The City of New York
Executive Budget
Fiscal Year 2026

Eric Adams, Mayor

Mayor's Office of Management and Budget
Jacques Jiha, Ph.D., Director

Technical Appendices:
New York City Climate Budgeting

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CLIMATE BUDGETING INTAKE FORM

Overview

To inform the city's Climate Budgeting process, the NYC Mayor's Office of Management and Budget (OMB) developed a Climate Budgeting Intake Form that allows for a more uniform evaluation of the climate impacts of funding decisions. The form was designed to help evaluate funding proposals, understand where additional information is needed, and support the assessment of impacts, cost-effectiveness, and additional benefits and considerations. During the Fiscal Year (FY) 2025 and 2026 plan cycles, city agencies used the Climate Budgeting Intake Form to submit information on expense and capital funding needs for projects and programs that are relevant for meeting the city's climate goals. The form accompanies all expense and capital requests that meet the following criteria:

1. Requests that impact greenhouse gas emissions and/or resiliency to coastal flooding, stormwater flooding, or heat
2. New projects located in one or more high-risk locations
3. New building projects involving heating, ventilation, and air conditioning (HVAC) or appliances or building envelope work
4. Incremental needs associated with incorporating resiliency design or green building standards into an existing project

High-Risk Locations

The Climate Budgeting Intake Form considers a project location to be high-risk if the corresponding Community District is designated as highly vulnerable to extreme heat or flood according to the following definitions:

High Heat Risk
The city's Heat Vulnerability Index (HVI) measures neighborhood risk from the impacts of extreme heat.[1] This measure was developed by the NYC Health Department. A capital project is considered high risk for heat for the Climate Budgeting process if it takes place in one or more Community Districts with a HVI equal to or greater than four (on a scale of one through five).

High Flood Risk and Waterfront
Flood risk captures elevated neighborhood risk from the combined impacts of coastal and stormwater flooding projections. A capital project is considered high risk for flooding if located in one or more Community Districts with at least 30 percent area coverage within the estimated 2050s 100-year floodplain and 2050s high-tide floodplain, and 10 percent chance "Moderate" stormwater flood scenario.[2] [3] See Technical Appendix B for more information on the development of the flood risk measure. A capital project may also be located on the waterfront, independently of whether it is also

in a high-flood-risk area. This method provides a simple approach to identify projects with potential flood risk in a way that aligns with information in the city's centralized accounting and budgeting system, known as the Financial Management System (FMS), which includes the Community District for each capital project. Projects must be further evaluated for flood risk depending on the specifics of each location.

FIGURE 1 | HIGH-RISK COMMUNITY DISTRICTS BY HAZARD CATEGORY

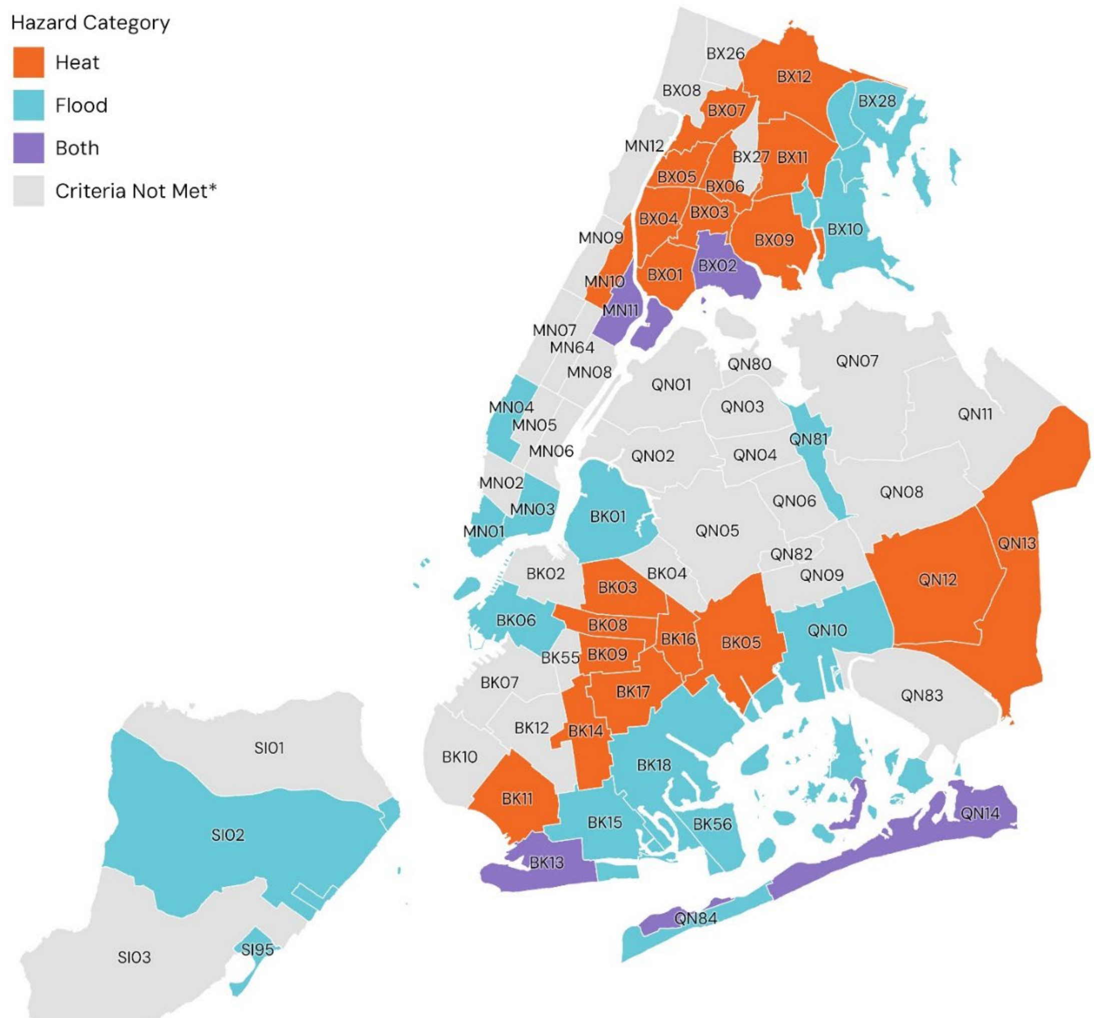

Figure Source: OMB

*Vulnerability Criteria requirements: Heat Vulnerability Index Score of 4-5 OR more than 30 percent of land area covered within the NPCC3's estimated 2050s medium-high sea-level rise floodplain and2050s high tide, and 10 percent moderate stormwater flood scenario (2.13 inches in one hour).[4]

High-Heat-Risk Community Districts: BK03, BK05, BK08, BK09, BK11, BK13, BK14, BK16, BK17, BX01, BX02, BX03, BX04, BX05, BX06, BX07, BX09, BX11, BX12, MN10, MN11, QN12, QN13 & QN14

High-Flood-Risk Community Districts: BK01, BK06, BK13, BK15, BK18, BK56, BX02, BX10, BX28, MN01, MN03, MN04, MN11, QN10, QN14, QN81, QN84, SI02, SI95

Project Examples

Examples of the types of work that may impact emissions and resiliency are listed below.

- **Building & Facilities:** HVAC; envelope, roof, and window replacement; flood protection; new construction
- **Energy & Utilities:** Solar panels, hydropower, battery storage, cogeneration plants, wind power
- **Equipment:** Emergency generators, construction equipment, electric vehicle chargers
- **Green & Natural Spaces:** Tree planting or removal, wetland restoration, flood mitigation, reforestation, heat mitigation in parks
- **Green Infrastructure:** Rain gardens, bioswales, retention basins, permeable pavement
- **IT & Technology:** IT or technology to support flood mapping, new data centers, emissions tracking, local law compliance, other climate initiatives
- **Public Space & Recreation:** Playground water features, water fountains, flood or heat mitigation in public spaces
- **Sewers & Grey Infrastructure:** Sewer buildout, catch-basin cleaning, combined sewer overflow management
- **Site Development:** Multi-scope site development (including utilities, buildings, green space, and street work) in high-risk flood or heat areas
- **Street & Road Projects:** Bike lanes, bus infrastructure, traffic mitigation measures, heat or flood mitigation strategies
- **Vehicles:** Light-, medium-, and heavy-duty vehicles, electric vehicles, hybrid vehicles, ferries, aircraft, off-road vehicles
- **Water Supply Infrastructure**: Water mains, aqueducts, or reservoirs that impact flood resiliency
- **Waterfront Assets:** Coastal protection projects, docks and piers, coastal infrastructure
- **Other:** Waste, addressing fugitive emissions, initiatives to reduce consumption-based emissions (food, concrete, steel)
- **Programmatic (Expense):** Staffing to support sustainability or resiliency programs, green workforce, consultant services, reporting

Intake Form Questions

The questions in the Intake Form are broken into three main sections: questions asked for all identified needs that may implicate the city's climate goals, followed by questions specific to capital proposals, and questions specific to requests impacting buildings.

All identified relevant funding proposals are required to include responses to the following requests:

A. What is the request amount by fiscal year?
B. Project/program name
C. Please describe any other sources of funding expected to support this project/program
D. If this need is time-sensitive, please explain why and the implications of a delay
E. Does this request support compliance with a local law, mandate, or stated climate goal of the city?

F. Does this request support any of the environmental justice (EJ) topics identified through the city's Environmental Justice NYC (EJNYC)[5] report, or otherwise support EJ in the city?
G. What type of work does this project involve?
H. What is this request's expected impact on greenhouse gas emissions?
I. What is this request's expected impact on heat and/or flood resiliency?
J. Please explain how this request impacts greenhouse gas emissions and/or resiliency towards flooding or heat

All identified relevant funding capital proposals are required to include responses to the following requests:

A. Location of project
B. Is the project primarily located in at least one of the high-risk Community Districts? If yes, which?
C. Will this project follow any guidelines for resilient design, such as the Climate Resiliency Design Guidelines (CRDG)[6], Envision[7], or any specific guidelines the agency may use?
D. Is the project anticipated to include design strategies that address the impact of coastal flooding, storm surges, or heavier rainfall?
E. Is the project anticipated to include creating more shaded areas, planting vegetation, installing air -conditioning, or using materials that reflect sunlight to keep surfaces cooler?

All identified relevant funding in buildings are required to include responses to the following requests:

A. Are Local Law 51 of 2023 standards incorporated or planned to be incorporated into the scope of work, design, and construction of this project?
B. Does this project involve work on a building's envelope, windows, or roof?
C. Does this project involve work on heating equipment?
D. Does this project involve work on hot water equipment?
E. Does this project involve work on appliances?

Heating Equipment/Hot Water Equipment/Appliances:

F. What is the existing equipment?
G. What is the proposed replacement equipment?
H. What percentage of the building will be served by the proposed replacement equipment?
I. What is the upfront unit cost for the proposed replacement equipment?
J. What is the total projected annual operation and maintenance costs for the proposed replacement equipment?
K. What is the full useful life of the proposed replacement equipment?

GREENHOUSE GAS EMISSIONS AND CLIMATE RESILIENCY BUDGET TRACKING

Overview

The OMB Environmental Sustainability and Resiliency Task Force tracks capital and expense funding for investments planned to help the city advance its emission reduction and climate resiliency goals. This enables better understanding of climate-related spending across the entire city budget, providing more context for future budget decisions. For emissions reductions, funding is tracked by major sources of emissions. For resiliency, funding is categorized based on the primary climate risks described by the New York Panel on Climate Change (NPCC), plus planning and preparedness work.[8]

Climate Resiliency Categories:

- Coastal Flooding
- Stormwater Flooding
- Heat
- Planning and Preparedness

Emissions Categories:

- Buildings and Facilities
- Transportation
- Energy
- Waste

Tracking funding across agency budgets and city budget structures poses various challenges as described below. Tracking is continuously updated to reflect changes made during the city's financial and capital plans and advancements in internal processes. Both city funds and non-city funding sources are included.

Capital Tracking

Capital project tracking is closely related to the evaluation of capital projects via the annual Climate Alignment Assessment (CAA) (see page 11). Capital projects that are rated as Aligned with either Net-Zero Emissions, Flood Resiliency, or Heat Resiliency goals in the CAA are also tracked as climate investments in a corresponding category (see Figure 2: Capital Project Tracking Categories).

This approach differs from FY 2025's capital tracking methodology, which did not require that a project be rated as Aligned to be tracked as a climate investment. The methodology was updated as of the FY 2026 Climate Budgeting publication to bring the methods of tracking and evaluation that OMB uses to keep track climate-related spending into accordance.

The city's capital budget is organized in multiple structures. To track climate-related investments, OMB uses project IDs: unique project identifiers assigned in the city's centralized accounting and budgeting system, known as the Financial Management System, or FMS.

A limitation of this approach is that it does not capture funding for discrete climate-related elements within larger capital projects. For example, a project ID for a facility renovation project may include relevant scope, such as energy-efficient windows, alongside other unrelated scope such as bathroom renovations. This project ID would not be included in capital project tracking, but its positive climate impact would be recognized using the Aligned Component rating in the CAA. Capital project tracking, therefore, is not intended to reflect the total sum of all climate-related capital investments in the city's capital portfolio.

There are a few exceptions where this challenge is addressed by tracking funding by budget lines within a project ID. Budget lines are identifiers of capital units of appropriation, which reflect discrete projects or similar types of work done at multiple locations. Each budget line represents a particular program, purpose, activity, or institution in an agency's budget. A project ID can contain multiple budget lines. In certain circumstances, OMB found it necessary to use budget lines to track climate-related capital investments. For example, a capital project for street and utility reconstruction may include budget lines specific to sewer buildout, water main extensions, sidewalk construction, and street resurfacing. In this case, OMB tracks only the funding allocated to the sewer budget line, which contributes to stormwater flooding resiliency.

The table below details the methodology for capital project tracking across categories:

FIGURE 2 | CAPITAL PROJECT TRACKING CATEGORIES

	Category	Methodology
Climate Resiliency	Coastal Flooding	Large-scale neighborhood coastal flood protection, including: • Brooklyn Bridge-Montgomery Coastal Resilience • East Side Coastal Resiliency • Seaport Coastal Resilience • The Battery Coastal Resilience • Hunts Point Energy Resiliency • Red Hook Coastal Resiliency • Tottenville Shoreline Protection Project • The Raised Shorelines initiative • Coastal protection projects managed by the U.S. Army Corps of Engineers Other coastal resiliency projects, including: • Harlem River Park and Greenway • East River Esplanade • Riverside Park • Bayswater Park • the reconstruction of piers, seawalls, and other coastal infrastructure
	Stormwater Flooding	Sewer buildout in Southeast Queens and other priority areas, green infrastructure, tree planting and replacement, cloudburst management projects, wetland restoration, the Bluebelts program, flood protection for buildings, other flood resiliency initiatives
	Heat	Tree planting and replacement, wetland restoration, public pools, cooling upgrades in buildings and recreation and nature centers, cooling features in public spaces
	Planning & Preparedness	Emergency generators and other planning and preparedness projects
Emissions	Buildings	Decarbonization, electrification, and energy efficiency projects in city facilities
	Energy	Solar, wind, hydroelectric, energy storage, and other renewable energy projects
	Transportation	Electric vehicles (EVs) EV charging stations for city fleet and private vehicles
	Waste	Composting, emissions-reducing projects from solid waste, fugitive emissions-reducing projects from wastewater resource recovery facilities

Figure Source: OMB

Expense Tracking

OMB tracks investments in the expense budget using the same categories as capital investment tracking. The expense budget has certain dedicated budget structures for climate investments that OMB tracks centrally. However, typically expense funding supports programs or operations that are a combination of climate-related work and other work. As a result, the methodology for tracking each climate category is individualized. The expense programs tracked in the Climate Budgeting publication are not meant to reflect the total sum of all climate-related expense investments.

OMB began explicitly tracking expense climate investments in December 2021 when OMB's Environmental Sustainability and Resiliency Task Force was established. This is a natural starting point to begin to track expense investments, where there is otherwise no clear historical predecessor.

There are other cases where there is a clearer point-in-time to begin tracking historical investments in expense-funded climate programs. For example, Hurricane Ida in September of 2021 led to an increased focus on flood resiliency and a prioritization of strategies including expansion of grey and green infrastructure. These investments are important to include under Stormwater Flooding.

OMB will continue to track these programs over time, and any new programs that fall into the scope of these categories will be added as necessary.

The table below details the methodology and timeline for expense tracking across categories:

FIGURE 3 | EXPENSE PROGRAM TRACKING CATEGORIES

	Category	Methodology
Climate Resiliency	Coastal Flooding	Funding added for coastal protection programs since the release of *PlaNYC: Getting Sustainability Done*, which announced the creation of a Bureau of Coastal Resilience within DEP (April 2023).[9]
	Stormwater Flooding	Funding added for programs to address flooding from extreme rain events added since Hurricane Ida (September 2021).
	Heat	Funding allocated to NYC Parks Department's programs that support tree work and maintenance, wetlands, and other cooling programs. Includes personal services and other than personal services. Current funding allocated as of the FY 2026 Executive Plan.
	Planning & Preparedness	Funding added for planning efforts related to climate resiliency and programs that increase general preparedness for extreme weather events, including Be-A-Buddy, [10] starting in 2022.
Emissions	Buildings	Funding allocated to NYC Department of Citywide Administrative Services Department of Energy Management, Department of Buildings Bureau of Sustainability, the NYC Accelerator,[11] and the Property Assessed Clean Energy (PACE) program.[12] . Current funding allocated as of the FY 2026 Executive Plan.

	Energy	Funding allocated for clean and renewable energy (including Renewable Energy Certificate purchases, and wind, solar, and geothermal power) since the city commitment to power its operations with 100-percent renewable electricity made in the city's *1.5 Climate Action Plan* (2017).[13] Current funding allocated as of the FY 2026 Executive Plan.
	Transportation	Funding added for purchasing electric vehicles and since the updated *Clean Fleet Plan* (September 2021)[14] as well as electric vehicle charging infrastructure. Includes the incremental cost of purchasing renewable diesel for city use.
	Waste	Funding added for organics collection and community composting. Initiatives since FY 2016 Preliminary Plan.

Figure Source: OMB

CLIMATE ALIGNMENT ASSESSMENT

Overview

As part of the Climate Budgeting process, OMB conducts an annual Climate Alignment Assessment (CAA) of New York City's planned capital investments. This assessment provides a citywide view of how planned spending aligns with long-term climate needs. Each capital project in the current fiscal year (FY 2025) and the FY 2026–2035 Ten-Year Capital Strategy has been evaluated to determine if it supports or meets relevant goals or standards in each of three climate priority areas: Net-Zero Emissions, Flood Resiliency, and Heat Resiliency. Examples of the city's goals and standards include:

- The commitment to achieve net-zero greenhouse gas emissions by 2050
- The commitment to achieve PlaNYC initiatives (e.g., 30 percent canopy cover)
- The CRDG[15]
- Agency-specific design guidelines that consider future flood or heat risk projections

The CAA rating scheme has been revised for the FY 2026 budget cycle to identify Missed Opportunities to incorporate resilient design elements in projects in areas at elevated risk of heat or flood impacts. This revised methodology helps to identify types of projects for which incorporating consistent design standards, such as the CRDG, may help better protect the city's assets and residents from climate threats.

This exercise also tracks Environmental and Social Benefits related to projects, including benefits to local ecology and air quality.

Climate Priorities and Assessment Ratings

Projects are evaluated to understand their impacts across three distinct climate priorities: achieving net-zero greenhouse gas emissions, improving resiliency to flooding, and improving resiliency to extreme heat. How projects align with each of these priorities is considered separately. In some instances, the same project may be rated differently under each climate priority.

Projects Pending Rating
Projects marked Pending Rating may impact the city's climate priorities, but their impact cannot be assessed at this time. Specific climate-related details are needed to determine alignment. Details may not be available yet if the project is still in the early stages of design.

Special Projects
The city funds some public authorities, quasi-public entities, and unique programs through grants, loans, and lump payments. Due to their unique financial structures, these are marked as Special Projects and are evaluated on a case-by-case basis.

Net-Zero Emissions

FIGURE 4 | NET-ZERO EMISSIONS GOALS

Primary Goal Achieve net-zero greenhouse gas emissions by 2050	
Supporting Standard or Goal	**Source**
All-electric new construction	Local Law 154 of 2021[16]
Fossil-fuel-free city operations	Executive Order 52 of 2020[17]
Light-, medium-, and heavy-duty fleet electrification	PlaNYC, NYC Clean Fleet Plan
Zero-emissions electricity for city operations	NYC 1.5 Climate Action Plan
Solar capacity on city buildings	PlaNYC

Figure Source: OMB

In 2017, New York City released a city-scale climate action plan explicitly intended to comply with the Paris Agreement's 1.5°C goal.[18] The plan established the target of achieving net-zero emissions citywide by 2050. Achieving net-zero means directly reducing Scope 1 and 2 emissions to as close to zero as technically feasible and finding meaningful ways to compensate for residual emissions.

- Scope 1 emissions: Greenhouse gases emitted within New York City. Scope 1 emissions include direct emissions, such as burning fossil fuels for heat and driving gas-powered cars. These emissions may be decreased through projects like heat electrification and switching to electric vehicles or sustainable modes of transit.
- Scope 2 emissions: Greenhouse gases emitted inside or outside of New York City as a result of the city's consumption of electricity or district steam from the local utility. Changes in electricity use may increase or decrease Scope 2 emissions.

The analysis does not yet consider the impacts on Scope 3 emissions, which can include embodied or consumption-based emissions. Scope 3 emissions include the greenhouse gases resulting from mining, harvesting, processing, manufacturing, transporting, and installing goods, services, and materials consumed within New York City.

FIGURE 5 | CLIMATE ALIGNMENT ASSESSMENT: NET-ZERO EMISSIONS RATING

Assessment Rating	Project Criteria	Examples
Aligned	The project's primary intent is to reduce greenhouse emissions and it is compatible with the city's net-zero goal. Scope that reduces emissions constitutes most or all of the project cost.	• Heat electrification in city facility • Electric vehicle purchase • Purchase of solar panels
Aligned Component	The project reduces greenhouse gas emissions and it is compatible with the city's net-zero goal, but its primary intent is not emissions reduction. Reducing emissions may be a co-benefit of the project, or the project may be a mix of emissions-reducing scope and unrelated scope.	• Construction of protected bike lanes in support of Vision Zero[19] • Full facility renovation that includes lighting efficiency upgrades
Not Aligned (Short-Term Benefit)	The project offers short-term greenhouse gas emissions reduction benefits but is incompatible with the city's net-zero goal.	• Oil to gas boiler conversion • Hybrid vehicle purchase
Not Aligned	The project is incompatible with the city's net-zero goal.	• Fossil fuel vehicle purchase • Fossil fuel boiler purchase
No Impact	The project does not contain scope that involves greenhouse gas emissions.	• IT upgrades • Sidewalk paving

Figure Source: OMB

Flood Resiliency

FIGURE 6 | FLOOD RESILIENCY GOALS & STANDARDS

Primary Goal	
Bolster long-term resiliency to the impacts of coastal and stormwater flooding	
Supporting Standard or Goal	**Source**
Climate Resiliency Design Guideline (CRDG)	Mayor's Office of Climate and Environmental Justice
100-year flood plain design standards	Federal Emergency Management Agency [20] U.S. Army Corps of Engineers[21]
Agency-specific design standards	e.g. NYC Parks Department Design and Planning for Flood Resiliency[22]
Implement a multilayered strategy for flood resilience	PlaNYC
Improve the health and ecological function of wetlands	PlaNYC

Figure Source: OMB

New York City employs a variety of measures to bolster resiliency to the impacts of storm surges, high tides, sea-level rise, extreme precipitation and other sources of flooding exacerbated by the changing climate. In April 2023, PlaNYC outlined several long-term goals for protecting against flood risk, including protecting the city's waterfront infrastructure and investing in nature-based mitigation measures.

Projects that affect the continuity of essential services and operations during weather-related power outages, floods, storms, or other natural disasters may also be considered to impact flood resiliency.

Projects may now be identified as Missed Opportunities to incorporate resilient design elements if they are located in areas with elevated flood risk (high flood risk or waterfront). This differs from the FY 2025 Executive Budget CAA, where projects were identified as Not Aligned, defined as "increasing vulnerability to flooding."[23] Projects tagged as Missed Opportunities do not necessarily reduce resiliency or increase vulnerability to climate risks, and this analysis does not suggest these projects should not proceed as intended. This new framework facilitates a broader analysis of location, asset type, and other features, helping the city draw conclusions about gaps in its approach to protecting residents and assets from the risks to which they are exposed.

FIGURE 7 | CLIMATE ALIGNMENT ASSESSMENT: FLOOD RESILIENCY RATING

Assessment Rating	Project Criteria	Examples
Aligned	The project's primary intent is to increase resiliency to flooding. The project furthers one of the resiliency goals in PlaNYC or other resiliency plans. If applicable, it is designed to withstand flood risk through the end of its useful life using the CRDG or other equivalent resiliency standards. Resiliency-related scope constitutes most or all of the project cost.	• Green infrastructure installation • Neighborhood-wide coastal protection project • Floodproofing building, following CRDG
Aligned Component	The project provides flood resiliency benefits, but its primary intent is not resiliency. The project furthers one of the resiliency goals in PlaNYC or other resiliency plans. If applicable, it is designed to withstand flood risk through the end of its useful life using the CRDG or other equivalent resiliency standards. Improving resiliency could be a co-benefit of the project, or the project may be a mix of resiliency scope and unrelated scope.	• Playground renovation including tree planting and stormwater retention • Building renovation that including elevating critical systems
Missed Opportunity	The project does not incorporate flood resiliency strategies and is located in an area of elevated flood risk (high flood risk or waterfront).	• Building renovation in a high-flood-risk area, without flood mitigation design features
No Impact	The project does not contain scope that involves flood resiliency.	• Vehicle purchase • Streetlight installation

Figure Source: OMB

Heat Resiliency

FIGURE 8 | HEAT RESILIENCY GOALS & STANDARDS

Primary Goal Bolster long-term resiliency to the impacts of extreme heat	
Supporting Standard or Goal	**Source**
Climate Resiliency Design Guideline (CRDG)	Mayor's Office of Climate and Environmental Justice
Heat Emergency Plan	NYC Emergency Management[24]
Maximize access to indoor cooling	PlaNYC
Cool our built environment	PlaNYC
Achieve a 30 percent tree canopy cover	PlaNYC

Figure Source: OMB

New York City is working to protect its assets and residents from the physical and socioeconomic impacts of extreme heat, including increases in heat-related mortality. In April 2023, PlaNYC outlined several goals and strategies for protecting residents against the risks of extreme heat, including improving access to indoor cooling and increasing the city's tree canopy cover.

