to shore up its vulnerabilities. To its credit, the Battery Park City Authority recognizes the ongoing issues the neighborhood is facing and has adopted a resilience plan for BPC's future. Their report, *Resilience Planning for Battery Park City* (Battery Park City Authority, 2020), highlights the need to adapt and protect Battery Park City from the threat of coastal flooding by exploring innovative financing, operating, and maintenance mechanisms for upgrading the infrastructure to minimize the risks associated with climate change. One specific proposal states the need to protect Pier A in the southern part of BPC, a geographic low point, the BPC Ball Fields, which over 50,000 residents use, and the Community Center, which has a flood barrier system. The BPC Authority is working with the City of New York, which has also implemented the East Side Coastal Resiliency Project to protect the other side of Lower Manhattan from storm surges and SLR.

Figure 2: Map of Battery Park City,

Another example is Broad Channel in Queens (Figures 3 and 4). This unique community differs from the other two densely populated neighborhoods of BPC and Red Hook; however, its location is potentially dangerous and unforgiving.

Situated in the center of Jamaica Bay, in the southern part of Queens, this small, tight-knit maritime island community is extremely close to sea level, with some areas only reaching 1 foot above the average high water level. It faces severe difficulty concerning storm-related flooding and the gradual inundation of SLR because it is surrounded by tidal waters, enhancing the neighborhood's susceptibility to high tide flooding and storm surges during weather events.

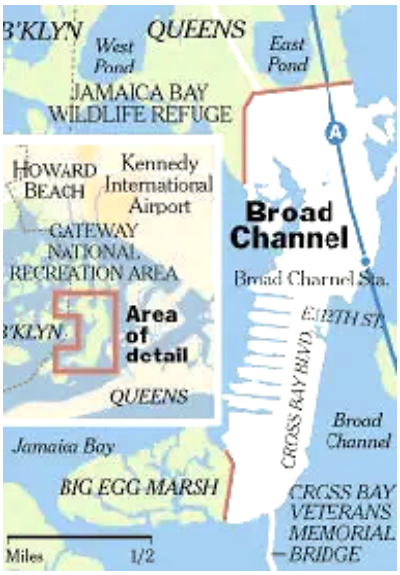

Figure 3: Broad Channel, Jamaica Bay, NYC

Figure 4: FEMA Flood Map risk assessment of Broad Channel

Once again, Hurricane Sandy in 2012 devastated the community with 1 in 260-year storm surge levels (McCallum et al., 2013). Roads, utilities, and infrastructure were ravaged by the more than 8-foot seas that impacted some areas. Broad Channel is a perfect neighborhood example where buildings and homes must be designed to meet the nearly 2.5-foot sea level rise in NYC by 2050 projections (Horton et al., 2015).

If these projected increases hold, they would render parts of the neighborhood uninhabitable and cause severe and frequent flooding for those areas that weren't already underwater. This is a very tight-knit community, somewhat isolated and unique from other NYC neighborhoods, with generational family ties to the seaside area. It provides an additional social vulnerability with its maritime culture. A further study done by Orton et al. (2020) predicts that due to Broad Channel's low lying area of elevation and its exposure to tidal waters under specific high emissions scenarios, extreme flooding will increase by almost 50% for the entire Jamaica Bay region which would further endanger resilience efforts in the Broad Channel neighborhood. This thesis discusses two methods of mitigating crises by design, as possible solutions: elevating housing and other buildings that would comply with updated Federal Emergency Management Agency (FEMA) flood maps and rapidly improving stormwater and drainage systems to help improve shoreline protections.

Proactive adaptation planning can also incorporate community-controlled land frameworks, such as community land trusts (CLTs) and community land banks, which secure land for public benefit, preserve long-term housing affordability, and enable strategic relocation

or redevelopment in safer areas before climate threats force unplanned displacement. In New York City, for example, the East Harlem/El Barrio CLT has acquired vacant city-owned lots to develop permanently affordable housing and community space, while policy advocates have explored establishing a municipal land bank to repurpose underutilized properties for resilience-oriented redevelopment (Alexander & Williams, 2008; Angotti, 2007; Meehan, 2014).

A final and more drastic option has been championed by some scholars, like Siders et al. (2019), who hold less hope that design and water management options will provide the necessary resilience that some communities like Broad Channel need, and discuss the difficult decision of managed retreat. This concept relocates the neighborhood's residents to safer areas due to the current one being unmanageable in the face of rising seas and flooding. In practice, managed retreat strategies can be paired with community-centered tools such as community land banks or community land trusts (CLTs) to preserve affordability and prevent displacement in receiving neighborhoods. Community land banks—often managed by local or regional authorities—can acquire and repurpose vacated or at-risk properties for flood mitigation, ecological restoration, or public use (Alexander & Williams, 2008). CLTs can secure land in safer areas for permanently affordable housing, ensuring that displaced residents are not priced out of the communities they relocate to (Angotti, 2007; Meehan, 2014). Integrating these mechanisms into planning for managed retreat helps maintain social networks, protect vulnerable populations from speculative real estate pressures, and foster equitable redevelopment. The Broad Channel community could face the reality of this last effort option without substantial investment in large-scale climate mitigation measures such as flood barriers, elevated buildings, and wetland restoration. This research evaluates these adaptive strategies, such as elevated infrastructure, managed retreat, and the potential role of community-controlled land frameworks, to provide insights into how NYC can build resilience against rising seas.

1.3 Stormwater Management

As climate change intensifies, New York City is experiencing more frequent and intense rainfall events, overwhelming its aging stormwater management systems. The city's infrastructure, designed for a 20th-century climate, is struggling to cope with the increased volume and intensity of precipitation. Combined sewer overflows (CSOs) and urban flooding have become increasingly common, threatening water quality, public health, and the resilience of communities. Traditional gray infrastructure, such as pipes, storage tanks, and centralized

drainage systems, is often insufficient to manage the volume of stormwater generated during extreme weather events (Zimmerman & Faris, 2010). Moreover, NYC's current building codes and stormwater management standards do not fully account for the increased intensity of storms projected under future climate scenarios, leaving many neighborhoods vulnerable to flooding. Many of the most severely affected areas and communities in NYC are densely populated and face severe flooding and an increased risk of pollution and contamination in their water supply and ground soil from poor stormwater management.

One of the most infamous and severely affected areas is the Newtown Creek watershed, which partially divides the boroughs of Queens and Brooklyn (Figure 5). As a 3.8-mile-long tributary flowing into the East River, the creek was once a thriving ecosystem. However, urbanization and industrialization over the past century have turned it into one of the most polluted waterways in the United States. Due to decades of damage from various sources of contamination of the Newtown Creek site, such as Combined Sewage Overflow and oil spills, it has been known as a Superfund site (U.S. Environmental Protection Agency, n.d.) since 2010. The Newtown Creek tributary area interacts with and affects multiple neighborhoods in the region, including Long Island City, Greenpoint, East Williamsburg, and Maspeth.

Figure 5: Map of Newtown Creek

Stormwater management is a critical issue for Newtown Creek, as the area is highly vulnerable to flooding and water pollution. The creek receives 1,161 million gallons of untreated sewage annually from CSOs, which account for 70% of the pathogen and nitrogen loads in the watershed (Figure 6).

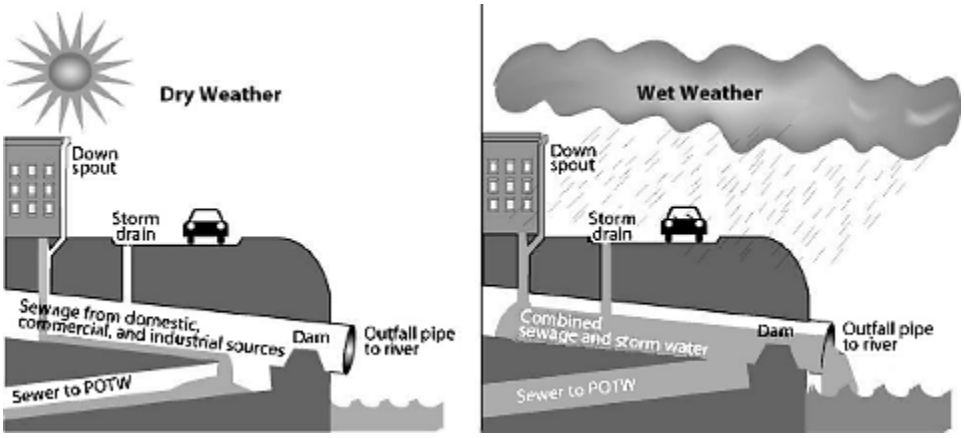

Figure 6: CSO Explanation Diagram of NYC

Additionally, stormwater runoff from impervious surfaces like roads and parking lots contributes to the contamination by depositing trash, debris, and metals into the creek. The area has suffered from decades of neglect by the city, state, and federal governments. In 2010, the federal Environmental Protection Agency (EPA) designated Newtown Creek a Superfund Site under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). As of 2025, the EPA has begun to clean it up. Supported by the State of New York. The remediation is focusing on sediment restoration, contaminant removal, and ecosystem recovery. The plan outlines several strategies to address these issues, including implementing green infrastructure such as bioswales and rain gardens, which can capture and filter stormwater before it reaches the creek. These solutions mimic the natural absorption of wetlands, help reduce flooding, and improve water quality.

The Lower East Side of Manhattan is another area heavily affected by stormwater issues. This densely populated neighborhood has two main issues concerning stormwater management: aging infrastructure and a high percentage of impervious surfaces. Alphabet City, a community just north of the Lower East Side (Figure 7), is a prime example of how aging drainage infrastructure and combined sewer system failures contribute to flooding. During heavy rainfall, stormwater accumulates in the streets and the basements of houses and buildings. One notable extreme event was during Tropical Storm Ida in 2021, when the neighborhood's

outdated sewer system could not handle the increased volume of water due to the storm's intensity, which caused massive disruptions and widespread property damage. Like Newtown Creek, water quality issues are a significant concern for Alphabet City and other communities like Seward Park and the waterfront in the Lower East Side. Runoff from impervious surfaces carries pollutants such as trash, heavy metals, and oil into the sewer system and gets discharged into the East River when CSO events occur. NYC's own Department of Environmental Protection (NYC DEP) has estimated that 80-90% of the Lower East Side comprises impervious land, and 65% of Manhattan as a borough overall (New York City Department of Environmental Protection [NYC DEP], 2010). The Lower East Side's paved streets, minimal green space, and tightly packed buildings are optimal for extensive and integrated green infrastructure plans, which NYC DEP has already started. However, it is still insufficient for areas like Alphabet City, which require additional green space such as tree cover, pocket parks, and community gardens to help absorb stormwater and reduce runoff. This thesis discusses an integrated stormwater management strategy to ensure the long-term monitoring and restoration of areas like Newtown Creek, Red Hook, Battery Park City, Broad Channel, Alphabet City, Hunts Point and mitigate future pollution risks across the city. In industrial districts like Hunts Point, piloting 'Sponge Block' retrofits which are permeable, modular stormwater units, can rapidly cut runoff and pollutant loads; this is critical because industrial areas generate around 50% more runoff than residential blocks.

Figure 7: Map of Alphabet City & Lower East Side neighborhoods, Manhattan

1.4 Urban Heat Island Effect

The UHI effect, characterized by elevated temperatures in urban areas compared to their rural surroundings, poses significant health and environmental risks to NYC residents. The city's dense built environment, extensive impervious surfaces, and limited green spaces contribute to heat retention, exacerbating temperature extremes during heat waves (Figure 8).

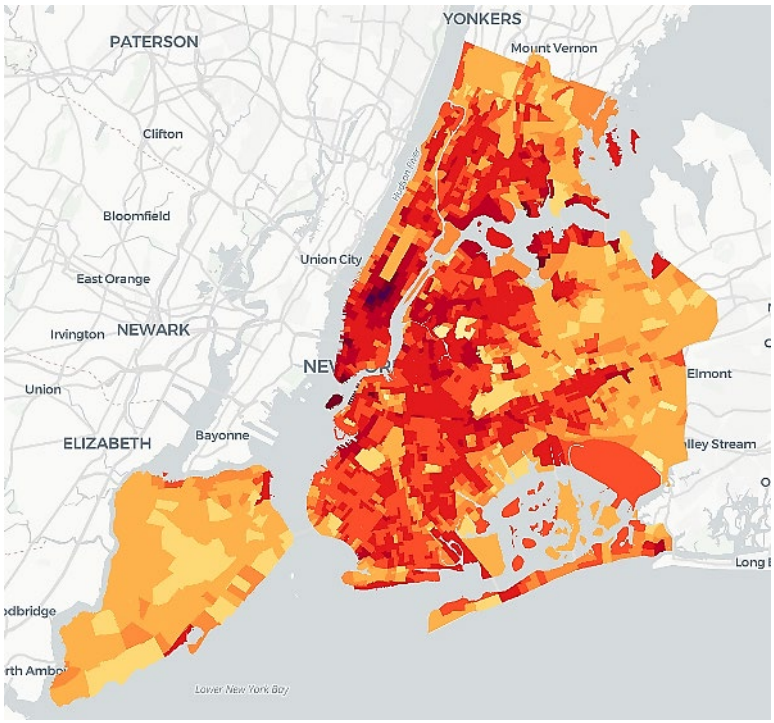

Figure 8: Map of NYC indicating areas with above-average land surface temperature (NYC Climate Central)

NYC's building codes lack stringent requirements for heat resilience. The UHI effect exacerbates temperatures in the city, which are projected to increase by 5.7°F by the 2050s (Rosenzweig et al., 2011). Several neighborhoods in NYC are at extreme risk of the effects of UHI, including Hunts Point/Mott Haven in the Bronx, East New York in Brooklyn, and Midtown Manhattan due to their lack of green space, high density of impervious surfaces, and limited access to cooling resources.

The neighborhood of Hunts Point, located in the Southeastern part of the Bronx, is an overwhelmingly low-income and highly industrialized area (Figure 9).

Figure 9: Map of Hunts Point neighborhood, The Bronx

Large swaths of land are dominated by asphalt and concrete for transportation infrastructure and industrial facilities that heavily influence heat retention. Hsu et al. (2021) have shown that during recent heat waves in Hunts Point, the ambient temperature can be as much as 5-10°F

higher than in the surrounding areas, which harms neighborhood residents and contributes to increased heat-related illnesses. Because industrial blocks shed around 50% more runoff than residential streets (Minnesota Pollution Control Agency [MPCA], 2023), pairing shade/heat measures with Sponge Block permeable modules can tackle heat and stormwater together in Hunts Point. Another derogatory effect UHI has in Hunts Point is the increased use of and demand for cooling, putting additional stress on the energy grid. The July 2021 heat wave exposed the vulnerabilities in Hunts Point's urban planning and infrastructure as residents experienced prolonged periods of heat exhaustion from the extreme heat, and some residents started exhibiting respiratory issues due to the lack of cooling resources and poor air quality.

Like the Hunts Point neighborhood, East New York faces significant challenges with resilience to UHI, as an extremely high percentage of the neighborhood infrastructure is impervious. The area has seen some of the highest temperatures in the city, especially during a July 2021 heatwave, when recorded temperatures reached 98°F, according to the National Weather Service (NWS). Due to the extreme heat, hospitalizations exponentially increased for heat-related illnesses, especially for those with pre-existing conditions and the elderly (Klein Rosenthal et al., 2020). The leading cause for the soaring heat in East New York is that it has minimal tree cover, as low as 11%, which is half the citywide average of 22% (NYC Parks, 2021). These vulnerabilities are exacerbated by the lack of access to cooling centers and the need for more urban parks and green spaces.

The final neighborhood in NYC that experienced severe UHI was Midtown Manhattan, which may be the most classic recognized area associated with UHI. Known for its high density of high-rise buildings, skyscrapers, and a densely packed street grid, the neighborhood has abundant asphalt and concrete. The overcrowding of midtown with business professionals, tourists, and residents, the lack of green space in a business district, and the prevalence of dark, heat-absorbing materials cause significantly elevated temperatures during the day and evening. An example of the lack of relief, even in the evening, was in August 2023, when nighttime temperatures were often 7-10°F above the nearby areas, causing increased air conditioning consumption and energy use. Due to the dense urban fabric within Midtown and its grid structure, skyscrapers often impede airflow, trapping heat and pollution between buildings, contributing to worsening air quality and smog that increases respiratory conditions. The lack of green space in Midtown heavily exacerbates respiratory conditions due to these trapped pollutants between high-rise buildings, with only 5% of the land area in Midtown covered by trees.

Current codes are adapting quickly to mitigate UHI using reflective materials, green roofs, and advanced cooling systems that could reduce heat impacts. One key initiative in this area is the NYC Cool Neighborhoods program, which aims to reduce the urban heat island effect by increasing tree cover and improving access to cooling centers. The program targets neighborhoods with high heat vulnerability indices, often found in low-income and marginalized communities, to gain access to green spaces and cooling resources. The program also includes outreach and education efforts to raise awareness of the health risks associated with extreme heat and promote community-based solutions (Hsu et al., 2021). Vulnerable populations, including the elderly, low-income communities, and those with pre-existing health conditions, are disproportionately affected by heat-related illnesses and mortality (Rosenthal et al., 2014). Green infrastructure, such as green roofs, urban parks, and tree canopies, has emerged as a promising strategy to mitigate the UHI effect by providing cooling benefits and improving air quality. This thesis evaluates the efficacy of green infrastructure in reducing urban temperatures. Additionally, the research will identify neighborhoods that lack access to cooling resources and propose policy interventions to address these disparities

1.5 Research Goals

While sea level rise, urban heat islands, and stormwater management are often studied in isolation, they are deeply interconnected. For example, green infrastructure designed to mitigate the UHI effect can also enhance stormwater retention, while coastal resilience measures must account for both flooding and heat stress. By addressing these challenges holistically, this thesis seeks to provide a more integrated approach to urban climate adaptation in NYC. The findings will advance academic understanding and inform policymakers, urban planners, and community stakeholders in their efforts to create a more resilient and equitable NYC. Combining holistic risk assessments provides a comprehensive framework integrating the interconnected climate change risks of sea-level rise, UHI, and stormwater management. Using future climate projections and socio-economic data to identify vulnerable areas and populations, this research develops integrated adaptation strategies that provide equity, resilience, and sustainability to the NYC region.

1.6 Research Questions

This thesis addresses the following research questions:

1) What design innovations and materials can be used to create climate-resilient buildings in New York City?

I investigate innovative Passive House building designs targeted to provide resiliency and enhance building performance to help mitigate climate change issues and decrease the demand on the energy grid. I conducted two small case studies on 425 Grand Concourse in the Bronx and Cornell's Tech Building on Roosevelt Island. As some of the largest Passive House Designs in the world, these developments demonstrate the use of resilience measures such as high insulation methods, elevated buildings, green roofs, rain gardens, and ventilated facades to combat urban heat island effects, flooding, and wind damage. I also examine adaptive materials such as phase-change materials (PCMs) for thermal regulation, permeable pavements for stormwater management, or high-performance glazing to protect against heat and cold. I analyze current building materials and methods and how we can use more efficient materials, technology, and practices to better adapt to our changing climate.

2) How can LEED and other building rating systems promote the design innovations and materials that can be used to create climate-resilient buildings in New York City?

This thesis addresses the role of LEED (Leadership in Energy and Environmental Design) and other building rating systems in promoting climate-resilient design innovations and materials through a multi-faceted approach. To analyze the impacts LEED can have on some large-scale skyscrapers, I include two case studies on One Bryant Park and the new JP Morgan Chase Headquarters, both in Midtown Manhattan. The study explores what makes these buildings unique in LEED ratings and how effective their design and materials are at minimizing climate change impacts. The thesis explores how these rating systems incentivize the adoption of sustainable and resilient practices, such as energy efficiency, water conservation, and durable, low-impact materials. It also examines how LEED and similar frameworks can be tailored or expanded to better address NYC-specific climate risks.