Projects that affect the continuity of essential services and operations during weather-related power outages, including from heat waves or other natural disasters, may also be considered to impact heat resiliency.

Projects may now be identified as Missed Opportunities to incorporate resilient design elements if they are in areas with elevated heat risk (high-heat-risk areas). This differs from the FY 2025 Executive Budget CAA, where projects were identified as Not Aligned, defined as "increasing vulnerability to extreme heat." Projects tagged as Missed Opportunities do not necessarily reduce resiliency or increase vulnerability to climate risks, and this analysis does not suggest these projects should not proceed as intended. This new framework facilitates a broader analysis of location, asset type, and other features, helping the city draw conclusions about gaps in its approach to protecting residents and assets from the risks to which they are exposed.

FIGURE 9 | CLIMATE ALIGNMENT ASSESSMENT: HEAT RESILIENCY RATING

Assessment Rating	Project Criteria	Examples
Aligned	The project's primary intent is to increase resiliency to extreme heat. The project furthers one of the resiliency goals in PlaNYC or other resiliency plans. If applicable, it is designed to withstand heat risk through the end of its useful life using the CRDG or other equivalent resiliency standards. Resiliency-related scope constitutes most or all of the project cost.	• Tree planting and maintenance • Public pool construction • Upgrade to facility cooling capacity to handle increasing temperatures
Aligned Component	The project provides extreme heat resiliency benefits, but its primary intent is not resiliency. The project furthers one of the resiliency goals in PlaNYC or other resiliency plans. If applicable, it is designed to withstand heat risk through the end of its useful life using the CRDG or other equivalent resiliency standards. Improving resiliency could be a co-benefit of the project, or the project may be a mix of resiliency scope and unrelated scope.	• Playground renovation including tree planting and spray showers • Building renovation, including upgrade to cooling capacity to handle increasing temperatures
Missed Opportunity	The project does not incorporate heat resiliency strategies and is located in an area of elevated heat risk (high-heat-risk areas).	• Building renovation in a high-heat-risk area, without cooling
No Impact	The project does not contain scope that involves heat resiliency.	• Vehicle purchase • Streetlight installation

Figure Source: OMB

FIGURE 10 | CLIMATE ALIGNMENT ASSESSMENT: UPDATED RESILIENCY METHODOLOGY

Is This Project Located in a High-Risk Area?
Flood Resiliency: High Flood Risk or Waterfront
Heat Resiliency: High Heat Risk Vulnerability Index (HVI)

Does This Project Contain a Resiliency Component to Address the Risk?	Yes	No
Yes	**Aligned** Flood Resiliency Example: In a high-flood-risk area, a shoreline is raised to prevent coastal flooding. Heat Resiliency Example: In a high-heat-risk-area, a public pool is constructed to provide cooling benefits to the community during the summer. or **Aligned Component** Flood Resiliency Example: In a high-flood-risk area, a large playground renovation also adds trees and bioswales. This increases the area's ability to absorb rainwater during storms. Heat Resiliency Example: In a high-heat-risk area, a large playground renovation also adds spray showers and water fountains. This helps visitors stay cool during extreme heat events.	**Aligned** Flood Resiliency Example: In a low-flood-risk area, a building is floodproofed against stormwater. Heat Resiliency Example: In a low-heat-risk area, a public pool is constructed to provide cooling benefits to the community during the summer. or **Aligned Component** Flood Resiliency Example: In a low-flood-risk area, a large playground renovation also adds trees and bioswales. This increases the area's ability to absorb rainwater during storms. Heat Resiliency Example: In a low-heat-risk area, a large playground renovation also adds spray showers and water fountains. This helps visitors stay cool during extreme heat events.
No	**Missed Opportunity** Flood Resiliency Example: In a high-flood-risk area, a building's mechanical systems are renovated without elevating critical equipment located in the basement. Heat Resiliency Example: In a high-heat-risk-area, a playground renovation does not include heat resiliency components, such as shade structures or water spray features.	**No Impact** Flood Resiliency Example: In a low-flood-risk area, a building's mechanical systems are renovated without elevating critical equipment located in the basement. Heat Resiliency Example: In a low-heat-risk area, a playground renovation does not include heat resiliency components, such as shade structures or water spray features.

Figure Source: OMB

Environmental and Social Benefits

Many capital projects that the city undertakes have additional benefits beyond reducing emissions or improving climate resiliency, including benefits to health, local ecology, and air quality.

In previous CAAs, these benefits were tracked using the following tags: Air Quality, Ecology, Sustainable Living, Circular Economy. These tags have been revised to align with the EJNYC report's categorization of environmental burdens and benefits, outlined in the table below.[25] While projects are tagged based on the report's categorizations, this analysis does not summarize EJ investments because it does not consider whether projects are located in EJ areas, as defined by the report.

FIGURE 11 | ENVIRONMENTAL AND SOCIAL BENEFITS

Benefit	Project Criteria *Projects that support…*	Examples
Access to Resources	• Public spaces • Natural areas • The health and ecological function ecosystems and wildlife habitats	• Parks, plazas, community gardens, playgrounds • Forests, conservation work, wetlands, Bluebelts • Biodiversity projects, erosion control, pest regulation
Access to Safe & Healthy Housing	• Access to affordable housing for New Yorkers	• The New York City Housing Authority, the New York City Department of Housing Preservation and Development
Air Quality	• Reduction of local indoor and outdoor air pollutants • Improvement to local air quality through green space and vegetation	• Electric vehicles, hybrid vehicles, micro-mobility, mass transit, appliance upgrades, heat electrification • Trees, wetlands, parks, community gardens, green infrastructure
Water Quality	• Sewers and wastewater management • Improved water quality in local and upstate waterways • Nature-based solutions	• Wastewater treatment plants, Combined Sewer Overflow management • Water supply infrastructure • Shoreline restoration, wetlands, Bluebelts, green infrastructure
Reduced Exposure to Climate Change	• Resiliency to the long-term impacts of flood risk • Resiliency to the long-term impacts of heat risk	• Neighborhood-scale coastal protection projects, floodwalls, sewer buildout, green infrastructure • Public pools, shade structures in playgrounds, tree planting, enhanced cooling in buildings
Reduced Exposure to Hazardous Materials	• Reducing exposure to outdoor hazards • Reducing exposure to indoor hazards	• Environmental testing, soil remediation, Superfund sites • Lead paint testing and removal, lead pipe testing and removal, asbestos testing and removal
Circular Economy	• Waste reduction • Beneficial reuse	• Recycling, composting, waste management • Gas-to-grid

Figure Source: OMB

** Circular Economy is not identified as a priority in EJNYC, but is tracked as a benefit in the CAA.*

CITATIONS

[1] NYC Department of Health and Mental Hygiene, Bureau of Environmental Surveillance and Policy, "Interactive Heat Vulnerability Index," Environment & Health Data Portal, accessed March 19, 2025, https://a816-dohbesp.nyc.gov/IndicatorPublic/data-features/hvi/.
[2] Department of Environmental Protection (DEP), "NYC Stormwater Flood Maps," 2024, NYC Open Data, https://data.cityofnewyork.us/Environment/NYC-Stormwater-Flood-Maps/9i7c-xyvv/about_data.
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The City of New York
Executive Budget
Fiscal Year 2026

Eric Adams, Mayor

Mayor's Office of Management and Budget
Jacques Jiha, Ph.D., Director

Technical Appendix B: Resiliency Exposure Inventory and Forecast

New York City Climate Budgeting

CONTENTS

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Figure 37 updated June 6th, 2025.

INTRODUCTION

New York City currently faces multiple climate threats, including coastal storms, intense rain events, extreme heat, drought, poor air quality, wildfire, extreme winter storms, and others. The NYC Mayor's Office of Management and Budget's (OMB) Environmental Sustainability and Resiliency Task Force has conducted new analysis to better understand present and future risk and investments as part of the city's ongoing Climate Budgeting initiative. This document summarizes the methods surrounding this inaugural assessment as part of the Fiscal Year 2026 Executive Budget.

For this analysis, OMB has focused on three threats: extreme heat, stormwater flooding (also known as rainfall or inland flooding), and coastal flooding. OMB is seeking to understand more about the trajectory of these threats over time and the interventions being taken to lessen their effects. OMB aims to update this work annually. In this work, the terms **adaptation, resiliency,** and **resilience** are used interchangeably, though different contexts and sources may consider them differently and nuances exist.

Context and Focus for Analysis

Adaptation Goals and Strategy

On top of the wealth of climate projections, citywide actions to combat climate hazards, and strategic plans that already exist, the city needs a unified analysis to understand the combined progress of the many adaptive actions being taken over time and how these projects will change the risk the city faces in real terms. OMB's work through Climate Budgeting focuses on filling this information gap and enabling the city to better align its adaptive measures with climate goals and evaluate progress consistently across locations, ensuring that efforts are effective and data-driven. Climate budgeting seeks to incorporate climate considerations into all decision-making; tracking cumulative progress toward city climate goals in projects, spending, and strategy requires analysis to align with those goals, such as those set out in *PlaNYC: Getting Sustainability Done*. Some guiding climate actions include:

- In 2021, the city passed Local Law 122 requiring the establishment of a citywide adaptation strategy to combat climate threats (realized as AdaptNYC)[1]
- In 2023, the Mayor's Office of Climate and Environmental Justice (MOCEJ) released its updated sustainability plan, PlaNYC, which outlined some key actions to take to combat the threats of heat and flooding[2]
- In 2024, the New York City Panel on Climate Change (NPCC), the advisory body of scientists and experts convened to provide the city with regional climate projections and information, released their most recent guidance[3]

Filling Gaps in Existing Information

The city currently publishes valuable datasets, reports, and analyses regarding a wide variety of climate resiliency topics. Examples include the Department of Environmental Protection's (DEP) State of the Sewers report,[4] the Heat Vulnerability Index[5] (HVI) published by the NYC Health Department, and NYC Emergency Management's (NYCEM) Flood Insurance Policies map layer,[6] which is included in the city's Hazard Mitigation Plan, to name a few. Additionally, external data are also available from a variety of sources. The new analysis conducted as part of Climate Budgeting combines and adds to these resources but does not recapitulate or replace them. These resources are crucial parts of the information ecosystem when understanding climate risks. However, challenges in using existing resources remain:

- It can be difficult to combine them (e.g., different metrics, assumptions, scales, outputs)
- They often take different forms and formats (e.g., datasets, maps, reports)
- Some are recurring and others only released once (or update frequency is irregular)
- Methodologies may not include full process details
- Many are backward-looking; climate scenarios focus on the future but may require substantial know-how or computing power to translate or analyze

Evaluating Risk

Risk is comprised of three elements–hazard, exposure, and vulnerability. Here, OMB uses definitions aligned with the Federal Emergency Management Agency (FEMA) when considering hazard, an act or phenomenon with potential to do harm; exposure, the people, property, and systems in the area affected by a hazard; and vulnerability, the susceptibility to harm, damage, or loss.[7] In addition to the challenges described previously, available resiliency-focused data sets may target or combine any of these element categories, making their applications difficult to parse.

FIGURE 1 I THREE PILLARS OF RISK

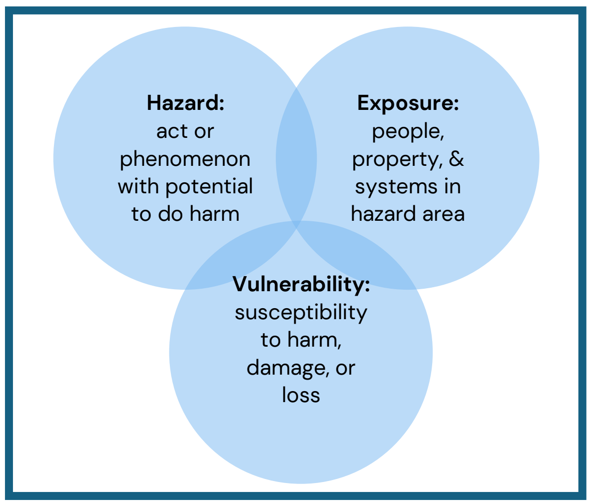

Figure Source: OMB; Definitions Source: FEMA

According to the Intergovernmental Panel on Climate Change, exposure indicates what exists in hazard areas, such as population or economic resources.[8] The authors describe that historically the term *vulnerability* has been used to mean the lack of protections (what now may be referred to as adaptive capacity) for assets, but has more recently transformed to describe the situation-specific social and environmental processes that leave certain areas or groups susceptible. The work described here uses the latter definition, conceptualizing *exposure* as the people, spaces, and assets expected to be within the areas affected at different levels by present and future hazards (and *vulnerability* as the factors that leave some individuals more or less able to thrive despite disaster, which may be endogenous such as race or exogenous such as income, community support, financing, and other topics).

Overview of Analysis

Present-Day Resiliency Exposure Inventory

As a first prong of analysis to fill the gaps described above, OMB has created a baseline inventory of the city's existing resiliency measures based on a suite of relevant metrics, or Key Performance Indicators (KPIs). These are referred to as KPIs or indicators throughout this document. The city already publishes numerous indexed, scored, and combined data products in addition to its individual data sets. For example, the HVI comprises information on surface temperature, greenspace cover, race/ethnicity, income, and air conditioning (A/C); and a partnership through the Town+Gown program, the *Climate Vulnerability, Impact, and Adaptation (VIA) Analysis* project,[9] recently furthered research into Flood Vulnerability Indices. There are also broader social indices, such as the federal Social Vulnerability Index.[10]

In addition to those *vulnerability*-focused data, there are many *hazard*-focused datasets that can be combined, such as the city's Stormwater Flood Maps,[11] coastal Flood Hazard Mapper,[12] and Surface Temperature layer.[13] NYCEM's Community Risk Assessment Dashboard allows the user to see various hazard, exposure, and vulnerability layers for their neighborhood on-demand, including summarized reports.[14]

Despite these innovative resources, stand-alone information on the combined *exposure* of the city's neighborhoods to heat and flooding threats is needed. The challenges include:

- Including the most important metrics, supported by research literature
- Attempting to fill gaps in data, which are often sparse or idiosyncratic
- Understanding the location of individual metrics, when hazards and resiliency measures are both highly location specific
- Combining these in a meaningful way to inform decision making

To overcome this, OMB has created an inventory of the city's **adaptation** to heat and flood threats, highlighting areas that have the most adaptive capacity stemming from physical resiliency measures and features and those with the most residual **exposure**. This can and should be combined with other existing information, such as vulnerability indices and social factors. OMB's new **Resiliency Exposure Inventory** (in these documents often referred to as "the inventory") does not replace or conflict with existing efforts or data. This inventory seeks to measure the factors and efforts that reduce exposure (increase adaptive capacity) that would leave fewer people, areas, or assets at risk despite varying levels of vulnerability (which is not included in the inventory, but can be combined with it).

The inventory provides a view of the important KPIs of resiliency in each neighborhood, creating a baseline assessment of the state of the city. The inventory will be updated as new data are available to assess progress, and fill information and action gaps. This work does not provide a comprehensive picture or measurement of resiliency as a whole, but focuses on design and policy strategies to evaluate exposure and adaptive measures, often as features of the natural (e.g., tree canopy) or built (e.g., flood barriers) environments. Work is underway to include measures of social and community resiliency in future iterations.

Future-Looking Resiliency Exposure Forecast

In addition to establishing a baseline view of the city's resiliency efforts and updating this over time, OMB has begun estimating how planned actions impact future exposure. This is a common exercise in the field of climate change mitigation, in which climate models are used to establish potential greenhouse gas mitigation scenarios into the future, for example. However, this is a newer frontier for climate change adaptation.
OMB has taken the first steps into projecting adaptive capacity and exposure given the city's plans, actions, and projects. This will continue to be expanded upon in the future. This establishes two conditions:

- A **Control** Scenario of local heat and flood conditions using scientific estimates of temperature, sea-level, and weather events
- A set of **Planned Action** Scenarios, whereby the control conditions are overlaid with anticipated future "Planned Actions" undertaken based on city regulations, plans, and goals

The change in exposure (future worsening climate scenarios minus future exposure-reduction efforts) is calculated for decades through 2050. This has been conducted for a small, initial set of Planned Actions, with more to be added in the future.

Partnerships and Feedback

In addition to the in-house work conducted by OMB, for this first iteration of a Resiliency Exposure Inventory and Forecast, partners participated in advising and feedback. OMB worked with dozens of experts, including representatives from city government agencies, academic and non-profit researchers and practitioners, and other professionals. Throughout the process, OMB partnered with MOCEJ to garner consistent feedback and ensure these processes are in alignment with the ongoing development of the city's Climate Resiliency Design Guidelines[15] (CRDG), as per Local Law 41 of 2021, and other efforts. Key partnering agencies that substantially supported the inventory and forecast efforts included the DEP Bureau of Coastal Resilience, NYC Economic Development Corporation (NYCEDC), the NYC Parks Department, and the NYC Health Department.

In addition, OMB formalized an external expert Technical Advisory Group (TAG) to provide peer-review-style feedback on materials. This was conducted in phases so to incorporate feedback early and throughout the development of the process steps. See the following box for the individuals and institutions represented by the TAG.

FIGURE 2 | EXPERT ADVISORY MEMBERS, IN ALPHABETICAL ORDER

Anushi Garg, Senior Analyst, Climate Resilient Coasts and Watersheds New York-New Jersey, Environmental Defense Fund

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Erika Jozwiak, Climate Resiliency Subject Matter Expert

Franco Montalto, P.E., Professor, Dept. of Civil, Architectural and Environmental Engineering, Drexel University | President, eDesign Dynamics LLC

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Luis Ortiz, Assistant Professor of Climate Applications, George Mason University

Mehdi P. Heris, Assistant Professor in Urban Data Analytics, Hunter College

Prathap Ramamurthy, Associate Professor, Mechanical Engineering, The City College of New York

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Timon McPhearson, Director and Professor, Urban Systems Lab, The New School

Ting Sun, Associate Professor, Department of Risk and Disaster Reduction, University College London

Substantial support was provided by Mehdi P. Heris at Hunter College, Ting Sun at University College London, Luis Ortiz at George Mason University, and Timon McPhearson at The New School, with support from Madhavi Jain at the New School.

RESILIENCY EXPOSURE INVENTORY

OVERVIEW

This section walks through the steps OMB undertook to inventory resiliency exposure:

- The first subsection, **KPI Selection**, discusses the process for choosing the KPIs appropriate for an inventory of adaptation levels at the neighborhood level
- The second subsection **Score Creation**, describes the analytical processing of input data on each KPI and generating scores
- The third subsection, **Indicators**, enumerates the literature, reasoning, assumptions, sources and specific analytical details for each KPI selected to include in the inventory
- The fourth subsection, **Limitations**, describes some of the caveats of the data, analysis, and results with an eye on what can be expanded upon in future iterations.

The inventory provides a unified way to view levels of adaptive capacity across locations. There are many factors that contribute to a location's resiliency levels to various threats. This analysis takes a holistic view to combine and analyze datasets in new ways to compare and contrast strategies, levels of exposure and adaptation, and aid in science-based decision making, though more work will be done to expand this in the future.

Note that the inventory includes evaluation of outdoor heat, indoor heat, coastal flooding, and stormwater flooding separately, though strategies for addressing these hazards may overlap. Additionally, the stormwater flooding inventory analysis is considered preliminary at this time, as more information on sewers will be included in future iterations, through collaboration with ongoing DEP analysis.

KPI SELECTION

KPI Research and Evaluation

OMB compiled a list of KPIs based on research and consultation according to four criteria. KPIs should not be considered exhaustive or a full picture of adaptive measures.

FIGURE 3 | KPI SELECTION PROCESS STEPS

1. Research Support
- Conduct background research and consultations to generate KPI options

2. Data Availability
- Determine the KPIs for which reliable data are available

3. Spatial and Temporal Reliability
- Determine which data can be used at the neighborhood scale and updated in the future

4. Feasibility
- Select KPIs that speak to potential changes in city resiliency over time, trackable against goals

Figure Source: OMB

1. **Research support**: KPIs must represent strategies to reduce exposure with support from the academic literature or in practice from designers and engineers. Some KPIs are eliminated from consideration based on a lack of research body. One example includes cooling center prevalence. New York City has a summertime Cooling Center[16] program whereby libraries, senior centers, and other facilities with A/C are used and advertised as locations to stay cool during extreme heat events. Research is clear that A/C is a crucial predictor of heat-related morbidity and mortality,[17] but the body of analysis on municipal-run cooled spaces across cities, including on health outcomes, the level of cooling inside centers, and the adoption by visitors seeking a cooled space in a municipal-partnered center, remains under-researched and context-dependent, which is why this is not selected as a KPI at this time. Having a place to "get cool" in a neighborhood with low rates of A/C may represent a life-or-death strategy for some residents,[18] but research mostly focuses on residential A/C or the importance of cooled spaces in general (which could include malls, movie theaters, and other non-municipal spaces).[19]

2. **Data availability**: Datasets must be broadly available for the KPIs. KPIs for which information is generally not collected or easily triangulated from available data in a standard and uniform manner are excluded from this analysis. Similarly, data that only exist privately or would not be shared reliably for analysis are excluded. Some KPIs of exposure are highly represented in the literature, but available data are limited. One example of a KPI removed from contention due to this stipulation is anthropogenic heat from buildings. Wang et al. (2023) show that heat-generating mechanical systems in buildings, such as air conditioners themselves, can cause ambient heat to rise.[20] However, information on heat-capture technologies (systems that recover and reuse waste heat from building process) implemented as a resiliency strategy in buildings is not available in New York City, and so this KPI is not included in these analyses.[21] This informs where more data must be collected.

3. **Spatial and temporal reliability**: KPIs must have citywide and cyclical data. If data are only available in certain neighborhoods or without a clear recurrence interval, they are excluded from this analysis. Though the analysis described in this document is conducted at the sub-borough level, data must be comparable across the city to be used. Otherwise, this risks disadvantaging some communities with little research or data. One example is tree health on private property. Privately owned trees represent 47 percent of citywide tree canopy and information on the health status of those trees is limited.[22] OMB worked with The Nature Conservancy and the NYC Parks Department to obtain data from the Healthy Trees, Healthy Cities Program, but these data are collected at an irregular interval and only in specific locations.[23] This serves the aims of the program, which focuses on targeted assessments, but cannot be

used for a citywide inventory of adaptation efforts. Similarly, at this time, the KPIs exclude data that cannot easily be mapped, such as some community-based measures, which are important for resiliency. It is important to note that future iterations of this work must consider changing population and demographic contexts within neighborhoods when attempting to compare KPIs temporally—exposure is not only measured here by the KPI itself in isolation but the relative KPI per neighborhood attribute, such as assets protected out of total assets.

4. **Feasibility**: KPIs must reflect feasible adaptation strategies that could be employed in New York City. For example, building attributes, such as height, can influence temperature both via shade and the urban canyon effect.[24] However, it is not reasonable at this time to believe that city buildings will be built to more or fewer stories due to the result on heat, given other constraints such as the need for housing, leading this to be excluded in the KPIs. Other building-level attributes could be included instead, such as passive design, indoor A/C, or other street-level shade measures. KPIs are structured to be focused on interventions that can be influenced by design and policy decisions for resiliency, but are not required to be fully within the purview of city government, as KPIs cover both the public and private sectors (e.g., all tree canopy rather than just city-owned trees, because all trees have the potential to provide resiliency benefits). However, some data are only available at the city-government level and are thus limited (e.g., tree health assessments).

More KPIs are considered than are selected for this iteration of analysis, due to data gaps. These and other potential KPIs will aid in future analysis decisions.

FIGURE 4 | EXCLUDED KPIS FOR FUTURE CONSIDERATION

Backflow valve installations	Sewer conveyance volumes	Tree biodiversity/ Taxonomy	Self-reported flood protective measures
Building design standards (e.g., LEED, Passive House)	A/C prevalence in congregate living (e.g., prisons, shelters, seniors)	Community support/ Activation/Preparedness	Anthropogenic- & waste-heat recovery technology
Sidewalk shade structures (e.g., bus stops)	Fire hydrant water pressure/Spray caps	Housing mobility/Buyouts & Acquisitions	Infrastructure/Transit protections
Private tree health	Subgrade spaces	Rain barrels	Cooling centers
Outdoor water features	Energy burden/ Affordability/Cost	Infrastructure/Transit protections	Sewer/Catch basin maintenance
Green infrastructure volumes	Deployable flood barriers	Green infrastructure maintenance	Deployable flood barriers
A/C usage	Electric grid stability/Disruption	Low-heat-retention building materials	Elevated equipment and mechanicals
Contiguous permeable surfaces	Contiguous cool surfaces	Socially important buildings protected	Premature tree mortality
Street-level surface color	Housing energy/Cooling efficiency/Weatherization	Building shade/Ventilation	Emergency power/Generators

Figure Source: OMB

Spatial Relationships

The hazards New York City faces and the resiliency strategies to combat them are location specific, requiring spatial analysis. Ideally, research on resiliency exposure attributes would be at the most granular level possible, the sub-block scale. Even at the micro-scale variations, such as at the level of a single city block, in elevation, infrastructure, and asset and population distribution can affect the level of exposure and resiliency. However, at this time such a granular scale is not possible for analysis due to data availability across KPIs. In the future, finer spatial data could be considered to account for these variations. Currently, the "neighborhood" level of analysis is used. Neighborhoods in this analysis are classified by Neighborhood Tabulation Areas (NTAs) 2020, mid-sized statistical geographic distinctions that aggregate census tracts, developed by the New York City Department of City Planning.[25] Benefits of processing data at the NTA level include a higher level of granularity than other common scales, such as Community District, while still containing enough population to mitigate sampling error common with smaller units, such as Census Tracts.

NTAs are designed to be intuitive for residents, by combining areas according to commonly understood neighborhoods. However, NTAs are still an imperfect measure. Neighborhoods are a subjective classification and can change. Furthermore, because NTAs do not nest coterminously into administrative boundaries, it can be unclear the course of action, such as the local elected representative to engage on issues (e.g., assembly districts, council districts) for those who want to influence resiliency. Lastly, they do not represent natural or infrastructural boundaries, such as sewersheds, which represent natural features or infrastructure corridors that can be useful for context and intervention with actionable consequences. In future iterations, other or additional geographic boundaries, such as administrative or natural boundaries, may be considered for this analysis.

FIGURE 5 | KPIS SELECTED FOR INVENTORY

Hazards	Key Performance Indicators		
Indoor Heat	Functional A/C prevalence for residences	Tree canopy over greenspace	Area served by sewers
Outdoor Heat	A/C prevalence for NYCHA	Tree canopy cover	Green infrastructure installations
Stormwater Flooding	A/C prevalence - school classrooms	Contiguous canopy cover	Buildings at risk protected by contemporary building code requirements
Coastal Flooding	A/C prevalence - school assembly	Fulfilled tree potential	Buildings at risk protected by previous building code requirements
	A/C capacity - school classrooms	Tree health	Residential units at risk protected by contemporary building code requirements
	A/C capacity - school assembly	Permeable surface cover	Residential units at risk protected by previous building code requirements
	Central A/C - residential	Greenspace cover	Critical buildings at risk protected by building code requirements
	Central A/C - school classrooms	Permeability coefficient	Insured non-critical buildings
	Central A/C - school assembly	Wetland area	Insured residential buildings
	Cool roof cover	Wetland health	Insured critical buildings
	Albedo	Tree guards	
	Adjacency to green areas	Separate sewer coverage	

Figure Source: OMB

SCORE CREATION

In order to create neighborhood-level scores of baseline resiliency strategies, OMB developed a methodology for conducting the indexing exercise and generating scores. OMB reviewed expert literature and drew from professional experience creating indexed products to develop the steps described below. The process begins with obtaining and processing the datasets, then determining which need cleaning, and geocoding. This includes contending with idiosyncratic geospatial data, reducing risk of double counting and over- or under-weighting variables, and accurately representing scores, with transparency for underlying KPIs. The process is described in more detail in this section, from data receipt to score generation.

Data Processing Steps

OMB follows a general set of procedures to process data and geographically analyze them for each KPI used in the inventory.

FIGURE 6 | KPI PROCESSING STEPS

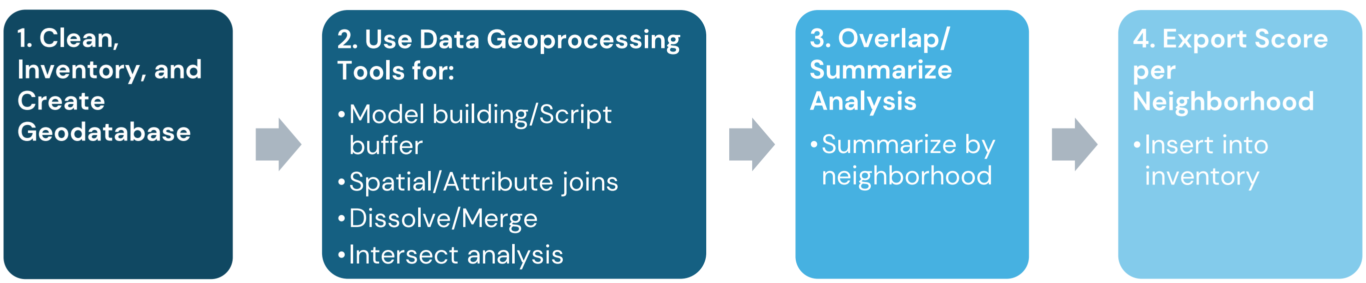


Figure Source: OMB

1. **Data cleaning and geodatabase creation:** For each KPI, data are received and prepared to be inserted into a map layer in QGIS or ArcGIS Pro. This is done either in Microsoft Excel or in Geographic Information Systems (GIS) platform directly.

2. **Data geoprocessing:** Datasets are then manipulated using a suite of geoprocessing tools available between the two GIS platforms before aggregating at the NTA level. These tools include but are not limited to: Script Building in Python for GIS, Model Building, Buffer, Intersect, Spatial and Attribute Joins, Hot-Spot Analysis, Dissolve and Merge, Union, and Overlap Analysis.

3. **Overlap and summary tools:** Once geoprocessing is complete, data are processed using the Overlap Analysis tool in QGIS or the Summarize Within tool in ArcGIS Pro to calculate percent area or points within each NTA. As described in more detail in subsequent sections, all values in the inventory are calculated as proportions (e.g., area of tree canopy per total neighborhood area). This processing step calculates those proportions. This is important to be able to compare NTAs. As they have different sizes, densities, and contexts.

4. **Neighborhood-level exports:** Scores are then exported to tabular form and inserted into the Microsoft Excel inventory model.

Scoring Process

Data Compilation

A literature review (for which details can be found subsequently in the "Inventory" section, per KPI) is conducted and strategies and topics for improving resiliency to heat and flooding are listed out. These are then culled of ideas that do not apply to New York City. KPIs are reviewed based on their predictive value, specifically how much the literature indicated that strategies corresponded, contribute to, or cause changes in resiliency outcomes. There are many strategies to improve resiliency, but not all are similarly impactful at reducing the harm of heat and flooding in the city context. Measures that are shown to have poorly established adaptive impacts are not included.

KPIs that speak to these broader strategies are then enumerated based on their influencing factors. For example, trees are shown to reduce heat due to shade and evapotranspiration.[26] However, "trees" are not themselves a KPI. Measurable KPIs that impact trees' abilities to mediate heat in a city are researched and enumerated, such as the overall canopy cover, trees' overlap with greenspace, and trees' health. Once the list of KPIs is selected, the first step is to collect data and consult with city agencies and practitioners.

Data are compiled by asking agencies and reviewing reliable and replicable sources of available data. Predictive KPIs are outlined in a matrix according to the known data availability. Gaps are filled systematically and some KPIs removed (for this iteration) due to lack of data. More KPIs may be considered in the future by replicating this process.

Spatial Processing

Data sets are compiled from sources (e.g., NYC Open Data, city agencies, external partners) and processed as needed. Some data sets are delivered in a usable form, while others are raw and required processing. For example, some data are delivered at a facility-by-facility level, with aggregation required to generate NTA-level values (e.g., KPIs on school A/C). Others may need decisions in conjunction with expert partners (e.g., deciding what threshold to use for the dataset).

Data are then input into QGIS and ArcGIS Pro software platforms to map them by location. These data are processed spatially and aggregated at the NTA level and exported into Microsoft Excel.

Data are then standardized to a percentage from zero to 100. For example, tree canopy cover information is available on NYC Open Data[27] as a shapefile containing different surface classifications from a Light Detection and Ranging (LiDAR) evaluation of the city. In QGIS, OMB isolates and computes the tree layer as the percentage of an NTA's area covered by trees. This is then output for each NTA.

NTAs are broken into three categories:

1. **Core NTAs**: NTAs with residences and often other basic features of neighborhoods, such as roads and facilities. These can be easily compared to one another across KPIs.

2. **Adjacency NTAs**: NTAs that are open space, parks, cemeteries, or similar land uses that abut Core NTAs. These may have facilities on them (such as the NYC Parks Department's Department buildings) but lack other typical features of a neighborhood that impact how people interact with daily needs. These NTAs are crucial for the functioning of the city and can even provide some of the most resiliency benefits in the city. However, they are difficult to compare to Core NTAs. These NTAs are included in the model and datasets for the KPIs that apply but are not included in the scored inventory. However, they are featured in scores by contributing to an "adjacency" KPI for outdoor heat (see following sections for more details). A KPI of each Core NTA score is how much proximity it has to one of these Adjacency NTAs, so that Core NTAs with little greenspace are not discounted if they are near a large green area that is not accounted for in other Core NTAs. This is a middle ground between including Adjacency NTAs fully in the score and excluding them entirely from analysis.

FIGURE 7 | ADJACENCY NTAS

NTA	NTA Name	NTA	NTA Name
BK0471	The Evergreens Cemetery	MN6491	Central Park
BK0571	Highland Park-Cypress Hills Cemeteries (South)	QN0161	Sunnyside Yards (North)
BK0771	Green-Wood Cemetery	QN0171	St. Michael's Cemetery
BK0891	Lincoln Terrace Park	QN0191	Astoria Park
BK1061	Fort Hamilton	QN0261	Sunnyside Yards (South)
BK1091	Dyker Beach Park	QN0271	Calvary & Mount Zion Cemeteries
BK1391	Calvert Vaux Park	QN0571	Mount Olivet & All Faiths Cemeteries
BK1771	Holy Cross Cemetery	QN0572	Middle Village Cemetery
BK1891	Marine Park-Plumb Island	QN0573	St. John Cemetery
BK1892	McGuire Fields	QN0574	Highland Park-Cypress Hills Cemeteries (North)
BK1893	Canarsie Park & Pier	QN0761	Fort Totten
BK5591	Prospect Park	QN0791	Kissena Park
BK5691	Barren Island-Floyd Bennett Field	QN0871	Mount Hebron & Cedar Grove Cemeteries
BK5693	Shirley Chisholm State Park	QN0891	Cunningham Park
BX0391	Crotona Park	QN1091	Spring Creek Park
BX0491	Yankee Stadium-Macombs Dam Park	QN1191	Alley Pond Park
BX0492	Claremont Park	QN1371	Montefiore Cemetery
BX0991	Soundview Park	QN1491	Rockaway Community Park
BX1091	Ferry Point Park-St. Raymond Cemetery	QN8191	Flushing Meadows-Corona Park
BX1161	Hutchinson Metro Center	QN8291	Forest Park
BX1271	Woodlawn Cemetery	QN8491	Jamaica Bay (East)
BX2691	Van Cortlandt Park	QN8492	Jacob Riis Park-Fort Tilden-Breezy Point Tip
BX2791	Bronx Park	SI0191	Snug Harbor
BX2891	Pelham Bay Park	SI0291	Freshkills Park (North)
MN0191	The Battery-Governors Island-Ellis Island-Liberty Island	SI0391	Freshkills Park (South)
MN0661	United Nations	SI9561	Fort Wadsworth
MN1291	Highbridge Park	SI9592	Miller Field
MN1292	Inwood Hill Park	SI9593	Great Kills Park

Figure Source: OMB

3. **Excluded NTAs**: NTAs consisting of the city's two airports and green NTAs without adjacency (e.g., islands). Given that these have unusual KPI profiles unlike other NTAs (they cannot be compared across many of the residential KPIs and they do not present substantial potential green adjacency benefits), they are excluded from analysis at this time. These are: BK5692 (Jamaica Bay (West)), BX0291 (North & South Brother Islands), BX1071 (Hart Island), MN1191 (Randall's Island), QN0151 (Rikers Island), QN8081 (LaGuardia Airport), QN8381 (John F. Kennedy International Airport), and SI9591 (Hoffman & Swinburne Islands).

NTA Exceptions

KPIs related to coastal flooding are only applicable for coastal NTAs, here defined as any NTAs that overlap with the FEMA Preliminary Flood Insurance Rate Map (PFIRM) or existing Flood Insurance Rate Map (FIRM) 100-year floodplain. All other NTAs are considered not applicable for coastal resiliency and are not deducted or given any inventory values for resiliency measures or lack thereof.

FIGURE 8 | COASTAL NTAS

BK0101	BK1103	BX0201	BX0991	MN0102	MN0801	QN0103	QN0704	QN1402
BK0102	BK1301	BX0291	BX1001	MN0191	MN0803	QN0105	QN0706	QN1403
BK0103	BK1302	BX0303	BX1002	MN0201	MN0901	QN0151	QN0707	QN1491
BK0104	BK1303	BX0401	BX1003	MN0203	MN0902	QN0191	QN0761	QN8081
BK0201	BK1391	BX0402	BX1004	MN0301	MN0903	QN0201	QN0801	QN8191
BK0202	BK1501	BX0491	BX1071	MN0302	MN1002	QN0202	QN0871	QN8381
BK0203	BK1503	BX0501	BX1091	MN0303	MN1101	QN0261	QN1003	QN8491
BK0261	BK1802	BX0601	BX1102	MN0401	MN1102	QN0302	QN1091	QN8492
BK0504	BK1803	BX0701	BX1104	MN0402	MN1191	QN0303	QN1102	SI0101
BK0505	BK1891	BX0703	BX1161	MN0601	MN1201	QN0402	QN1103	SI0102
BK0601	BK1892	BX0801	BX1201	MN0603	MN1202	QN0501	QN1191	SI0103
BK0702	BK1893	BX0802	BX1202	MN0604	MN1203	QN0502	QN1203	SI0104
BK1001	BK5691	BX0803	BX1203	MN0661	MN1291	QN0602	QN1204	
BK1061	BK5692	BX0901	BX2791	MN0701	MN1292	QN0701	QN1306	
BK1091	BK5693	BX0902	BX2891	MN0702	QN0101	QN0702	QN1307	
BK1102	BX0101	BX0903	MN0101	MN0703	QN0102	QN0703	QN1401	

Figure Source: OMB

Select few NTAs in the Core group do not have any surveyed schools in their geographies, namely MN0202 and MN0601 (and all Adjacency KPIs). The inapplicable KPIs are excluded from calculation of scores related to school A/C and are not deducted or given any inventory values for resiliency measures or lack thereof.

Some NTAs in the Core group do not have any surveyed New York City Housing Authority (NYCHA) buildings in their geographies. The inapplicable KPIs are excluded from calculation of scores related to residential cooling and are not deducted or given any inventory values for resiliency measures or lack thereof.

FIGURE 9 | NTAS WITHOUT SURVEYED NYCHA PROPERTIES

BK0101	BK1102	BK1701	BX1102	MN0902	QN0401	QN0706	QN1101	SI0204
BK0201	BK1103	BK1702	BX1203	MN1203	QN0402	QN0707	QN1102	SI0301
BK0261	BK1201	BK1802	MN0101	QN0101	QN0501	QN0802	QN1103	SI0302
BK0501	BK1202	BX0403	MN0102	QN0102	QN0502	QN0803	QN1104	SI0303
BK0701	BK1203	BX0502	MN0201	QN0103	QN0503	QN0804	QN1301	SI0304
BK0702	BK1204	BX0603	MN0202	QN0104	QN0504	QN0901	QN1302	SI0305
BK0703	BK1303	BX0702	MN0203	QN0201	QN0601	QN0902	QN1306	+ All Adjacency KPIs
BK0801	BK1401	BX0703	MN0501	QN0202	QN0602	QN0903	QN1307	
BK0901	BK1402	BX0803	MN0502	QN0203	QN0701	QN0904	QN1403	
BK1001	BK1403	BX0904	MN0601	QN0301	QN0702	QN0905	SI0105	
BK1002	BK1501	BX1004	MN0602	QN0302	QN0703	QN1002	SI0106	
BK1101	BK1502	BX1101	MN0604	QN0303	QN0705	QN1003	SI0202	

Figure Source: OMB

Organizing and Processing Scores: Indicators Level

KPI Hierarchy

Each KPI is organized into an Indicator Category, which represents the overall strategy the KPIs within take to reduce the hazard itself or the impact of the hazard. For example, deploying trees and implementing light-colored roofs are both strategies to reduce extreme heat impacts. These would be two Indicator Categories to address the heat hazard. Within the Indicator Category for heat managed by trees, the KPIs could be tree canopy cover, tree health, and others. These are the individual action types within the overall strategic category.

FIGURE 10 | KPI HIERARCHY

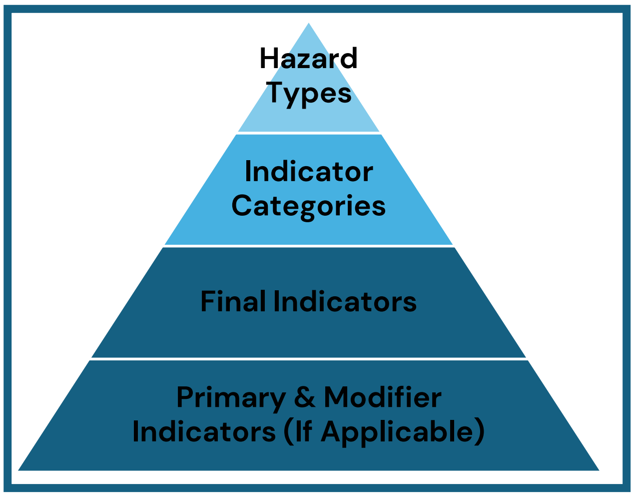


Figure Source: OMB

In the model, KPIs are differentiated by Type, which determines how they are treated in the scores. Before KPIs are combined together into Categories, some KPIs get merged together first because they are highly related and considering them each individually would lead to duplication and redundancy. These KPIs that get merged are labeled as Primary Indicators and Modifying Indicators. Primary Indicators represent the independent variable that is correlated with subordinate Modifier variables (e.g., tree canopy cover would be a Primary Variable to be Modified with tree canopy over greenspace). Modifier variables are considered subordinate because they can highlight nuances in the Primary variable, such as in distribution or co-benefits, but are ultimately a measure derived from the Primary variable with slight variations that make their relationships unique. Once a variable is ready to be combined into Categories, either because it is a stand-alone KPI or because several Primary and Modifier KPIs have been merged together, the resulting variable is referred to as a Final Indicator.

Treating Correlated and Related Variables

Modifiers represent small "boosts" to the Primary Indicator value in calculation. Rather than averaging the variables and undermining the raw value of the Primary Indicator, 10 percent of the value of the Modifier(s) is added on top of the Primary Indicator score. Selecting 10 percent stems from the desire to balance the low relative value of the modifier, as ancillary to the Primary Indicator, while still including these correlated variables in the model because of their importance for parsing sub-strategies for adaptation. For example, tree canopy cover could be equivalent but yield different benefits in different neighborhoods depending on their distribution or correlated variables. Modifiers shed more light on the application of strategies, but 10 percent is not a perfect estimation of their relative importance. Modifiers at 10 percent balance are used to serve as a middle ground between choosing an overly simplistic parsimonious model and removing correlates to prevent double counting.

Final Indicator (for Related Indicators) = (Primary Indicator + $(Modifier_1*0.1)+(Modifier_2*0.1)...)$

FIGURE 11 | SCORING EXAMPLE FOR SELECT INDICATORS

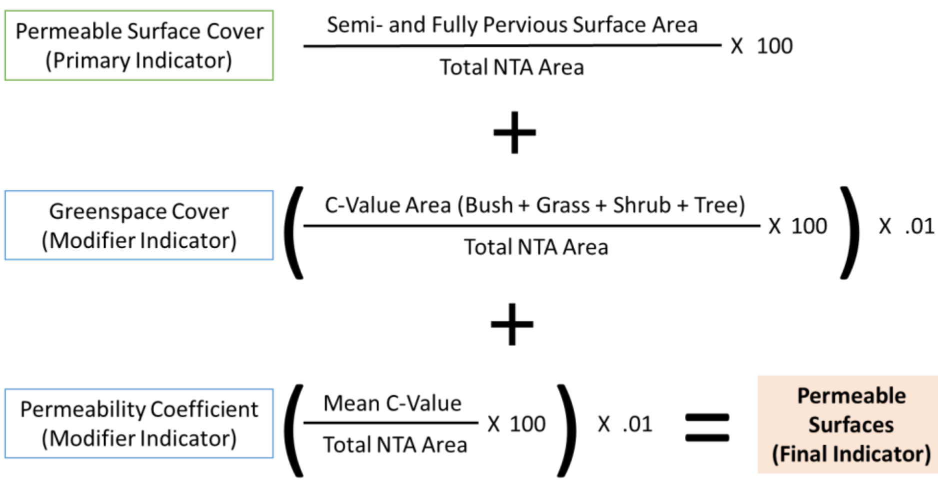


Figure Source: OMB

There are two ways to determine that a variable should not be stand-alone:

1. **Correlation:** Each KPI's NTA-level data is assessed using Pearson's Correlation analysis. To avoid redundancy, closely correlated KPIs are aggregated. Each KPI (proportions) is compared to every other KPI to determine their correlation. Correlation Coefficients (R values) >0.7 or <-0.7 are individually considered to determine if removal or Primary-Modifier aggregation is more appropriate.
   For example, tree canopy cover has a high correlation with tree canopy over greenspace, because they are both features of a tree canopy metric. However, Rahman et al. (2020) show that tree canopy provides additional heat mitigation benefits when planted over greenspace that either tree canopy or greenspace added together.[28] The distribution adds an additional layer of practicable knowledge for understanding the impacts of various resilient design options and strategies. Two neighborhoods with the same tree canopy cover (all else being equal) may see different heat attenuations based on the distribution of planting. Thus, both KPIs are retained, but due to their redundancy, one becomes a modifier and is treated like a sub-index.

FIGURE 12 | CORRELATION ANALYSIS RESULTS (CORRELATION COEFFICIENTS)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH
A	1.00																																	
B	0.80	1.00																																
C	0.90	0.58	1.00																															
D	0.40	0.32	0.25	1.00																														
E	0.02	-0.01	0.01	0.06	1.00																													
F	0.69	0.46	0.85	-0.15	-0.01	1.00																												
G	0.76	0.54	0.89	-0.10	-0.01	0.98	1.00																											
H	0.55	0.35	0.72	-0.13	-0.01	0.86	0.83	1.00																										
I	0.03	0.17	-0.06	0.05	0.02	-0.07	-0.07	-0.07	1.00																									
J	-0.25	-0.14	-0.20	-0.12	-0.11	-0.17	-0.18	-0.15	0.03	1.00																								
K	-0.20	-0.01	-0.23	0.18	-0.03	-0.32	-0.33	-0.27	0.13	0.60	1.00																							
L	0.16	0.07	0.35	-0.15	0.06	0.58	0.51	0.60	-0.09	0.01	-0.24	1.00																						
M	0.24	0.13	0.34	-0.01	-0.06	0.39	0.42	0.39	-0.07	-0.10	-0.23	0.42	1.00																					
N	-0.01	0.00	0.02	0.13	0.06	-0.01	-0.02	0.00	-0.16	-0.02	0.09	-0.12	-0.12	1.00																				
O	0.12	0.11	0.06	0.08	-0.07	0.03	0.05	0.04	0.08	-0.07	-0.19	0.06	0.02	-0.23	1.00																			
P	0.24	0.03	0.39	0.14	0.00	0.37	0.37	0.39	-0.18	-0.24	-0.40	0.42	0.23	-0.10	0.32	1.00																		
Q	-0.08	-0.07	-0.11	-0.04	0.01	-0.10	-0.09	-0.08	-0.02	-0.03	-0.18	0.06	-0.04	-0.27	0.37	0.24	1.00																	
R	-0.19	-0.29	-0.11	-0.01	0.00	-0.10	-0.12	-0.01	0.20	-0.06	-0.11	0.02	-0.01	-0.22	0.08	0.14	0.32	1.00																
S	0.00	-0.06	0.01	0.02	0.04	-0.01	-0.01	-0.04	-0.15	-0.09	-0.17	0.05	-0.02	-0.08	0.01	0.16	0.23	0.17	1.00															
T	-0.15	-0.18	-0.11	0.12	0.09	-0.16	-0.17	-0.07	0.09	0.06	-0.02	0.09	-0.05	-0.32	0.17	0.23	0.32	0.52	0.28	1.00														
U	-0.18	-0.22	-0.14	0.06	-0.04	-0.16	-0.17	-0.06	0.20	0.04	-0.10	0.01	-0.03	-0.21	0.14	0.09	0.25	0.71	0.18	0.78	1.00													
V	-0.12	-0.12	-0.09	0.13	0.06	-0.11	-0.13	-0.05	0.14	0.07	0.00	0.09	-0.07	-0.16	0.10	0.15	0.26	0.44	0.28	0.91	0.71	1.00												
W	-0.17	-0.31	-0.10	0.08	-0.01	-0.09	-0.13	-0.04	-0.14	0.10	0.00	0.09	-0.04	-0.18	0.15	0.22	0.22	0.22	0.13	0.19	0.20	0.19	1.00											
X	-0.08	-0.03	-0.06	-0.10	0.13	0.01	-0.01	0.05	-0.02	-0.01	-0.01	0.14	0.04	-0.06	0.05	0.05	0.12	0.07	0.08	0.10	0.05	0.04	0.01	1.00										
Y	-0.20	-0.21	-0.15	0.02	0.20	-0.13	-0.17	-0.14	-0.18	0.04	0.06	-0.01	-0.10	0.15	-0.09	0.04	0.12	-0.01	0.01	0.09	0.02	0.08	0.09	0.02	1.00									
Z	-0.11	-0.16	-0.05	-0.08	-0.03	0.00	-0.03	0.02	-0.17	-0.12	-0.11	0.05	-0.04	0.08	-0.05	0.12	-0.02	0.06	0.03	0.12	0.00	0.11	0.07	0.06	0.10	1.00								
AA	-0.26	-0.28	-0.22	-0.10	0.09	-0.19	-0.22	-0.13	-0.09	0.02	0.07	-0.07	-0.10	0.18	-0.11	-0.07	0.04	0.02	-0.03	0.11	0.04	0.10	0.12	0.12	0.21	0.30	1.00							
AB	-0.24	-0.35	-0.21	0.06	-0.02	-0.19	-0.22	-0.11	-0.23	-0.17	-0.20	-0.02	-0.03	0.03	0.09	0.20	0.15	0.11	0.22	0.17	0.01	0.16	0.34	0.09	0.22	0.43	0.23	1.00						
AC	-0.15	-0.28	-0.08	0.02	-0.03	-0.03	-0.07	0.03	-0.26	-0.21	-0.23	0.07	-0.02	0.00	0.05	0.29	0.17	0.14	0.20	0.08	0.00	0.11	0.38	0.08	0.38	0.48	0.16	0.74	1.00					
AD	-0.33	-0.34	-0.27	-0.32	0.00	-0.08	-0.17	-0.01	-0.12	0.01	-0.07	0.10	-0.04	0.16	-0.07	0.04	0.11	-0.06	0.03	0.06	-0.06	0.06	0.16	0.22	0.20	0.30	0.58	0.36	0.26	1.00				
AE	-0.19	-0.16	-0.28	0.56	-0.03	-0.48	-0.47	-0.35	-0.02	-0.09	0.07	-0.22	-0.12	0.09	0.11	0.20	0.07	0.08	-0.01	0.20	0.19	0.21	0.28	-0.05	0.18	0.03	0.11	0.34	0.22	0.05	1.00			
AF	-0.14	-0.20	-0.16	0.14	0.08	-0.23	-0.22	-0.21	-0.13	0.05	0.07	-0.15	-0.10	0.10	-0.05	0.05	0.11	0.02	0.04	-0.01	-0.06	-0.03	0.07	-0.01	0.21	0.07	-0.03	0.28	0.27	-0.04	0.21	1.00		
AG	0.13	0.09	0.03	0.12	0.08	-0.09	-0.04	-0.18	-0.16	0.00	0.03	-0.17	-0.03	0.04	-0.06	-0.10	-0.09	-0.17	-0.04	-0.09	-0.16	-0.10	-0.05	-0.16	-0.07	0.02	0.00	-0.08	-0.16	-0.04	0.05	0.06	1.00	
AH	0.11	0.04	0.22	-0.38	-0.07	0.45	0.40	0.39	-0.16	-0.07	-0.29	0.39	0.23	0.02	0.14	0.23	0.00	-0.12	-0.08	-0.09	-0.18	-0.08	-0.03	0.05	-0.11	0.01	-0.01	-0.03	0.07	0.30	-0.32	-0.19	-0.06	1.00