Chapter 2. Methodology

2.1 Methodology

This thesis uses mixed methods to gather, analyze, and synthesize data, developing recommendations for designing and implementing green infrastructure projects that address climate resilience, mitigate urban heat island effects, manage stormwater, and enhance air quality. It analyzes existing data to understand current conditions, identify vulnerabilities, and establish a baseline for measuring progress. The data-driven methodology ensures the framework is evidence-based, inclusive, aligned with NYC's climate goals, and tailored to address its diverse and unique neighborhoods. Below is an outline of the methods and data collection process:

2.2 Research Framework

1. **Conduct Literature Review and Policy Analysis**
   - Review existing literature, including peer-reviewed articles, government reports, and case studies on climate-resilient building codes.
   - Analyze NYC's existing climate policies, such as PlaNYC, the Climate Mobilization Act, and Local Law 97, using existing studies to identify their effectiveness.
   - Review emissions levels and reduction targets before the implementation of these laws and identify opportunities for improvement.

2. **Design Methods and Materiality**
   - Analyze the history of materials and construction methods used throughout New York City's history. Identify reasons for design flaws and material failures concerning climate change issues.
   - Identify innovative materials that build on and expand on previous materials, providing new layers of resilience and environmental benefits for the construction field.

3. **Micro Case Studies**
   - Provide two case studies of current initiatives or buildings that exhibit exemplary climate mitigation and environmental practices.
   - Provide two case studies of LEED and Passive House building practices

4. **Interviews**
    - Conduct three semi-structured interviews with David Burney, John Mandyck, and Dr. Paul Crovella
    - Summarize and analyze the interviews to find common themes and trends for policy recommendations, impactful material, and design metrics

5. **Data Collection Methods**
    - **Quantitative Data Collection**
    - **Data Sources**
    - Building Energy Data: Energy use and emissions data from NYC's Benchmarking Law (Local Law 84).
    - Climate Risk Data: Climate projections from the New York City Panel on Climate Change (NPCC), National Oceanic & Atmospheric Administration (NOAA), and Federal Emergency Management Agency (FEMA), including sea-level rise, extreme heat, and precipitation trends.
    - Building Stock Data: Data on the age, type, and condition of NYC's building stock from the Department of Buildings (DOB).

    - **Qualitative Data Collection**
    - **Semi-structured Interviews**
    - Collect information and data from NYC climate policy decision-makers and climate change professionals using Zoom interviews and questionnaires. Interview questions are in Appendix C.

6. **Findings and Analysis**
    - Summarize the information and research from the Literature Review (Chapter 3), Building Methods and Materials (Chapter 4), the case studies in Modern, Sustainable, and Resilient Building Methods (Chapter 5), discuss the findings from the interviews (Chapter 6) and identify takeaways from this research in Findings and Analysis (Chapter 7).

7. **Recommendations and Conclusion**
    - Provide structured and actionable recommendations based on the gathering of information and analysis.
    - Outline a climate action plan for the three climate change issues.

Chapter 3. Literature Review: New York City's Climate Change Policy History

3.1 Overview and History

New York City has emerged as a global leader in urban climate action, developing innovative policies and regulations to address the dual challenges of climate change mitigation and adaptation. As a low-lying coastal megacity with over 520 miles of shoreline, NYC faces significant risks from sea-level rise, extreme weather events, and intensifying urban heat islands. Scientific projections indicate that sea levels around NYC could rise by as much as 30 to 50 inches by the 2080s (NPCC, 2019), while the frequency of extreme heat events is expected to triple by the 2050s (Rosenzweig et al., 2019). These threats, compounded by the city's dense urban fabric and aging infrastructure, have necessitated a robust policy response.

Over the past two decades, NYC has implemented groundbreaking climate initiatives, beginning with *PlaNYC* (2007), the city's first comprehensive sustainability plan under Mayor Michael Bloomberg. *PlaNYC* set ambitious targets, including a 30% reduction in greenhouse gas (GHG) emissions by 2030, and introduced measures such as energy-efficient building retrofits, expanded green spaces, and congestion pricing (though the latter was delayed due to political opposition). The plan laid the foundation for subsequent policies by integrating climate resilience into urban planning.

A major turning point came in 2012 with Hurricane Sandy, which exposed NYC's vulnerability to climate disasters. The storm caused $19 billion in damages, flooded 17% of the city's land area, and triggered widespread power outages (City of New York, 2013). In response, Mayor Bill de Blasio's administration launched *OneNYC* (2015), an updated sustainability agenda incorporating Sandy's lessons. *OneNYC* introduced mandatory building retrofits under Local Law 97 (part of the Climate Mobilization Act of 2019), which requires large buildings to cut emissions by 40% by 2030 and by 80% by 2050. These actions have led to the most stringent regulations in any U.S. city. This literature review synthesizes peer-reviewed studies, city reports, and policy evaluations to analyze NYC's climate policy history, assessing its successes, limitations, and future directions in global urban climate governance.

3.2 Early Awareness and Initial Responses (1990s-2000s)

The 1990s marked the beginning of NYC's formal engagement with climate change issues, spurred by growing scientific consensus on global warming and early signs of local impacts, such as increased coastal flooding and heat-related mortality. During this period, the city began to recognize the potential threats posed by climate change to its infrastructure, economy, and population, particularly given its dense urban environment and extensive waterfront. One of the earliest institutional responses was the 1997 NYC Watershed Memorandum of Agreement, which, while primarily focused on water quality, indirectly addressed climate resilience by protecting upstate reservoirs, a critical drinking water source, from pollution and erosion exacerbated by extreme weather (Platt, 2005).

Concurrently, NYC began aligning local policies with broader climate goals. In 2005, under Mayor Michael Bloomberg, the city joined the U.S. Mayors Climate Protection Agreement, pledging to meet or exceed the Kyoto Protocol's GHG reduction targets (7% below 1990 levels by 2012). While NYC did not achieve the specific Kyoto-equivalent goal of reducing emissions 7% below 1990 levels by 2012, NYC's emissions did reduce by 19% between 2005 and 2012, which is still a significant decline (New York City Mayor's Office of Sustainability, 2012). This commitment spurred early mitigation efforts, including pilot programs for energy-efficient street lighting, which helped decrease municipal electricity usage by 6%, and tax incentives for green buildings.

3.3 PlaNYC: A Comprehensive Climate Action Plan (2007)

The launch of *PlaNYC* in 2007 marked a turning point in NYC's climate policy history. Released by Mayor Michael Bloomberg, *PlaNYC* was a groundbreaking, long-term sustainability plan designed to prepare the city for a projected population increase of one million residents by 2030 while addressing climate change, air quality, energy, transportation, and water management. The plan set ambitious goals for reducing GHG emissions by 30% below 2005 levels by 2030, focusing on improving energy efficiency in buildings, expanding public transportation, and increasing the use of renewable energy (City of New York, 2007).

PlaNYC was notable for its integrated approach to climate change mitigation and adaptation. The plan recognized that reducing GHG emissions alone would not be sufficient to protect NYC from climate change's impacts. It included a range of adaptation measures, such as improving the resilience of critical infrastructure and enhancing coastal defenses

(Rosenzweig et al., 2011). For example, the plan called for creating a comprehensive coastal protection strategy and developing green infrastructure to manage stormwater and reduce flooding risks (Foster et al., 2011). PlaNYC also emphasized the importance of stakeholder engagement and public participation in shaping the city's climate policies, which helped to build broad-based support for the plan.

A pivotal moment came in 2008 with the establishment of the New York City Panel on Climate Change (NPCC), a body of climate scientists, engineers, and policy experts. The NPCC's first assessment report (2010) provided localized climate projections, warning that sea levels around NYC could rise 4 to 12 inches by the 2020s and up to 55 inches by the 2080s, with increased frequency of intense hurricanes (New York City Panel on Climate Change [NPCC], 2010). These findings directly informed early adaptation strategies, such as elevating critical infrastructure and revising floodplain maps.

The success of *PlaNYC* along with the establishment of the NPCC paved the way for creating *OneNYC* in 2015, which expanded *PlaNYC*'s goals to include social and economic equity, further solidifying NYC's position as a global leader in urban climate action. By 2011, NYC had already reduced its GHG emissions by 13%, primarily due to improved energy efficiency and the adoption of cleaner energy sources (City of New York, 2011). This early progress demonstrated the effectiveness of *PlaNYC*'s integrated approach to sustainability, which combined climate mitigation, adaptation, and urban planning. Further expanding on its earlier progress, NYC has since introduced new plans, such as *OneNYC* 2050 in 2019 to include economic and social equity, and *PlaNYC: Getting Sustainability Done* in 2023 as the latest iterations to accelerate climate action and enable more equity in the face of growing climate risks.

3.4 The Role of Local Governance and Policy Innovation

New York City's climate policies have been shaped by its unique governance structure and strong "home rule" authority, which grant it a high degree of local autonomy compared with most U.S. cities. This independence enables the city to enact ambitious climate initiatives, such as Local Law 97 and the Climate Mobilization Act, that often surpass both state and federal standards. In contrast, municipalities in many other states operate under restrictive pre-emption laws that limit their ability to adopt local building performance mandates, renewable energy requirements, or emissions caps, leaving them more reliant on state-led climate action. New

York City's mayors and city councils have played a central role in driving climate action, leveraging municipal authority to implement aggressive sustainability measures. For example, in 2009, under Mayor Bloomberg, NYC adopted Local Law 84 (LL84), as a part of the *Greener, Greater Buildings Plan* (GGBP), one of the nation's first mandatory energy benchmarking laws, which required large buildings to track and disclose energy and water usage. This policy improved transparency and spurred market-driven efficiency upgrades, reducing citywide emissions by 8% within its first decade. The success of LL84 inspired similar laws in over 30 U.S. cities, cementing NYC's role as a model for urban climate governance (NYC Mayor's Office of Long-Term Planning and Sustainability, 2012).

Another landmark innovation was the 2010 *NYC Green Infrastructure Plan*, which reimagined stormwater management by prioritizing nature-based solutions over traditional "gray" infrastructure. The plan mandated the integration of green roofs, bioswales, and permeable pavements to absorb rainfall, reducing combined sewer overflows (CSOs) by 1.5 billion gallons annually (Foster et al., 2011). Beyond water quality benefits, these measures mitigated urban heat islands—a critical co-benefit for neighborhoods like Hunts Point, where temperatures can spike 10°F above surrounding areas due to asphalt-heavy landscapes. The plan's community-focused implementation, including partnerships with nonprofits to maintain rain gardens in low-income areas, demonstrated how local governance could address both ecological and equity challenges.

NYC's ability to tailor policies to its dense urban environment has been key to its leadership. For instance, Local Law 97 (2019), the central piece of legislation of the Climate Mobilization Act, set stringent carbon caps for large buildings, a bold move given that structures account for 70% of the city's emissions. Unlike federal or state regulations, LL97 included penalties for noncompliance, ensuring accountability. Similarly, the Zoning for Carbon Neutrality (2024) initiative introduced solar access overlays and "cool corridor" requirements, directly linking land-use policy to climate goals.

However, challenges remain, including fragmented agency coordination and underfunded mandates. For example, while the city's Department of Environmental Protection (DEP) oversees green infrastructure, the Department of Buildings (DOB) enforces energy codes, creating silos that delay projects. Experts like David Burney (former NYC Chief Architect) have called for a centralized Climate Resilience Office to streamline cross-agency efforts (see Chapter 6). Ultimately, NYC's governance innovations highlight the power of local action. Still,

sustained progress will require binding regional partnerships, equitable funding, and scalable pilot programs to ensure resilience reaches all five boroughs.

3.5 Post-Sandy Climate Resilience Efforts (2012-Present)

The devastation caused by Hurricane Sandy in 2012 served as a catalytic moment for New York City's climate adaptation planning, exposing critical vulnerabilities in the city's infrastructure systems and emergency preparedness. The storm's impacts were staggering: floodwaters inundated 17% of the city's land area, damaged 90,000 buildings, and caused $19 billion in economic losses (City of New York, 2013). These impacts were disproportionately concentrated in low-lying coastal communities like Red Hook, where flood depths exceeded 10 feet, and Broad Channel, where 80% of homes were damaged (Orton et al., 2015). The disaster revealed systematic gaps in flood protection standards, as much of the inundation occurred in areas outside FEMA's outdated 100-year floodplain zones, previously considered low-risk (Figure 24, Appendix B).

In response, the de Blasio administration's *A Stronger, More Resilient New York* (2013) plan adopted a multi-layered resilience strategy combining gray infrastructure, nature-based solutions, and policy reforms. The $20 billion initiative prioritized:

1. **Physical protections:** Construction of the 5.3-mile Big U flood barrier system (completed in 2023) along Manhattan's East Side, designed to withstand 1-in-100-year storms while incorporating public amenities like parks and bike paths (Bader et al., 2021).

2. **Building retrofits:** Mandatory elevation of electrical and mechanical systems in 40,000 flood-prone buildings through Local Law 100 (2013), reducing flood damage risks by an estimated 65% in subsequent storms (City of New York, 2013).

3. **Community-scale adaptation**: Creation of the Community Reconstruction Zone Program, which allocated $25 million to neighborhood-designed projects like Red Hook's elevated power grid and Staten Island's living breakwaters (NPCC, 2019).

Scientific advances in climate projection modeling underpinned these efforts. The NPCC's 2015 report introduced compound flood risk assessments, analyzing how sea-level rise (projected at 30-50 inches by the 2080s) would amplify storm surge impacts (Horton et al., 2015). This informed the revision of building codes to require that new floodplain developments elevate structures by 2 feet above FEMA's 100-year base flood elevation. This standard would

later be adopted statewide. However, implementation challenges persist as a 2023 audit found that only 42% of planned resilience projects met original timelines, with delays concentrated in environmental justice communities due to complex permitting processes (NYC Comptroller, 2022). Environmental justice (EJ) communities face disproportionate permitting delays for climate resilience projects due to systemic inequities. Aging infrastructure, such as outdated drainage and electrical systems in neighborhoods like the South Bronx and Red Hook, requires costly upgrades and additional environmental reviews (e.g., asbestos remediation), complicating project timelines. Mixed-use zoning and brownfield sites also trigger multi-agency approvals and lengthy assessments, unlike wealthier areas with simpler land use profiles.

Community distrust and bureaucratic hurdles further slow progress. Residents often oppose projects due to historical disinvestment, demanding redesigns or filing lawsuits, while language barriers prolong consensus-building. EJ projects frequently rely on state or federal grants, which impose strict compliance rules, and understaffed agencies prioritize high-value developments elsewhere. Competing projects such as affordable housing and transit repairs often overwhelm local permitting capacity, creating bottlenecks that delay critical upgrades. These layered challenges perpetuate disparities in climate resilience investment. While New York City has made strides in integrating climate science into policy, disparities in project implementation highlight the need for more streamlined processes and equitable resource allocation to ensure resilience measures reach all communities effectively.

3.6 The Role of the NYC Climate Mobilization Act (2019)

In 2019, NYC took a significant step forward in its climate policy by passing the Climate Mobilization Act (CMA), a package of laws to reduce the city’s GHG emissions and improve energy efficiency. The Climate Mobilization Act represents New York City's most comprehensive legislative effort to combat climate change, marking a paradigm shift in urban climate governance. Enacted as a package of ten interlocking laws, the CMA emerged from years of advocacy following the Paris Agreement (2015) and built upon the foundation laid by *PlaNYC* and *OneNYC*.

At its core, the legislation addresses the stark reality that buildings account for nearly 70% of NYC's greenhouse gas emissions (City of New York, 2019), with the office, residential, and institutional sectors being the largest contributors. The CMA's centerpiece, Local Law 97 (LL97), established the nation's first mandatory carbon caps for existing buildings over 25,000

square feet, which amounts to approximately 50,000 structures in NYC covering 60% of the city's built area (Urban Green Council, 2020). LL97 introduced a phased compliance system with escalating stringency. Starting in 2024, all buildings over 25,000 square feet must meet initial emissions intensity limits ($kgCO_2e/sf/year$) based on occupancy type, with hospitals allowed 8.46 kg of CO2 per square foot per year while office buildings face a limit of 4.53. In 2030, these emissions limits will tighten by 40% from the initial 2005 emission levels, and by 2050, an 80% mandated emissions reduction will be enforced to align with NYC's carbon neutrality goals.

The law's technical sophistication is evident in its 10 occupancy-specific limits and renewable energy credits (RECs) provisions. Buildings can offset 10% of emissions through REC purchases from NYC-based solar or wind projects, creating a local green economy stimulus (NYC Mayor's Office of Sustainability, 2021). The legislation also established the LL97 Technical Advisory Board, whose 2022 report introduced crucial flexibilities: hospitals may count cogeneration systems toward compliance if achieving 70% efficiency, while residential buildings gained thermal envelope improvement options ((New York City Local Law 97 Advisory Board, 2022).

As significant as LL97 has been, as it is projected to eliminate 5.3 million metric tons of emissions annually by 2030, or the equivalent of removing 1.1 million cars from roads, the law has faced significant implementation hurdles (Chervonski et al., 2023). A 2022 NYC Comptroller audit revealed that 38% of covered buildings failed to submit required benchmarking data, with non-compliance concentrated in older, low-income housing (NYC Comptroller, 2022). The NYC Housing Authority (NYCHA) estimates retrofitting its 2,400 buildings to meet 2030 targets would require $40 billion, a sum greatly exceeding its capital budget, which in 2021 was $7.4 billion for the period 2021-2025 (Steele, 2022). Recognizing that some of these targets would require flexibility to implement, a number of complementary measures are afforded in the CMA, which include three local laws to help address disparities:

1. **Local Law 94:** Requiring green roofs or solar panels on all new constructions.

2. **Local Law 95:** Mandating energy efficiency letter grades displayed at building entrances, creating market pressure for upgrades.

3. **Local Law 96:** Created the NYC Accelerator program, providing free technical assistance that has assisted over 20,000 buildings and help initiate 25,000 retrofits since 2015 to identify hundreds of millions in annual energy savings since 2020 (MOCEJ, 2024)

Early outcomes demonstrate the CMA's transformative potential. A 2024 Columbia University study found that buildings complying with 2024 standards reduced emissions by 22% while creating 23,000 green jobs (Chervonski et al., 2024). The law's public health benefits are equally significant: EPA models project the 2030 targets will prevent 130 premature deaths annually by reducing PM2.5 emissions (NYC DOH, 2023).

However, the law's market-based mechanisms remain contentious. The proposed carbon trading system, modeled after California's cap-and-trade program, could allow buildings to purchase offsets for up to 30% of emissions. Critics argue that this provision may perpetuate pollution in environmental justice communities (NYC Environmental Justice Alliance, 2023). As NYC entered the first compliance period in 2024, the CMA represented both a groundbreaking climate policy experiment and a test case for balancing regulatory ambition with equitable implementation.

3.7 The Role of Equity and Environmental Justice in NYC's Climate Policies

The integration of equity and environmental justice (EJ) principles into New York City's climate policy framework has emerged as a critical area of scholarly and policy focus, particularly following Hurricane Sandy's disproportionate impacts on marginalized communities. Academic research demonstrates that systemic inequities which are rooted in historical disinvestment, industrial zoning decisions, and infrastructure disparities, have amplified climate vulnerabilities in low-income neighborhoods and communities of color (Chervonski et al., 2024; Klinenberg, 2015). These findings have catalyzed institutional reforms and targeted programs to address spatial inequalities in climate resilience.