A Tree canopy cover
B Contiguous canopy cover
C Tree canopy over greenspace
D Fulfilled tree potential
E Tree health
F Permeable surface cover
G Greenspace cover
H Permeability coefficient
I Adjacency to green areas
J Cool roof cover
K Albedo
L Wetland area
M Wetland health
N A/C prevalence for NYCHA
O Functional A/C prevalence for residences
P Central A/C - residential
Q A/C prevalence - school classrooms
R Central A/C - school classrooms
S A/C Capacity - school classrooms
T A/C prevalence - school assembly
U Central A/C - school assembly
V A/C Capacity - school assembly
W Buildings at risk protected by contemporary building code requirements
X Buildings at risk protected by previous building code requirements
Y Residential units at risk protected by contemporary building code requirements
Z Residential units at risk protected by previous building code requirements
AA Critical buildings at risk protected by building code requirements
AB Insured non-critical buildings
AC Insured residential buildings
AD Insured critical buildings
AE Tree guards
AF Green infrastructure installations
AG Area served by sewers
AH Separate sewer coverage

Highlighted cells represent those KPIs with high correlation (R >0.7 or R<-0.7); Figure Source: OMB

FIGURE 13 | KPI PAIRS WITH HIGH CORRELATION

Variable 1	Variable 2	R	Determination
Tree canopy cover	Contiguous canopy cover	0.8045	Combined into "Tree Canopy" Final Indicator, with Variable 1 as primary and Variable 2 as modifiers
Tree canopy cover	Tree canopy over greenspace	0.8985	
Tree canopy cover	Greenspace cover	0.7634	N/A because separate Categories
Tree canopy over greenspace	Permeable surface cover	0.8532	N/A because separate Categories
Tree canopy over greenspace	Greenspace cover	0.8886	
Tree canopy over greenspace	Permeability coefficient	0.7210	
Permeable surface cover	Greenspace cover	0.9789	Combined into "Permeable Surfaces" Final Indicator, with Variable 1 as primary and Variable 2 as modifiers
Permeable surface cover	Permeability coefficient	0.8567	Combined into "Permeable Surfaces" Final Indicator, with 'Permeable surface cover' as primary and others as modifiers
Greenspace cover	Permeability coefficient	0.8349	
Central A/C – school assembly	A/C prevalence – school assembly	0.7806	Combined into "A/C – school assembly" Final Indicator, with A/C prevalence as primary and others as modifiers
A/C capacity – school assembly	A/C prevalence – school assembly	0.9068	
A/C capacity – school assembly	Central A/C – school assembly	0.7116	
Central A/C – school assembly	Central A/C – school classrooms	0.7108	N/A because Central A/C – school assembly already combined with others
Insured non-critical buildings	Insured residential buildings	0.7399	*N/A at this time because in future will measure residential units when data available (rather than measuring buildings)*

Figure Source: OMB

It is important to note that correlation does not represent causality or a physical relationship between variables. At this time, many of the correlated variables share physical bases, such as permeable surface cover and greenspace and tree canopy cover and greenspace. These are physically related and likely explain at least some of the relationship. However, other KPIs could be correlated and not share underlying physicality.

2. **Relatedness:** In addition to highly correlated variables being grouped by primary and modifying KPIs, two additional variables are included as modifiers due to relatedness despite low Pearson's correlation.

a. *A/C prevalence for NYCHA.* This KPI includes data from surveyed NYCHA residents on their A/C. The larger-scale *functional A/C prevalence for residences* KPI already represents information on A/C across housing types for the city through a different survey. Because NYCHA residents are a subset of residents in the larger survey, which is less comprehensive for NYCHA residents because it entails a broader population view, NYCHA residents are included as a separate KPI because of their unique attributes and types of A/C policies. These are thus not highly correlated but one is a subset of the other and they are combined as Primary and Modifying Indicators.

b. *Adjacency to green areas.* This KPI aims to cover a gap in evaluation of permeable surfaces. Parks and large, green, open spaces such as cemeteries provide value in their ability to manage heat (they often also have sizable tree canopy cover). Some of these spaces are included in NTAs, while others are so sizable they receive their own NTA, such as Central Park or Green-Wood Cemetery. Despite their benefits, these NTAs are difficult to include in indexes such as this because these NTAs are incomparable with other areas, such as residential neighborhoods. Rather than leaving them out of analysis entirely, Core NTAs are evaluated for their adjacency (the proportion of their area that contacts an Adjacency NTA) to large greenspace that is not already included in an NTA, and this proportion is used as its own KPI. This is not highly correlated with other measures, but is a Modifier because of its quality as a “booster” rather than a typical KPI.

FIGURE 14 | ALL INDICATORS

Hazard	Indicator Category	Indicator	Indicator Type
Outdoor Heat	Outdoor heat managed by trees	Tree canopy cover	Primary
		Contiguous canopy cover	Modifier
		Tree canopy over greenspace	Modifier
		Tree canopy	Final
		Fulfilled tree potential	Final
		Tree health	Final
	Outdoor heat managed by permeable surfaces	Permeable surface cover	Primary
		Greenspace cover	Modifier
		Permeability coefficient	Modifier
		Adjacency to green areas	Modifier
		Permeable surfaces	Final
	Outdoor heat managed by light-colored surfaces	Cool roof cover	Final
		Albedo	Final
	Outdoor heat managed by wetlands	Wetland area	Final
		Wetland health	Final
Indoor Heat	Indoor heat managed by residential A/C	Functional A/C prevalence for residences	Primary
		A/C prevalence for NYCHA	Modifier
		A/C prevalence – residential	Final
		Central A/C – residential	Final
		A/C prevalence – school classrooms	Final
		Central A/C – school classrooms	Final

	Indoor heat managed by school A/C	A/C capacity – school classrooms	Final
		A/C prevalence – school assembly	Primary
		Central A/C – school assembly	Modifier
		A/C capacity – school assembly	Modifier
		A/C – school assembly	Final
Coastal Flooding	Area physically protected – non-critical buildings	Buildings at risk protected by previous building code requirements	Final
		Buildings at risk protected by contemporary building code requirements	Final
		Buildings at risk protected by coastal measures*	Final
	Area physically protected – residential	Residential units at risk protected by previous building code requirements	Final
		Residential units at risk protected by contemporary building code requirements	Final
		Residential units at risk protected by coastal measures*	Final
	Area physically protected – critical buildings	Critical buildings at risk protected by building code requirements	Final
		Critical buildings at risk protected by coastal measures*	Final
	Area financially protected	Insured non-critical buildings	Final
		Insured residential buildings	Final
		Insured critical buildings	Final
Stormwater Flooding	Water managed by trees	Tree canopy cover	Primary
		Tree canopy over greenspace	Modifier
		Tree canopy	Final
		Fulfilled tree potential	Final
		Tree health	Final
		Tree guards	Final
	Water managed by permeable surfaces	Permeable surface cover	Primary
		Greenspace cover	Modifier
		Permeability coefficient	Modifier
		Permeable surfaces	Final
	Water managed by green infrastructure	Green infrastructure installations	Final
	Water managed by wetlands	Wetland area	Final
		Wetland health	Final
	Water managed by sewer coverage	Area served by sewers	Final
		Separate sewer coverage	Final

Figure Source: OMB

**Stormwater KPIs are preliminary, as they do not yet include sewer capacity at this time. KPIs in the table above with background color are grouped together whereby the Final Indicator results from a combination of Primary and Modifier Indicators, rather than being a standalone Final Indicator. Note that more detail of these KPIs can be found in section "Indicators" later in this document. Some additional Indicators and Categories are not included here, but are in consideration:*

- *Under the coastal flooding hazard, KPIs related to areas Protected by Coastal Measures for each of the categories (Area Physically Protected – Non-Critical Buildings; Area Physically Protected – Residential, and Area Physically Protected – Critical Buildings) do not have data at this baseline because few coastal barriers have yet been completed. However, many are being created and so this is included here as a placeholder, as it is relevant for future levels of protection. No scoring is conducted yet for this.*
- *Under the coastal flooding hazard, infrastructural protections and other avenues of protection aside from building codes and coastal measures are being considered.*
- *At this time residential financial Coastal Protections (insurance) is measured in "buildings," but may be changed in the future to measure the number of "units" as data become available.*

Indicator Weighting

Final Indicators are normalized, weighted, and combined to create Indicator Category-level scores. Then category scores are normalized, weighted, and scored to create hazard-level scores. See the upcoming sections for more details.

Weights are assigned to KPIs and categories according to the following weighting rubric. Weightings may be subjective. They approximate the relative importance of variables in explaining exposure to heat and flooding based on an assessment of the literature and consultations with experts.

FIGURE 15 | WEIGHTING RUBRIC

High (3)	An abundance of literature or expert knowledge supports that this variable is a crucial strategy toward reducing hazard exposure when applied.
Medium (2)	The literature or expert knowledge supports that this variable reduces hazard exposure, but the relationship may be less strong than other factors.
Low (1)	This variable relates to the reduction of hazard exposure, but outcomes may depend highly on context and is weaker than other factors.

Figure Source: OMB

For the first step of weighting, weighting decisions per Final Indicator are found below. Note that weights are only relevant within Indicator Categories. For example, a score of three for *Tree canopy* should not be directly compared to a score of two for *Wetland area*. These scores only matter in their relativity within categories and represent relative support for their importance in the literature. When a category only has one Final Indicator within, it is automatically given a three.

FIGURE 16 | WITHIN-CATEGORY WEIGHTING

Category	Normalized Final Indicators	Weight (1-3)
Outdoor heat managed by trees	Tree canopy	3
	Fulfilled tree potential	1
	Tree health	1
Outdoor heat managed by permeable surfaces	Permeable surfaces	3
Outdoor heat managed by light-colored surfaces	Cool roof cover	3
	Albedo	3
Outdoor heat managed by wetlands	Wetland area	2
	Wetland health	1

Indoor heat managed by residential A/C	A/C prevalence – residential	3
	Central A/C – residential	1
Indoor heat managed by school A/C	A/C prevalence – school classrooms	2
	Central A/C – school classrooms	1
	A/C capacity – school classrooms	1
	A/C – school assembly	2
Area physically protected – non-critical buildings	Buildings at risk protected by previous building code requirements	1
	Buildings at risk protected by contemporary building code requirements	3
	Buildings at risk protected by coastal measures*	2
Area physically protected – residential	Residential units at risk protected by previous building code requirements	1
	Residential units at risk protected by contemporary building code requirements	3
	Residential units at risk protected by coastal measures*	2
Area physically protected – critical buildings	Critical buildings at risk protected by building code requirements	3
	Critical buildings at risk protected by coastal measures*	2
Area financially protected	Insured non-critical buildings	3
	Insured residential buildings	3
	Insured critical buildings	3
Water managed by trees	Tree canopy	3
	Fulfilled tree potential	1
	Tree health	1
	Tree guards	1
Water managed by permeable surfaces	Permeable surfaces	3
Water managed by green infrastructure	Green infrastructure installations	3
Water managed by wetlands	Wetland area	3
	Wetland health	1
Water managed by sewer coverage	Area served by sewers	3
	Separate sewer coverage	1

Figure Source: OMB

**Green text represents KPIs for outdoor heat, purple for indoor heat, orange for coastal flooding, and blue for stormwater flooding. See previous pages for description of protections by "coastal measures."*

Weighting reasoning for Final Indicators is as follows. More information for each Indicator can be found in the Indicators section of this document.

- *Outdoor Heat Managed by Trees:* The most important factor established by the literature is canopy cover itself (3), but this is supported by subordinate factors such as planting location (1) and tree attributes (1).
- *Outdoor heat managed by permeable surfaces:* There is only one Final Indicator (3).

- *Outdoor heat managed by light-colored surfaces:* Cool roof cover (count) and albedo (average) both represent important information about the presence of cool roofs (breadth and intensity) (3).
- *Outdoor heat managed by wetlands:* Wetlands have more recently been found to provide cooling benefits (2), and health (1) can play a role, but this is less established in the research. To account for this, the difference in scores between these factors is one (2-to-1) rather than two (3-to-1).
- *Indoor heat managed by residential A/C:* Access to A/C (3) is considered extremely important for reducing heat-stress mortality, and central air (1) can provide better and more reliable cooling, but is less important than simply access to cooling.
- *Indoor heat managed by school A/C:* The access to school A/C (2) is correlated with academic performance, but less information exists on the relative importance of cooling for health outcomes among youth–it is unclear the relative importance of central air (1), so the relationship is kept at 2-to-1. While A/C capacity is relevant for the ability to install A/C expediently, it is unclear to what degree electrical requirements deter A/C installation, so this is kept at a (1). Similarly, the importance of A/C prevalence for classrooms compared to assembly spaces is under-researched, so these are rated the same (2).
- *Area physically protected – non-critical buildings:* Protections build to contemporary standards (3) are better than out-of-date measures (1)
- *Area physically protected – residential:* Protections build to contemporary standards (3) are better than out-of-date measures (1)
- *Area physically protected – critical buildings:* Protections build to contemporary standards (3) are better than out-of-date measures (1)
- *Area financially protected:* While the importance of insurance for recovery of buildings is established, this comes after the fact and does not in itself prevent harm. It is unclear if there are any particular benefits for recovery of residences versus businesses versus critical facilities, so all are rated the same (3).
- *Water managed by trees:* The most important factor established by the literature is canopy cover itself (3), but this is supported by subordinate factors such as planting location (1) and tree attributes (1).
- *Water managed by permeable surfaces:* There is only one Final Indicator (3).
- *Water managed by green infrastructure:* There is only one Final Indicator (3).
- *Water managed by wetlands:* Wetlands can manage substantial amounts of rainfall (3), but the relationship to wetland degradation level and is less clear (1).
- *Water managed by sewer coverage:* Sewers (3) are often considered the most important water management strategy in the urban environment and separate storm sewers can help efficiently manage stormwater. However, water management strategies are highly location dependent and separate sewer coverage may not be the only measure (e.g., sewer pipe capacity) (1).

Organizing and Processing Scores: Category Level

After weighing Final Indicators, scores for each category are generated (see more in the following sections) and categories are then weighed, Weighting decisions per Indicator Category are found below. These compare scores across Categories and should not be compared to the relative weightings of underlying KPIs from the table above, or across hazards. The reasoning and formulation of category weightings is the same as the previously described Indicator Weightings. See the next section for more details.

FIGURE 17 | CATEGORY WEIGHTING

Category	Weight (1-3)
Outdoor heat managed by trees	3
Outdoor heat managed by permeable surfaces	1
Outdoor heat managed by light-colored surfaces	2
Outdoor heat managed by wetlands	1
Indoor heat managed by residential A/C	3
Indoor heat managed by school A/C	2
Area physically protected – non-critical buildings	2
Area physically protected – residential	2
Area physically protected – critical buildings	3
Area financially protected	1
Water managed by trees	1
Water managed by permeable surfaces	2
Water managed by green infrastructure	2
Water managed by wetlands	1
Water managed by sewer coverage	3

Figure Source: OMB

Weighting reasoning for Indicator Categories is as follows. More information for each Indicator can be found in the Indicator section of this document.

- *Outdoor heat:* Trees (3) are the most important indicator, as they provide shade and evapotranspiration, providing cooling overall. Light-colored surfaces (2) are also important, but are not as straightforward to implement at ground-level compared to roofs. Permeable surfaces (1) and wetlands (1) provide cooling, but do not have the same impact for shade or albedo.
- *Indoor heat:* Residential A/C (3) is very important for reducing mortality, particularly for immobile populations. Scholastic A/C is important for student attainment and youth outcomes, but health impacts are less characterized.
- *Coastal flooding:* Critical infrastructure (3) protections impact not only individual assets but functioning of services, such as power and transportation. Residential impacts are also very important, as they implicate life safety and wellbeing, including mortality (2). Other buildings (2), such as businesses, can also be impacted and influence the services of a community during disaster. Final measures such as insurance (1) are crucial for recovery, but do not play as proactive a protective role.

- *Stormwater flooding:* Sewers (3) are often considered the most important urban water management strategy given limitations for green infrastructure (2) and permeable surfaces (2), which are also important for soaking up rain. Trees (1) and wetlands (1) can help manage rainfall but trees may quickly saturate in their ability to hold water and wetland impacts are less well quantified in how they compare to grey infrastructure such as sewers.

Organizing and Processing Scores: Overall Scores

To combine KPIs within an Indicator Category into scores, Final Indicators are normalized using a min-max normalization:

Normalized Final Indicator = 100(x-x_{min})/(x_{max}-x_{min})*, where *x* represents the Final Indicator for a given KPI across NTAs.
Values are multiplied by 100 so that values range from 0-100 rather than 0-1. Higher scores refer to more adaptation measures in place (less exposure). Higher scores are better for resiliency, and lower scores are worse.

Final Indicators are weighted by importance based on the literature and expert consultation (see the *Normalized* sections above) and combined into a score using a geometric mean. The geometric mean is used to reduce the impact of outliers and changes in score relativity over time compared to the arithmetic mean.[29] The geometric mean is calculated for each NTA across all KPIs per category to yield a category score. This is conducted using the formula for the weighted geometric mean:

$$\left(\left(\prod_{i=1}^{n} x_i^{w_i}\right)^{1/\sum_{i=1}^{n} w_i}\right)$$

Operationalized as: *(((X_1+1)^W_1)*((X_2 +1)^W_2)*((X_3 +1)^W_3)...)^(1/(W_1+ W_2+ W_3...)),* where *x* refers to a Normalized Final Indicator and *w* refers to the associated weighting.

One is added to each Normalized Final Indicator score in the formula for the calculation of the category scores as to avoid zeros in the range, as they disrupt calculating the geometric mean.

Once NTA-level category scores are created from underlying KPIs, these category scores are normalized to create Normalized Category scores, using min-max normalization.

These are then combined using the same process for the weighted geometric mean as described above to create ultimate hazard-level scores. Hazard scores are normalized to achieve a range from 0-100 percent relative scores.

To create overall total scores across hazards, a simple average (arithmetic mean) is used and all hazards considered equally important (no weighting applied).

Note that when KPIs are not relevant (e.g., a non-coastal NTA when calculating the coastal flooding hazard-level score; an NTA without any school buildings for *A/C Prevalence – Classrooms* KPI), these are left out of calculations (as n/a rather than zero). The same formulas as above apply, but they will be calculated without the irrelevant KPI or skip the irrelevant NTA. See the previous section for the list of NTAs and KPIs for which this applies.

Summarization

Data are then summarized in Microsoft Excel. Comparing neighborhoods, higher scores refer to more adaptation work being conducted and thus less remaining exposure to threats. Higher scores mean neighborhoods are more protected, though there may be other features that mediate overall levels of risk, such as relative vulnerability. These can be combined or overlaid with these scores but are not included in these measures that focus on levels of exposure. Scores of 100 percent (the highest score) do not represent perfect or "full" resiliency. Rather they represent locations that contain relatively large coverage of resiliency design strategies included as KPIs. These neighborhoods may lack resiliency in many ways and have different absolute values of adaptation measures than other neighborhoods. Scores are relative to each neighborhood (due to using proportions within the NTA) and across neighborhoods (due to scores being normalized compared to peers.

Sensitivity Analysis

A sensitivity analysis is conducted to evaluate how sensitive the resultant final scores are to various weighting schemes. Four different options are evaluated:

1. Default: low=1, middle=2, high=3
2. Wide Spread: low=1, middle=3, high=5
3. Narrow Spread: low=.75, middle=1, high=1.5
4. Binary: low=1, high=2
5. None: all=1

To compare the outcomes of scoring for each of the weighting options, the Total scores for each NTA are compared between weighting options, using ranks. Each NTA is assigned its score rank (from one to 198). For the chosen weighting scheme (#1) and the no-weighting option (#5), 127 out of 198 NTAs fall within the same quartile of score ranking (the scores for 64 percent of the NTAs fell within the same quartile regardless of if Weighting #1 and Weighting #5), leaving 71 NTAs with greater differences in scores. Five of these can be disregarded as they have minimal differences in rank (less than 10 rank spots difference) despite falling on either side of a quartile boundary. This leaves 66 NTAs with what could be considered substantial different relative score placement compared to the other NTAs when weighted differently. For comparison to the None set, the Wide Spread saw 105 in the same quartile (plus 10 suitable to disregard); the Narrow Spread saw 166 in the same quartile (plus five eligible to disregard); and the Binary saw 143 in the same quartile (plus nine to disregard).

FIGURE 18 | CATEGORY WEIGHTING SENSITIVITY ANALYSIS

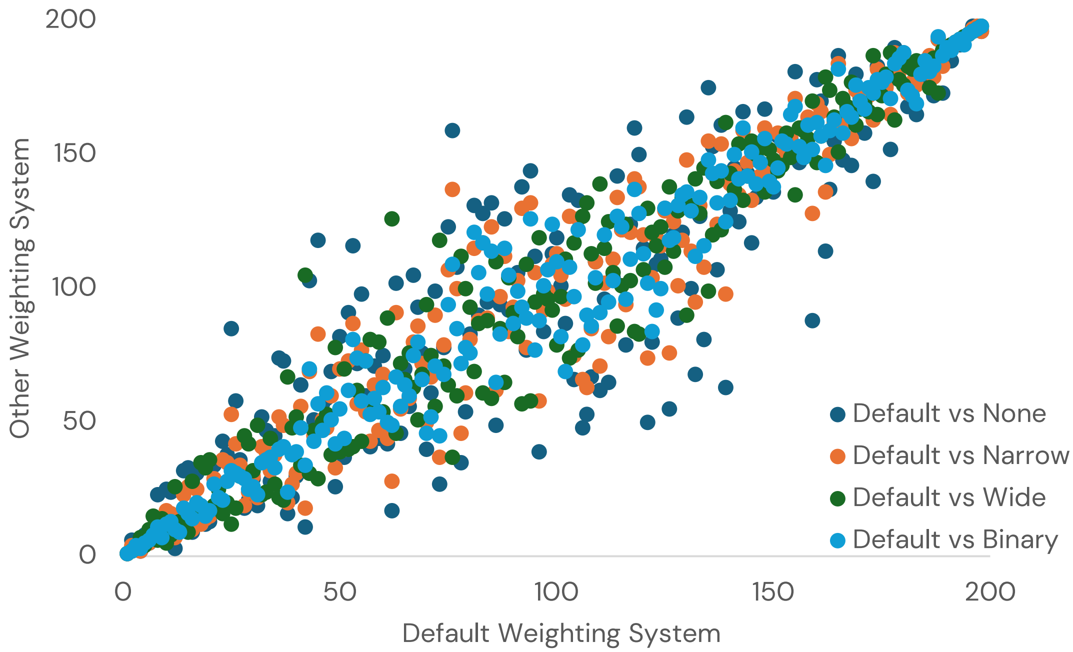


Figure Source: OMB

INDICATORS

This section describes the KPIs used in the inventory. Lowest-level, standalone KPIs are described here: Primary Indicators and Modifier Indicators, as well as Final Indicators that are not comprised of other Primary/Modifier Indicators. KPIs are separated by their Indicator Categories and hazards and include the justification, analytical details, assumptions, data sources, update logs, and other pertinent details related to the inclusion of each KPI in the inventory.

OUTDOOR HEAT EXPOSURE KPIS

Category 1 – Outdoor Heat Managed by Trees

Indicator 1 (Primary Indicator) – Tree canopy cover

Description: Proportion of land surface (aerial) overlapped by tree crowns

Background and Justification: Trees reduce outdoor temperature via shade and evaporative cooling.[30] Blocks with high densities of tree canopy cover in New York City can be several degrees cooler than comparable areas.[31] Trees provide more cooling than other vegetation, such as grasses, because they offer shade and their deep roots support greater evapotranspiration from the land surface.[32] The effectiveness of tree shading depends on the structure and height of the trees, as well as canopy characteristics such as density, width, area, and albedo.[33]

Lower temperatures can reduce the risk of heat related illnesses across a population.[34] It is important to consider factors that can limit trees' temperature-relieving effects such as surrounding infrastructure, including nearby buildings, which may impede a tree's ability to expand its canopy. Limitations on planting trees such as biophysical constraints and species suitability to the environment should be taken into account when choosing whether to increase tree canopy in an area.[35]

Processing:

- Source: NYC Open Data Land Cover Raster—6inch Resolution[36]
- Most Recent Data Update: 2017
- Assumptions: This includes canopy on public and private property—while these trees may provide different benefits or be managed differently, they both provide cooling benefits in their own domains. Source data assume vegetation 8-feet tall is tree canopy and 8-feet tall is grass/shrub; Data is determined using aerial imagery, not on-the-ground surveys.
- Notes: Future data updates will be conducted every five years as per LL148 of 2023.[37] Tree canopy as a measure includes overhang of tree leaves, whereas the permeable surfaces describe the ground, which include tree-planted areas and vegetative cover.
- Final Indicator: *Tree canopy cover* is combined with two other KPIs—*contiguous canopy* and *tree canopy over greenspace*—to comprise the "tree canopy" Final Indicator.

Indicator 2 (Modifier) – Contiguous canopy

Description: Proportion of tree canopy cover on the sidewalk (right-of-way) that is continuous in distribution (touching)

Background and Justification: The distribution of canopy cover over sidewalks can influence the walkability of thoroughfares during hot weather. More studies on canopy distribution in NYC are needed, as locations and sub-climates can influence planting optimization.[38] Generally, greater cover in areas with low shade cool pedestrians better than low tree cover.[39] However, overlapping canopy may lead to diminishing marginal cooling returns for additional canopy after a certain saturation, highlighting the importance of filling gaps in canopy. At larger spatial scales, canopy that is more continuously distributed—with larger perimeters and larger patches—across a right-of-way can provide greater cooling to a community than densely packed or isolated trees.[40] Zhou et al. (2017) compared the effect of tree spatial configurations on cooling in Sacramento and Baltimore. They characterize that tree cover is a better indicator of lower surface temperature than connected tree canopy, but spatial configurations have important effects related to shade and evapotranspiration efficiency.

Processing:

- Source: NYC Open Data Land Cover Raster Data—6inch Resolution[41] and NYC Open Data Planimetric Sidewalk Database[42]
- Most Recent Data Update: 2017
- Assumptions: Source canopy data assumes vegetation greater than 8 feet is tree canopy and less than 8 feet is grass/shrub; Data determined using aerial imagery, not on-the-ground surveys. For sidewalks, areas under construction/protected from scaffolds are collected along an imaginary line to complete the right-of-way (ROW) polygon. The scaffolded areas would be shaded and thus cooler, but not captured in this analysis as they are not shaded by tree canopy. While contiguity may play a role in cooling non-ROW spaces, ROW is selected here to account for locations where individuals will be impacted by shade continuously, though this is an imperfect measure for locations that affect pedestrians and others outdoors.
- Notes: To create the count of right-of-way segments of sidewalk are shaded by contiguous canopy, the sidewalk polygons are split into equal area breaks of 450 feet^2. This area is chosen to resemble the distance between individual street trees. Then, canopy coverage is clipped to the ROW breaks. Canopy overlapping ROW breaks are then extracted if they are adjacent other breaks with canopy coverage, and thus contiguous. The extracted count is compared to the total number of breaks per NTA.
- Final Indicator: *Canopy contiguity* is combined with two other KPIs—*tree canopy cover* and *tree canopy over greenspace*—to comprise the *tree canopy* Final Indicator.

Indicator 3 (Modifier) – Tree canopy over greenspace

Description: Proportion of tree canopy that overlaps with vegetated area

Background and Justification: Tree canopy that exists over vegetated area (greenspace) has shown to lower surface temperature more than canopy over asphalt/concrete. Trees planted over grass exhibited a transpiration rate ten times greater (4.15 grams per meter^{-2} min^{-1}) compared to those planted in paved cut-out pits (0.44 grams per meter^{-2} min^{-1}), according to meta-analysis by Rahman et al. (2020).[43] This cannot be explained due to the additive benefits of grass' transpiration along with the tree's because this is calculated using porometric and sap flux data directly from the tree, and other evidence shows the relationship to root space is an important consideration.[44] It is of note that Rahman et al. describe that, across the climatic zones compiled in their analysis, change in surface temperature (between shaded and unshaded areas) is most greatly reduced by trees over asphalt, whereas evapotranspiration is maximized by grass below. While this may seem to support the supposition that trees over asphalt are more critical for reducing outdoor urban temperature than those over vegetated areas, in the discussion of desirable design strategies, creating more soil/root/grass space underneath tree plantings would be the goal, to reduce the heat overall through shading and evapotranspiration (the delta in surface temperature is likely so great because of the undesirable heat-absorbing qualities of asphalt).

Processing:

- Source: NYC Open Data Land Cover Raster Data—6inch Resolution[45] and NYC Open Data DEP Citywide Parcel-Based Impervious Area GIS Study[46]
- Most Recent Data Update: 2017
- Assumptions: Source canopy data assumes vegetation greater than 8 feet is tree canopy and less than 8 feet is grass/shrub; Green space area determined using aerial imagery, not on-the-ground surveys. Classification of green spaces are "grass/bush", per DEP.
- Notes: Tree canopy details the overhang of tree leaves, whereas the permeable surfaces describe the surfaces, which include tree planted areas and vegetative cover. Datasets are based on the same LiDAR flyover period, so areas adjacent are defined by using the "Select by Location" tool. Different mechanisms of cooling and measurement are included here.
- Final Indicator: *Tree canopy over greenspace* is combined with two other KPIs—*tree canopy cover* and *contiguous canopy*—to comprise the *tree canopy* Final Indicator.

Indicator 4 (Final Indicator) – Fulfilled tree potential

Description: Proportion of potential tree canopy growth area that has existing canopy

Background and Justification: Fulfilled tree potential tells us which neighborhoods are the most equipped to increase canopy via new planting, available sky area for future crown growth, and neighborhoods that are maximizing their capacity for new trees based on the practicality of its sidewalk spaces to grow healthy trees free from interruptions from infrastructure, clear lines of sight, and capacity for planted canopy to naturally overhang.[47] This is not an assessment of proposed street tree planting spaces but analyzes the number of existing planting spaces that have live street trees (not dead trees or stumps) in them and the potential canopy area trees could occupy based on urban infrastructure characteristics. Additionally, this measure accounts for the maximum horizontal capacity for growth from current street trees and private tree canopy growth captured by LiDAR and planimetric data.

There are limitations to tree planting potential in the urban environment. Buildings, traffic, and impervious surfaces can cause growth issues in trees.[48] If trees are located too close to a building, their crown development potential decreases. Additionally, urban soil can have limited organic matter and nutrients available for plants. Construction with cementitious materials can also increase nutrient deficiencies by raising soil alkalinity.[49] There can also be pollutants and other debris from urban areas that can make it toxic for plants.

Urban land ownership is complex, making it challenging to find space for expanding canopy coverage in many cities.[50] Canopy coverage and its potential for growth vary significantly across different types of greenspaces. Considering these constraints, it is crucial to assess the planting potential in each neighborhood to optimize the cooling benefits provided by trees.

Processing:

- Source: Practical Canopy for New York City;[51] Understanding Opportunities for Urban Forest Expansion to Inform Goals: Working Toward a Virtuous Cycle in New York City;[52] NYC Open Data Parks and Recreation Forestry Tree Points,[53] NYC Open Data Building Footprints;[54] NYC Open Data Land Cover Raster Data—6inch Resolution[55]
- Most Recent Data Update: 2017
- Assumptions: A buffer around each Forestry Tree Point is selected as 4.11 meters in radius (8.22 meter diameter of canopy per tree), which was calculated by Treglia et al. (2022) using the average diameter of trees owned by the NYC Parks Department for the most common ten species.[56] This included tree planting spaces in the right-of-way that do not have live trees in them (such as exclusively empty tree beds, listed as "PSStatus = Empty", only) This count does not include other variations of tree beds that are potentially empty intentionally, such as "Retired", "Retired-Do Not Plant" or "Empty-Do Not Plant". Hypothetical canopy extents are then clipped by building areas according to the city's Building Footprints dataset provided by the NYC Department of Technology and Innovation. This achieves a "potential" canopy value for street trees. Some street trees' aerial canopy cover extents already cover some or all of the potential area, which would be classified as the fulfilled area. Existing trees may go beyond the hypothetical extents in real cases, such as for mature trees, and these overhangs is not considered in the ratio—these are additional canopy areas beyond the "potential" extents.
- Notes: Some data, such as tree planting spots, are updated frequently but the update date of this overall KPI is considered to be 2017 due to that being the most recent update of the LiDAR Raster survey.

Indicator 5 (Final Indicator) – Tree health

Description: Street trees' conditions as assessed by the New York City Parks Department (proportion of street trees with Fair, Good, or Excellent health)

Background and Justification: The NYC Parks Department uses a tree valuation protocol to assess tree health. The trees' conditions are based on their roots, trunk, branches/twigs, and foliage and/or buds.[57] As Rahman et al. (2020) have described that various attributes such as foliage density influence shading effects from trees, it would stand to reason that health characteristics that impact heat-related attributes are important to manage.[58] It is well established that tree crown serves as an indicator of tree health.[59] Trees with higher leaf area index (a measure of total leaf area of the tree) values across species have been found to provide more cooling benefits than those with low areas.[60] In one study, increasing the total canopy index (which combines crown width, trunk height, and leaf area) by 10 percent would further reduce the radiant temperature by 0.83° Celcius.[61] Assessing the factors that allow trees to grow is crucial, given that approximately 87 percent of tree canopy growth between 2010 and 2017 is a result of existing canopy growth compared to new plantings.[62] In one study examining several U.S. cities, including New York, healthy forested areas were significantly cooler than degraded forests at the hottest part of the day.[63]

Processing:

- Source: NYC Open Data Parks and Recreation Forestry Tree Points[64]
- Most Recent Data Update: 2024
- Assumptions: Trees are selected as being "healthy" if they are rated by the NYC Parks Department as Fair, Good, or Excellent. The proportion of street trees included all categories of tree condition (Excellent, Good, Fair, Poor, Critical, Dead, Unknown). The canopy area of trees that met the criteria listed above, by point, are extracted from the possible tree point classifications and the resulting "healthy canopy area" of the resulting points are translated per neighborhood.
- Notes: None

Category 2 – Outdoor Heat Managed by Permeable Surfaces

Indicator 1 (Primary Indicator) – Permeable surface cover

Description: Proportion of surfaces that allow for water infiltration

Background and Justification: Permeable surfaces, such as grass, offer an alternative to impermeable, engineered surfaces by allowing stormwater to seep through gaps in the substrate into underlying reservoirs, where it either infiltrates the soil or is temporarily stored.[65] Permeable spaces can influence surrounding heat by collecting water and allowing for cooling evaporation.[66] It is notable that these effects can be mediated by humidity, reducing the effect,[67] and also does not include engineered permeable pavements. Zou, et al. (2021) demonstrated that "natural" land cover types, namely grassland, woodland, bare land, and water bodies are cooler than other surfaces (asphalt, concrete, brick, buildings).[68] Bare soil, as characterized by the Normalized Difference Bareness Index (NDBaI), in temperate cities has some effect on temperature during warm months but less than vegetation or building characteristics, which are dominant.[69] Overall, permeable land types appear to have a cooling effect compared to impervious surfaces, even with varying levels of vegetation, though this increases the cooling effect (see *Indicator 2* below).[70]

Processing:

- Source: NYC Open Data DEP Citywide Parcel-Based Impervious Area GIS Study[71]
- Most Recent Data Update: 2020
- Assumptions: This includes what DEP considers in analysis to be both "semi-pervious" and "pervious," which includes the land cover classes: gravel, synthetic turf, bare soil, sand, grass, bush, and tree.[72] Permeable surfaces here do not likely include engineered porous pavements, as these would likely present in a LiDAR analysis as asphalt or concrete. These specialty pavements (a type of green-grey infrastructure), though porous, are not added into this analysis in any way, as they show varying effects on heat abatement depending on dry or wet conditions.[73] Trees are considered permeable surfaces in the DEP land classification, but this

is not measuring the same features as in the *Outdoor Heat Managed by Trees* Indicator Category described above.
- Notes: Tree canopy details the overhang of tree leaves, whereas the permeable surfaces describe the surfaces, which include tree planted areas and vegetative cover. Different mechanisms of cooling and measurement are included here.
- Final Indicator: *Permeable surface cover* is combined with three other KPIs—*greenspace cover*, *permeability coefficient*, and *adjacency to green areas*—to comprise the *permeable surfaces* Final Indicator.

Indicator 2 (Modifier) – Greenspace cover

Description: Proportion of surface area covered by vegetation

Background and Justification: Compared to asphalt and concrete (even though concrete is typically light in color), grasses cool the surface and air temperatures.[74] Greenspace cover includes grass, trees, and bushes as the three vegetation-related land cover types in DEP's impervious surface analysis.[75] The literature includes investigation of the cooling abilities across various shapes and sizes, such as small local parks, gardens, and green roofs.[76] Since greenspace is a sub-type of permeable surface, see *Indicator 1* above for more information on the difference between bare soil and vegetation. The cooling effectiveness of greenspace versus permeable surfaces relates to the vegetation's ability to cool via evapotranspiration.[77]

Processing:

- Source: NYC Open Data DEP Citywide Parcel-Based Impervious Area GIS Study[78]
- Most Recent Data Update: 2020
- Assumptions: This includes what DEP considers in analysis to be grass, bush, and tree.[79] Trees are considered permeable surfaces in the DEP land classification, but this is not measuring the same features of canopy as in the *Outdoor Heat Managed by Trees* Indicator Category described above.
- Notes: Tree canopy details the overhang of tree leaves, whereas the permeable surfaces describe the surfaces, which include tree planted areas and vegetative cover. Different mechanisms of cooling and measurement are included here.
- Final Indicator: *Greenspace cover* is combined with three other KPIs—*permeable surface cover*, *permeability coefficient*, and *adjacency to green areas*—to comprise the *permeable surfaces* Final Indicator.

Indicator 3 (Modifier) – Permeability coefficient

Description: Weighted average of permeabilities associated with substrate type

Background and Justification: The permeability coefficient is a valuation of substrate porosity. Larger pores result in a looser soil structure and higher permeability, while denser soil has lower permeability.

NYC DEP has conducted a permeability study, which classifies surface types into impervious, semi-pervious, pervious, and not applicable (open water) groupings.[80] Within each of these categories are individual surface types, such as bare soil, gravel, concrete, and brick, which all have associated ranges of permeabilities, identified by C-values, the runoff coefficient. Higher C-values indicate less perviousness. Though the above Indicator measures the proportion of non-impervious surface cover in the city, this feature provides additional detail on the level of permeability. The weighted average area of surface covers is assigned the average permeability for that cover type and provided for the neighborhood.

Processing:

- Source: NYC Open Data DEP Citywide Parcel-Based Impervious Area GIS Study[81]
- Most Recent Data Update: 2020
- Assumptions: Permeability coefficients are averages and are typically assigned ranges for different substrate types. The average may or may not accurately reflect the permeability in practice, including if it is clogged or compacted. Weighted averages of the average permeabilities for substrate types by area for each NTA are taken. This includes what DEP considers in analysis to be both "semi-pervious" and "pervious," which includes the land cover classes: gravel, synthetic turf, bare soil, sand, grass, bush, and tree.[82] Trees are considered permeable surfaces in the DEP land classification, but this is not measuring the same features as in the *Outdoor Heat Managed by Trees* Indicator Category described above.
- Notes: Permeable surfaces do not likely include engineered porous pavements, as these would likely present in a LiDAR analysis as asphalt or concrete. These specialty pavements (a type of green-grey infrastructure), though porous are not added into this analysis in any way, as they show varying effects on heat abatement depending on dry or wet conditions.[83]
- Final Indicator: *Permeability coefficient* is combined with three other KPIs—*permeable surface cover*, *greenspace cover*, and *adjacency to green areas*—to comprise the *permeable surfaces* Final Indicator.

Indicator 4 (Modifier) – Adjacency to green areas

Description: Proportion of neighborhood area bordering NTA-sized greenspace, parks and cemeteries.

Background and Justification: Urban parks are widely regarded as effective strategies in mitigating the urban heat island effect .[84] These nature-based solutions provide cities with a more comfortable outdoor environment, and ecological parks and have the highest cooling area and relatively high cool gradients, compared to other urban landscapes.[85] There are hundreds of small-to-medium sized parks in New York City that exist within Core NTAs, however, the context and impact of larger neighborhood-sized parks and greenspaces would be lost without a metric calculating these, as they are not comparable themselves to Core NTAs. This KPI provides a way to include the benefits of large green spaces in analysis without making these directly comparable to other Core NTAs with other uses.

Processing:

- Source: NYC Open Data 2020 Neighborhood Tabulation Areas (NTAs)[86]
- Most Recent Data Update: 2024
- Assumptions: Large parks and greenspaces are selected manually based on the name of the NTA or known attribute of the area (e.g., Central Park). Cemeteries are included in this evaluation as they contribute to large urban green features. This list includes what the NYC Parks Department considers to be a non-residential park or cemetery (see the preceding sections of these methods for which KPIs are included in this list).
- Notes: Buffer zones of 100 feet are added to the boundaries of each large "green" NTA to strengthen the quality and accuracy of the analysis, and to ensure all neighboring residential NTAs are added to the Final Indicator. The proportion of overlap with Core NTAs is calculated for each of the Core NTAs and this used as a measure of adjacency to one or more large-scale greenspaces otherwise not captured by another Core NTA, attributed to those Core NTAs.
- Final Indicator: *Adjacency to green areas* is combined with three other KPIs—*permeable surfaces, greenspace cover*, and *permeability coefficient*—to comprise the *permeable surfaces* Final Indicator.

Category 3 – Outdoor Heat Managed by Light-Colored Surfaces

Indicator 1 (Final Indicator) – Cool roof cover

Description: Proportion of building roofs with high solar reflectance (light color)

Background and Justification: Heat gain through a roof can substantially contribute to the total cooling load of a single-story building.[87] In addition to individual building effects, high-albedo (light reflective) roofs and surfaces cool ambient temperature.[88] Albedo is measured from 0-1, where 1 represents 100 percent of light being reflected from an object. In a New York City study, light-colored roofs reduced the air temperature by 0.4° Fahrenheit throughout the day, while light surfaces reduced the air temperature by 1.3° Fahrenheit throughout the day.[89]

In the U.S., many roofs are dark and poorly insulated, leading to increased cooling energy use, especially in hot and sunny climates.[90] High-albedo roofing, which reflects more sunlight than traditional roofs, has been used globally to reduce cooling loads and improve comfort. Although high-albedo roofs may slightly increase heating costs by absorbing less sunlight in colder months, the cooling energy savings have been found outweigh these cold-month additions in New York City. The technology is also often considered a low-cost cooling option as there can be small cost difference between black and white asphalt shingles, and flat-top roofs may be "cooled" via painting.[91]

Processing:

- Source: NYC Open Data Building Footprints;[92] Dr. Mehdi Heris, Hunter College
- Most Recent Data Update: 2023

- Assumptions: There is no one standard for "high" albedo. A value of 0.6 is used as the threshold for high albedo in this study, as advised by researchers conducting heat resiliency work in New York City. However, other values could be suitable, with common values between 0.5 and 0.9.[93.] Note that some green roofs may be double counted between this Indicator and the permeable surfaces Indicator. These are derived from different source datasets and for different Indicator Categories. Light-colored roofs mostly apply to synthetic surfaces with colors such as white and cooling benefits are derived from high reflectance of light, whereas the cooling benefits of permeable surfaces and vegetation are from shade and evapotranspiration. Cool roofs may include some green roofs, as green roofs often have a higher albedo than traditional roof cover, despite having lower albedo than white or other "cool roofs." Green roofs are checked against maps of the city's green roof spaces by Treglia et al. (2022) and NYC DEP to check that most green roofs are being included in the "outdoor heat managed by greenspace" Indicator Category, but will not be included fully in the Light-Colored Roofs or Albedo Indicators.[94] Roof spaces only are assessed. While ground-level surface albedo may impact urban heat, the effects are less established, with some studies showing that despite overall temperature reductions, pedestrian 'felt-heat' is greater.[95] Unlike for roofs, there is no public city strategy to change the color of dark-colored ground-level spaces such as roadways and the implications would need to be assessed before deciding to include.
- Notes: Large rooftop items such as electrical equipment may interfere with the calculation of solar reflectance. To account for this, the reflectivity of at least 65 percent rooftop cover is used to generalize the status of the roof surface. Other impacts, such as steeply sloped roofs (e.g., skyscrapers) are harder to accurately assess using the current methodology. Rooftops with solar panels covering 65 percent of rooftop cover or less are assessed for their background albedo. Rooftops above this threshold are read for their solar panel albedo, though these systems may be warmer than a cool roof given their heat absorption for energy conversion. These are not a large proportion of rooftop spaces, though may represent a complex case.

Indicator 2 (Final Indicator) – Albedo

Description: Weighted average surface albedo (by area) for roofs

Background and Justification: Light-colored materials can lower peak city temperatures by several degrees.[96] However, high-albedo surfaces are not monolithic. While they are often classified as a binary cool versus traditional (see *Indicator 1* above), even variations in the light-colored category can yield different levels of cooling. For example. Zhang et al. (2017) established that a change from 0.5 albedo to 0.7 (50 percent to 70 percent) represented additional reductions in the ambient temperature at 2 meters of 0.2° Celsius and of simulated skin surface temperature of 1° Celsius.[97] Krayenhoff and Voogt describe an average reduction of diurnal maximum air temperature in summer of 0.5° Celsius per 0.1 increase in neighborhood albedo.[98] Li et al. (2014) and Imran et al. (2018) describe the relationship between cool roofs and near-surface heat as largely linear.[99]

One limitation to light-colored surfaces as a strategy is that they can collect dirt or debris that darkens the surface and reduce the cooling efficiency, particularly in urban environments, such as New York City with high levels of air particulates.[100] For example, the Cool Roof Rating Council includes a list of 750 bright white roof products with tested three-year results of solar reflectance (measured from 0 to 1, low to high).[101] An average reduction of nearly 0.13 is found. Using self-cleaning agents and photocatalytic coatings can help maintain their effectiveness by minimizing these impacts.[102] Emissivity, on top of reflectance, contributes to heat, such as seen with "cool coatings" on differently colored materials.[103]

Processing:

- Source: NYC Open Data Building Footprints;[104] Dr. Mehdi Heris, Hunter College
- Most Recent Data Update: 2024
- Assumptions: Roof spaces only are assessed. While ground-level surface albedo may impact urban heat, the effects are less established, with some studies showing that despite overall temperature reductions, pedestrian 'felt-heat' is greater.[105] Furthermore, unlike for roofs there is no public city strategy to change the color of dark-colored ground-level spaces such as roadways and the implications would need to be assessed before deciding to include.
- Notes: Large rooftop items such as electrical equipment may interfere with the calculation of solar reflectance. To account for this, the reflectivity of at least 65 percent rooftop cover is used to generalize the status of the roof surface. Other impacts, such as steeply sloped roofs (e.g., skyscrapers) are harder to accurately assess using the current methodology. Rooftops with solar panels covering 65 percent of rooftop cover or less are assessed for their background albedo. Rooftops above this threshold are read for their solar panel albedo, though these systems may be warmer than a cool roof given their heat absorption for energy conversion. These are not a large proportion of rooftop spaces, though may represent a complex case.

Category 4 – Outdoor Heat Managed by Wetlands

Indicator 1 (Final Indicator) – Wetland area

Description: Proportion of land cover that is natural wetland area

Background and Justification: Wetlands function as natural area and greenspace, providing heat relief to communities nearby.[106] A forested wetland is a type of wetland dominated by a closed canopy of trees that is adapted to endure flooded conditions, including maintaining wet soil. A freshwater wetland contains shrubs and other herbaceous plants inland that are saturated with seepage, and are periodically or constantly flooded.[107] In an examination of several cities, it is found that forested wetlands are several degrees cooler than the city average temperature. In this evaluation in New York City, forested wetlands are the coolest land use type, even compared to other forested areas, and provided 5.8° Fahrenheit of cooling. Freshwater wetlands are 4.7° Fahrenheit lower than the citywide average. When considering the cooling impact of wetlands, it is important to consider the shape and location as irregular-shaped wetlands tend to be less efficient at cooling.[108] Some studies describe how conditions such as humidity, size, and connectedness may change the cooling effects of wetlands.[109]

Processing:

- Source: NYC Open Data Wetlands Map;[110] U.S. Geological Survey Wetlands Mapper[111]
- Most Recent Data Update: 2020
- Assumptions: Note that this does not necessarily include engineered spaces such as green infrastructure Bluebelts,[112] but may incorporate these features where they are built into existing wetland areas. Double counting may occur between cover and forested wetland area for forested wetlands, though it is clear that wetlands take unforested forms and may provide benefits separate from the canopy benefits alone. Furthermore, double counting may occur between this Indicator and permeable surfaces/greenspace, but wetlands provide more substantial benefits compared to other vegetated spaces. This Indicator does not include water-estuaries or riverine areas within its area calculation.
- Notes: Wetlands are included if they are included in the NYC Parks Department's wetland inventory, as well as the NY State and U.S. Federal wetlands delineations. The NYC Parks Department's wetlands were mapped using remote sensing analysis in conjunction with the University of Vermont. The NYC Parks Department has verified and updated this through an assessment with the Natural Areas Conservancy on the ground.

Indicator 2 (Final Indicator) – Wetland health

Description: Percent of wetland area that is classified as Healthy, Threatened, or In Transition

Background and Justification: For the purposes of this work, health of the wetland features is split into four categories (healthy, degraded, in transition, and threatened) based on source data. Wetlands can suffer from degradation due to various factors including wastewater, industrial pollution, human disturbances, and invasive species.[113] Many case studies have expressed the critical value of wetlands in providing cooling benefits.[114] Wetland degradation leading to loss reduces the efficiency at managing water and providing cooling.[115] For example, several studies have identified that wetlands with high connectivity provide more cooling, and the Wetlands Management Framework for New York City includes connectivity bolstering as strategies for increasing feature health.[116] This KPI assesses the proportion of wetland areas that are not degraded, though different causes of degradation may be important to parse.