A pivotal development in this evolution was the establishment of the NYC Environmental Justice Advisory Board (EJB) in 2018, which institutionalized community representation in climate policymaking. As city reports (City of New York, 2018) outlined, the EJB's hybrid composition of grassroots advocates and technical experts directly influenced the Climate Mobilization Act (2019), ensuring provisions to mitigate displacement risks in vulnerable areas. This model was expanded in 2022 by creating the Mayor's Office of Climate and Environmental Justice (MOCEJ), which consolidated previously fragmented equity initiatives. Evaluations of

MOCEJ's Climate Justice Hubs, neighborhood centers providing resilience training and green job placement, show measurable improvements in resource access for environmental justice communities (NYC MOCEJ, 2023).

Technical tools like the Climate Vulnerability Index (CVI), launched in 2023, represent advancements in data-driven equity planning. By synthesizing 24 indicators of social and environmental risk (NYC DOH, 2023), the CVI has guided targeted investments, such as the $100 million flood resilience program for Red Hook and Hunts Point. Similarly, the Cool Neighborhoods NYC initiative increased tree canopy coverage in heat-vulnerable areas like East New York from 11% to 18% between 2021 and 2023 (Hsu et al., 2021). However, critical analyses reveal persistent gaps: Chervonski et al. (2024) identified regressive cost burdens from Local Law 97 compliance in Sunset Park, while Klinenberg (2015) documented uneven post-Sandy recovery funding favoring Manhattan's Financial District over working-class Queens neighborhoods.

Community-led adaptation efforts have emerged as vital complements to municipal action. Partnerships like the Newtown Creek Alliance's bioswale projects demonstrate effective hybrid governance models, combining DEP technical expertise with community knowledge to manage stormwater in industrial areas (Zimmerman & Faris, 2023). Yet structural barriers persist, including protracted timelines for Superfund cleanups and misaligned procurement systems that limit minority contractor participation.

Comparative policy studies highlight NYC's innovative yet uneven progress. While the city's EJ frameworks exceed federal standards, analyses of California's SB 535 funding mechanisms suggest opportunities to strengthen resource targeting (California Environmental Protection Agency [CalEPA], n.d.). The academic consensus underscores that despite institutional advances—from the EJB to MOCEJ—operational challenges in funding distribution, cross-agency coordination, and community capacity-building continue to hinder equitable outcomes for frontline communities.

3.8 Recent Developments in NYC's Climate Policy Framework (2020-2024)

The period from 2020 to 2024 has seen New York City double down on its climate commitments through a series of innovative policies and programs. The updated *PlaNYC: Getting Sustainability Done* (City of New York, 2023) represents a significant evolution from previous plans, incorporating climate justice as a central pillar and introducing sector-specific

decarbonization roadmaps. A critical development has been the establishment of the Mayor's Office of Climate and Environmental Justice (MOCEJ) in 2022, which consolidated previously fragmented initiatives under one umbrella (NYC Mayor's Office, 2022).

The city's approach to building emissions has become increasingly sophisticated. The LL97 Technical Advisory Board's 2023 report introduced building-type-specific compliance pathways, recognizing that a hospital's needs differ fundamentally from those of a residential high-rise (City of New York Department of Buildings, 2023). For instance, hospitals can now count cogeneration systems toward compliance if they meet strict efficiency standards, while residential buildings have new options for thermal envelope improvements. The city has also launched the Building Energy Exchange, a technical assistance program that has helped over 500 buildings identify cost-effective retrofits since 2021 (BE-Ex, 2023).

Equity initiatives have moved beyond planning documents into concrete programs. The Climate Justice Hub initiative, launched in 2023, has established neighborhood resource centers in all five boroughs, providing everything from heat pump installation assistance to job training in green industries (NYC MOCEJ, 2024). These hubs are strategically located in environmental justice areas identified through the city's Climate Vulnerability Index, which combines 24 indicators of social and environmental risk (NYC DOH, 2023).

3.9 The Role of Zoning and Building Codes in Climate Resilience

New York City's zoning and building code innovations have positioned it as a global leader in climate-resilient urban development. The Climate Resiliency Design Guidelines (NYC DCP, 2023) represent a paradigm shift in urban planning by mandating developers to integrate forward-looking climate projections from the New York City Panel on Climate Change into all design and construction phases. These guidelines require site-specific vulnerability assessments that account for multiple climate hazards, including compound flooding from combined sea-level rise and extreme precipitation (NPCC, 2024). For instance, new developments in the Gowanus rezoning area must elevate critical infrastructure and incorporate amphibious foundation systems that allow structures to float during flood events while remaining anchored to their bases (NYC Planning Commission, 2024). This approach, inspired by Dutch "water plazas," has reduced flood damage risks by an estimated 60% in pilot projects (Waterfront Alliance, 2024).

The city has also recently implemented a new zoning initiative known as the Zoning for Carbon Neutrality, which introduces three groundbreaking provisions: Solar Access Overlays, Cool Corridor Requirements, and Resilience Setbacks. In zones with high solar potential, the Department of City Planning determined that new buildings must maximize photovoltaic-ready roof areas and avoid shading adjacent solar installations (NYC DCP, 2023. This zoning ordinance helps promote renewable energy by encouraging the installation of photovoltaic (PV) systems, protecting solar access by restricting new buildings from casting shadows on existing solar panels and solar-ready roofs. New building construction must also designate flat or south-facing roof areas to maximize future solar installation space and sun alignment. These developments also undergo rigorous solar shadow studies to demonstrate they will not cast shade on adjacent solar installations during peak solar hours (9 AM - 3 PM).

3.10 Conclusion

NYC's climate change policies and regulations have evolved significantly since the mid-1990's, reflecting the city's growing awareness of the risks posed by climate change and its commitment to acting. From the early days of *PlaNYC* to the passage of Local Law 97 through the Climate Mobilization Act in 2019 to the 2023 *PlaNYC: Getting Sustainability Done*, NYC has demonstrated a willingness to take bold and innovative steps to address climate change. However, the city also faces significant challenges, particularly in retrofitting existing buildings and addressing the social and economic impacts of climate change. As NYC grapples with these challenges, it will be essential to focus on equity and environmental justice to ensure that all residents benefit from the city's climate initiatives.

The literature reveals that NYC's policy innovations have often outpaced its implementation capacity, creating gaps between legislative ambition and on-the-ground outcomes. While the Climate Mobilization Act set world-leading emissions targets, studies show that 42% of covered buildings remain non-compliant with benchmarking requirements, particularly in low-income neighborhoods where retrofit costs are prohibitive (NYC Comptroller, 2022). Similarly, the city's post-Sandy resilience investments, though technologically sophisticated, have been unevenly distributed, with flood protection projects in the Financial District progressing three times faster than those in working-class communities like Broad Channel (Klinenberg, 2015). These disparities underscore the tension between NYC's role as a global climate leader and its struggle to ensure equitable implementation, a challenge that mirrors findings in other coastal megacities (Rosenzweig et al., 2018).

Looking ahead, emerging research highlights three critical priorities for NYC's next policy phase. First, the city must reconcile its aggressive decarbonization timeline with housing affordability constraints, possibly through expanded funding mechanisms like the proposed Climate Justice Bond Act (CJBA), which is a New York State voter-approved measure authorizing $4.2 billion in bonds to fund climate mitigation, resilience, and environmental justice projects (New York State Department of Environmental Conservation [NYSDEC], n.d.). This act would allow NYC to issue municipal bonds specifically earmarked for climate resilience and equity projects in frontline communities. CBJA paired with LL97 reforms can create a cohesive "green and just" policy framework (New York City Environmental Justice Alliance [NYCEJA], 2023). Second, institutional fragmentation, which is evident in the separate oversight of DEP stormwater projects and DOB energy codes, requires structural reforms, potentially through the creation of a Climate Resilience Office with cross-agency authority. Finally, the success of community-led adaptation models, from the Newtown Creek Alliance's bioswales to the Climate Justice Hubs' workforce programs, suggests that scaling up hyper-local solutions may be key to bridging policy gaps (Zimmerman & Faris, 2023). As climate impacts accelerate, NYC's ability to learn from these lessons while maintaining its tradition of policy innovation will determine whether it can achieve its dual goals of carbon neutrality and equitable resilience by 2050.

Chapter 4. Building Methods and Materials in New York City

New York City boasts some of the country's most renowned architectural and building histories. From iconic skyscrapers that have existed for over a century to more sustainable urban design, the city's built environment history is rich in diversity and innovative spirit. The city's architectural and construction history reflects its evolution from a small colonial settlement in the 17th century to the global metropolis it is today. Understanding historical methods of construction, building, and design provides valuable insights into how the city's historical architecture can influence more contemporary efforts to adapt to climate change issues through technological advancements and innovation.

Key Historical Building Methods

1. Brownstones

Figure 10: Classic New York Brownstone

Figure 11: Brownstone 2

a. Description. Brownstones are a specific type of townhouse generally constructed from brown sandstone. They form the backbone of historical housing in New York City and were a popular method of building from the mid-19th century until the early 20th century Brownstones were initially developed as a burgeoning middle class arose within the city in the early 19th century, and sandstone material was considered cheaper to use than either limestone, marble, or granite. Some of the most famous brownstone neighborhoods in the city are Park Slope, Harlem, Brooklyn Heights, and the Upper West Side (Mahzabin, 2024).

b. Construction Method. The buildings are row houses of three or four stories, built of wood and brick, and the facing material of the primary façade is made of soft brown or reddish sandstone quarried from nearby Connecticut and Pennsylvania. Brownstone

façades are renowned for their intricate detailing, craftsmanship, and historical charm, and many have been historically protected as districts around the city (Figures 10 and 11).

c. Climate Change Issues and Adaptation Methods

Many of these structures were built in the 19th and early 20th centuries, long before the advent of energy efficiency standards and sustainable building practices. As a result, NYC brownstone buildings, as opposed to the limestone material itself, often suffer from poor insulation, outdated heating systems, and single-pane windows, leading to significant energy loss and higher greenhouse gas emissions (Gouldson et al., 2015). This is particularly problematic in a densely populated city like New York, where buildings account for nearly 70% of the city's carbon emissions. Additionally, the aging infrastructure of brownstones makes them vulnerable to climate-related risks, such as flooding from rising sea levels and storm surges, which are increasingly common in coastal areas like Brooklyn and Manhattan.

Despite these shortcomings, brownstones exemplify an adaptive and valuable design approach for 21st-century sustainable architecture, offering innovative solutions for climate-resilient urban environments like NYC. Their thick masonry walls, traditionally constructed with sandstone and brick, provide exceptional natural insulation, reducing energy demands for heating and cooling while combating the urban heat island effect. These time-tested materials inspire modern construction techniques, such as insulated concrete forms (ICF), which leverage rigid foam insulation to encase concrete, creating highly efficient thermal barriers. Once the concrete is cured, the foam remains as a dual-layer insulator, enhancing energy efficiency. Beyond thermal performance, ICF walls deliver multiple sustainability benefits, including continuous high-performance insulation, fire resistance, superior soundproofing, and resilience against extreme weather events like hurricanes and tornadoes. By adapting the principles of brownstone construction, contemporary design can merge historic durability with cutting-edge sustainable materials, fostering resilient, energy-efficient cities for the future.

2. Cast-Iron Architecture

Figure 12: James White Building, 1882, Soho

Figure 13: Carey Building, 1857, Soho

a. Description. Cast iron was widely used in NYC during the 19th century because of its strength and resistance to fire, and it could be molded into various and often intricate designs, particularly in commercial buildings in areas like SoHo (Figures 12 and 13). Its versatility and strength allowed for the creation of elaborate facades and large windows (Stephens, 2024).

b. Construction Method. When used in building design and construction, cast iron is recognized for its prefabrication techniques and modular components. Many spandrels, columns, and panels were assembled off-site and could easily be transported to the installation site, allowing workers to assemble quickly and providing some flexibility during installation. The prefabrication of cast iron was done in foundries to produce columns, facades, beams, and other decorative ornaments that provided structural support to buildings while also being made from fire-resistant materials (Craven, 2018).

c. Climate Change Issues and Adaptation Methods. Cast Iron buildings have several limitations regarding sustainable development. They were built at a time when environmental and climate change issues were not considered priorities. As a result, these structures often lack energy-efficient windows, modern insulation, and updated heating, ventilation, and air conditioning systems (HVAC), leading to significant energy loss and increased carbon emissions (Rosenbloom et al., 2020). Furthermore, the creation and production of cast iron are highly energy-intensive, resulting in increased greenhouse gas emissions. Due to its aging infrastructure, vulnerabilities, and inefficiencies regarding climate-related hazards such as flooding and extreme heat are rampant.

Although these challenges exist, some valuable lessons and information can be incorporated into modern design by mimicking the modular construction and prefabrication methods, thereby improving efficiency as a construction, time, and energy waste-reducing measures. Combining the modular design process with the integration of solar or insulated panels will significantly reduce energy consumption, thereby helping to mitigate the Urban Heat Island (UHI) effect. Cast Iron facades also have the unique ability to provide natural shading, which can inspire the use of manual or mechanical shading devices, such as louvers or perforated screens, to improve energy efficiency and provide thermal regulation.

3. Art Deco and Terracotta Facades

Figure 14: Chrysler Building, 1930, NYC

Figure 15: Empire State Building, 1931, NYC

a. Description. Terracotta, a fired clay material, became popular for facades in the late 19th and early 20th centuries due to its durability, fire resistance, and aesthetic versatility. It was used in both commercial and residential buildings. Terracotta is known for being lightweight, durable, and highly customizable. It was often used as a cladding material or as a weather-resistant exterior. Some of the most famous buildings in New York City's history, the Empire State Building and the Chrysler Building, are prime examples of Art Deco buildings that feature terracotta (Figures 14 and 15).

b. Construction Method. Terracotta's highly customizable nature allowed architects to create unique and elaborate designs. However, it lacks strength, and as brownstone and cast iron, was never used as a structural material but generally as veneers or decorative pieces on the tops of structures. Usually pre-molded into modular panels, blocks, or

decorative pieces and then assembled on-site, this process allowed for ornamental details, grotesques, or floral patterns of intricate detailing. This combination of versatility, durability, and fire resistance was perfectly suitable for an urban environment in NYC. However, the metal anchors that keep it attached to the building can sometimes corrode, requiring ongoing maintenance. Both Beaux-Arts and Art Deco building styles championed terracotta as the material of choice, often featuring glazing with multiple colors through different clay mixtures, which added visual depth and character to the exteriors of the buildings (Tunick, 2017).

c. Climate Change Issues and Adaptation Methods. Most Art Deco and terracotta-designed buildings in NYC are 90 to 100 years old. When constructed, they generally did not use many sustainable methods compared to today's standards and awareness. The most significant issues concerning these structures are the lack of energy efficiency, resulting in energy loss and increased carbon emissions, particularly in insulation, as well as outdated HVAC systems. Despite the high durability of the terracotta facades, they were never designed to optimize thermal performance, thus making it extremely difficult to regulate indoor temperatures and they expend excessive heating or cooling energy. Retrofitting these historic structures with green roofs, stormwater management systems, and energy-efficient interior systems is necessary. However, aspects of this design style can be incorporated into future structures.

Terracotta, as a material, provides long-lasting durability while additionally providing fire resistance and reducing the need for frequent repairs. Modern buildings can draw inspiration from this material for incorporating high-performance ceramic cladding. The Art Deco style also features many design elements suited explicitly for dense urban areas, such as shading elements that can now be adapted into more contemporary designs, including louvers, perforated screens, and brise-soleils installed on the exterior of buildings. Le Corbusier, the renowned Swiss-French architect, was notable for incorporating horizontal or vertical louvers into the facades of his buildings, such as the Mill Owners Association building in India and five Unités d'Habitation in Marseille, Rezé, Berlin, Briey, and Firminy (Graf, 2019).

4. Steel-Frame Construction

Figure 16: Original World Trace Center construction 1966-1973, NYC

Figure 17: Flatiron Building construction 1901-1902, NYC.

a. Description. The advent of steel-frame construction revolutionized NYC's skyline, enabling the construction of skyscrapers. This method replaced load-bearing masonry walls, allowing for taller and more flexible building designs.

b. Construction Method. The structural support of large buildings now uses steel frames that can handle significantly more force than previous methods, such as masonry. Significant advancements in elevator technology engineering, combined with steel frames, enabled the construction of high-rise buildings throughout the city and country. Some of the most iconic skyscrapers in NYC include the Flatiron Building (1902), (Figure 17), the Equitable Building (1915), the Chrysler Building (1930) (Figure 14), the Empire State Building (1931) (Figure 15) , and the original World Trade Center (1973) (Figure 16).

c. Climate Change Issues and Adaptation Methods. Steel-frame construction has long underpinned high-rise urban development in skyscraper-heavy cities such as New York City. However, its sustainability profile is challenged by steel's high embodied carbon. According to the World Steel Association, global steel production accounts for approximately 7% of total anthropogenic CO_2 emissions, and emits on average about 1.9 tonnes of CO_2 for every tonne of crude steel produced, largely due to reliance on coal-fired blast furnaces (World Steel Association, 2022). In New York City, around 70% of total carbon emissions originate from steel buildings with inadequate thermal energy insulation, which necessitates extensive heating and cooling systems, significantly contributing to climate change (NYC Mayor's Office of Sustainability, 2023).

Steel-frame buildings, while allowing for expansive, vertical development and durable structural systems, are typically associated with dense urban forms and large footprints of impervious surfaces such as rooftops and paved surroundings. These impervious materials prevent water infiltration into the soil, exacerbating stormwater runoff and contributing to urban flooding challenges. As a result, steel-framed developments, especially in high-density cities, intensify pressure on stormwater infrastructure. Additionally, despite steel's durability and recyclability, its production carries a high initial carbon footprint and energy intensity, complicating its sustainability profile across the building lifecycle.

Despite these significant environmental drawbacks, steel-frame construction offers opportunities for modern design methods and innovation to support climate-responsive design.

5. Tenement Housing

Figure 18: 65 Mott St., NY Tenement Housing

Figure 19: 309 East 5th St, NY. Tenement Housing c. 1940

a. Description. Tenement buildings were large housing structures constructed in the mid to late 19th century to accommodate the influx of immigrants that New York City experienced between 1860 and 1900. These buildings, which defined density and overcrowding, were poorly ventilated and lacked proper sanitation.

b. Construction Method. These buildings were generally five or six stories tall and constructed with wood frames, and load-bearing brick or masonry exterior walls (Figures 18 and 19). Tenements lacked ventilation and eventually received some air shafts to improve airflow, although they still did so inadequately. Many modern housing regulations and building codes regarding light, air quality, and sanitation are derived directly from the shortcomings of tenement housing design.

c. Climate Change Issues and Adaptation Methods. The design principles of historic tenement housing, when thoughtfully adapted, can provide innovative solutions for climate change challenges in urban areas. The inherent density and compact footprint of tenements offer a sustainable model for modern housing, reducing energy consumption and land use while promoting walkable neighborhoods. Their shared walls and vertical construction create natural thermal buffers that, when combined with modern insulation and ventilation upgrades, can significantly improve energy efficiency. The original air shafts and rear courtyards - though inadequate in their time - can be reengineered to enhance passive cooling through cross-ventilation, while green roofs and reflective surfaces can mitigate urban heat island effects.

These historic structures also present opportunities for climate adaptation through strategic retrofitting. The sturdy masonry construction provides excellent thermal mass that, when properly insulated, helps regulate indoor temperatures year-round. Basement spaces, traditionally problematic, can be redesigned with flood-resistant materials or converted to stormwater collection areas. Shared infrastructure in tenement buildings - from communal stairwells to courtyards - creates natural opportunities for district heating and cooling systems, renewable energy installations, and community green spaces that both cool the neighborhood and manage stormwater. By preserving the urban density that makes tenements inherently sustainable while integrating modern resilient technologies, these historic structures can become models for climate-adaptive housing in cities worldwide.