Processing:

- Source: NYC Nature Map;[117] Natural Areas Conservancy; U.S. Geological Survey Wetlands Mapper[118]
- Most Recent Data Update: 2014

- Assumptions: Only city-owned wetland property is assessed, though much wetland space may be privately owned. Only "degraded" as a classification is not included in the determination of wetlands as constitutes appropriate health, as this represents wetlands where substantial restoration is needed. The health assessment is conducted by the NYC Parks Department and Natural Areas Conservancy according to rubrics for salt marshes, freshwater wetlands, and streams outlined in the 2021 Wetlands Management Framework and for forested wetlands outlined in the 2018 Forest Management Framework.[119]
- Notes: None

INDOOR HEAT EXPOSURE KPIS

Category 5 – Indoor Heat Managed by Residential A/C

Indicator 1 (Primary Indicator) – Functional A/C prevalence for residences

Description: Proportion of households (general population) who have A/C

Background and Justification: This KPI reflects the average New Yorker's likelihood of having A/C (in-window/wall or central) at home and is based on the Housing and Vacancy Survey, which is conducted for households every three years by the Department of Housing Preservation and Development (HPD). The data are statistically extrapolated by geography based on survey responses. Extreme heat in the U.S. kills more people than all other hazards combined.[120] In New York City alone, an estimated 580 New Yorkers die prematurely due to heat each summer, with double the likelihood for Black individuals of dying from heat stress (deaths caused directly by heat as attributed on death certificates).[121] Those dying from heat stress most commonly perished in un-air-conditioned homes, making residential A/C a crucial strategy to reducing heat-related mortality, with a particular emphasis on indoor spaces. A/C prevalence can decrease the occurrence of heat-related illnesses indoors.[122]

Processing:

- Source: New York City Housing and Vacancy Survey 2023;[123] NYC Department of Housing Preservation and Development
- Most Recent Data Update: 2023
- Assumptions: Data are self-reported via survey and may contain sampling error, which is unavoidable in survey research. In the Housing and Vacancy Survey, data on window/wall A/Cs are combined with non-responsive participant data, which introduces potential overcounting of A/C prevalence. Data are aggregated at the smallest geography that ensures protection against data disclosure, the Public Use Microdata Area (PUMA). Because NTAs are smaller than PUMAs, for the purposes of this NTA-level analysis, the proportions for each PUMA are applied to all constituent NTAs, which may not be accurate. This translation was conducted using the Department of City Planning's resources on PUMA geographic relationships to equivalent Community District Tabulation Area for 2020 and subsequently translated to NTA 2020

boundaries using the second crosswalk provided in the 2020 Census Reconfiguration of Statistical Geographies tool.[124]

- Notes: Disclaimer regarding source data at PUMA level—The Census Bureau has reviewed this data product for unauthorized disclosure of confidential information and has approved the disclosure limitation practices applied. (Approval ID: CBDRB FY24 0145). Note that data includes various types of housing, including that owned and operated by the New York City Housing Authority (NYCHA), financed by the New York City Department of Housing Preservation and Development (HPD), and others.[125] According to the city's initial findings from the 2023 HVS representative sample, approximately 7 percent of rental units surveyed were public housing.[126] Note that this is a measure of prevalence and energy reliability or affordability.
- Final Indicator: *Functional A/C prevalence for residences* is combined with one other Indicator—*A/C prevalence for NYCHA fee residents*—to comprise the *central A/C – residential* Final Indicator.

Indicator 2 (Modifier) – A/C prevalence for NYCHA fee residents

Description: Proportion of NYCHA units that pay a set A/C fee who have an A/C

Background and Justification: Most New York City Housing Authority (NYCHA) residences are required to pay a charge to register a window A/C unit for their apartment and a set recurring fee for the associated electricity for using the air conditioner, rather than paying a metered electricity cost directly to the utility. The data for this KPI are based on a survey on NYCHA residences and the prevalence of A/C in the home by a self-reported survey. Extreme heat in the U.S. kills more people than all other hazards combined.[127] In New York City alone, an estimated 580 New Yorkers die prematurely due to heat each summer.[128] Those dying from heat stress most commonly perished in un-air-conditioned homes, making residential A/C a crucial strategy to reducing heat-related mortality, with a particular emphasis on indoor spaces. A/C prevalence can decrease the occurrence of heat-related illnesses indoors.[129] Note that this is a measure of prevalence and energy reliability or affordability.

Particular populations, such as the elderly, are more vulnerable to temperature increases.[130] Similarly, Black individuals are twice as likely to die from heat stress (deaths caused directly by heat as attributed on death certificates) than White individuals.[131] Furthermore, in a study conducted in 2023 by the NYC Health Department, more than half of those surveyed indicated that the cost of A/C prevented them from having A/C in the past.[132] The cost of running A/C (electricity costs or fees) is a component of this. Approximately 45 percent of individuals living in public housing in New York City are Black, yet among the general population only 20 percent of New Yorkers are Black.[133] Nearly 25 percent of the NYCHA population are 62 years or older, compared to 21 percent overall being 60 or older.[134] Furthermore, 14 percent of New Yorkers living under the federal poverty level live in NYCHA facilities, despite comprising only 5 percent of the city's population. Features of the NYCHA populations that put them vulnerable warrant specific inclusion in analyses of city cooling capacities.

Processing:

- Source: New York City Housing Authority
- Most Recent Data Update: 2020
- Assumptions: This includes developments surveyed by NYCHA—surveyed units mostly include those where NYCHA residents do not pay their own utility costs (they pay a set fee to NYCHA for the presence of the air conditioner) and for buildings that are owned/managed by NYCHA—there are limited exceptions to these rules where survey data are available. Note that to these conditions there are four exceptions for properties where NYCHA informed that the property received either central A/C or all residents received wall units. These properties are considered to have 100 percent A/C in this analysis. Self-reported A/C values represent underestimations (which may differ in severity by building) because they are collected via self-reported surveys and those with unregistered A/Cs are unlikely to report having them. Validation has been conducted at select properties and these have shown more A/C units to be installed than reported—however, because validation data focuses on the number of air conditioners and not units and because it was only conducted in a few cases, this is not included in analysis here. This analysis only measures the number of units that have A/C, not the number of A/Cs per housing unit or the effectiveness/functioning of the A/C.
- Notes: Note that not every NTA has an evaluation for this KPI—some NTAs don't have a NYCHA development or one that is part of the Air Conditioning survey. NTAs without data for this KPI are not discounted in their scores—category scores for those NTAs are calculated without this KPI. NYCHA developments are characterized and geolocated according to their Tenant Data System (TDS) number as per the 2023 NYCHA Development Data Book.[135] Note that these attributes are retrieved for 2023, though the survey is conducted in 2020 and development attributes can change over time. Approximately two-thirds of developments are surveyed, which includes those that pay their own utilities or are managed by other entities, such as through the Permanent Affordability Commitment Together (PACT)/Rental Assistance Demonstration (RAD) initiative.[136] Note that the previous Indicator Functional A/C Prevalence for Residences includes NYCHA facilities, but this represents a relatedly small proportion (under 10 percent) of renters surveyed.
- Final Indicator: *A/C prevalence for NYCHA fee residents* is combined with one other Indicator —*functional A/C prevalence for residences*—to comprise the *central A/C – residential* Final Indicator.

Indicator 3 (Final Indicator) – Central A/C – residential

Description: Percent of households (general population) that have central A/C

Background and Justification: This KPI reflects the average New Yorker's likelihood of having central A/C unit at home and is based on the Housing and Vacancy Survey, which is conducted for households every three years by the Department of Housing Preservation and Development (HPD). Central A/C has substantial cooling benefits as compared to other types of A/C such as window units or fans.

Quinn and Shaman (2017) found that NYC homes with central A/C had significantly lower indoor heat index compared to homes with portable and window A/C.[137] The researchers also found that the homes with higher indoor heat indices tended to stay hotter for longer, some even past the heat advisory periods.

Central A/C tends to be more expensive and intensive to install compared to other methods like fans or window units, and that it relies on the building owner, which means it is not an option for some residents in the near-term.

Processing:

- Source: New York City Housing and Vacancy Survey 2023;[138] NYC Department of Housing Preservation and Development
- Most Recent Data Update: 2023
- Assumptions: Data are self-reported via survey and may contain sampling error, which is unavoidable in survey research. Data are aggregated at the smallest geography that ensures protection against data disclosure, the Public Use Microdata Area (PUMA). Because NTAs are smaller than PUMAs, for the purposes of this NTA-level analysis, the proportions for each PUMA are applied to all constituent NTAs, which may not be accurate. This translation is conducted using the Department of City Planning's resources on PUMA geographic relationships to equivalent Community District Tabulation Area for 2020 and subsequently translated to NTA 2020 boundaries using the second crosswalk provided in the 2020 Census Reconfiguration of Statistical Geographies tool.[139]
- Notes: Disclaimer regarding source data at Public Use Microdata Area (PUMA) level—The Census Bureau has reviewed this data product for unauthorized disclosure of confidential information and has approved the disclosure limitation practices applied. (Approval ID: CBDRB FY24 0145). Note that data includes various types of housing, including that owned and operated by the New York City Housing Authority (NYCHA), financed by the New York City Department of Housing Preservation and Development (HPD), and others.[140] According to the city's initial findings from the 2023 HVS representative sample, approximately 7 percent of rental units surveyed are public housing.[141]

Category 6 – Indoor Heat Managed by School A/C

Indicator 1 (Final Indicator) – A/C prevalence – school classrooms

Description: Proportion of school instructional, traditional rooms with functioning A/C

Background and Justification: Heat discomfort negatively impacts learning ability and students' academic performance.[142] In a study in the U.S., elementary and middle school students scored 0.12 standard deviations worse on math tests if they resided in the hottest areas of the country. Heat waves in NYC can be particularly challenging for a student as they cause discomfort without sufficient A/C.[143] Based on a 2016 survey, students in no-A/C classrooms saw one-fifth less learning toward a standardized exam on hot days than students in classrooms with A/C, demonstrating the ability for A/Cs to help mitigate heat-related learning impacts.[144]

Processing:

- Source: NYC Public Schools
- Most Recent Data Update: 2024
- Assumptions: This only includes information from schools surveyed (89 percent of buildings)—these schools are public schools that manage their own school facilities with a custodial engineer. Private schools are not captured. Not all schools or rooms are surveyed. These "traditional classrooms" are considered rooms labeled as Regular Classrooms functioning for Instructional Space or Under Construction, or Other room spaces with area greater than 500 square feet functioning as Instructional Space or Under Construction.
- Notes: Note that not every NTA has an evaluation for this KPI—a few NTAs don't have schools that are inventoried for the A/C survey. NTAs without data for this KPI are not discounted in their scores—category scores for those NTAs are calculated without this KPI. Note that a few instances of double counting of classrooms are removed, as well as few instances where central A/C appeared to have been installed in only a single room in the building with no further details. The A/C survey is a snapshot in time and A/C prevalence may change. Some schools may change locations or layouts and school lists and locations are identified based on 2019-2020 school location data and 2021 school-room comparisons. Some data where addresses are not available relied on QGIS NYS based geocoding software and manual searches, which could include georeferencing errors.

Indicator 2 (Final Indicator) – Central A/C – school classrooms

Description: Proportion of school instructional, traditional rooms that have central A/C

Background and Justification: Central air is often more efficient than window A/Cs, and provides systematic cooling for students compared to window A/Cs. Quinn and Shaman (2017) found that NYC homes with central A/C had significantly lower indoor heat index compared to homes with portable and window A/C.[145] The researchers also found that the homes with higher indoor heat indices tended to stay hotter for longer, some even past the heat advisory periods. This study can apply to schools to demonstrate the efficiency of central A/C in cooling instructional spaces, though more research is needed in the educational setting.

Processing:

- Source: NYC Public Schools
- Most Recent Data Update: 2024
- Assumptions: Only includes information from schools surveyed—these schools are public schools that manage their own school facilities with a custodial engineer. Private schools are not captured. Not all schools or rooms were surveyed. These "traditional classrooms" were

considered rooms labeled as Regular Classrooms functioning for Instructional Space or Under Construction, or Other room spaces with area greater than 500 square feet functioning as Instructional Space or Under Construction.

- Notes: Note that not every NTA has an evaluation for this KPI—a few NTAs don't have schools that are inventoried for the A/C survey. NTAs without data for this KPI are not discounted in their scores—category scores for those NTAs are calculated without this KPI. Note that there is some overlap with the A/C prevalence—schools Indicator, as rooms with central A/C are considered alongside removal A/C units. Note that a few instances of double counting of classrooms are removed, as well as few instances where central A/C appeared to have been installed in only a single room in the building with no further details. The A/C survey is a snapshot in time and A/C prevalence may change. Some schools may change locations or layouts and school lists and locations are identified based on 2019-2020 school location data and 2021 school-room comparisons. Some data where addresses are not available relied on QGIS NYS based geocoding software and manual searches, which could include georeferencing errors.

Indicator 3 (Final Indicator) – A/C capacity – school classrooms

Description: Proportion of school instructional, traditional rooms that have electrical capacity for A/C

Background and Justification: In 2017, the city announced a goal for every school classroom to attain A/C by 2022.[146] As a result, most classrooms received A/C. However, over time A/C units can break and room layouts can change, leading to un-air-conditioned rooms becoming instructional spaces. For these reasons, A/C attainment may vary over time, though it is still close to 95 percent. Broken units or un-air-conditioned spaces may be retrofitted if there is the capacity for A/C in those spaces already, but providing A/C for spaces without the electrical capacity will be less simple to fill or replace.

Processing:

- Source: NYC Public Schools
- Most Recent Data Update: 2024
- Assumptions: Only includes information from schools surveyed—these schools are public schools that manage their own school facilities with a custodial engineer. Private schools are not captured. Not all schools or rooms are surveyed. These "traditional classrooms" are considered rooms labeled as Regular Classrooms functioning for Instructional Space or Under Construction, or Other room spaces with area greater than 500 square feet functioning as Instructional Space or Under Construction. This Indicator measures the capacity of traditional classrooms to receive A/C without system intervention. Rooms are considered to not have capacity if in the survey they are identified as having no dedicated outlet, no ritter kit, no electric, or a combination of these conditions.
- Notes: Note that not every NTA has an evaluation for this KPI—a few NTAs don't have schools that are inventoried for the A/C survey. NTAs without data for this KPI are not discounted in

their scores—category scores for those NTAs are calculated without this KPI. Note that a few instances of double counting of classrooms are removed, as well as few instances where central A/C appeared to have been installed in only a single room in the building with no further details. The A/C survey is a snapshot in time and A/C prevalence may change. Some schools may change locations or layouts and school lists and locations are identified based on 2019-2020 school location data and 2021 school-room comparisons. Some data where addresses are not available relied on QGIS NYS based geocoding software and manual searches, which could include georeferencing errors.

Indicator 4 (Primary Indicator) – A/C prevalence – school assembly

Description: Proportion of school assembly spaces with functioning A/C

Background and Justification: Heat discomfort negatively impacts learning ability and students' academic performance.[147] Heat waves in NYC can be particularly challenging for a student as they cause discomfort without sufficient A/C.[148] Based on a 2016 survey, students in no-A/C classrooms saw one-fifth less learning toward a standardized exam on hot days than students in classrooms with A/C, demonstrating the ability for A/Cs to help mitigate heat-related learning impacts.[149] While assembly spaces are not traditional classrooms, it remains unclear how students' performance and health is affected in these spaces, particularly as they may be used as multipurpose spaces. The aforementioned study investigates schools with no A/C versus full A/C, so the effects may be felt in assembly spaces in a yet uninvestigated way.

Processing:

- Source: NYC Public Schools
- Most Recent Data Update: 2024
- Assumptions: This only includes information from schools surveyed (89 percent of buildings)—these schools are public schools that manage their own school facilities with a custodial engineer. Private schools are not captured. Not all schools or rooms are surveyed. Assembly spaces are considered as Auditorium, Cafeteria, Library, Multipurpose, or Gym spaces.
- Notes: Not every NTA has an evaluation for this KPI—a few NTAs don't have schools that are inventoried for the A/C survey. NTAs without data for this KPI are not discounted in their scores—category scores for those NTAs are calculated without this KPI. Note that a few instances of double counting of classrooms are removed, as well as few instances where central A/C appeared to have been installed in only a single room in the building with no further details. The A/C survey is a snapshot in time and A/C prevalence may change. Some schools may change locations or layouts and school lists and locations are identified based on 2019-2020 school location data and 2021 school-room comparisons. Some data where addresses are not available relied on QGIS NYS based geocoding software and manual searches, which could include georeferencing errors.

- Final Indicator: *A/C prevalence – school assembly* is combined with two other Indicators—*central A/C – school assembly* and *A/C capacity – school assembly*—to comprise the *A/C – school assembly* Final Indicator.

Indicator 5 (Modifier) – Central A/C – school assembly

Description: Proportion of school assembly spaces that have central A/C

Background and Justification: Central air is often more efficient than window A/Cs, and provides systematic cooling for students compared to window A/Cs. Quinn and Shaman (2017) found that NYC homes with central A/C had significantly lower indoor heat index compared to homes with portable and window A/C.[150] Notably, assembly spaces are less likely than traditional classrooms to be able to be cooled sufficiently or efficiently using traditional, removable window A/C units, because spaces such as gymnasiums are typically larger and have different layout. Central A/C is particularly important to consider for these spaces.

Processing:

- Source: NYC Public Schools
- Most Recent Data Update: 2024
- Assumptions: Only includes information from schools surveyed—these schools are public schools that manage their own school facilities with a custodial engineer. Private schools are not captured. Not all schools or rooms are surveyed. Assembly spaces are considered as Auditorium, Cafeteria, Library, Multipurpose, or Gym spaces.
- Notes: Not every NTA has an evaluation for this KPI—a few NTAs don't have schools that are inventoried for the A/C survey. NTAs without data for this KPI are not discounted in their scores—category scores for those NTAs are calculated without this KPI. Note that there is some overlap with the A/C prevalence—schools Indicator, as rooms with central A/C are considered alongside removal A/C units. Note that a few instances of double counting of classrooms are removed, as well as few instances where central A/C appeared to have been installed in only a single room in the building with no further details. The A/C survey is a snapshot in time and A/C prevalence may change. Some schools may change locations or layouts and school lists and locations are identified based on 2019-2020 school location data and 2021 school-room comparisons. Some data where addresses are not available relied on QGIS NYS based geocoding software and manual searches, which could include georeferencing errors.
- Final Indicator: *Central A/C – school assembly* is combined with two other Indicators—*A/C prevalence – school assembly* and *A/C capacity – school assembly*—to comprise the *A/C – school assembly* Final Indicator.

Indicator 6 (Modifier) – A/C capacity – school assembly

Description: Proportion of school assembly spaces that have electrical capacity for A/C

Background and Justification: In 2017, the city announced a goal for every school classroom to attain A/C by 2022.[151] As a result, most classrooms received A/C. However, over time A/C units can break and room layouts can change, leading to un-air-conditioned rooms becoming instructional spaces. For these reasons, A/C attainment may vary over time, though it is still close to 95 percent. Broken units or un-air-conditioned spaces may be retrofitted if there is the capacity for A/C in those spaces already, but providing A/C for spaces without the electrical capacity will be less simple to fill or replace.

Processing:

- Source: NYC Public Schools
- Most Recent Data Update: 2024
- Assumptions: Only includes information from schools surveyed—these schools are public schools that manage their own school facilities with a custodial engineer. Private schools are not captured. Not all schools or rooms are surveyed. Assembly spaces are considered as Auditorium, Cafeteria, Library, Multipurpose, or Gym spaces. This indicator measures the capacity of traditional classrooms to receive A/C without system intervention. Rooms are considered to not have capacity if in the survey they are identified as having no dedicated outlet, no ritter kit, no electric, or a combination of these conditions.
- Notes: Note that not every NTA has an evaluation for this KPI—a few NTAs don't have schools that are inventoried for the A/C survey. NTAs without data for this KPI are not discounted in their scores—category scores for those NTAs are calculated without this KPI. Note that a few instances of double counting of classrooms are removed, as well as few instances where central A/C appeared to have been installed in only a single room in the building with no further details. The A/C survey is a snapshot in time and A/C prevalence may change. Some schools may change locations or layouts and school lists and locations are identified based on 2019-2020 school location data and 2021 school-room comparisons. Some data where addresses are not available relied on QGIS geocoding and manual searches, which could include georeferencing error.
- Final Indicator: *A/C capacity – school assembly* is combined with two other Indicators—*A/C prevalence – school assembly* and *Central A/C – school assembly*—to comprise the *A/C – school assembly* Final Indicator.

COASTAL FLOOD EXPOSURE KPIS

Note that at this time, coastal flood KPIs include only individual building- or unit-level protections through Appendix G of the NYC Building Code (see more details in the following subsections). In the future, OMB aims to include protections from other standards, particularly large coastal flood protection barriers, such as the NYC East Side Coastal Resiliency Project, and design guidelines. Many large-scale coastal flood barriers and similar plans, which would provide swaths of protection, will be completed in coming years, so they are not included as KPIs at this time. Furthermore, other measures could include places that are able and designed to flood to reduce unwanted flooding elsewhere, whereas the measures included at this time focus on the ability to resist water intrusion (outside of floodproofing certificates through the Department of Buildings, DOB). Lastly, building protections here include those largely for a full building; other protections, including elevated equipment or mechanicals, emergency backup power, or other partial protections could be considered in the future.

Importantly, the KPIs below refer to only current, present-day risk and use the PFIRMs and FIRMs for this purpose. Future-looking work is being examined and will be expanded upon, including using floodplain projections that include climate change scenarios and sea-level rise (SLR). Some of the KPIs included below are split into two—the first representing protections to previous building code requirements and the second to contemporary building code requirements).

Note that building criticality is not a standardized definition. Criteria are considered by examining Appendix G, the NYCEM Hazard Mitigation Plan and the CRDG. However, the categories do not perfectly overlap, and criteria are tailored to this analysis—in the future, further alignment between definitions of "critical" buildings will be considered, including for infrastructure, which is currently not included here.

Category 7 – Area Physically Protected – Non-Critical Buildings

Indicator 1 and 2 (Final Indicator) – Buildings at risk protected by building code requirements (1. previous; 2. contemporary)

Description: Proportion of buildings within FEMA 2007 FIRM or 2015 PFIRM with building-level flood protections as expected by implementation of the NYC Building Code (non-critical buildings, and not solely residential buildings)

Background and Justification: The NYC Building Code has included provisions related to flood protection since the first FIRMs were used in 1983. Since then, the city's Building Codes have included requirements for new and substantially renovated buildings to include flood protections if they exist in the FIRMs.[152] In 2013, FEMA released new FIRMs (updated in 2015), but the city has challenged these maps, so they are considered Preliminary (PFIRMs), though both the most recent 2007 FIRMs and the PFIRMs are used in the Building Codes.[153] The floodplain may get redefined over time, and different storm intensities have different floodplains.

Appendix G (Flood-Resistant Construction) applies to new and substantially renovated buildings and data for this KPI are pulled from building permit data by the DOB. Any building that would have likely been subject to Appendix G requirements are collated and mapped—this includes new builds and major alterations (Alt 1/2/CO) made after 1983 that overlapped with the floodplain at the time of construction—and also combined with any buildings with evidence of flood protections, such as floodproofing certificates or elevation certificates.

This search included buildings that meet any of the below criteria:

- The building was part of the Build It Back program having been State Acquired, City Acquired, or Major Renovation—these categories mean that the building was substantially affected by flooding after Hurricane Sandy in 2012 and therefore subject to the flood protection requirements in Appendix G of the NYC Building Code and FEMA's floodplains standards
- The building has an Elevation Certificate or Floodproofing Certificate on file with DOB
- The building was a new build or substantial renovation (Alteration Type 1 or 2) during the period when the city was complying with floodproofing requirements in Building Code Appendix G
- The building underwent Substantial Damage or Substantial Improvement that would have required compliance with the floodproofing requirements in Building Code Appendix G
- The building had self-reported flood shields to DOB

See the Indicators on critical buildings later in this section to see which building types are excluded from this category. All buildings are assessed only for their protections to the 100-year floodplain in the FIRMs and PFIRMs, because Appendix G indicates that at this time both floodplains apply and the strictest building requirements across both flood maps will be used until they are reconciled. For previously built structures, only the applicable FIRM at the time would have applied (for example if the building falls into today's PFIRM but not in the FIRM and was built prior to the publishing of the PFIRM, the structure would be assumed to be unprotected since it would not have been subject to Appendix G at the time of the building permit issuance). The time periods are:

- Pre-1983 (prior to any FIRMS and building code flood requirements (pre): not included in dataset
- 1983-January 2013: (when FIRM was in place, but before Design Flood Elevation was adopted as a standard (Base Flood Elevation used)): categorized as Previous Protections
- January 2013-January 2014: (when the firm was in place and Design Flood Elevation adopted as a standard, but before PFIRMs were adopted or North American Vertical Datum adopted as a standard): categorized as Previous Protections
- 2014 and onward: (after PFIRMs and North American Vertical Datum adopted): categorized as having Contemporary Protections

Processing:

- Source: DOBNOW, DOB Building Information Search; NYC DCP Primary Land Use Tax Lot Output[154]
- Most Recent Data Update: 2024
- Assumptions: Only includes properties where use type is not solely residential—mixed use properties are included. At this time, all properties with likely protections are included in the data set, though some properties have protections built to contemporary standards and others used now-outdated standards at the time of construction. Not all buildings that would likely have been subject to Appendix G flood-resistant standards may in actuality be built to those standards, which could result in overestimating the proportion of buildings in the

floodplain that have protections. Also note that some buildings may elect to have protections without it being required, having fallen into our search criteria or being disclosed to the DOB, which could lead to underestimating the number of buildings with protections in the floodplain. Only the proportion of buildings with likely protections in the floodplain out of all buildings in the floodplain are calculated (buildings not in the FEMA Special Flood Hazard Area (SFHA) are excluded, here both the FIRM and PFIRM areas). Analyzed data does not fully extend as far back as 1983, due to limitations on historical data availability. Flood maps incur some periodic revisions for minor areas—only the 2015 FEMA PFIRM and 2007 FIRM are used in these analyses, though there have been updates throughout to various areas.

- Notes: Building permit requirements for flood-resistant construction have changed over time, including shifting from using the "base flood elevation" to a generally more protective (higher elevation) "design flood elevation." Levels of protection are considered based on date of permitting and associated requirements. Information on building protections has not been validated on the ground for the purposes of these analyses and they represent desktop exercises on the basis of legal building requirements.

Indicator 3 (Final Indicator) – Buildings at risk protected by coastal measures

Description: Proportion of buildings within FEMA 2007 FIRM or 2015 PFIRM that are protected because they exist behind a flood barrier or other coastal adaptation strategy (non-critical buildings, and not solely residential buildings)

Background and Justification: Flood barriers provide protection against flood damage. This measure is an inventory of all assets that will be alleviated by flood mitigation efforts to build resiliency.

Processing:

- Not included yet at this time because most flood barrier projects are still being designed and constructed, but included in the future projections (see later sections) in the future as more coastal assets such as flood walls come online.

Category 8 – Area Physically Protected – Residential Units

Indicator 1 and 2 (Final Indicator) – Residential units at risk protected by building code requirements (1. previous; 2. contemporary)

Description: Proportion of residential building units within FEMA 2007 FIRM or 2015 PFIRM with building-level flood protections as expected by implementation of the NYC Building Code

Background and Justification: The NYC Building Code has included provisions related to flood protection since the first FIRMs were used in 1983. Since then, the city's Building Codes have included requirements for new and substantially renovated buildings to include flood protections if they exist in the FIRMs.[155] In 2013, FEMA released new FIRMs (updated in 2015), but the city has challenged these maps, so they are considered Preliminary (PFIRMs), though both the most recent 2007 FIRMs and the PFIRMs are used in the Building Codes.[156] The floodplain may get redefined over time, and different storm intensities have different floodplains.

Appendix G (Flood-Resistant Construction) applies to new and substantially renovated buildings and data for this KPI are pulled from building permit data by the DOB. Any building that would have likely been subject to Appendix G requirements are collated and mapped—this includes new builds and major alterations (Alt 1/2/CO) conducted after 1983 that overlapped with the floodplain at the time of effect—and also combined with any buildings with evidence of flood protections, such as floodproofing certificates or elevation certificates.

This search included buildings that meet any of the below criteria:

- Are part of the Build It Back program having been State Acquired, City Acquired, or Major Renovation—these categories mean that the building was substantially affected by flooding after Hurricane Sandy in 2012 so as to be subject to the flood protection requirements in Appendix G of the NYC Building Code and FEMA's floodplains standards.
- The building has an Elevation Certificate or Floodproofing Certificate on file with DOB
- The building was a new build or substantial renovation (Alteration Type 1 or 2) during the period when the city was complying with floodproofing requirements in Building Code Appendix G
- The building underwent Substantial Damage or Substantial Improvement that would have required compliance with the floodproofing requirements in Building Code Appendix G
- The building had self-reported flood shields to DOB

All buildings are assessed only for their protections to the 100-year floodplain in the FIRMs and PFIRMs, because Appendix G indicates that at this time both floodplains apply and the most strict building requirements across both flood maps will be used until they are reconciled. For previously built structures, only the applicable FIRM at the time would have applied (for example if the building falls into today's PFIRM but not in the FIRM and was built prior to the publishing of the PFIRM, the structure would be assumed to be unprotected since it would not have been subject to Appendix G at the time of the building permit issuance). The time periods for this are:

- Pre-1983 (prior to any FIRMS and building code flood requirements (pre): not included in dataset
- 1983-January 2013: (when FIRM was in place, but before Design Flood Elevation was adopted as a standard (Base Flood Elevation used)): categorized as Previous Protections
- January 2013-January 2014: (when the FIRM was in place and Design Flood Elevation adopted as a standard, but before PFIRMs were adopted or North American Vertical Datum adopted as a standard): categorized as Previous Protections
- 2014 and onward: (after PFIRMs and North American Vertical Datum adopted): categorized as having Contemporary Protections

Processing:

- Source: DOBNOW, DOB Building Information Search; NYC DCP Primary Land Use Tax Lot Output[157]
- Most Recent Data Update: 2024
- Assumptions: Only residential properties—mixed use properties are included. At this time, all properties with likely protections are included in the data set, though some properties have protections built to contemporary standards and others used now-outdated standards at the time of construction. Not all buildings that would likely have been subject to Appendix G flood-resistant standards may in actuality be built to those standards, which could result in overestimating the proportion of buildings in the floodplain that have protections. Also note that some buildings may elect to have protections without it being required, having fallen into our search criteria or being disclosed to the DOB, which could lead to underestimating the number of buildings with protections in the floodplain. Only the proportion of buildings with likely protections in the floodplain out of all buildings in the floodplain are calculated (buildings not in the FEMA Special Flood Hazard Area (SFHA) are excluded, here both the FIRM and PFIRM areas). Residential units are aggregated if a Building Identification Number (BIN) or Borough Block Lot (BBL) had records of a floodproofing measures implemented.
    - For BBLs with multiple buildings (e.g., co-ops, campuses), the following assumptions are made:
        - If the number of building records matched the number of buildings within the BBL, the entire campus was considered protected, including all units
        - If the number of building records is less than the number of buildings within the BBL, the percentage of records compared to total buildings is calculated, and the resulting ratio is applied to the total number of units.
        - If the number of building records is less than the number of buildings within the BBL *and* the additional building is determined to be an accessory building (e.g., garage, shed), the residential unit was determined to be fully covered (count of properties with accessory buildings that could not be matched directly to BINs: 311 BBLs)

  Analyzed data does not fully extend as far back as 1983, due to limitations on historical data availability. Flood maps incur some periodic revisions for minor areas—only the 2015 FEMA PFIRM and 2007 FIRM are used in these analyses, though there have been updates throughout to various areas.
- Notes: Building permit requirements for flood-resistant construction have changed over time, including shifting from using the "base flood elevation" to a generally more protective (higher elevation) "design flood elevation." Levels of protection are considered based on date of permitting and associated requirements. Note that no information on building protections has been validated on the ground for the purposes of these analyses and they represent desktop exercises on the basis of legal building requirements.

Indicator 3 (Final Indicator) – Residential units at risk protected by coastal measures

Description: Proportion of residential building units within FEMA 2007 FIRM or 2015 PFIRM that are protected because they exist behind a flood barrier or other coastal adaptation strategy

Background and Justification: Flood barriers provide protection against flood damage. This measure is an inventory of all assets that will be alleviated by flood mitigation efforts to build resiliency.

Processing:

- Not included yet at this time because most flood barrier projects are still being designed and constructed, but included in the future projections (see later sections) as more coastal assets such as flood walls come online.

Category 9 – Area Physically Protected – Critical Buildings

Indicator 1 (Final Indicator) – Critical buildings at risk protected by building code requirements

Description: Proportion of critical buildings within FEMA 2007 FIRM or 2015 PFIRM with flood protections as expected by implementation of the NYC Building Code

Background and Justification: Protecting critical buildings is key to ensuring social services and emergency operations remain functional during an emergency, such as a flood. For this KPI, critical buildings are defined as adult-care facilities, nursing homes, hospitals, hospice centers, public and non-public schools, colleges, EMS, police, and fire stations, homeless shelters, and the Hunts Point Food Distribution Center, as informed by the NYCEM Hazard Mitigation Plan and other sources.[158]

The NYC Building Code has included provisions related to flood protection since the first FIRMs were used in 1983. Since then, the city's Building Codes have included requirements for new and substantially renovated buildings to include flood protections if they exist in the FIRMs.[159] In 2013, FEMA released new FIRMs (updated in 2015), but the city has challenged these maps, so they are considered Preliminary (PFIRMs), though both the most recent 2007 FIRMs and the PFIRMs are used in the Building Codes.[160] The floodplain may get redefined over time, and different storm intensities have different floodplains.

Appendix G (Flood-Resistant Construction) applies to new and substantially renovated buildings and data for this KPI are pulled from building permit data by the DOB. Any building that would have likely been subject to Appendix G requirements are collated and mapped—this includes new builds and major alterations (Alt 1/2/CO) conducted after 1983 that overlapped with the floodplain at the time of effect—and also combined with any buildings with evidence of flood protections, such as floodproofing certificates or elevation certificates.

This search included buildings that meet any of the below criteria:

- Are part of the Build It Back program having been State Acquired, City Acquired, or Major Renovation—these categories mean that the building was substantially affected by flooding after Hurricane Sandy in 2012 so as to be subject to the flood protection requirements in Appendix G of the NYC Building Code and FEMA's floodplains standards. (This likely does not apply for critical facilities).
- The building has an Elevation Certificate or Floodproofing Certificate on file with DOB
- The building was a new build or substantial renovation (Alteration Type 1 or 2) during the period when the city was complying with floodproofing requirements in Building Code Appendix G
- The building underwent Substantial Damage or Substantial Improvement that would have required compliance with the floodproofing requirements in Building Code Appendix G
- The building had self-reported flood shields to DOB

All buildings are assessed only for their protections to the 100-year floodplain in the FIRMs and PFIRMs, because Appendix G indicates that at this time both floodplains apply and the most strict building requirements across both flood maps will be used until they are reconciled.

Processing:

- Source: DOBNOW, DOB Building Information Search; NYC DCP Primary Land Use Tax Lot Output[161]
- Most Recent Data Update: 2024
- Assumptions: Only critical facilities as defined above included—other critical facilities may exist and for the purposes of future exercises, infrastructure will likely be included as separate, though this is not included in any of the categories here at this time and may arguably be critical (e.g., wastewater treatment, public transit). At this time, all properties with likely protections are included in the data set, though some properties have protections built to contemporary standards and others used now-outdated standards at the time of construction. Not all buildings that would likely have been subject to Appendix G flood-resistant standards may in actuality be built to those standards, which could result in overestimating the proportion of buildings in the floodplain that have protections. Also note that some buildings may elect to have protections without it being required, having fallen into our search criteria or being disclosed to the DOB, which could lead to underestimating the number of buildings with protections in the floodplain. Only the proportion of buildings with likely protections in the floodplain out of all buildings in the floodplain are calculated (buildings not in the FEMA Special Flood Hazard Area (SFHA) are excluded, here both the FIRM and PFIRM areas). Analyzed data does not fully extend as far back as 1983, due to limitations on historical data availability. Flood maps incur some periodic revisions for minor areas—only the 2015

FEMA PFIRM and 2007 FIRM are used in these analyses, though there have been updates throughout to various areas.

- Notes: In future iterations of this work, partly and fully protected may be separated out. Building permit requirements for flood-resistant construction have changed over time, including shifting from using the "base flood elevation" to a generally more protective (higher elevation) "design flood elevation." At this time buildings are grouped together for having any protections. Information on building protections has not been validated on the ground for the purposes of these analyses and they represent desktop exercises on the basis of legal building requirements. The definition of "critical" buildings is tailored at this time for this analysis and may be reconsidered in the future to be more or less inclusive. Hospitals are required to have protections to the 500-year storm, but this is not accounted for at this time outside of the 100-year floodplain—this will be considered in future in a separate category related to large asset protections that are neither standard building code requirements for new builds or renovations or neighborhood-level coastal barriers.

Indicator 2 (Final Indicator) – Critical buildings at risk protected by coastal measures

Description: Proportion of critical buildings within FEMA 2007 FIRM or 2015 PFIRM that are protected because they exist behind a flood barrier or other coastal adaptation strategy

Background and Justification: Flood barriers provide protection against flood damage. This measure is an inventory of all assets that will be alleviated by flood mitigation efforts to build resiliency. This considers neighborhood-level coastal barriers. Individual asset-level barriers (protections outside the realm of neighborhood-sized barriers and standard building code requirements for large assets will be considered separately).

Processing:

- Not included yet at this time because most flood barrier projects are still being designed and constructed, but included in the future projections (see later sections) as more coastal assets such as flood walls come online.

Category 10 – Area Financially Protected

Indicator 1 (Final Indicator) – Insured non-critical buildings

Description: Proportion of non-critical properties within FEMA 2007 FIRM or 2015 PFIRM with flood insurance (non-residential uses, though mixed use included)

Background and Justification: Flood insurance provides financial resiliency to policyholders, ensuring easier and perhaps quicker recovery from storm damage. Insurance can be used to spread out financial risk and reduce losses, though the magnitude of flooding disasters is unsettling the insurance markets due to worsening hazards.[162] Flood insurance is typically a reactive, rather than an anticipatory approach, allowing for recovery but not necessarily prevention. Financial protections such as insurance can complement physical protections.[163]

Processing:

- Source: U.S. Federal Emergency Management Agency
- Most Recent Data Update: 2023
- Assumptions: Data at this time are calculated for policy contracts at the building level, though there may be individual policies within. This only includes data through the FEMA National Flood Insurance Program (NFIP), though buildings may carry flood insurance through other private carriers. Additionally, this only includes a calculation of properties in the FIRM and PFIRM that carry NFIP flood insurance, though other properties may carry insurance and only properties in the FIRM with federally backed mortgages are required at this time to carry flood insurance through the program. FEMA states that as of 2024, 40 percent of flood insurance claims occur outside of high flood-hazard areas and that federally 82 percent of properties in the Special Flood Hazard Area do not have NFIP coverage.[164] This KPI does not account for the level of insurance protection or repetitive claims/losses, just the presence of insurance. Mixed use properties included.
- Notes: More research will be attempted to break out individual policies from aggregate contracts to show more granular protections.

Indicator 2 (Final Indicator) – Insured residential buildings

Description: Proportion of residential properties within FEMA 2007 FIRM or 2015 PFIRM with flood insurance

Background and Justification: Flood insurance provides financial resilience to policyholders, who may be owners or renters, ensuring easier and perhaps quicker recovery from storm damage. Insurance can be used to spread out financial risk and reduce losses, though the magnitude of flooding disasters is unsettling the insurance markets due to worsening hazards.[165] Flood insurance is typically a reactive, rather than an anticipatory approach, allowing for recovery but not necessarily prevention. Financial protections such as insurance can complement physical protections.[166]

Processing:

- Source: U.S. Federal Emergency Management Agency
- Most Recent Data Update: 2023
- Assumptions: Data at this time are calculated for policy contracts at the building level, though there may be individual policies within. This only includes data through the FEMA National Flood Insurance Program (NFIP), though buildings may carry flood insurance through other private carriers. Additionally, this only includes a calculation of properties in the FIRM and

PFIRM that carry NFIP flood insurance, though other properties may carry insurance and only properties in the FIRM with federally backed mortgages are required at this time to carry flood insurance through the program. FEMA states that as of 2024, 40 percent of flood insurance claims occur outside of high flood-hazard areas and that federally 82 percent of properties in the Special Flood Hazard Area do not have NFIP coverage.[167] This KPI does not account for the level of insurance protection or repetitive claims/losses, just the presence of insurance. Mixed use properties included.

- Notes: More research will be attempted to break out individual policies from aggregate contracts to show more granular protections.

Indicator 4 (Final Indicator) – Insured critical buildings

Description: Proportion of critical properties within FEMA 2007 FIRM or 2015 PFIRM with flood insurance

Background and Justification: Flood insurance provides financial resiliency to policyholders, ensuring easier and perhaps quicker recovery from storm damage. Insurance can be used to spread out financial risk and reduce losses, though the magnitude of flooding disasters is unsettling the insurance markets due to worsening hazards.[168] Flood insurance is typically a reactive, rather than an anticipatory approach, allowing for recovery but not necessarily prevention. Financial protections such as insurance can complement physical protections.[169] Insurance payouts can help cover the costs of recovery, potentially freeing up capital to make future-looking improvements during the recovery process.

Processing:

- Source: U.S. Federal Emergency Management Agency
- Most Recent Data Update: 2023
- Assumptions: At this time, data are calculated for policy contracts at the building level, though there may be individual policies within. This only includes data through the FEMA National Flood Insurance Program (NFIP), though buildings may carry flood insurance through other private carriers. Additionally, this only includes a calculation of properties in the FIRM and PFIRM that carry NFIP flood insurance, though other properties may carry insurance and only properties in the FIRM with federally backed mortgages are required at this time to carry flood insurance through the program. FEMA states that as of 2024, 40 percent of flood insurance claims occur outside of high-hazard flood areas and that federally 82 percent of properties in the Special Flood Hazard Area do not have NFIP coverage.[170] This KPI does not account for the level of insurance protection or repetitive claims/losses, just the presence of insurance.
- Notes: More research will be attempted to break out individual policies from aggregate contracts to show more granular protections.

STORMWATER FLOOD EXPOSURE KPIS

Storms are typically classified by how often they occur (frequency) and how severe they are (intensity). Generally, the city experiences frequent milder storm events in a year, but only a few major. A "100-year storm" refers to an event so powerful that it has just a 1 percent or greater chance of occurring in any given year. In contrast, a 10-year storm (10 percent or greater chance of occurring in any given year), for example, is more likely and less intense than a 100-year storm. The city could see two 100-year storms in the same year, because these labels represent statistical probabilities rather than absolute guarantees. Over time, more intense events are expected to occur more frequently—so today's 100-year storm intensity may be more common in the future.

OMB developed inventory analysis for stormwater, but this is considered preliminary at this point, because it does not yet include information on sewer capacity, which is an important indicator of stormwater adaptation. OMB will update this in the future according to DEP's ongoing stormwater analysis.[171]

Category 11 – Water Managed by Trees

Indicator 1 (Primary Indicator) – Tree canopy cover

Description: Proportion of land surface (aerial) overlapped by tree crowns

Background and Justification: Trees absorb water and their root systems impede water runoff, taking pressure off of the sewer system to convey water.[172] Tree canopy can intercept the water either through retaining it or losing the water through evaporation from its surfaces. This type of loss can be assessed indirectly by subtracting stemflow and throughfall from the total precipitation that reaches the tree. Stemflow is the water that flows down the tree's trunk to the ground, while throughfall is the water that either falls through the canopy or drips off the tree onto the ground. This water either infiltrates the soil or creates runoff if it is delivered more quickly than the soil can absorb it. By reducing the volume of stormwater runoff, canopy interception loss helps protect water quality, decrease soil erosion, and minimize pollutant washout.[173] However, effectiveness may vary with conditions, and tree-related factors may play a relatively minor role in attenuating water during an intense rain event that results in the most substantial flooding.[174]

Processing:

- Source: NYC Open Data Land Cover Raster Data—6in Resolution[175]
- Most Recent Data Update: 2017
- Assumptions: Source data assumes vegetation greater than 8 feet is tree canopy and less than 8 feet is grass/shrub; Data determined using aerial imagery, not on-the-ground surveys.
- Notes: Future data updates will be conducted every five years as per LL148 of 2023. Tree canopy details the overhang of tree leaves, whereas the permeable surfaces describe the

surfaces, which include tree planted areas and vegetative cover. Different mechanisms of cooling and measurement are included here.
- Final Indicator: *Tree canopy cover* is combined with two other KPIs—*contiguous canopy* and *tree canopy over greenspace*—to comprise the *tree canopy* Final Indicator.

Indicator 2 (Modifier) – Tree canopy over greenspace

Description: Proportion of tree canopy that overlaps with vegetated area

Background and Justification: Trees absorb water and their root systems impede water runoff, taking pressure off of the sewer system to convey water.[176] Tree canopy can intercept the water either through retaining it or losing the water through evaporation from its surfaces. Allowing trees to send stem flow and throughfall to soil rather than running off on impervious surfaces can implicate flooding.

Processing:

- Source: NYC Open Data Land Cover Raster Data—6inch Resolution;[177] NYC Open Data DEP Citywide Parcel-Based Impervious Area GIS Study[178]
- Most Recent Data Update: 2017
- Assumptions: Source data assumes vegetation greater than 8 feet is tree canopy and less than 8 feet is grass/shrub; Data determined using aerial imagery, not on-the-ground surveys.
- Classification of green spaces are "grass/bush", per DEP.
- Notes: Tree canopy details the overhang of tree leaves, whereas the permeable surfaces describe the surfaces, which include tree planted areas and vegetative cover. Different mechanisms of cooling and measurement are included here. Both features are complimentary in the same dataset; to identify intersecting polygons, the “Select by Location” tool is used to pull the area of overlap.
- Final Indicator: *Tree canopy over greenspace* is combined with two other KPIs—*tree canopy cover* and *contiguous canopy*—to comprise the *tree canopy* Final Indicator.

Indicator 3 (Final Indicator) – Fulfilled tree potential

Description: Proportion of potential tree canopy growth area that has existing canopy

Background and Justification: Fulfilling more areas with canopy can increase the ability for water to be trapped, slowed, or retained rather than runoff to the sewer system. Fulfilled tree potential tells us which neighborhoods are the most equipped to increase canopy via new planting, available sky area for future crown growth, and neighborhoods that are maximizing their capacity for new trees based on the practicality of its sidewalk spaces to grow healthy trees free from interruptions from infrastructure, clear lines of sight, and capacity for planted canopy to naturally overhang.[179] This is not an assessment of proposed street tree planting spaces but analyzes the number of existing planting spaces that have live street trees (not dead trees or stumps) in them and the potential canopy area trees could occupy based on urban infrastructure characteristics. Additionally, this measure accounts for the maximum horizontal capacity for growth from current street trees and private tree canopy growth captured by LiDAR and planimetric data.

Different locations may have differing abilities to expand canopy cover. In one study, incompact urban areas, commercial zones are the densest and have the lowest tree canopy cover.[180] Residential areas are mostly high-density, with some medium-density and few low-density zones. Industrial zones, with multistory factories, also have high density. Older urban cores are mostly asphalt or concrete, with limited open spaces for solar access and ventilation. Trees are mainly found in low-density areas like open spaces, green belts, low-density residential zones, and government institutions. Tree canopy cover reflects urban greenery quality.

There are limitations to tree planting potential in the urban environment. Buildings, vehicles, and impervious surfaces can cause growth issues in trees.[181] If trees are located too close to a building, their crown development potential decreases. There are also soil constraints as urban soil can have limited organic matter and nutrients available for plants.[182] Construction, pollutants, and other debris from urban areas can disrupt soil and plant activity.

Urban land ownership is complex, making it challenging to find space for expanding canopy coverage in many cities.[183] Canopy coverage and its potential for growth vary significantly across different types of greenspaces. Considering these constraints, it is crucial to assess the planting potential in each neighborhood to optimize the stormwater benefits provided by trees.

Processing:

- Source: Practical Canopy for New York City;[184] Understanding Opportunities for Urban Forest Expansion to Inform Goals: Working Toward a Virtuous Cycle in New York City;[185] NYC Open Data Parks and Recreation Forestry Tree Points;[186] NYC Open Data Building Footprints;[187] NYC Open Data Land Cover Raster Data—6in Resolution[188]
- Most Recent Data Update: 2017
- Assumptions: A buffer around each Forestry Tree Point is selected as 4.11 meters in radius (8.22 diameter of canopy per tree), which is calculated by Treglia et al. (2022) using the average diameter of trees owned by the NYC Parks Department for the most common ten species.[189] This included tree planting spaces in the right-of-way that do not have live trees in them (such as stumps or dead trees, or empty tree beds). Hypothetical canopy extents are then clipped by building areas according to the city's Building Footprints dataset provided by the NYC Department of Technology and Innovation. This is used to achieve a "potential" canopy value for street trees. Some street trees' aerial canopy cover extents already cover some or all of the potential area, which would be classified as the fulfilled area. Existing trees may go beyond the hypothetical extents in real cases, such as for mature trees, and these overhangs is not considered in the ratio—these are additional canopy areas beyond the "potential" extents.
- Notes: Some data, such as tree planting spots are updated frequently, but the update date of this overall KPI is considered to be 2017 due to that being the most recent update of the LiDAR Raster survey.

Indicator 4 (Final Indicator) – Tree health

Description: Street trees' conditions as assessed by the New York City Parks Department (proportion of street trees with Fair, Good, or Excellent health)

Background and Justification: Tree health is impacted by soil and root conditions, which can impact water retention and water management performance of tree, such as when compacted.[190] The NYC Parks Department uses a tree valuation protocol to assess tree health. The tree's condition is based on its roots, trunk, large branches, small branches/twigs, and foliage and/or buds.[191]

Processing:

- Source: NYC Open Data Parks and Recreation Forestry Tree Points[192]
- Assumptions: Trees are considered "healthy" if they are rated by the NYC Parks Department as Fair, Good, or Excellent. The proportion of street trees included all categories of tree condition (Excellent, Good, Fair, Poor, Critical, Dead, Unknown). The canopy area of trees that met the criteria listed above are extracted from the possible tree point classifications and the resulting "healthy canopy area" of the resulting points are translated per neighborhood.
- Notes: None

Indicator 5 (Final Indicator) – Tree guards

Description: Proportion of street trees with guards around their tree pits

Background and Justification: Tree guards are protective fences that are installed around tree pits.[193] These can prevent harm to the tree and importantly limit compaction of soil in the tree pits, which can reduce the water infiltration capabilities.[194]

Processing:

- Source: The NYC Parks Department Neighborhood Tree Planting Program; 2015 Street Tree Census – Tree Data;[195] NYC Open Data Parks and Recreation Forestry Tree Points[196]
- Assumptions: All tree guards from the Neighborhood Tree Planting Plan are considered, and only those tree guards in the 2015 Street Tree Census deemed Helpful (not Harmful or Unsure).[197]
- Notes: None

Category 12 – Water Managed by Permeable Surfaces

Indicator 1 (Primary Indicator) – Permeable surface cover

Description: Proportion of surfaces that allow for water infiltration

Background and Justification: Permeable surfaces allow stormwater to seep through gaps in the substrate into underlying reservoirs, where it either infiltrates the soil or is temporarily stored.[198] Permeable surfaces can capture water at varying levels (depending on the size and depth) and are effective for managing small rains events, but can become saturated by heavier rainfall.[199]

Processing:

- Source: NYC Open Data DEP Citywide Parcel-Based Impervious Area GIS Study[200]
- Most Recent Data Update: 2020
- Assumptions: This includes what DEP considers in analysis to be both "semi-pervious" and "pervious," which includes the land cover classes: gravel, synthetic turf, bare soil, sand, grass, bush, and tree.[201] Permeable surfaces do not likely include engineered porous pavements, as these would likely present in a LiDAR analysis as asphalt or concrete. Trees are considered permeable surfaces in the DEP land classification, but this is not measuring the same features as in the *Stormwater Flooding Managed by Trees* Indicator Category described above.
- Notes: Tree canopy details the overhang of tree leaves, whereas the permeable surfaces describe the surfaces, which include tree planted areas and vegetative cover. Different mechanisms of cooling and measurement are included here.
- Final Indicator: *Permeable surface cover* is combined with two other KPIs—*greenspace cover* and *permeability coefficient*—to comprise the *permeable surfaces* Final Indicator.