6. Future Design using Sustainable, Resilient, and Innovative Materials

New York City’s architectural legacy, from brownstones to steel-framed skyscrapers, reflects a history of innovation tailored to the needs of its time. However, the climate crisis demands a paradigm shift in construction practices. While traditional materials like steel and concrete have shaped the city’s skyline, their environmental costs, high carbon emissions, contribution to urban heat islands, and vulnerability to climate impacts, are no longer sustainable.

The transition to contemporary and future materials is not just about replacing old with new; it’s about reimagining resilience. Sustainable materials, such as mass timber, phase-change materials (PCMs), and glass fiber-reinforced concrete (GFRC), offer solutions that align with NYC’s climate goals. These innovations reduce embodied carbon, enhance energy

efficiency, and withstand extreme weather, all while maintaining the aesthetic and functional demands of urban architecture.

This shift also addresses equity. Many of NYC's most vulnerable communities reside in buildings with outdated materials ill-suited for rising temperatures or flooding. By integrating advanced materials into affordable housing and infrastructure upgrades, the city can ensure climate resilience is accessible to all. The following sections explore these cutting-edge materials and methods, demonstrating how NYC can lead the way in sustainable urban design.

Innovative Material

Facade and Envelope- Glass Fiber Reinforced Concrete (GFRC)

Glass Fiber Reinforced Concrete (GFRC) is a material that was initially created in the 1940s by Soviet Russian researchers who experimented with adding glass fibers to cement mixtures. This wasn't very viable at the time due to the high levels of alkali in the cement, which corroded the fibers. However, GFRC started to become more common after the 1970s when alkali-resistant glass fibers were developed by The Owens-Corning Fiberglas Company (USA) and Pilkington Brothers (UK), which helped to commercialize GFRC and make it available to architects and builders in the 1980s (ConcreteNetwork, n.d.). GRC transforms ordinary concrete by incorporating special glass fibers that form a microscopic crystal bond with the cement. The crystallization process between the glass fibers and the cement creates a "transition zone" where the fibers and cement interlock at the molecular level. In many cases, it better withstands heavy foot traffic, accidental impacts, and even fire exposure than steel. Examples of buildings using GFRC are the Aliyev Cultural Center in Baku, Azerbaijan (Figure 20), and The Broad Museum in Los Angeles (Figure 21).

Figure 20: Zaha Hadid's Aliyev Cultural Center, Baku, Azerbaijan

Figure 21: Diller Scofidio + Renfro's The Broad Museum, Los Angeles

Load-Bearing Material - Mass Timber in Resilient and Sustainable Building Design

Mass timber, particularly cross-laminated timber (CLT) and glue-laminated timber (GLT), presents a transformative solution that addresses many of the current climate change and energy challenges while advancing NYC's carbon neutrality goals. Developed in the 1990s in Europe, but rooted in much older timber engineering principles, these engineered wood products offer a unique combination of sustainability, resilience, and aesthetic potential that could redefine New York's skyline. Unlike conventional steel and concrete construction, which accounts for 8% of global CO_2 emissions, mass timber buildings actively sequester carbon while offering comparable structural performance for mid- and high-rise applications.

The use of mass timber construction has expanded rapidly from the first U.S. building in 2011 to over 2,000 buildings by 2023 (Winslett, 2025). These buildings become iconic precedents that help increase adoption. At 25 floors and 284 feet in height, the residential Ascent Tower in Milwaukee, Wisconsin (2022) is the tallest mass timber building in the world (U.S. Department of Agriculture Forest Service, 2022) (Figure 22). At Clemson University in South Carolina, the Andy Quattlebaum Outdoor Education Center (2020) is the first building east of the Mississippi and the second in the country to use cross-laminated timber (CLT) made from southern pine (Impson, 2021)(Figure 23).

Figure 22: The Ascent Tower, Milwaukee, WI

Figure 23: Andy Quattlebaum Outdoor Education Center at Clemson University

The environmental benefits of mass timber begin with its fundamental material properties. As trees grow, they absorb atmospheric CO_2, which remains stored in the wood throughout the building's lifespan. Studies demonstrate that mass timber construction can reduce embodied carbon by up to 60% compared to traditional methods (Andersen et al., 2021). A striking example is Milwaukee's Ascent Tower, which sequesters approximately 6,000 metric

tons of CO_2, equivalent to removing 1,200 cars from the road annually (Arup, 2022). Beyond carbon sequestration, mass timber offers advantages across the entire construction lifecycle. Prefabricated timber components enable faster, quieter construction with up to 25% less waste than steel framing (AIA, 2022). The material's lighter weight reduces foundation requirements and transportation emissions, while Forest Stewardship Council (FSC) certification ensures responsible sourcing from sustainably managed forests. These attributes align perfectly with NYC's Local Law 97 emissions targets and the Climate Mobilization Act's ambitious sustainability goals.

Another of mass timber's environmental benefits is its potential to help manage stormwater. New York's combined sewer system, which frequently overflows during heavy rainfall, presents one of the city's most persistent environmental challenges. Traditional impervious concrete surfaces exacerbate runoff issues, while mass timber construction enables innovative water management solutions. The material's compatibility with biophilic design enables the integration of green roofs, rainwater-retaining timber façades, and permeable surfaces, collectively mitigating stormwater surges. Research by the NYC Mayor's Office of Resiliency (2023) indicates that mass timber buildings with comprehensive water management systems can reduce peak stormwater discharge by 30% compared to conventional structures. The light weight of mass timber also facilitates the use of below-grade water retention systems that store stormwater for non-potable purposes, aligning with the city's *Cloudburst Management Plan*. (NYC MOCEJ, 2022) These features become increasingly valuable as climate change intensifies precipitation patterns, with the Northeast having experienced a 55% increase in heavy rainfall events since the 1950s.

HVAC and Energy Efficiency- Phase Change Materials (PCM)

Phase change materials (PCMs) have gained significant attention as a sustainable solution for thermal energy storage and climate mitigation. These materials absorb and release large amounts of thermal energy during phase transitions, primarily between solid and liquid states, making them highly effective in regulating temperature fluctuations (Thermtest, 2024). Examples of PCM materials are paraffin waxes, fatty acids, salt hydrates, and salt mixtures (Ibid.)Their ability to store energy passively aligns with global efforts to reduce carbon emissions and improve energy efficiency in buildings, industrial processes, and renewable energy systems. However, despite their advantages, challenges such as cost, material stability, and integration complexities must be addressed to facilitate widespread adoption. Below are

benefits and drawbacks of phase change materials (PCMs) in the context of sustainability and climate mitigation, drawing on peer-reviewed research.

One of the most notable advantages of PCMs is their contribution to energy efficiency in buildings. The construction sector accounts for nearly 40% of global energy consumption, with a substantial portion dedicated to heating and cooling (International Energy Agency, 2022). By incorporating phase change materials (PCMs) into walls, ceilings, and flooring, buildings can passively regulate indoor temperatures, thereby reducing their reliance on mechanical HVAC systems. Research by Zalba et al. (2003) demonstrated that PCM-enhanced gypsum boards in office buildings reduced cooling energy consumption by up to 30% in temperate climates. Similarly, bio-based PCMs have been shown to decrease peak cooling loads in residential buildings by 10–40%, further supporting their role in sustainable architecture (Souayfane et al., 2016).

Beyond buildings, PCMs enhance the efficiency of renewable energy systems, particularly solar thermal applications. Solar energy's intermittent nature necessitates reliable storage solutions to ensure consistent availability. PCMs store excess solar heat during peak sunlight hours and release it when needed, improving the performance of solar water heaters and space heating systems. Studies indicate that PCM-based thermal storage can increase solar collector efficiency by 20–25%, reducing dependence on fossil fuel backups (Sharma et al., 2015). In concentrated solar power plants, phase change materials (PCMs) enhance energy retention, making renewable energy more viable for large-scale applications (Kenisarin & Mahkamov, 2016).

The environmental benefits of PCMs extend to direct reductions in carbon footprint. By minimizing energy consumption in buildings and industrial processes, PCMs help reduce greenhouse gas emissions. The U.S. Department of Energy (2021) estimates that widespread PCM adoption in commercial buildings could reduce HVAC-related CO_2 emissions by 5–10% annually. Bio-based PCMs derived from plant oils and fatty acids offer a carbon-neutral alternative to conventional paraffin-based materials, further enhancing their sustainability (Cabeza et al., 2020).

Another significant advantage of PCMs is their ability to improve thermal comfort in indoor environments. Maintaining stable temperatures is crucial for occupant health and productivity. Research by Pomianowski et al. (2020) found that PCM-enhanced walls effectively regulated indoor temperatures within the human comfort range (20–24°C), reducing fluctuations

by 50% compared to traditional insulation. This stability reduces reliance on mechanical cooling systems, aligning with the principles of passive design in sustainable architecture.

Despite these benefits, several challenges hinder the widespread adoption of PCMs. One major obstacle is the high initial cost. Microencapsulated PCMs, commonly used in construction, can increase material costs by 20–30% compared to conventional insulation (Weinläder et al., 2017). While the long-term energy savings justify the investment, the payback period typically ranges from five to ten years, necessitating financial incentives or subsidies to encourage broader use. Material degradation over time is another concern. Some PCMs, particularly organic paraffin-based varieties, experience thermal cycling degradation, where repeated phase transitions reduce their heat storage efficiency. Studies indicate that after 1,000 thermal cycles, certain PCMs lose 10–15% of their effectiveness, necessitating maintenance or replacement (Rathod & Banerjee, 2013). This limitation highlights the need for more robust encapsulation techniques to enhance the lifespan of PCM applications.

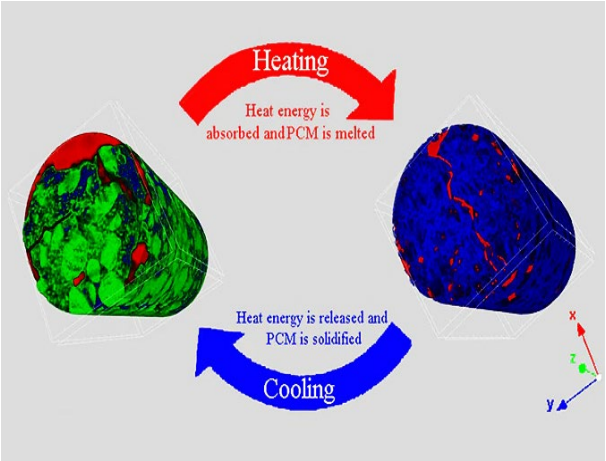

Figure 24: Phase Change Material Process

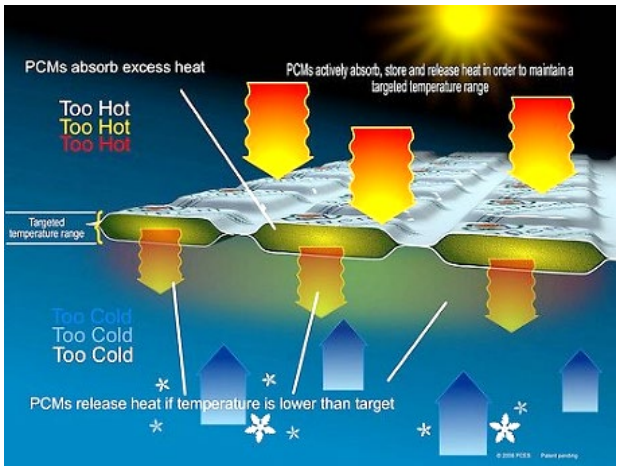

Figure 25: Temperature Regulation Phase Change Materials

Climate suitability also plays a crucial role in PCM performance. These materials are most effective in regions with significant daily temperature variations. In consistently hot or cold climates, their efficiency diminishes, often requiring hybrid systems that combine PCMs with traditional HVAC support. Research by Lamrani et al. (2021) found that PCMs alone could not eliminate the need for air conditioning in tropical climates, though they still reduced energy demand by 10–15%. Safety concerns further complicate PCM implementation. While inorganic PCMs such as salt hydrates are non-flammable, they may corrode building materials over time. Organic PCMs (e.g., paraffins) are inherently flammable and often require fire-retardant (Pielichowska et. al. 2023) additives, an approach that increases costs and can negatively affect

thermal properties. Some synthetic PCMs also release volatile organic compounds (VOCs), raising indoor air quality concerns and necessitating careful selection of materials.

Chapter 5. Modern, Sustainable, and Resilient Building Methods

1. Leadership in Energy Efficiency and Design (LEED)

LEED is the most globally recognized building rating and certification system developed by the U.S. Green Building Council (USGBC). The system provides a framework of recommendations for designing, constructing, operating, and maintaining energy-efficient and sustainable buildings. This encourages building developers to elevate their standards in materials selection, energy efficiency, indoor environmental quality, water conservation, and site development.

LEED employs a point-based accumulation system across several sustainable development and construction categories that buildings can achieve to receive certification. Based on the number of points a building gets, it achieves one of four certification levels: Certified, Silver, Gold, and Platinum.

Figure 26: Bank of America Tower, NYC 2007

Figure 27: JP Morgan Chase Tower, NYC 2025

Case Study #1: One Bryant Park

One Bryant Park, also known as the Bank of America Tower, is a 55-story skyscraper that reaches 1,200 feet to its pinnacle in the heart of Midtown Manhattan, setting a new standard for sustainable architecture (Figure 26). Completed in 2010, it became the first commercial high-rise in New York City to earn LEED Platinum certification, the highest

recognition from the U.S. Green Building Council. This achievement highlights the building's innovative design and cutting-edge technologies, which reduce its environmental footprint and actively combat climate change.

One Bryant Park stands out for its use of sustainable materials and forward-thinking design strategies. The building's structure incorporates recycled steel and concrete, with nearly half its materials sourced within 500 miles of the construction site. This local sourcing significantly reduces transportation-related emissions (USGBC, 2010). The tower's façade is made of high-performance, low-emissivity glass, which allows ample natural light to flood the interior while minimizing heat gain. This feature reduces the building's reliance on artificial lighting and air conditioning, leading to a 30% reduction in energy use compared to traditional office towers (Al-Kodmany, 2022).

Another standout feature is the building's rainwater harvesting system, which collects and reuses 100% of rainwater and greywater for cooling systems, irrigation, and toilet flushing. This system saves an impressive 10 million gallons of water yearly (The Durst Organization, 2010). Additionally, the tower has a cogeneration plant that generates 4.6 megawatts of clean, on-site electricity. This system meets 65% of the building's annual energy needs and slashes its carbon emissions by 50% (Al-Kodmany, 2022). The plant also captures waste heat to provide heating and cooling, boosting energy efficiency. To enhance indoor air quality and reduce energy consumption, the building uses an underfloor air distribution system, which delivers conditioned air more efficiently than traditional overhead systems.

One Bryant Park plays a significant role in fighting climate change through its energy-efficient systems and sustainable practices. The cogeneration plant prevents approximately 8,000 metric tons of CO2 emissions annually, equivalent to taking 1,500 cars off the road yearly (The Durst Organization, 2010). The building's water-saving technologies, including low-flow fixtures and the rainwater harvesting system, reduce potable water use by 50%, easing New York City's water infrastructure demand and conserving vital resources (USGBC, 2010). The building also helps mitigate the urban heat island effect, a common issue in densely populated cities with an abundance of heat-absorbing surfaces and little tree cover. Its reflective roof and energy-efficient façade reduce heat absorption, lowering surrounding temperatures and improving local air quality. Furthermore, One Bryant Park encourages sustainable commuting by providing bicycle storage facilities and being located near multiple public transportation options, thereby reducing the carbon footprint of its occupants.

One Bryant Park is a shining example of how innovative design and sustainable practices can create a high-performance building that addresses the urgent challenges of climate change. Using recycled materials, energy-efficient systems, and water-saving technologies minimizes environmental impact and sets a new standard for future developments. By achieving LEED Platinum certification, One Bryant Park is proof of concept that prominent skyscrapers can be both iconic and environmentally responsible, paving the way for a greener urban future.

Case Study #2: JP Morgan Chase Headquarters

Another supertall skyscraper, JPMorgan Chase's global headquarters at 270 Park Avenue in New York City, is a groundbreaking example of sustainable architecture and corporate responsibility (Figure 27). The new tower, currently under construction as of the writing of this thesis and scheduled for completion at the end of 2025, is also designed to achieve LEED Platinum certification. This 1,389-foot ambitious project reflects JPMorgan Chase's commitment to sustainability and its efforts to combat climate change through innovative design and cutting-edge technologies.

The JPMorgan Chase headquarters incorporates a plethora of sustainable materials and design strategies to minimize its environmental impact. The building is constructed using low-carbon concrete and recycled steel, significantly reducing the carbon footprint associated with traditional construction materials. Approximately 97% of the materials from the original building that was demolished at 270 Park Avenue are being recycled or reused, diverting thousands of tons of waste from landfills (JPMorgan Chase & Co., 2022). The tower's façade features high-performance glass that maximizes natural light while minimizing heat gain, reducing the need for artificial lighting and air conditioning. This design is expected to cut energy consumption by 40% compared to conventional office buildings (Architectural Digest, 2022).

One of the building's most innovative features is its all-electric design, which eliminates the use of fossil fuels on site. The headquarters will be powered entirely by renewable energy, including hydroelectric power from upstate New York, reducing its reliance on non-renewable energy sources. Additionally, the building will include a state-of-the-art water recycling system that captures and treats rainwater and greywater for reuse in cooling systems and irrigation. This system is projected to reduce the building's annual water usage by over 30% (JPMorgan Chase & Co.,, 2022). The headquarters is designed to combat climate change significantly

through energy-efficient systems and sustainable practices. The building's all-electric design and reliance on renewable energy are expected to reduce its carbon emissions by 50% compared to traditional office towers (Architectural Digest, 2022). This reduction is equivalent to removing thousands of cars from the road each year, making a meaningful contribution to New York City's climate goals.

The building also addresses the urban heat island effect, a common issue in densely populated cities with a predominance of heat-absorbing surfaces, through its reflective roof and energy-efficient façade. These features help lower surrounding temperatures and improve local air quality. Furthermore, the headquarters is conveniently located near multiple public transportation options, and the project features extensive bicycle storage facilities to promote sustainable commuting. By reducing the need for car travel, the building further decreases its carbon footprint and promotes a greener urban environment.

JPMorgan Chase's new headquarters at 270 Park Avenue is a shining example of how forward-thinking design and eco-friendly practices can come together to create a building that performs exceptionally and tackles the pressing issue of climate change head-on. The tower, the first of its size to feature a groundbreaking all-electric design, significantly reduces its environmental footprint by using low-carbon materials, energy-efficient systems, and advanced water-saving technologies, while raising the bar for future construction projects. With its LEED Platinum certification, the building sets the standard for environmental sustainability. It shows that corporate headquarters can be visually striking and deeply committed to sustainability, setting a powerful example for a greener, more responsible future.

2. Passive House (Passivhaus)

Passive House is a design method that aims to reduce a building's ecological footprint while increasing occupant comfort levels through rigorous, voluntary standards. It uses a building system to minimize energy consumption for heating and cooling while maintaining thermal comfort and indoor air quality. Passive Houses generate massive energy savings, typically achieving 75-90% energy reduction compared to conventional buildings, and provide additional climate resilience through their air-tight structure, which helps buildings withstand cold spells and heatwaves.

Various principles, building methods, and innovative technologies are incorporated into the Passive House design, including airtight construction, superinsulation, mechanical

ventilation and heat recovery, high-performance windows, solar optimization, and thermal bridge-free design. Passive House also uses advanced materials, such as cellulose and rigid foam boards, to achieve high insulation levels. Additionally, it employs prefabricated components, including wall panels and roof sections, to ensure the precision of an air-tight envelope.

Figure 28: 425 Grand Concourse, The Bronx, 2022

Figure 29: The House at Cornell Tech, NYC campus, 2017

Passive House Case Study #1: 425 Grand Concourse, the Bronx

425 Grand Concourse in the Bronx, completed in 2022, is the largest passive house mixed-use building in North America (Figure 28). At 310,000 square feet and 26 stories, it uses Passive House principles, prioritizing energy efficiency, airtightness, and thermal comfort . The building's envelope is a key feature, constructed with high-performance insulation and triple-glazed windows that minimize heat loss in winter and heat gain in summer. These materials ensure that the building maintains a consistent indoor temperature with minimal energy use, reducing heating and cooling demands by up to 80% compared to conventional buildings (White, 2022). This building is a game-changer for developers, architects, and climate activists as it is proof that high-rise building design can mitigate climate change and effectively address affordable housing while showing a path to a high-cost-benefit ratio. The building's reflective roof and energy-efficient façade reduce heat absorption, directly addressing the UHI effect that plagues neighborhoods like the Bronx, where temperatures can soar due to a lack of green space and an abundance of heat-absorbing surfaces.

The building's mechanical ventilation system, equipped with energy recovery ventilators (ERVs), ensures a constant supply of fresh air while retaining heat, thereby further enhancing energy efficiency. This system improves indoor air quality and reduces the building's reliance on energy-intensive HVAC systems, which are major contributors to urban heat islands. 425 Grand Concourse uses low-VOC (volatile organic compound) paints and finishes, enhancing indoor air quality and reducing harmful emissions, a crucial consideration in a city where air pollution is a persistent issue. Additionally, using durable, locally sourced materials minimizes the carbon footprint associated with transportation and construction waste.

425 Grand Concourse is a powerful tool in the fight against climate change. Its Passive House certification means it uses up to 90% less energy for heating and cooling than a typical residential building, significantly reducing its carbon footprint (White, 2022). To put this into perspective, the energy savings achieved by the building are equivalent to removing hundreds of cars from the road each year. The building also addresses stormwater management, a critical issue in a city like New York, where aging infrastructure struggles to handle heavy rainfall. While 425 Grand Concourse lacks a green roof, its design incorporates water-saving features, such as low-flow fixtures and efficient plumbing systems, which reduce water consumption and alleviate the strain on the city's water infrastructure. One area where 425 Grand Concourse could inspire further innovation is in addressing sea level rise. While the building itself isn't directly at risk, its design principles, like elevated mechanical systems and flood-resistant materials, could be adopted in coastal developments. As climate change accelerates, New York City will need more buildings that can withstand flooding and extreme weather, and 425 Grand Concourse offers valuable lessons in resilience.

Passive House Case Study #2: The House at Cornell Tech, Roosevelt Island, NYC

Cornell University's Cornell Tech campus in New York City, on Roosevelt Island, offers another example of a passive house. The House at Cornell Tech, built in 2017, is a 273,000-square-foot, 26-story residential hall, at that time the largest and tallest Passive House residential building in the world. This residential tower and the broader campus exemplify how cutting-edge design and sustainable practices can create a high-performance environment that addresses pressing climate challenges, including urban heat islands (UHI), stormwater management, and sea level rise. The House at Cornell Tech's building's envelope is a key feature, constructed with high-performance insulation and triple-glazed windows that minimize heat loss in winter and heat gain in summer. These materials ensure that the building maintains

a consistent indoor temperature with minimal energy use, reducing heating and cooling demands by up to 70-90% compared to conventional buildings (Passive House Institute US, 2020). This efficiency level is very high in New York, where buildings account for nearly 70% of the city's carbon emissions. One of the innovative aspects of the House at Cornell Tech is its mechanical ventilation system, which includes energy recovery ventilators (ERVs). These systems ensure a constant supply of fresh air while recovering heat from exhaust air, further enhancing energy efficiency. This approach improves indoor air quality and creates a healthier living environment for students and faculty. The building's airtight construction and advanced ventilation system set a new benchmark for sustainable residential design.

Beyond its energy-efficient systems, the House at Cornell Tech incorporates various sustainable materials that further reduce its environmental impact. Low-VOC (volatile organic compound) paints and finishes are used throughout the building, improving indoor air quality and reducing harmful emissions. The project also prioritizes the use of durable, locally sourced materials, minimizes the carbon footprint of transportation, and supports the local economy. By focusing on sustainability at every stage of construction, the building demonstrates that high-performance design can be both environmentally responsible and cost-effective.

The House at Cornell Tech stands out for its moderate affordability despite using Passive House standards and high quality sustainable material and its focus on accessible housing. The building offers 352 high-quality, energy-efficient units for students, faculty, and staff, addressing New York City's pressing housing challenges. Its design reflects a commitment to combining sustainability with practical solutions, demonstrating that environmentally conscious living can be attainable for a broader community. Alongside its innovative architecture, the House at Cornell Tech incorporates features like a high-reflectance roof and an energy-efficient façade, which help mitigate urban heat island effects, lower ambient temperatures, and improve local air quality (Gray, 2018).

Chapter 6. Interviews

To better understand how climate-resilient design can be implemented effectively in New York City, this chapter draws on insights from three experts whose professional backgrounds intersect with architecture, urban planning, climate policy, and sustainable construction. Each interviewee offers a distinct lens on the core research questions of this thesis, namely, how design innovations, building codes, and policy frameworks can address the converging challenges of sea level rise, stormwater management, and the urban heat island effect.

The first interviewee is David Burney, former Commissioner of the NYC Department of Design and Construction and current professor at Pratt Institute. Burney's interdisciplinary expertise in public architecture and civic design offered critical perspectives on the limitations of NYC's current building practices and the importance of equity-driven resilience strategies. His reflections on passive design, mass timber, and public space underscore the need for policy mandates and agency coordination to meet long-term climate goals.

The second interviewee, John Mandyck, CEO of the Urban Green Council, provided a policy-focused analysis of New York's evolving climate legislation, including Local Law 97 and *PlaNYC*. Mandyck's work positions him at the forefront of building decarbonization and equity integration, making his insights especially relevant to the thesis's emphasis on how regulatory frameworks can promote proactive, inclusive resilience.

Finally, Dr. Paul Crovella, a professor at SUNY College of Environmental Science and Forestry, offered technical expertise on mass timber construction and sustainable building materials. His research explores how renewable, low-carbon materials can address embodied emissions and enable innovative design solutions for affordable housing, which are key components of this thesis's focus on materiality and long-term climate adaptation.

Together, these interviews enrich the thesis by grounding theoretical frameworks in lived professional experience, bridging the gap between policy aspirations and implementation realities. Their input informs the analysis that follows, offering both critique and inspiration for building a more resilient, equitable New York City.

Interview #1- David Burney on Climate-Resilient Design in New York City

David Burney offered an assessment of the city's progress and shortcomings in integrating climate resilience into its built environment. Burney implemented the *Active Design Guidelines* (2010*)* and the *Cool Neighborhoods NYC* (2017) initiatives and has over two decades of experience as an urban designer and architect. Burney's expertise bridges architecture, public health, and climate adaptation. His academic and professional work focuses on interdisciplinary collaboration and preparing future architects and planners to address resilience and equity in urban development. His background aligns with the research questions of this thesis by providing insight into how urban design, building codes, and climate adaptation strategies can respond to challenges such as sea level rise, urban heat islands, and stormwater flooding. His roles in both government and academia position him to speak to the intersection of technical planning, policy implementation, and social considerations in climate-resilient design.

Burney noted that New York City's preparedness for climate change, approach to sea level rise, is like having its "head in the sand." He pointed to ongoing developments in vulnerable areas, such as the Rockaways, where new apartment complexes are being built despite projections that these neighborhoods could be underwater by 2050. Burney acknowledged the economic and social pressures driving such decisions, including the need for housing and services in historically underserved areas. However, he noted that without a fundamental shift in policy, these projects will ultimately exacerbate displacement and financial loss when climate impacts intensify.

During the discussion, Burney credited the city's Department of Environmental Protection (DEP) with incremental progress, including the installation of bioswales and underground retention tanks to mitigate combined sewer overflows (CSOs). Yet, he stressed that these measures are insufficient for a city where aging sewer systems routinely discharge untreated waste into waterways like Newtown Creek and the Gowanus Canal. "It could take 100 years to disconnect [stormwater and sewage systems]," he noted, underscoring the need for ambitious, large-scale interventions. Burney's critique aligns with research on urban climate adaptation, which often highlights the mismatch between piecemeal projects and the systemic transformation required to address interconnected risks like flooding, heat, and infrastructure failure (Rosenzweig et al., 2011).

A recurring theme in Burney's commentary was the construction industry's role in advancing or hindering climate resilience. He praised the growing use of mass timber, a low-carbon alternative to steel and concrete, and highlighted the Economic Development Corporation's (EDC) efforts to promote its adoption. However, he noted that mass timber remains rare in affordable housing due to perceived costs and developer resistance. This equity gap is critical: if sustainable materials are only deployed in high-end developments, their potential to reduce the city's carbon footprint will remain unrealized.

"The most sustainable building is the one you already have." With this principle, David Burney critiques NYCHA's plan to raze Chelsea Houses on the west side of Manhattan as an example of waste, advocating instead for retrofits over rebuilds. This philosophy, which he described as "long life, loose fit, low energy," promotes designing buildings for adaptability and longevity. For example, incorporating flexible floor plans and using durable materials can allow structures to meet evolving needs over decades, thereby avoiding the environmental costs of demolition and new construction. Burney's approach reflects the growing influence of circular economy principles in urban development, which emphasize reuse, material efficiency, and lifecycle analysis (Ellen MacArthur Foundation, 2019).

Burney's remarks also centered on the social dimensions of resilience, particularly the role of public space in fostering community cohesion. He pointed to NYC's Plaza Program, which has created over 100 pedestrian plazas, as a model for equitable design. Corona Plaza in Queens, for example, was transformed into a hub for the local Ecuadorian community through culturally responsive programming like food trucks and art installations. "Placemaking is about building communities," Burney explained, linking social capital to climate resilience. Burney noted persistent disparities in access to quality public spaces, particularly in low-income areas and communities of color. To address these gaps, he called for targeted investments in green infrastructure, such as parks, tree canopies, and cooling centers. This aligns with NYC's Cool Neighborhoods program and highlights the need for broader policy mandates to ensure equitable distribution of resources.

Burney suggested that voluntary frameworks like LEED were "too easy" to achieve and insufficiently rigorous. Instead, he suggested that binding policies, such as Local Law 97, which mandates emissions reductions for large buildings, may be more effective. "Nobody would [adopt resilient design] unless the city required it," he observed, citing stormwater retention rules as an example of effective regulation. Burney lamented the lack of coordination among city

agencies, from the Department of Transportation (DOT) to the Parks Department. He proposed a centralized resilience office akin to the now-defunct Office of Long-Term Sustainability to harmonize policies across sectors.

Burney emphasized the critical role of academia in advancing climate-resilient design, from developing innovative materials such as hempcrete to creating models for policy frameworks. He encouraged researchers to demonstrate the practical applications of their work to industry professionals, pointing to mass timber's journey from an experimental material to a widely adopted solution as a successful example. This approach reflects the concept of translational research, where academic findings are systematically applied to real-world challenges (Cash et al., 2003).

Looking forward, Burney stressed the importance of policies that establish clear, ambitious objectives like New York City's 2050 carbon neutrality target while providing flexibility in implementation methods. He argued that cities should focus on setting performance standards rather than prescribing specific solutions, comparing this approach to California's vehicle emissions regulations, which set strict requirements but allow manufacturers to determine how to meet them.

Interview #2- John Mandyck- Climate Policy, Resilience, and Equity in New York City

John Mandyck leads a New York–based nonprofit that researches and advocates for high-performance building practices. His work focuses on building decarbonization, energy codes, and climate-resilient policy, directly informing this thesis’s investigation of how local regulations can align equity, mitigation, and adaptation goals.

Mandyck stated that while the city has made significant progress in this area, the work remains incomplete. He explained that true resilience requires addressing the disproportionate climate risks faced by low-income communities and vulnerable populations. The conversation turned to specific projects designed with equity in mind, particularly the South Battery Park Resiliency Project (Young & Pruznick, 2024). In that project, parkland elevation and deployable flood barriers illustrate how technical design is integrated with community engagement to avoid displacement and maintain neighborhood access. Mandyck described how such projects must balance technical requirements with community needs, ensuring that protective measures do not inadvertently displace or disadvantage residents. What became clear during this portion of our discussion was that equity cannot be treated as an afterthought in resilience planning. Mr.

Mandyck stressed that considering vulnerable populations must happen at the project conception phase, not as a box to check during implementation. He shared examples of how community engagement processes have shaped resilience projects, leading to designs that better serve neighborhood needs while providing critical climate protections.

A significant portion of our conversation focused on the difficult transition from reactive to proactive climate policies. Mandyck provided commentary on why governments tend to be reactive, explaining that political systems and public budgets are typically structured to respond to immediate crises rather than prevent future ones. He referenced a pending “maximum indoor temperature” standard, intended to protect residents during heat waves by requiring landlords to maintain safe summer temperatures, mirroring existing winter heating rules. He identified this proposal as an example of shifting toward anticipatory policy that targets climate-equity gaps in housing.

Mr. Mandyck noted that while systems like LEED have evolved, a gap remains between sustainability metrics and the true needs of climate adaptation. He then described how changes in building codes reflect hard-learned lessons from Hurricane Sandy, when basement-level infrastructure failures left many buildings uninhabitable. He acknowledged the effectiveness of green roofs and bioswales in managing stormwater, but cautioned against viewing them as universal solutions to stormwater management. He explained how Manhattan's verticality and limited roof space creates unique implementation challenges, with much of the available roof area already occupied by mechanical equipment and other building systems.

Mr. Mandyck described how green infrastructure might be more feasible in outer boroughs with diverse building types, suggesting that a one-size-fits-all approach would not work for a city as diverse as New York. He provided data suggesting that roughly 90% of New York City's 2050 building stock already exists today, making retrofits essential for meeting climate goals. However, he presented a nuanced view of this challenge, explaining how building age and construction quality create vastly different retrofit scenarios. For example pre-war buildings often perform surprisingly well due to their durable construction and passive design features. In contrast, mid-century buildings frequently present greater challenges due to their energy-inefficient designs. He noted that 270 Park Avenue (the new JPMorgan Chase headquarters) illustrated these complexities. John described how the project incorporated recycled materials and all-electric systems to offset the carbon costs of new construction, while

also noting Local Law 154, passed in 2021, which requires new construction to eliminate on-site fossil-fuel combustion.

Mr. Mandyck provided historical context about NYC's climate policy evolution from its origins under Mayor Bloomberg through subsequent updates by Mayors de Blasio and Adams. He explained how the current iteration, *PlaNYC: Getting Sustainability Done*, incorporates both mitigation and adaptation strategies while emphasizing equity considerations. What proved particularly valuable was John's explanation of how *PlaNYC* informs specific policies without being legally binding itself. He described it as a "north star" for city agencies and policymakers, providing direction while allowing flexibility in implementation.

Mr. Mandyck identified several critical barriers to more effective climate policies: the accelerating pace of climate hazards advancing faster than planning cycles, funding constraints that force prioritization among projects, agency silos that hamper integrated solutions. He noted that an upcoming Urban Green Council conference will address coordination between sustainability and resilience practitioners. This interview supplies empirical detail for evaluating equity metrics in infrastructure projects, comparing reactive and proactive governance models, analyzing retrofit versus rebuild trade-offs for different building eras, and assessing *PlaNYC*'s effectiveness as a policy-alignment tool. All of these are central components of this study's research questions on climate-resilient design and policy in New York City.

Interview #3- Dr. Paul Crovella- Mass Timber and Climate-Resilient Construction in NYC

Dr. Paul Crovella's expertise, which includes both academic research and practical industry applications, offered a perspective on how mass timber can contribute to sustainable urban development while confronting the complex realities of policy implementation, market adoption, and equitable housing distribution.

Dr. Crovella began by situating his work within the historical context of the SUNY College of Environmental Science and Forestry (ESF), an institution founded over a century ago as the New York State College of Forestry. At SUNY ESF, he serves as the primary liaison for mass timber initiatives, a role that requires him to translate technical research into practical applications for architects, policymakers, developers, and builders. When examining the potential of mass timber to address New York City's specific climate vulnerabilities, particularly sea level rise, the urban heat island effect, and stormwater management, Dr. Crovella identified several advantages. He noted that the material's natural thermal properties help regulate indoor

temperatures, thereby reducing the energy demands of mechanical cooling systems during increasingly frequent heat waves. This characteristic directly addresses the urban heat island effect while simultaneously lowering operational carbon emissions from buildings. Additionally, he mentioned that the hygroscopic nature of wood (readily taking up and retaining moisture) enables it to moderate indoor humidity levels, creating more comfortable living environments with reduced energy consumption.

Dr. Crovella also emphasized the role of mass timber as a carbon sink. Unlike steel or concrete, which generate substantial embodied carbon during production, wood products continue to store carbon absorbed during the growth cycle of the trees. This dual function, reducing both operational and embodied carbon, he notes, makes mass timber particularly valuable for cities like New York that have committed to aggressive decarbonization targets under initiatives like Local Law 97. However, he cautioned that these benefits depend entirely on proper design and implementation, noting that building codes have not yet caught up with the need for climate-adaptive construction standards. Current regulations, primarily based on historical climate data rather than future projections, may inadvertently leave mass timber structures vulnerable to moisture damage from increased flooding or humidity if they are not properly detailed and protected.

Dr. Crovella acknowledged the current reality that most mass timber projects serve luxury markets, but pointed to several pioneering efforts that demonstrate the material's potential for broader application. The 340+ Sticks development in New Haven, Connecticut, stood out as a compelling example. This 68-unit affordable housing project, developed without special subsidies for timber construction, proved that mass timber could be economically viable for moderate-income housing when paired with innovative financing and strong community partnerships.


Figures 30 and 31. 340+Dixwell Ave (also called 350+ Sticks) Affordable Housing project, New Haven, Connecticut.

He also referenced ongoing research at Pratt Institute, supported by New York State Energy Research and Development Authority (NYSERDA) funding, that explores the use of mass timber for vertical expansions of existing city-owned buildings. This approach leverages timber's light weight to add stories to current structures, potentially creating hundreds of new affordable units while avoiding the lengthy permitting processes associated with ground-up construction. He emphasized that such strategies could be particularly valuable in New York City, where the affordable housing crisis demands creative solutions that balance speed, cost, and sustainability. Dr. Crovella argued that the benefits of timber construction should not be reserved exclusively for wealthy residents but should be accessible to all New Yorkers through thoughtful policy and design interventions. Despite mass timber's considerable advantages, Dr. Crovella identified multiple systemic barriers that inhibit the broader adoption of mass timber in New York City's construction landscape. The most commonly cited challenge, cost, has proven to be more nuanced upon examination. While initial estimates suggested a 3-5% premium for mass timber construction, Dr. Crovella explained that these figures typically resulted from retrofitting timber into designs that were optimized initially for steel and concrete. When architects design specifically for mass timber from the project's inception, accounting for its unique properties and advantages, the cost differential often shrinks to just 1-2%. However, this requires early commitment to timber construction and familiarity with its design parameters, which are conditions not always present in conventional development processes.

The construction industry's inherent conservatism emerged as another significant barrier. Contractors accustomed to traditional materials frequently inflate cost estimates for mass timber projects to account for perceived risks associated with unfamiliar techniques and supply chains. This cautious approach, while understandable from a risk management perspective, creates a self-reinforcing cycle that discourages experimentation with timber systems. Dr. Crovella noted that this resistance stems not from opposition to sustainability goals, but from practical concerns about workflow disruptions and potential delays. This is a reality that demands targeted education and demonstration projects to overcome.

Regulatory hurdles, particularly concerning fire safety, presented another substantial challenge. New York City's fire department initially expressed significant reservations about mass timber construction, citing concerns about combustibility. While modern engineering has developed practical solutions, including calculated charring rates that maintain structural integrity during fires, these technical answers require ongoing dialogue with code officials and

first responders. Dr. Crovella emphasized that such conversations must balance legitimate safety concerns with evidence-based assessments of timber's actual performance characteristics. Supply chain considerations added another layer of complexity. Unlike concrete, which can typically be sourced and delivered on short notice, mass timber components often require several months of lead time for fabrication and delivery. This necessitates more advanced planning from developers accustomed to just-in-time material procurement, representing a cultural shift for many construction teams. While not an insurmountable obstacle, this difference in project timelines has slowed adoption among developers working under tight schedules and financial constraints.

To address these barriers, Dr. Crovella proposed several policy interventions that could accelerate the adoption of mass timber while ensuring equitable access to its benefits. He suggested expanding the framework of Local Law 97, which currently focuses on operational carbon emissions, to include embodied carbon standards for construction materials. This would create market incentives for low-carbon materials, such as mass timber, while maintaining flexibility in how developers meet these targets. Such an approach could mirror successful models from the Carbon Leadership Forum, which has compiled life cycle assessment data from over 1,000 buildings to establish realistic benchmarks for material emissions.

He noted that public funding agencies, such as NYSERDA and HCR (Housing and Community Renewal), could play a pivotal role by revising their funding criteria to prioritize projects that utilize sustainable materials. By incorporating mass timber requirements or incentives into affordable housing financing programs, these organizations could stimulate market demand while directing the material's benefits toward communities that need them most. Dr. Crovella also highlighted the potential for streamlined permitting processes for timber projects, particularly those on public land or involving public-private partnerships, to reduce barriers to entry for developers considering this technology.

The New York City Economic Development Corporation's (EDC) establishment of a dedicated mass timber division represented an encouraging institutional development in Dr. Crovella's view. This specialized focus within city government could facilitate coordination between researchers, developers, and policymakers, helping to align incentives and overcome fragmentation in the construction ecosystem. He suggested that such offices could serve as clearinghouses for best practices, technical resources, and case studies that demonstrate the viability of mass timber across different project types and scales.

Addressing common concerns about the durability of mass timber, Dr. Crovella pointed to numerous historical examples of wooden structures that have endured for centuries when properly designed and maintained. Japanese temples and Scandinavian churches, some over a thousand years old, attest to the longevity of wood when protected from excessive moisture. Modern engineering has developed additional protective measures, including specialized coatings and moisture barriers during construction, that further enhance timber's resilience in challenging urban environments. Dr. Crovella emphasized that all building materials face durability challenges in flood-prone areas, and the performance of mass timber depends on proper detailing and maintenance rather than any inherent weakness. Timber's reparability, the relative ease with which damaged components can be identified and replaced, may offer advantages over more monolithic materials, such as concrete, in climate adaptation scenarios. This reparability, combined with timber's lower embodied carbon, suggests that life-cycle assessments favor mass timber when evaluating long-term resilience and sustainability. Dr. Crovella saw particular promise in interdisciplinary collaborations that bring together materials scientists, structural engineers, and urban planners to address the multifaceted challenges of sustainable construction.

Chapter 7: Findings and Analysis

This chapter synthesizes findings from the case studies, literature review, and stakeholder interviews around five central climate change areas: sea level rise, stormwater management, urban heat island effects, building material innovation, and environmental justice. Together, these findings demonstrate that an integrated strategy combining policy reform, sustainable materials, and equitable community engagement is essential to strengthening New York City's climate resilience.

1. Sea Level Rise and Coastal Flooding

The case examples of Red Hook, Battery Park City, Broad Channel, Newtown Creek, Alphabet City, and Hunts Point illustrate a clear pattern: New York City's current flood adaptation measures are increasingly inadequate in the face of accelerating sea level rise. Interviews with John Mandyck and Dr. Paul Crovella confirmed that forward-looking flood risk assessments and design adaptations are critical but inconsistently applied.

Despite a consistent stream of data corroborating the increased flood risk for low lying areas within the city,, the city continues to approve new developments in flood-prone areas, such as the Rockaways, creating what Mandyck called "climate denial dressed up as progress." Hurricane Sandy highlighted these vulnerabilities, and the disconnect is particularly alarming for neighborhoods like Red Hook and Broad Channel, where elevations barely exceed high tide levels, and Hurricane Sandy's 10-foot storm surges demonstrated their existential vulnerability. The reliance on outdated FEMA Flood Insurance Rate Maps (FIRMs), based on historical rather than forward-looking data, creates a dangerous false sense of security because these maps fail to account for current and future climate risks, leading to underprepared communities, mispriced insurance, and unchecked development in high-risk zones.

The interviews revealed that recent waterfront projects failed to incorporate future Sea Level Rise projections, despite the data being readily available. These policy failures leave critical infrastructure within the city, ranging from the Brooklyn-Battery Tunnel to subway systems, exposed to saltwater inundation, which can corrode electrical systems. Current building codes remain reactive, focusing on flood-resistant construction but failing to mandate proactive measures, such as elevated foundations or managed retreat strategies, in flood-prone areas within the city.

Community engagement is a critical yet underused tool in designing effective and equitable strategies for adapting to sea level rise. The South Battery Park City Resiliency Project (2020) exemplifies how collaboration with local residents can produce tailored, innovative solutions. Planners worked directly with the community to identify flood risks and co-develop interventions such as adjustable floodwalls, raised green spaces, and rain gardens that not only manage stormwater but also enhance public amenities. This inclusive approach ensured that affordable housing and essential facilities received priority upgrades, helping to prevent displacement and fostering trust through transparency about design trade-offs, costs, and long-term vulnerabilities. However, this level of engagement remains the exception rather than the norm across New York City. In Red Hook, a complex mix of industrial and residential land uses has hindered integrated planning, while in Broad Channel, the absence of proactive engagement leaves the community vulnerable to unplanned displacement rather than coordinated managed retreat. Along Newtown Creek, the Newtown Creek Alliance has built strong community partnerships and led participatory planning efforts focused on water quality, habitat restoration, and flood mitigation, demonstrating how local stewardship can advance environmental resilience (Zimmerman & Faris, 2023). In Alphabet City, engagement has largely occurred through formal city-led resiliency projects, but community participation has been inconsistent and often limited to feedback sessions rather than co-design (NYC DEP, 2010). In Hunts Point, robust organizing by local environmental justice groups has increased awareness of climate risks, but sustained, coordinated engagement in long-term adaptation planning remains limited, leaving gaps in integrating resident priorities into infrastructure investments (Hsu et al., 2021).These cases underscore the need to embed community voices at the center of climate adaptation planning citywide.

Three critical gaps stand out in current climate adaptation efforts, each undermining the effectiveness of resilience planning. First, despite the increasing availability of sea-level rise projections from sources like the New York City Panel on Climate Change (NPCC), most zoning regulations fail to incorporate these forecasts into enforceable building codes, because they rely on FEMA’s FIRMs which are based on historical flood events, not future projections. There are proven models that are being followed by such projects like the East Side Coastal Resiliency Project, demonstrating how this can be done. Second, policymakers continue to greenlight roads, utilities, and housing in high-risk flood zones for several reasons, which are rooted in outdated planning frameworks, economic pressures and political incentives. Third, and perhaps most consequential, adaptation investments remain disproportionately allocated, with

marginalized communities consistently receiving fewer resources despite facing greater climate threats, effectively making them bear the heaviest burdens of flooding and extreme weather. The interviews noted that addressing gaps requires a fundamental shift in strategy: moving beyond reactive measures, such as flood-resistant construction, and instead designing infrastructure and policies that proactively anticipate and adapt to future climate conditions.

2. Urban Heat Island (UHI) Effect

This section summarizes the findings related to the urban heat island (UHI) effect. As with sea level rise (SLR), New York City's approach to UHI remains largely reactive rather than preventative. Rather than addressing the root causes of heat retention, such as excessive impervious and heat-absorbing surfaces, limited tree canopy, and outdated building materials, the city has focused on short-term relief measures like temporary cooling centers

As in the case of flooding, the UHI effect disproportionately impacts low-income communities and communities of color, where disinvestment has left neighborhoods with minimal tree cover, inadequate housing insulation, and limited access to cooling resources. The neighborhood of Hunts Point, situated in the southeastern part of the Bronx, is an area characterized by high poverty rates and significant industrialization. Large swaths of land are dominated by asphalt and concrete in transportation infrastructure and industrial facilities, which significantly influence heat retention. In Hunts Point, an industrial zone with only 11% tree cover (compared to the citywide average of 22%) (NYC Parks and Recreation, 2021), heatwaves trigger spikes in hospitalizations, particularly among elderly and low-income residents who lack air conditioning or cannot afford its cost. Another effect of UHI in Hunts Point is the increased use and demand for cooling, which puts additional stress on the energy grid. The July 2022 heat wave exposed vulnerabilities in Hunts Point's urban planning and infrastructure, as residents experienced prolonged periods of heat exhaustion due to the extreme heat. Some residents also began experiencing respiratory issues, which were attributed mainly to the lack of cooling resources and poor air quality.

Like the Hunts Point neighborhood, East New York faces significant challenges in terms of resilience to UHI, as a high percentage of the neighborhood's infrastructure and ground surfaces is impervious. The area has experienced some of the highest temperatures in the city, particularly during a July 2021 heatwave, when temperatures reached 98°F, according to the National Weather Service (NWS). Due to the extreme heat, hospitalizations exponentially

increased for heat-related illnesses, especially for those with pre-existing conditions and the elderly (Rosenthal et al., 2014). These vulnerabilities are exacerbated by the lack of access to cooling centers and the need for more urban parks and green spaces.

Midtown Manhattan's skyscrapers, while symbols of economic power, exacerbate the problem by trapping heat and maintaining elevated nighttime temperatures. Known for its high density of high-rise buildings, towers, and a densely packed street grid, the neighborhood features an abundance of asphalt and concrete. The overcrowding of Midtown with business professionals, tourists, and residents, the lack of green space in a business district, and the prevalence of dark, heat-absorbing materials contribute to significantly elevated temperatures during the day and evenings. Dark rooftops and pavement absorb up to 90% of solar radiation, creating a thermal feedback loop that intensifies energy demand and air pollution. NYC's "reactive" approach underscores a fundamental flaw in current strategies. Programs like Cool Neighborhoods NYC and the Plaza Program have made incremental progress by planting trees and establishing cooling centers, but these measures are Band-Aids rather than cures. Cooling centers, for instance, rely on vulnerable populations traveling to designated sites, a logistical challenge during extreme heat events. Meanwhile, tree-planting initiatives often prioritize aesthetics over equitable distribution of the canopy. There is a need for policies that compel systemic change, such as requiring reflective roofing materials or green infrastructure in zoning codes.

The proposed maximum indoor temperature policy, which would mandate safe indoor conditions during heat waves, is a step toward equity but faces bureaucratic inertia. Similarly, voluntary frameworks like LEED certification, which Burney dismissed as "too easy to achieve and insufficiently rigorous," fail to address the urgency of heat adaptation. Without enforceable standards, market-driven solutions will continue to prioritize high-end developments (e.g., luxury towers) over affordable housing retrofits, where the need is greatest.

The interviews reveal untapped potential in material science and urban design to combat UHI. Mass timber offers inherent thermal benefits, including humidity regulation and reduced cooling loads. While its adoption has often been perceived as limited to high-end projects due to cost concerns, long lead times, and outdated building codes, there are notable exceptions in the affordable housing sector. Projects such as 340 + Dixwell Avenue in New Haven, profiled through the interview with Dr. Crovella, demonstrate that mass timber can be successfully implemented in cost-sensitive developments. Across the U.S., and increasingly in urban centers, affordable multi-family projects are leveraging mass timber's speed of

construction, lower embodied carbon, and occupant comfort benefits (Shakun, 2025). Similarly, retrofitting existing buildings with heat-reflective materials and installing green roofs could be a strategy that simultaneously addresses UHI and housing affordability.

Nature-based solutions, such as bioswales and green roofs, encounter implementation barriers in densely populated areas like Manhattan, where unencumbered rooftop space is scarce. Mandyck's pragmatic critique of these solutions highlights the need for context-specific approaches, such as expanding green infrastructure in outer boroughs while investing in reflective pavements and shade structures in skyscraper-dominated zones.

3. Stormwater Management

Interviews and observations reveal two main findings. First, aging infrastructure in combination with increasing climate volatility will mean that NYC must undertake large-scale, proactive upgrades to its sewer and drainage systems. This includes expanding green infrastructure, modernizing combined sewer systems, and investing in long-term capital improvements that can accommodate more frequent and intense rainfall events. Secondly, while the city has developed comprehensive stormwater management plans, such as the *NYC Green Infrastructure Plan* (2010) and various borough-specific resilience strategies, implementation often lacks robust enforcement mechanisms. Without binding regulations, clear accountability, and consistent monitoring, these initiatives risk remaining aspirational rather than producing measurable, system-wide improvements. Strengthening policy enforcement and ensuring interagency coordination will be critical to making stormwater infrastructure more resilient and equitable.

The challenges of stormwater management in NYC are deeply intertwined with its aging infrastructure and increasing climate volatility. NYC's combined sewer system, designed for 20th-century rainfall, overflows during intense storms, discharging millions of gallons of untreated sewage annually into waterways like Newtown Creek. The Newtown Creek watershed is a 3.8-mile-long tributary flowing into the East River, which partially divides the boroughs of Queens and Brooklyn, and was once a thriving ecosystem. However, urbanization and industrialization over the past century have turned it into one of the most polluted waterways in the United States. Due to decades of damage from various sources of contamination at the Newtown Creek site, including Combined Sewage Overflow and oil spills, it has been designated as a Superfund site (U.S. Environmental Protection Agency, n.d.) since 2010. The

Newtown Creek tributary area interacts with and affects multiple neighborhoods in the region, including Long Island City, Greenpoint, East Williamsburg, and Maspeth. Stormwater management is a critical issue for Newtown Creek, as the area is highly vulnerable to flooding and water pollution. The creek receives approximately 1,161 million gallons of untreated sewage annually from CSOs, which account for 70% of the pathogen and nitrogen loads in the watershed.

The Lower East Side of Manhattan (LES) is another area heavily affected by stormwater issues. This densely populated neighborhood faces two primary challenges related to stormwater management: aging infrastructure and a high percentage of impervious surfaces. Alphabet City, a community just north of the Lower East Side, is an example of how aging infrastructure, outdated drainage systems, and combined sewer system failures contribute to flooding. During heavy rainfall, stormwater accumulates in the streets and in the basements of houses and buildings. Tropical Storm Ida (2021) exposed vulnerabilities in neighborhoods like Alphabet City, where basements were flooded. Like Newtown Creek, water quality issues are a significant concern for Alphabet City and other nearby communities like Seward Park and the waterfront in the Lower East Side. Runoff from impervious surfaces carries pollutants, such as trash, heavy metals, and oil, into the sewer system and is discharged into the East River during CSO events. NYC's Department of Environmental Protection, NYC DEP. (2010) has estimated that 80-90% of the Lower East Side comprises impervious land, and 65% of Manhattan as a borough overall.

The Lower East Side's paved streets, minimal green space, and tightly packed buildings are ideal for extensive and integrated green infrastructure plans, which the NYC DEP has already initiated. While green infrastructure initiatives, such as bioswales and permeable pavements show promise, their limited coverage highlights a systemic issue of scalability. Local Law 92/94 mandates the installation of green roofs or solar panels on new buildings, yet compliance remains uneven. The city's reliance on combined sewer systems exacerbates pollution during heavy rainfall, disproportionately affecting environmental justice communities such as those near Newtown Creek, where industrial legacy and inadequate infrastructure converge. The Newtown Creek Superfund cleanup highlights the dual challenge of pollution remediation and stormwater capacity.

Traditional "gray" infrastructure (e.g., storage tanks) is insufficient to handle climate-driven increases in precipitation. To address this, NYC must prioritize integrated solutions that combine gray and green infrastructure, ensuring that projects like the DEP's *Green*

Infrastructure Plan are not just aspirational but rigorously enforced and expanded. Green infrastructure offers co-benefits: bioswales in the Lower East Side reduce flooding while improving air quality. Another example is incentivizing private property owners to adopt rain gardens or rooftop detention systems, which could accelerate progress. At the same time, updated zoning laws could mandate stormwater retention for new developments in flood-prone areas. However, implementation is slow due to funding gaps and bureaucratic silos.

The Department of Environmental Protection(DEP)'s *Green Infrastructure Plan* aims to achieve 10,000 green installations by 2030, but it lacks effective enforcement mechanisms. Equity also remains a critical gap in stormwater resilience efforts. Neighborhoods like Alphabet City, with high percentages of impervious surfaces and outdated drainage systems, face recurrent flooding, yet interventions often lag behind those in wealthier districts. The city's Climate Justice Hubs could play a pivotal role in directing resources to these vulnerable areas, coupling infrastructure upgrades with community education on flood preparedness. Predictive modeling can also be leveraged to identify high-risk zones and paired with targeted investments in green spaces and underground storage tanks. This could help mitigate the cascading effects of stormwater overflow; however, without binding mandates and cross-agency collaboration, NYC's stormwater management will remain reactive. In the absence of a coordinated, equity-centered approach, marginalized communities will continue to shoulder a disproportionate burden from climate-driven disasters which underscore the urgent need to transform stormwater from a hazard into a managed and resilient resource.

4. NYC Climate Change Policy

NYC's climate policy framework has made significant progress, transitioning from the foundational *PlaNYC* (2007) to the ambitious Climate Mobilization Act (2019), with Local Law 97 serving as a landmark mandate for building emissions reductions. This law mandates a 40% reduction in emissions by 2030 for large buildings. Post-Sandy initiatives, such as *A Stronger, More Resilient New York* (2013), prioritized floodwalls and elevated infrastructure. While *PlaNYC: Getting Sustainability Done* (2023) introduces equity-focused measures, such as Climate Justice Hubs and the Mayor's Office of Climate and Environmental Justice (MOCEJ), the lack of binding enforcement mechanisms undermines their potential impact. The interviews conducted with professionals working on the ground reveal fragmentation: agencies such as DEP and DOT operate in silos, while voluntary programs like LEED, although valuable, lack the regulatory authority to ensure widespread adoption, leaving gaps in resilience and sustainability

standards. The city's reactive approach, which is evident in the continued development in flood-prone areas like the Rockaways, highlights a persistent disconnect between long-term climate goals and short-term urban planning priorities. To bridge this gap, NYC must adopt a more integrated governance model, aligning agency mandates with climate resilience targets and embedding equity into every stage of policy implementation.

While Local Law 97 is groundbreaking, as it represents one of the most aggressive and comprehensive building emissions laws in the world, a significant limitation of current NYC policy is their narrow focus on operational carbon emissions, neglecting embodied carbon from construction materials. This is a critical oversight given that buildings account for nearly 70% of the city's carbon footprint. While the City of Yes for Carbon Neutrality (NYC DCP, 2023) introduces innovative measures, such as solar access overlays, its effectiveness is hampered by weak enforcement. Experts and stakeholders, such as Mr. Burney, critique reactive governance, arguing that without stringent mandates, market-driven solutions will fall short, particularly in the case of affordable housing, where retrofitting costs pose a significant barrier to progress. Equity-focused policies, such as the Climate Vulnerability Index, aim to direct resources to high-risk communities, which is a step toward equitable resource allocation, but require binding mandates to be effective. To truly lead in urban climate resilience, NYC must expand Local Law 97 to include embodied carbon, strengthen interagency coordination, and prioritize proactive, equity-centered policies that prevent displacement and ensure climate justice for all neighborhoods. Only then can the city's climate framework match the urgency of its environmental challenges.

5. Sustainable Construction Materials

The adoption of sustainable construction materials presents an opportunity for New York City to advance its climate mitigation goals while enhancing urban resilience. Cross-laminated timber (CLT), Glass Fiber Reinforced Concrete (GFRC), and phase-change materials (PCMs) offer low-carbon alternatives to steel and concrete. Mass timber products not only sequester carbon but also reduce construction waste by 25% and withstand flooding through the use of moisture-resistant treatments, which offer a viable alternative to carbon-intensive steel and concrete.

Projects like the Ascent Tower in Milwaukee, WI demonstrate that mass timber can achieve structural integrity comparable to traditional materials while storing thousands of metric

tons of CO2. A shift in industry skepticism is needed, along with the updating of outdated fire codes, to break down the barriers that exist preventing widespread adoption of mass timber products. By revising building regulations to accommodate modern fire-resistant treatments and incentivizing the use of mass timber in affordable housing, the city can accelerate the shift toward low-carbon construction without compromising safety or affordability. Passive House designs, as exemplified by 425 Grand Concourse, reduce energy consumption by 75–90% through airtight envelopes and energy recovery ventilation (ERV) systems. Glass Fiber Reinforced Concrete (GFRC) and phase-change materials (PCMs) further expand the toolkit for sustainable urban development. GFRC's durability and crack resistance make it particularly valuable in flood-prone areas, reducing long-term maintenance costs and improving climate resilience.

Meanwhile, PCMs enhance energy efficiency in buildings by regulating indoor temperatures, reducing reliance on HVAC systems, and mitigating the urban heat island effect. Despite these benefits, contractor unfamiliarity and upfront cost concerns slow their integration into mainstream construction. Policy levers, such as streamlined permitting for sustainable materials, workforce training programs, and subsidies for developers who use low-carbon alternatives, could help bridge this gap. Stakeholders like Dr. Paul Crovella (SUNY ESF) emphasize prioritizing FSC-certified timber in affordable housing and retrofits over demolitions to ensure that material innovation advances both environmental and societal equity goals. For NYC to meet its 2050 carbon neutrality commitments, a coordinated strategy combining updated codes, financial incentives, and equitable implementation will be essential to mainstreaming sustainable construction practices.

Chapter 8: Recommendations

This thesis presents a review of climate change impacts in New York City, assessing neighborhood-level vulnerabilities, key climate threats, and the effectiveness of current policy frameworks. Drawing from the literature review, policy analysis, interviews, case studies, and material innovations, the research reveals that NYC's existing resilience strategy, despite the city's leadership in climate policy, remains fragmented, reactive, and inequitable. The recommendations below form a streamlined, time-bound Climate Action Plan that aims to transform New York City's climate adaptation efforts into a cohesive and justice-centered approach.

Climate Action Plan

2025–2027 (Immediate Actions)

- Establish a centralized Office of Climate Resilience to coordinate cross-agency efforts, such as between the Department of Environmental Protection (DEP), Department of Buildings (DOB), and the Mayor's Office of Climate and Environmental Justice (MOCEJ).
- Pilot embodied carbon reporting (the process of measuring, documenting, and disclosinggreenhouse gas (GHG) emissions) in rezoned districts such as Gowanus and the South Bronx.
- Launch "Cool Corridors" (shaded, pedestrian-friendly routes enhanced with trees, reflective materials, and green infrastructure to reduce heat exposure along key urban pathways) in heat-vulnerable neighborhoods including Hunts Point, East New York, and the South Bronx.

2027–2030 (Systemic Reforms)

- Expand Local Law 97 to include Urban Heat Island (UHI) mitigation requirements and embodied carbon reporting.
- Allocate 40% of all resilience funding to frontline environmental justice communities.
- Mandate the use of dynamic flood modeling based on NPCC 2050 and 2100 climate scenarios.

2030–2035 (Long-Term Goals)

- Achieve 30% tree canopy coverage in all environmental justice neighborhoods.

- Retrofit 100% of NYCHA housing using Passive House or mass timber standards.
- Complete at least 300 acres of coastal wetland restoration for storm surge absorption.

The below recommendations outline the specific areas needed to reform, rethink, and mitigate the individual aspects of climate change plaguing NYC. The actions and recommendations within the larger scope of the climate action plan, ensure that each area is comprehensively addressed and prioritizes the most vulnerable communities affected by climate change in NYC. The climate action plan not only addresses the issues, but provides fairness, equity, and forward thinking solutions.

Recommendation 1: Strengthen NYC's Climate Change Framework

New York City has been a leader in climate policy with initiatives like *PlaNYC* and the Climate Mobilization Act, and the recent *PlaNYC: Getting Sustainability Done* (2023), but critical gaps remain currently, as overlapping responsibilities within governance and inconsistent standards slow progress. These initiatives have set bold targets for emissions reductions, green infrastructure, and equitable resilience, positioning NYC as a global model for urban sustainability, but fragmented governance, weak enforcement of resilience standards, and the lack of embodied carbon regulations threaten the city's ability to meet its climate goals of carbon neutrality and equitable resilience by 2050 and emissions reductions cut of 40% by 2030 and by 80% by 2050. As climate impacts accelerate, from record-breaking heatwaves and catastrophic flooding to worsening air quality and energy grid strain, the limitations of the city's current framework are becoming increasingly apparent and may undermine the city's ability to meet its 2050 carbon neutrality goals. Meanwhile, marginalized communities, particularly in flood-prone coastal areas and heat-vulnerable neighborhoods like Hunts Point and East New York, bear the brunt of these systemic gaps. Without urgent reforms to centralize authority, align policies with the latest climate science, and prioritize equity in resource allocation, NYC risks falling behind in the race to adapt to rising temperatures, intensifying storms, and deepening socioeconomic disparities.

To ensure a coordinated, science-driven, and equitable approach to climate change mitigation processes and frameworks, the city must:

- **Establish a centralized Office of Climate Resilience:** to align efforts across the Department of Environmental Protection (DEP), Department of Buildings (DOB), and the Mayor's Office of Climate and Environmental Justice (MOCEJ).

- **Mandate the use of NPCC's high-emissions scenarios (2100 projections):** in all land use, zoning, and capital planning decisions. *(Many policies rely on outdated climate models, leaving infrastructure vulnerable to future extremes.)*

- **Expand Local Law 97:**
  - Include lifecycle carbon assessments for new development and major renovations. *(Current rules ignore emissions from construction materials and their transportation)*
  - Impose embodied carbon limits on new buildings.
  - Reinvest 30% of LL97 penalty revenues into NYCHA retrofits to prevent displacement.
- **Develop a NYC-specific LEED Resilience certification:**
  - Climate risk assessments for floods, heat, and storms.
  - Equity impact evaluations to ensure benefits reach frontline communities.
- **Community benefits agreements to prioritize local hiring and anti-displacement measures**.
- **Fast-track permitting and providing technical assistance** for resilience projects in environmental justice neighborhoods.

These measures would close enforcement gaps, embed long-term climate science into decision-making, and direct resources to the neighborhoods most at risk, ensuring NYC's climate framework is as resilient as the city needs to be.

Recommendation 2: Sea Level Rise and Coastal Flooding Mitigation

Climate change poses an existential threat to NYC from rising seas, stronger storms, and outdated flood maps that underestimate risks. Current FEMA Flood Insurance Rate Maps (FIRMs) rely on historical data, ignoring future sea level rise projections from the NPCC which leaves communities unprepared for compound flooding (e.g., storm surge + heavy rainfall). Without urgent action, NYC risks repeating the failures that occurred during Hurricane Sandy, and with worsening storms and rising seas threatening critical infrastructure (subways, hospitals, power plants) and deepening housing inequities as vulnerable populations are forced into climate gentrification.

To avoid catastrophic losses of life and property due to SLR and coastal flooding as well as to ensure equitable resilience, NYC must:

- **Replace outdated FEMA FIRMs** with dynamic flood models based on NPCC projections.
- **Incorporate amphibious and elevated design standards** into zoning updates, especially in high-risk areas like Gowanus and Red Hook. *(Rigid building codes prevent flood-adaptive architecture, leaving homes and businesses vulnerable.)*
- **Implement a managed retreat framework**
  - Launch voluntary buyout programs in severely flood-prone areas like Broad Channel. *(Some neighborhoods will become uninhabitable; proactive relocation avoids chaotic displacement.)*
  - Offer affordable relocation options and preserve housing equity through a Community Land Bank. *(Without safeguards, retreat could accelerate gentrification.)*
- **Scale nature-based and hybrid infrastructure**
  - Expand Jamaica Bay wetlands by a minimum of 300-600 acres to absorb storm surges. *(NYC Department of Environmental Protection. (2016). Jamaica Bay Watershed Protection Plan., U.S. Army Corps of Engineers. (2020)., Jamaica Bay Reformulation Study.)*
  - Install living shorelines paired with floodwalls (e.g., East River). *(Hybrid systems are more cost-effective than concrete alone.)*
- **Use the Climate Vulnerability Index** to prioritize upgrades to energy grids, stormwater systems, and transit in low-income flood zones. *(Historically excluded communities face the highest risks but receive the least investment.)*
- **Reform the National Flood Insurance Program (NFIP)** with state partners to reduce premiums for low-income homeowners. *(Current rates force vulnerable residents to underinsure or abandon homes.)*
- **Explore climate bonds and public-private partnerships** to fund needed infrastructure upgrades. *(Traditional funding falls short; innovative financing is critical.)*

Recommendation 3: Combat Urban Heat Island Effects

The urban heat island effect in NYC has become a public health crisis, with summer temperatures in heat-vulnerable neighborhoods like Hunts Point and East New York reaching up to 20°F hotter than surrounding areas due to asphalt-dominated landscapes and as little as 11%

tree cover (vs. the citywide 22% average) (NYC Parks, 2023). Climate change is accelerating this threat and the NPCC is projecting heatwaves quadrupling in frequency and duration (NPCC, 2023) by 2050, and the city's current reactive approach (e.g., cooling centers opened *after* emergencies) fails to address systemic risks. Heat already kills more New Yorkers annually than all other weather disasters combined (New York City Department of Health and Mental Hygiene, n.d.), with Black and low-income residents disproportionately affected due to less tree cover, aging housing stock, and energy inequity. Without systemic intervention, heat-related deaths could rise by 90% by 2080 (Columbia Climate School, 2022), deepening racial and economic inequities.

To save lives and reduce energy burdens, NYC must adopt a proactive, place-based UHI strategy that combines building upgrades, green infrastructure, and community-driven solutions:

- **Expand Local Law 97 to require:**
  - Cool roof installation for new and retrofitted buildings. *(Reflective surfaces can lower rooftop temps by 50°F, reducing AC demand by 20%. (U.S. Environmental Protection Agency, 2023)*
  - Mass timber construction in new affordable housing projects. *(Thermally efficient materials cut cooling loads while sequestering carbon.)*
- **Retrofit NYCHA buildings with:**
  - Mass timber for substantial renovations, additions, and new construction. (Lower thermal conductivity, reduced heat absorption and release.)
  - Passive House design standards, with high quality ventilation and HVAC installation
  - Phase-change materials (PCMs) to absorb excess heat. *(PCMs in walls can maintain stable indoor temps during blackouts.)*
  - Energy recovery ventilation systems to reduce heat buildup without raising energy costs. *(NYCHA residents face 3x higher heatstroke risk than NYC average.)*
- **Scale green infrastructure:**
  - Plant 30,000+ trees in environmental justice neighborhoods to achieve 30% canopy coverage by 2035. (*Current canopy cover is just 14% in the South Bronx (Swanson, 2024)).*
  - Deploy "Cool Corridors" with solar-reflective pavement, bioswales, and modular green roofs. (*These measures can reduce street-level temps by 10°F.*)

- **Develop district cooling hubs in heat-vulnerable areas:** retrofitting libraries and community centers with solar-powered AC and green walls. (City of Medford Energy Office, n.d.)
- **Launch workforce programs to:**
  - Train residents for green infrastructure jobs (e.g., tree maintenance, cool roof installation). *(Creates local economic benefits while addressing maintenance gaps.)*
  - Require 25% local hiring for UHI projects and CBAs. *(Ensures community ownership of solutions.)*
- **Centralize UHI strategy under the Office of Climate Resilience**, coordinating across agencies using real-time heat ER visits, tree cover maps, and land surface temperature data. *(Current efforts are fragmented e.g., DOH tracks deaths but doesn't inform DOT street design.)*

Recommendation 4: Transform Stormwater Management

New York City's stormwater systems are at a breaking point. Climate change is delivering more intense, frequent rainfall, which is overwhelming its aging infrastructure and triggering billions of gallons of combined sewer overflows (CSOs) annually that flood streets and waterways with raw sewage and toxic runoff. Neighborhoods like Alphabet City and Newtown Creek bear the brunt, where 90% of residents live within a flood zone, yet lack adequate green infrastructure. The status quo, relying on century-old pipes and reactive fixes, fails both ecologically and socially, allowing pollution to concentrate in environmental justice communities while wasting a vital water resource.

To future-proof the city, NYC must rethink stormwater as an asset, not just a hazard, through decentralized, nature-based solutions paired with equitable policies, and by taking the following key actions:

- **Create a Stormwater Resilience Office under the Office of Climate Resilience** to unify DEP, DOT, and Parks Department efforts. (Currently, disjointed oversight delays projects e.g., bioswale approvals take 18+ months.)
- **Mandate:**
  - On-site stormwater retention (e.g., bioswales, permeable pavements) for all new construction and major renovations

- Expand Local Laws 92/94 to require retrofits of large rooftops in high-runoff zones. *(Flat commercial roofs cover 15% of NYC but contribute 30% of runoff.)(Jacques, 2022)*

- **Scale nature-based solutions:**
  - Co-design bioswales and pocket parks with groups like the Newtown Creek Alliance. *(Community input boosts adoption and maintenance.)*
  - Pilot "green alleyways" in flood-prone areas (e.g., Lower East Side).
  - Install subsurface storage beneath parks and schoolyards.

- **Incentivize private action through:**
  - Tax abatements for green roofs and rain gardens, prioritizing low-income owners. (Every 1,000 sq. ft. of green roof retains 10,000+ gallons annually.)
  - "Sponge Block" (permeable, modular infrastructure units) retrofits in industrial zones such as Hunts Point. *(Industrial areas generate 50% more runoff than residential blocks.)*

- **Upgrade critical infrastructure:**
  - Separate sewer/stormwater lines in CSO hotspots like Newtown Creek. *(Just 40% of NYC's sewers are separated, leading to 75% of CSOs. (New York State Department of Environmental Conservation, 2023))*
  - Achieve 30% reduction in CSOs by 2035 (cutting 1 billion gallons/year).
  - Deploy smart sensors at outfalls for real-time alerts. *(Early warnings could reduce flood damage by 25%.)*
  - Introduce "blue belts" (green infrastructure that uses natural drainage corridors, such as streams, ponds, wetlands, and other water bodies) in outer boroughs to mimic natural watersheds. (Staten Island's Bluebelt reduces flooding for 3,000+ homes.)
  - Require 100% compliance with stormwater retention mandates for new construction.

- **Advance equity through:**
  - Job training in green infrastructure maintenance. *(Creates local careers while ensuring long-term functionality.)*
  - Climate Justice Hubs for multilingual outreach.
  - A Flood Vulnerability Portal mapping risks and upgrades.
  - 50% increase in stormwater retention in EJ neighborhoods (prioritizing areas with <5% green space).

Conclusion

New York City faces a defining moment in its fight against climate change. The growing dangers of rising seas, extreme heat, and worsening floods demand bold, systemic change rather than small adjustments. This Climate Action Plan offers a clear, step by step strategy that combines scientific research, fairness, and creative solutions to protect the city's future.

By using advanced climate predictions in urban planning, fairly distributing green infrastructure, and improving coordination across government agencies, New York can become a national leader in equitable climate resilience. However, success depends on more than just adopting these ideas. The lives and safety of at risk communities, particularly in vulnerable neighborhoods, hinge on swift, accountable, and ambitious action.

The strategies proposed, from sponge block installations in industrial areas to passive house upgrades for housing and planned relocation for flood prone zones, show how New York can tackle climate threats while addressing long standing inequalities. The time to act is now. With decisive leadership and commitment, New York can transform from a city at risk into a global model of urban resilience, proving that even the greatest challenges can be overcome with vision, innovation, and determination equal to the crisis at hand.

Appendix A

Table 1. NYC Local Laws Summary, 2009 - 2021

Local Law #	Year	Category	Key Provisions
84	2009	Energy & Water Benchmarking	Applies to buildings over 50k sq. ft. Data is used to track progress toward energy efficiency goals Requires annual submission of data
87	2009	Energy Audits & Retro-Commissioning	Retro-commissioning ensures systems are functioning properly Energy audits assess building systems and recommend upgrades Compliance is required for the continued operation of covered buildings
88	2009	Lighting Upgrades & Submetering	Lighting upgrades must comply with NYC Energy Conservation Code Submeters provide tenants with detailed energy usage data Aims to reduce energy consumption and promote accountability
41	2010	Recycling in Public Spaces	Requires recycling bins alongside trash cans in all city parks, sidewalks, and public spaces. Separates paper, metal/glass, and compost (where available). Goal: Divert 75% of waste from landfills by 2030.
77	2013	Organic Waste Collection	Mandates curbside compost pickup for all residents by 2025 (pilot expanded citywide). Applies to food scraps, yard waste, and soiled paper. Exemptions: Buildings with less than 10 units can opt out.

100	2013	Building Code, Mechanical Code, and Fire Code	Requires relocation or flood-proofing of mechanical, electrical, plumbing, telecommunications, and fire-protection systems in flood-prone areas to at least the Design Flood Elevation (DFE) targets large buildings over 300,000 ft² and 6+ stories, as well as hospitals, nursing homes, and adult care facilities located in the 100-year floodplain or shaded X-zones.
38	2015	Flood Resilience Zoning	Updates zoning codes to require elevated foundations and flood-resistant materials in coastal areas. Aligns with post-Hurricane Sandy FEMA standards. Applies to new constructions in floodplains.
152	2016	Gas Line Inspections	Mandates gas piping inspections every 4 years for buildings (except 1-2 family homes). Licensed plumbers must submit reports to the DOB. Penalties: Up to $10,000 for failure to inspect.
32	2018	Bird-Safety Building Standards	Requires all new construction & major renovations to use bird-friendly materials Non-essential building lighting over buildings of 25,000 sq ft turned off between midnight and 6 AM Annual compliance reports must be submitted by building owners to DOB
33	2018	Building Energy Efficiency Benchmarking	Data is published on NYC Energy & Water Performance Map Building owners must submit annual benchmarking reports Aims to drive market-based energy efficiency improvements

97	**2019**	**Climate Mobilization Act**	**Establishes carbon emissions limits for covered buildings over 25k sq. ft. (2024 start)** **Requires building owners to submit annual emissions reports** **Provide flexibility through renewable energy credits & carbon offsets**
94	2019	Green Roofs & Solar Panels	Requires green roofs or solar panels on all new buildings and major renovations Green roofs must cover 100% of available roof space, and solar panels must meet specific energy requirements Exempts made for limited solar access or structural constraints
95	2019	Building Energy Efficiency Grades	Requires buildings over 25k sq. ft. to display energy-efficient letter grade (A-D) Grades are based on EPA's ENERGY STAR scoring system Buildings must post grades in a visible location
96	2019	Property Assessed Clean Energy (PACE)	Finance program that assists property owners in financing energy efficiency and renewable energy projects Special assessments allow property owners to repay upgrade costs through property tax bill Covers solar installation, energy-efficient HVAC, and green roofs
92/94	2019	Solar & Green Roof Mandates	Green roofs help reduce the UHI effect, manage stormwater, and improve air quality Solar panels contribute to renewable energy goals Promote the integration of green infrastructure into urban development

48	2020	Energy Efficiency & Building Performance	Buildings over 25,000 sq. ft. undergo comprehensive audits every 5 years for efficiency upgrades Must include ASHRAE Level II audit for HVAC & lighting Expands local law 97 compliance with real-time emissions monitoring for buildings over 50,000 sq. ft.
50	2020	Flood Resilience	Requires flood-resistant materials in new constructions in flood zones. Elevated electrical systems in basements. Aligns with FEMA's updated flood maps.
60	2020	Zero-Emission School Buses	All NYC school buses must be electric by 2035. Phased rollout: 25% electric by 2025, 50% by 2030. Funding: $108M allocated for charging infrastructure.
28	2021	Climate Resiliency Design Guidelines	Mandates climate risk assessments for all city-funded infrastructure projects. Requires elevation/flood-proofing in flood zones. Aligns with NYC's Climate Resiliency Design Standards.
132	2021	Plastic Bottle Recycling in Parks	Requires soil testing for lead/contaminants in city-funded projects. Promotes compost use in public landscaping. Supports urban farming initiatives.
142	2021	Urban Soil Health	Requires soil testing for lead/contaminants in city-funded projects. Promotes compost use in public landscaping. Supports urban farming initiatives.

146	2021	EV Charging in Garages	20% of parking spaces in new garages must have EV-ready wiring. Applies to residential and commercial developments. Goal: 10,000+ curbside chargers by 2030.
147	2021	Bike Parking, new buildings	Mandates secure bike storage in new residential/commercial buildings E-bike charging required in some cases Reduces car dependency to align with NYC's 25x25 plan (25% less car space by 2025)
154	2021	Fossil Fuel Ban (New Buildings)	Bans oil, natural gas, and propane in new construction Encourages use of electric heat pumps and other clean technology Aims to reduce GHG emissions from buildings
163	2021	Noise Pollution & Construction Equipment	Bans loud, diesel-powered construction equipment (e.g., pile drivers) without noise mitigation. Promotes electric machinery: Requires quieter alternatives where feasible. Fines: Up to $8,000 for violations.
183	2021	Tree Planting Equity	Prioritizes tree planting in heat-vulnerable neighborhoods (e.g., South Bronx). Goal: 30% canopy cover citywide by 2035. Community input: Residents can request street trees via 311.
195	2021	Solar Storage Incentives	Bans the sale of uncertified lithium-ion batteries for e-bikes/scooters. Requires fire-safe charging stations in apartments/commercial buildings. Fines: Up to $1,000 for violations.

Appendix B. Maps and Data

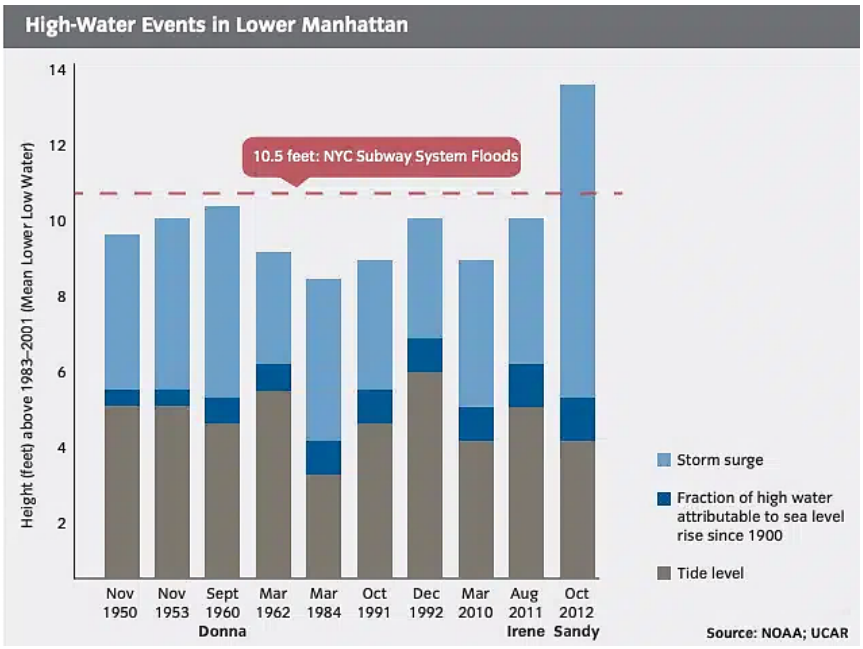

Figure 32.Chart displaying risk to subway system by high water events in Manhattan. **(NYC Report on Hurricane Sandy and its Impacts, 2013, p. 13.)**

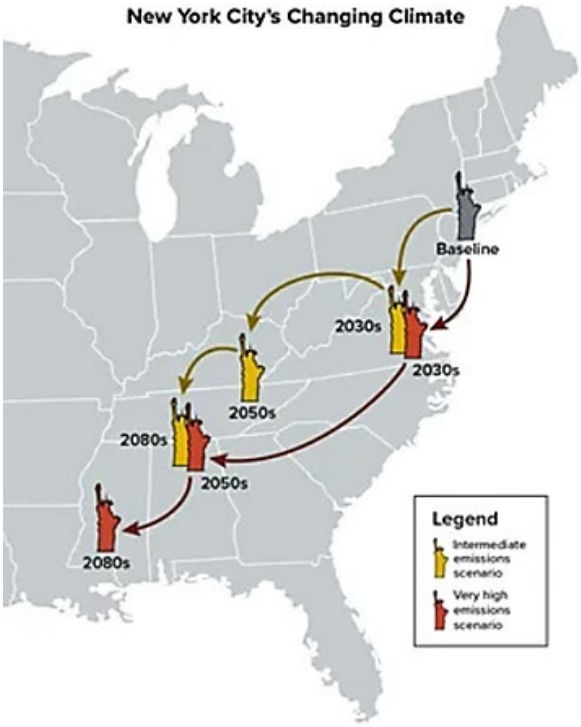

Figure 33. Climate change in New York: Effects on farmers and the economy. **(Mack, Jacob. (2024). Climate change in New York: Effects on farmers and the economy. *Ithaca Journal*, February 14, 2024. https://www.ithacajournal.com/story/news/2024/02/14/climate-change-in-new-york-effects-on-farmers-and-the-economy/72598032007/**

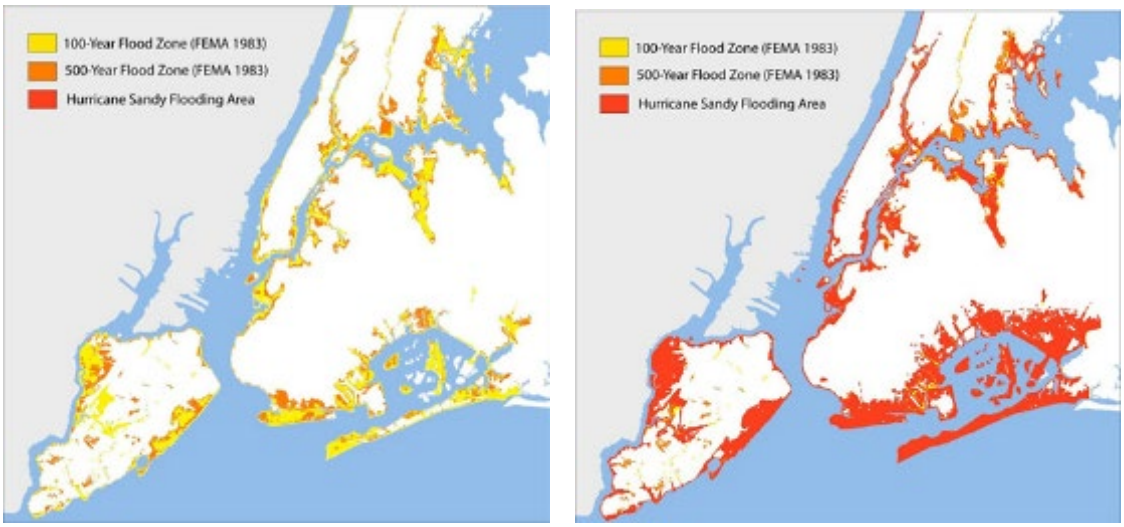

Figure 34. FEMA's 100-year flood map (left) compared to the flooding caused by Sandy (right) **https://www.dnainfo.com/new-york/20121206/new-york-city/fema-redrawing-citys-flood-zone-after-superstorm-sandy/)**

Figure 35. Aerial view of Hunts Point, Bronx, NY: lack of green space. (Google Maps)

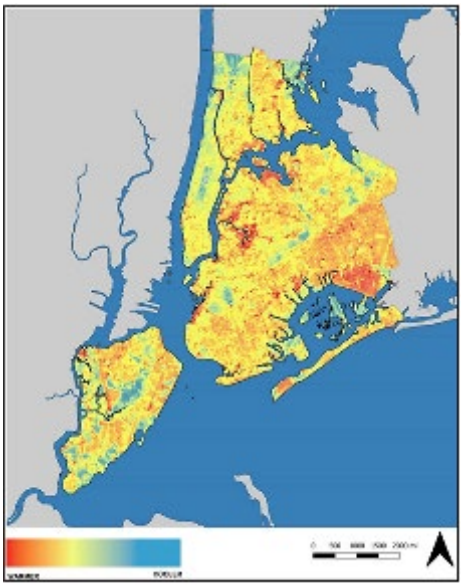

Figure 36. Composite thermal imagery of New York City, based on LANDSAT Thermal Data during the months of May through October 2015 to 2019., **(NYC Mayor's Office of Climate and Environmental Justice.**

2022. *Climate Resiliency Design Guidelines*, p.11. https://climate.cityofnewyork.us/wp-content/uploads/2024/05/CRDG41May_2022_digital_print.pdf

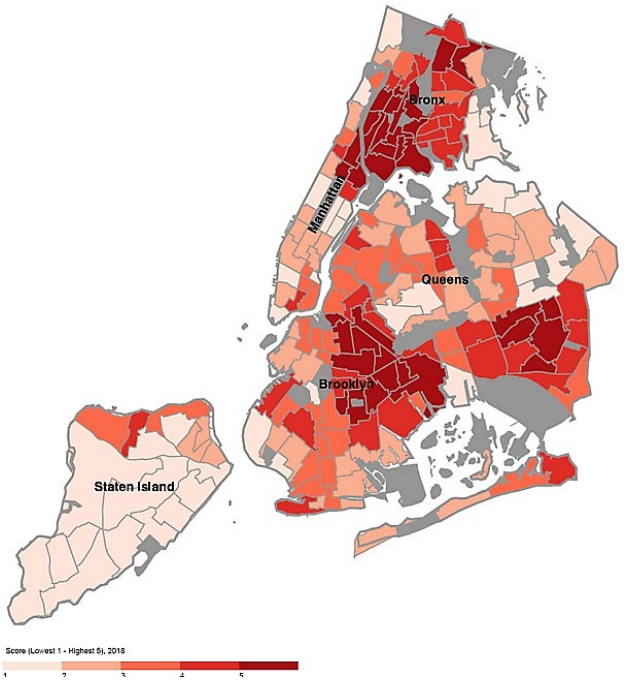

Figure 37. Heat Vulnerability Index (HVI) for New York City Neighborhood Tabulation Areas (NTA). This analysis identifies physical, social, and economic factors associated with increased risk of heat-related morbidity and mortality. NYC Mayor's Office of Climate and Environmental Justice. 2022. *Climate Resiliency Design Guidelines,* p. 13.

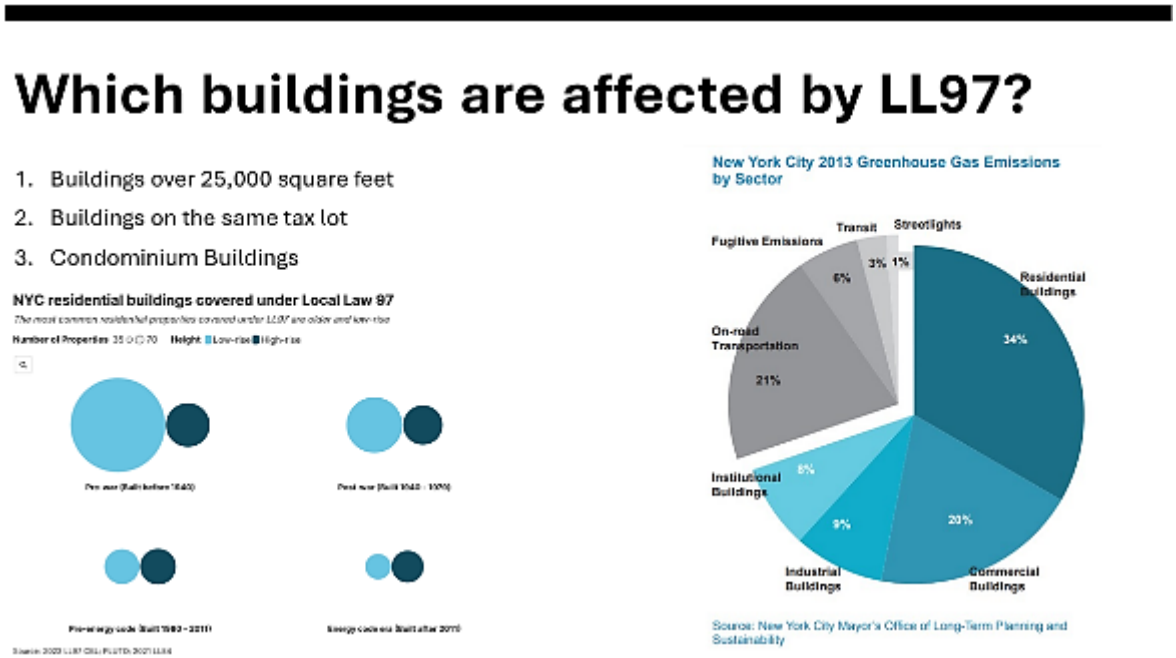

Figure 38. Buildings in NYC that will be affected by LL97. (Urban Green Council, 2023. LL97 in Focus: Multifamily pathways to 2030. *https://www.urbangreencouncil.org/ll97-multifamily-pathways-to-2030/*)

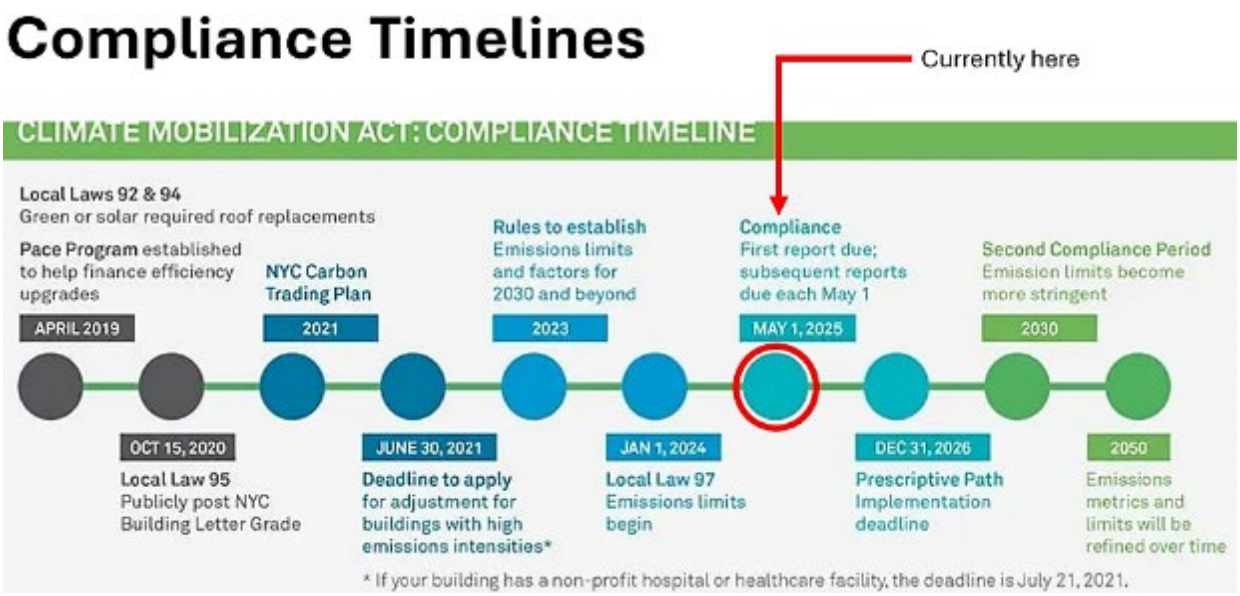

Figure 33. Compliance times for LL97 in NYC. **(Heat-Timer. 2023. Understanding Local Law 97 and its Impact in NYC. July 2023. *https://www.heat-timer.com/understanding-local-law-97-and-its-impact-in-nyc/***

Appendix C. Interview Questionnaire

Questionnaire: Climate-Resilient Building Design and Policy in New York City

Introduction

This questionnaire gathers general insights and opinions from government officials and, policymakers on climate-resilient building design, policy implementation, and strategies in New York City. The information collected will be used for informational purposes only and will not be used for research or publication.

Section 1: Climate-Resilient Building Design and Materials

A. Design Innovations for Climate Resilience

1. In your opinion, what design innovations are most effective for creating climate-resilient buildings in NYC? (e.g., elevated structures, green roofs, rain gardens, ventilated facades)

2. Are there specific building designs or materials that should be prioritized to address sea level rise, urban heat islands, and stormwater management?

B. Adaptive Materials

1. What role do you see for adaptive materials (e.g., phase-change materials, permeable pavements, high-performance glazing) in improving building resilience in NYC?

2. Are there any barriers to adopting these materials in new construction or retrofitting projects?

C. Current Building Codes

1. How effective are NYC's current building codes in addressing climate risks such as sea level rise, urban heat islands, and stormwater management?

2. What changes or updates to the building codes would you recommend to improve climate resilience?

Section 2: Building Rating Systems and Policy Implementation

A. Role of LEED and Other Rating Systems

1. How can LEED and other building rating systems (e.g., Passive House, Energy Star) be leveraged to promote energy efficiency, resilience, and climate mitigation in NYC?

2. Should these rating systems be mandatory for new construction or major renovations? Why or why not?

B. Policy Implementation

1. What policies or incentives would most effectively encourage adopting climate-resilient building practices in NYC?

2. Are there any challenges or barriers to implementing these policies, particularly in low-income or historic housing?

Section 3: Integrated Climate Adaptation Strategies

A. Interconnected Climate Risks

1. How can NYC better integrate strategies to address sea level rise, urban heat islands, and stormwater management in its climate adaptation plans?

2. Are there any existing policies or initiatives that successfully address these interconnected risks?

B. Green Infrastructure

1. What role do you see for green infrastructure (e.g., green roofs, urban parks, bioswales) in mitigating urban heat islands and improving stormwater management in NYC?

2. Are there any challenges to implementing green infrastructure at scale in NYC?

Section 4: Equity and Environmental Justice

A. Equity in Climate Policies

1. How can NYC ensure its climate policies and resilience initiatives benefit all residents, particularly those in low-income and marginalized communities?

2. Are there any specific programs or policies that you believe have successfully addressed equity and environmental justice in NYC's climate adaptation efforts?

B. Community Engagement

1. How can NYC improve community engagement in developing and implementing climate-resilient building policies?

2. What role should NGOs and community organizations play in shaping these policies?

Section 5: Future Directions

A. Future Research and Policy Needs

1. What research areas are most needed to inform climate-resilient building design and policy in NYC?

2. Are there any emerging technologies or practices that could significantly improve NYC's resilience to climate change?

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