Indicator 2 (Modifier) – Greenspace cover

Description: Proportion of surface area covered by vegetation

Background and Justification: Types of vegetation can add to the benefit of reducing runoff in porous systems, in addition to the value of it being permeable to begin with, though this may depend on the type of vegetation and substrate.[202] Greenspace cover includes grass, trees, and bushes as the three vegetation-related land cover types in DEP's impervious surface analysis.[203] Since greenspace is a sub-type of permeable surface, see *Indicator 1* above for more information on the difference between bare soil and vegetation.

Processing:

- Source: NYC Open Data DEP Citywide Parcel-Based Impervious Area GIS Study[204]
- Most Recent Data Update: 2020
- Assumptions: This includes what DEP considers in analysis to be grass, bush, and tree.[205] It is important to note that trees are considered permeable surfaces in the DEP land classification, but this is not measuring the same features as in the *Stormwater Flooding Managed by Trees* Indicator Category described above.
- Notes: Tree canopy details the overhang of tree leaves, whereas the permeable surfaces describe the surfaces, which include tree planted areas and vegetative cover. Different mechanisms of cooling and measurement are included here.

- Final Indicator: *Greenspace cover* is combined with two other KPIs—*permeable surface cover* and *permeability coefficient*—to comprise the *permeable surfaces* Final Indicator.

Indicator 3 (Modifier) – Permeability coefficient

Description: Weighted average of permeabilities associated with substrate type

Background and Justification: The permeability coefficient is a valuation of substrate permeability. Larger pores result in a looser soil structure and higher permeability, while denser soil has lower permeability. NYC DEP has conducted a permeability study, which classifies surface types into impervious, semi-pervious, pervious, and not applicable (open water) groupings.[206] Within each of these categories are individual surface types, such as bare soil, gravel, concrete, and brick, which all have associated ranges of permeabilities, identified by C-values, the runoff coefficient. Higher C-values indicate less perviousness. Though the above indicator measures the proportion of non-impervious surface cover in the city, this feature provides additional detail on the level of permeability. The weighted average area of surface covers is assigned the average permeability for that cover type and provided for the neighborhood. In areas of natural ground cover (100 percent pervious surface) runoff from stormwater is less than 10 percent as compared to upwards of 55 percent in areas of 0-15 percent pervious surfaces.[207] The permeability is directly related to the water infiltration.

Processing:

- Source: NYC Open Data DEP Citywide Parcel-Based Impervious Area GIS Study[208]
- Most Recent Data Update: 2020
- Assumptions: Permeability coefficients are averages and are typically assigned ranges for different substrate types. The average may or may not accurately reflect the permeability in practice, including if it is clogged or compacted. Weighted averages of permeability for each substrate type are taken by area, for each NTA. This includes what DEP considers in analysis to be both "semi-pervious" and "pervious," which includes the land cover classes: gravel, synthetic turf, bare soil, sand, grass, bush, and tree.[209] Trees are considered permeable surfaces in the DEP land classification, but this is not measuring the same features as in the *Stormwater Flooding Managed by Trees* Indicator Category described above.
- Notes: Permeable surfaces do not likely include engineered porous pavements, as these would likely present in a LiDAR analysis as asphalt or concrete. These specialty pavements (a type of green-grey infrastructure), though porous, are not added into this KPI as they are included in Green Infrastructure below.
- Final Indicator: *Permeability coefficient* is combined with two other KPIs—*permeable surface cover* and *greenspace cover*—to comprise the *permeable surfaces* Final Indicator.

Category 13 – Water Managed by Green Infrastructure

Indicator 1 (Final Indicator) – Green infrastructure installations

Description: Area of green infrastructure that helps to collect stormwater

Background and Justification: Green infrastructure includes measures engineered to manage stormwater runoff, such as detention systems, rain gardens, bioswales, permeable pavements, and green roofs. Green infrastructure effectiveness may vary by type, size, depth, location, and nearby features. They may perform better during shorter or lighter rain events than heavy and long events.[210] Permeable pavements and green infrastructure offer an alternative to traditional surfaces by allowing stormwater to seep through into underlying reservoirs, where it either infiltrates the soil or is temporarily stored.[211] In areas of natural ground cover (100 percent pervious surface) runoff from stormwater is less than 10 percent as compared to upwards of 55 percent in areas of 0-15 percent pervious surfaces.[212] For this reason, adding permeable surfaces can reduce runoff volume. By capturing some rainfall, these surfaces also reduce the amount of water traveling to the sewer system.

Processing:

- Source: Open Data Department of Environmental Protection Green Infrastructure[213]
- Most Recent Data Update: 2024
- Assumptions: Green infrastructure is included if it is tracked by the Department of Environmental Protection. However, other green infrastructure assets may exist, such as those on private property that are self-funded. Some private installments are included in this dataset if they are incentivized by the government, such as through the Green Infrastructure Grant Program.[214] However, most are publicly owned. This represents an underestimation of green infrastructure. Values are aggregated by NTA by the summed area of all green infrastructure installations of different types in the NTA as this is the level of data available. Note that this may not represent an ideal relationship to the water managed, as depths and design of green infrastructure, in addition to the area, implicate water volume capacity.
- Notes: Green infrastructure refers to the systems put in place to collect stormwater from hard surfaces before they can enter the sewer system or cause local flooding.[215] These can refer to measures in the right of way, such as raingardens on sidewalks, those on sites such as parks, porous pavements, green roofs, and others. Note that at this time Bluebelts are not included and cloudburst hubs are not counted separately or additionally from their constituent installments, though both of these types of green infrastructure act as large systems. These will likely be included in this tool in some way, such as through a separate metric of "system-wide" coverage, though this is still to be determined. Asset Types selected for this Indicator are listed below.

FIGURE 19 | GREEN INFRASTRUCTURE ASSET TYPES

Blue Roofs	"Multiple GI Components"	ROW Permeable Pavement
Cisterns	Permeable Pavers	ROW Porous Asphalt
Combined Blue/Green Roof	Porous Asphalt	ROW Porous Concrete
Constructed Wetlands	Porous Concrete	ROWB
Detention System	Rain Garden	ROWEB
Detention System (connected to sewer)	Rainwater Harvesting	ROWGS
Drywell	Rooftop Farm	ROWRG
Engineered Soil Tree Pit	ROW Infiltration Basin with Combination of Concrete and Grass Top	ROWSGS
Green Roof	ROW Infiltration Basin with Concrete Top	Subsurface Detention System
Impervious Area Reduction	ROW Infiltration Basin with Grass Top	Subsurface Storage
Media Filter	ROW Median	Synthetic Turf Field Storage Layer

Figure Source: OMB

Category 14 – Water Managed by Wetlands

Indicator 1 (Final Indicator) – Wetland area

Description: Proportion of land cover that is natural wetland area

Background and Justification: Wetlands function as a buffer for flooding events by trapping, slowly releasing, absorbing, and evapotranspiring flood waters.[216] Wetlands occur naturally in New York City, but may also be constructed or augmented. Wetlands can help filter out pollutants such as heavy metals and hydrocarbons.[217] They significantly enhance water quality from sources like agricultural runoff, urban areas, and wastewater.[218] The effectiveness of wetlands depends on factors such as their size, design, vegetation, location, water type and quantity, pollutant levels, degradation, and local conditions like climate.[219]

Processing:

- Source: NYC Open Data Wetlands Map;[220] U.S. Geological Survey Wetlands Mapper[221]
- Most Recent Data Update: 2020
- Assumptions: This does not necessarily include engineered spaces such as green infrastructure Bluebelts,[222] but may incorporate these features where they are built into existing wetland areas. Double counting may occur between canopy cover and forested wetland area for forested wetlands, though wetlands take unforested forms and may provide benefits separate from the canopy benefits alone. Furthermore, double counting may occur between this Indicator and permeable surfaces/greenspace, but wetlands provide more substantial benefits compared to other vegetated spaces. This dataset removes Estuarine–

Water and related polygons, such as riverine features from the area calculation, due to area calculation inaccuracies observed.

- Notes: Wetlands are included if they are included in the NYC Parks Department's wetland inventory, as well as the NY State and U.S. Federal wetlands delineations. The NYC Parks Department's wetlands are mapped using remote sensing analysis in conjunction with the University of Vermont. The NYC Parks Department has verified and updated this through an assessment with the Natural Areas Conservancy on the ground.

Indicator 2 (Final Indicator) – Wetland health

Description: Percent of wetland area that is classified as Healthy, Threatened, or In Transition

Background and Justification: The health/risk of the wetland helps with the assessment of how effective each feature will be at protecting against flooding events.[223] For the purposes of this study, health of the wetland features is split into four categories (healthy, degraded, in transition, and threatened) based on the source data. Wetlands can suffer from degradation due to various factors including wastewater, industrial pollution, human disturbances, and invasive species.[224] Many studies have expressed the critical value of wetlands.[225] Yet, wetlands across the U.S. have experienced continual damage to their health.[226] Degradation of wetlands reduces their efficiency in performing ecosystem services, such as water management.

Processing:

- Source: NYC Nature Map;[227] Natural Areas Conservancy; U.S. Geological Survey Wetlands Mapper[228]
- Most Recent Data Update: 2014
- Assumptions: Only city-owned wetland property is assessed, though much wetland space may be privately owned. Only "degraded" as a classification is not included in the determination of wetlands as having high health, as this represents wetlands where substantial restoration is needed. The health assessment is conducted by the NYC Parks Department and Natural Areas Conservancy according to rubrics for salt marshes, freshwater wetlands, and streams outlined in the 2021 Wetlands Management Framework and for forested wetlands outlined in the 2018 Forest Management Framework.[229]
- Notes: None

Category 15 – Water Managed by Sewer Coverage

Indicator 1 (Final Indicator) – Area served by sewers

Description: The proportion of city area that receives sewer service by either combined or separate sewer pipes.

Background and Justification: Stormwater management practices can take two primary forms: infiltration and conveyance. Infiltration allows water to seep into the ground or storage areas (see *Permeable Surfaces* and *Green Infrastructure* Categories above). Conveyance moves water away from the site of rainfall, to outfalls or treatment locations. Sewers, the primary type of conveyance, are widely considered to be the most effective type of stormwater management strategy, due to the large quantities of water they can move from a site.[230] Hybrid approaches can help to handle different types of storms, but sewers are necessary in urban spaces where buildings, utilities, impervious surfaces, and other obstructions limit alternatives.

Processing:

- Source: NYC DEP Sewershed Map[231]
- Most Recent Data Update: 2020
- Assumptions: Understanding the areas serviced by different types of sewers may be a first step, but is not sufficient for capturing the amount of water conveyed. Until conveyance information can be incorporated, this is a partial proxy.
- Notes: Most of the city area is covered by sewers/direct outlet drainage.

Indicator 2 (Final Indicator) – Separate sewer coverage

Description: The proportion of city area that receives separate (MS4) sewer service.

Background and Justification: New York City is split into two types of sewer systems: combined sewers and separate sewers (also called Municipal Separate Storm Sewers, or MS4). Separate sewers have separate conveyance systems for sanitary wastewater (from buildings) and stormwater (from street drains).[232] Approximately 40 percent of the city is serviced by separate sewers. During a rain event, combined sewers can struggle to keep up with the high volume of water from rain and the baseline level of sanitary wastewater. Separating these allows for dedicated stormwater pipes to convey stormwater during a rain event, which can reduce flooding.[233] This can also help prevent sanitary wastewater from backing up into buildings and causing additional flooding indoors. A detriment of the separate system is that stormwater, which may carry pollutants, does not go through wastewater treatment plants. However, this is balanced against the fact that during heavy rain events, combined sewers discharge sewage into water bodies when wastewater treatment plants cannot keep up with the volume of water.

Processing:

- Source: NYC Open Data Municipal Separate Storm Sewer System (MS4) Data[234]
- Most Recent Data Update: 2020
- Assumptions: This assumes that separate sewers will benefit stormwater management compared to combined sewers, though this may be dependent on other conditions, such as

the size and location of pipes. Until more precise conveyance information can be incorporated, this is a partial proxy.

- Notes: None

LIMITATIONS

Measuring KPIs as proportions allows for inter-neighborhood comparisons, but also has downsides compared to evaluating overall levels of protection across locations. For example, a neighborhood with five out of 10 protected buildings from coastal flooding would show as being 50 percent protected, whereas a neighborhood with 200 of 1,000 buildings protected would show up as 20 percent. More buildings are protected in the latter example and the average protective level across neighborhoods is not 35 percent (the average), but rather 20.3 percent. Furthermore, showing scores as relative to one another (normalized by location) provides information on which neighborhoods have more average adaptive measures, but at this time this is not directly scaled to levels of risk or vulnerability.

An alternative to normalizing inventory results by location is to normalize to targets and goals. The option to make scores relative to goals is limited at this time because goals are established citywide and not at a neighborhood-level. Some goals are clearly stated (e.g., 30 percent canopy cover) while others are implicit (e.g., healthy tree canopy). Downscaled goals at the neighborhood level reference established targets and not *potential*. The potential to achieve goals varies by neighborhood (e.g., not all neighborhoods will be able to achieve 30 percent cover, which is a citywide target). Normalizing to goals will be investigated more in future iterations of this work.

Scores are impacted by the KPIs chosen–including a different set of KPIs would change the results. Scores may also be skewed by data availability. While KPIs are chosen for their applicability across geographies, data gaps may exist. Furthermore, in its current form, a "total score" averages all hazard scores equally, though locations may be impacted by hazards at different magnitudes. Future iterations could seek to weigh the hazard scores by intensity in a neighborhood, though this introduces questions about how to compare hazards to one another when they represent different types of risk (e.g., property damage, mortality, flooding, heat).

Weightings are inherently subjective and may not accurately represent the directionality or level of relative importance of KPIs. Furthermore, some KPIs may be more important for some locations over others, though at this time KPI weightings are applied uniformly to all NTAs. In the future, weightings could be applied to each NTA depending on their individual vulnerability, hazard, or level of attainment, need, or potential for each KPI, if enough data are available.

Selected KPIs primarily represent physical measures, though this is not to understate the importance of social and community capacity, such as emergency preparedness plans, neighbor-to-neighbor support, economic resources, outreach, education, communication types, studies, technology improvements, or sensors and monitoring, to name a few strategies. These could be included in future iterations depending on the level of established research support and data availability. Some physical measures are excluded at this time due to lack of data, such as information on maintenance, state of good repair, pipelines of investment, or staffing, for example.

At this time, KPIs most directly map to capital work and physical assets, though Climate Budgeting focuses on both capital and expense budget alignment with climate goals. This will be an area for continued work in future iterations of these analyses.

At this time, infrastructure and out-of-city networks are largely excluded from analysis. For example, coastal protective measures for city streets and transit networks are important for considering impacts to residents, visitors, and public infrastructure. Similarly, telecommunications, power, and other utilities that are not solely within the city purview are pertinent for measuring resiliency. These types of metrics are not included in this iteration due to complexity of analysis. This will be a focus of future inquiry.

Measures of indoor heat at this time do not include KPIs for energy cost burden, due to data availability at the neighborhood level (though this is known to be an important consideration for A/C usage and outcomes). Other measures related to emergency services, power service interruptions, and other types of metrics are also not included due to data availability. This will be a focus of further inquiry.

At this time, KPIs for stormwater flooding are limited. The NYC DEP is undergoing an in-depth stormwater analysis and this will be a point of collaboration to investigate expanding this area of Climate Budgeting work in tandem in future years.[235]

The NTA is an imperfect level of analysis for management, as interventions are often at a sub-neighborhood scale and other tools, such as those on social vulnerability, may be at other scales. See the previous sections for more details. Additional statistical geographies will be examined in the future with comparability and actionability in mind.

Scoring here only conveys effects of adaptive measures additively–all KPIs are treated as complementary in the indexing, augmented only by their weighting. In actuality, some KPIs may interact with others in ways that are more than the sum of their parts (e.g., tradeoffs, multiplicative effects, etc.). For example, in some but not all cases redundant protections are important for resiliency, as they reduce the risk when one intervention fails (e.g., the break or overtopping of a flood barrier), so they cannot be considered interchangeable.

RESILIENCY EXPOSURE FORECAST

This analysis serves as an inaugural effort to evaluate the scope of planned adaptation initiatives and their potential to reduce exposure to escalating climate risks. While it is not feasible to mitigate all risks across every type and magnitude of climate event, it is essential to assess which risks are likely to be addressed through planned adaptation efforts and how these measures affect future risk. This work builds on the Resiliency Exposure Inventory.

At this stage, three hazards were treated with various forecasting exercises to compare what the future could be like with and without targeted adaptation efforts: outdoor heat, coastal flooding, and indoor heat. Outdoor heat and coastal flooding projections are conducted at the Neighborhood Tabulation Area (NTA) level, highlighting differences in implementation across neighborhoods for citywide goals. Indoor heat projections are conducted at the city level based on available data. Forecasting is not conducted for stormwater flooding at this time due to ongoing modeling being undertaken by DEP. This will be considered for more analysis for Climate Budgeting in the future.

OVERVIEW

The document walks through the steps OMB undertakes to forecast resiliency *exposure*. Refer to previous sections for more information on exposure versus hazards and vulnerability.

- The first section, **Forecast Planning**, discusses selections of actions and scenarios to forecast.
- The second section, **Outdoor Heat Forecast**, describes the forecast of temperatures across city neighborhoods using an urban heat flux model. This is broken into two main subsections:
    - *Control Scenario* describes the methods to determine future local heat in the absence of new adaptation interventions
    - *The Planned Action Scenario* describes the methods to determine how tree canopy expansion could change heat profiles compared to the Control Scenario
- The third section, **Coastal Flooding Forecast**, describes the forecast of at-risk buildings (buildings in areas likely to flood) using spatial analysis. This is broken into two main subsections:
    - *Control Scenario* describes the methods to determine how many buildings will be at risk of flooding in the absence of large-scale coastal flood protection projects.
    - *Planned Action Scenarios* describes the methods to determine how many buildings will have risk managed if various infrastructure projects are built.

- The fourth section, **Indoor Heat**, describes the estimation of public schools with A/C at the citywide level. This is described separately for classrooms and public assembly spaces, such as gymnasia. This forecast shows how the city's school electrification targets could implicate A/C uptake for schools.

For more information on the research behind trees as a determinant of outdoor heat, coastal flood protections, and the impacts of heat on school students, see the previous sections of this Appendix.

FORECAST PLANNING

To forecast the effects of targeted actions on hazard exposure–referred to as Planned Actions–OMB uses projections of climate conditions developed by the NPCC for decadal periods out to 2050. For each hazard, described individually in the following sections, neighborhood-level (NTA) data are used to project the impact of those adaptation measures, and the residual risk that remains.

For each hazard's forecast, a Control Scenario is developed for each decade serving as an example of the future under business-as-usual conditions, followed by one or more Planned Action Scenarios of potential action. The Control Scenario reflects changes determined solely by NPCC climate projections, without incorporating any other changes in city conditions or the broader contextual environment. The Planned Action Scenarios are based off the Control and add in Planned Actions that represent potential changes to the city in preparation for and response to worsening risks. These are likely to alleviate some of the future risk compared to the Control Scenario by providing adaptation solutions at scale.

Selecting Planned Actions

Three criteria are used to determine which Planned Actions should be modeled and included in the forecast:

- **Resiliency Impact:** Actions impact the resiliency of the city in a systematic or programmatic way. Actions meeting this standard contribute to long-term risk reduction across neighborhoods, infrastructure systems, or key city services.
- **Commitment:** Actions are required by local legislation OR committed to by a mayoral administration. This ensures that the modeled actions reflect legally or politically endorsed priorities, including executive orders, climate action plans, or public commitments.
- **Responsibility:** Actions will be carried out by mayor-appointed leadership OR funded in the city's budget or capital plan. This ensures that projects have clear ownership and the necessary financial support for implementation.

To determine which Planned Actions could be included in the hazard-specific forecasts, a series of steps are taken. First, research is conducted based on the KPIs used in the inventory (see previous sections) to answer the questions:

1. *Can this be forecasted?* A KPI can be forecasted here if the city has a specific target for the KPI or if a desired direction (e.g., increase) for action is known.

2. *Can this be translated to impact?* The intent of forecasting is not only to see how the KPIs themselves change over time, but what the impact would be on the city's climate exposure if they change. A KPI can be translated to impact if there are enough available data and quantitative modeling options to project exposure to hazards as influenced by the city's plans and goals.

3. *Can #1 and #2 be answered for the neighborhood level?** Just as with the inventory, the forecast analyses are conducted at the NTA level due to the localized nature of climate risk and resiliency. City plans and impacts need to be assessed at the neighborhood level to be completed as part of this work. If the answer is "no" to this question, the target is deferred to a later date. *An exception is made for indoor heat, to show a citywide view in the absence of local planning data.

OMB started with the list of goals laid out in the 2022 *PlaNYC: Getting Sustainability Done* report.[236] Other targets laid out in local laws, mandates, executive orders, city agency plans, and initiatives were then added. From there, a systematic process was used to whittle down the list and determine which targets could be used in forecasting Planned Actions for this iteration of Climate Budgeting. In the future, additional Actions can be added.

FIGURE 20 | PLANNED ACTIONS DECISION PROCESS

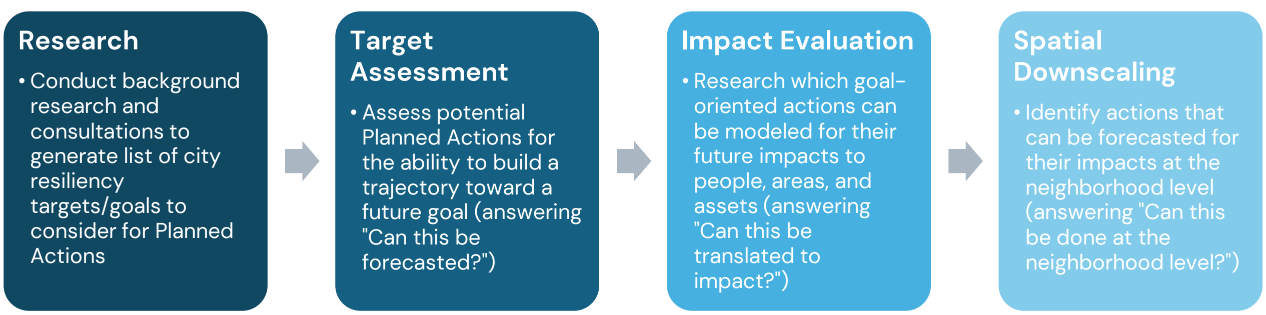


Figure Source: OMB

This process resulted in a list of Planned Actions to be forecasted for this iteration of Climate Budgeting and a further list of potential Planned Actions to be investigated in the future.

- Increased canopy due to growth and planting: Canopy growth refers to the natural expansion of trees from growing year-on-year. Planting is a manual intervention conducted by the city. Canopy size implicates widescale outdoor heat as trees exchange water in the air. Trees are just one strategy to reduce outdoor heat.

- Neighborhood-scale coastal flood barriers in the face of high-tide and storm-surge flooding: These reflect large physical protective measures located on the coasts and around water bodies in the city. This is just one type of measure, as individual buildings can also protect themselves and neighborhoods can build other forms of resiliency, such as emergency preparedness and natural measures.

- The city's Leading the Charge initiative aims to electrify schools in the coming years. Electrification will lead to dedicated or central A/C in those schools. A/C may be provided through other means, but electrification is specifically examined.

FIGURE 21 | FORECASTED PLANNED ACTIONS

Outdoor Heat	Coastal Flooding (Two Parts)	Indoor Heat
Increasing canopy cover due to: 1. Tree growth 2. Street tree planting	Construction of neighborhood-scale coastal flood barriers for: 1. High-tide flooding 2. Storm-surge flooding (with sea-level rise) Presence of federal projects, such as the NY & NJ Harbor and Tributaries Feasibility Study (NYNJHATS)	A/C uptake in schools as per: 1. Leading the Charge school electrification initiative *at the citywide scale*

Figure Source: OMB

This first resiliency forecast marks a significant step forward in planning for climate adaptation, with future iterations set to incorporate additional Planned Actions, assets, and more granular evaluations as new data become available.

Purpose

Projections and forecasts can help fill an important gap to make sure the city's investments are spent efficiently and effectively, opportunities are maximized, and data are transparent on how city work affects those on the ground for years to come. These Planned Actions represent the beginning of this work to better understand how initiatives can alleviate the impacts of worsening climate change over time. These analyses show what is and will likely be protected and where gaps remain, comparing the Planned Actions future against Control future. Conducting this work at a neighborhood view allows the consideration of equity in decisions by seeing which areas are likely to have the greatest gaps in adaptation remaining in the future.
The year 2050 is selected as the end-year benchmark for two reasons:

1. NPCC data exist for this future time point, allowing the development of a Control scenario out to 2050, and

2. 2050 aligns with many of the city's climate goals, such as net-zero emissions. Resiliency actions often have less concrete target dates than do emissions actions. To be able in the future to add many resiliency Planned Actions together to get a sense of overall trajectory, 2050 is selected as a consistent and comparable year. Mid-century leaves several decades

to achieve goals, but with a foreseeable future within the time horizon of many projects' useful lives (25 years away at the time of writing).

Limitations

Planned Actions are a partial picture of adaptive measures and do not represent all the work being done that could impact the effects of climate change on communities. In future iterations, more Planned Actions will be considered, along with other ways to show future adaptation scenarios. Planned Actions may be changed at any point and inclusion here does not mean these efforts cannot be altered, cancelled, or augmented. Analysis will be updated in future to account for changes to the science, project design, program parameters, and other considerations.

At this time, Planned Actions and Control scenarios are developed using single NPCC projections (see below sections for details for each hazard). In the future, projections could be conducted using several NPCC scenarios to show a range of forecasted impacts based on climate conditions. This would reflect the various probabilities put forward by the NPCC (10, 25, 75, and 90 percent). For the purposes of this first iteration of analysis, single projection probabilities are selected (e.g., 75 percent) as described below.
While the outdoor heat and coastal flooding forecast is conducted at the NTA level, any spatial scale will come with caveats. NTAs are still too large to account for changes in felt impacts at a fine scale (e.g., the felt heat under a tree or the impact of flooding from one block to the next) and are also too small to account for connected, system-wide impacts (e.g., transit networks that route through impacted neighborhoods). This will be investigated more in the future.

OUTDOOR HEAT FORECAST

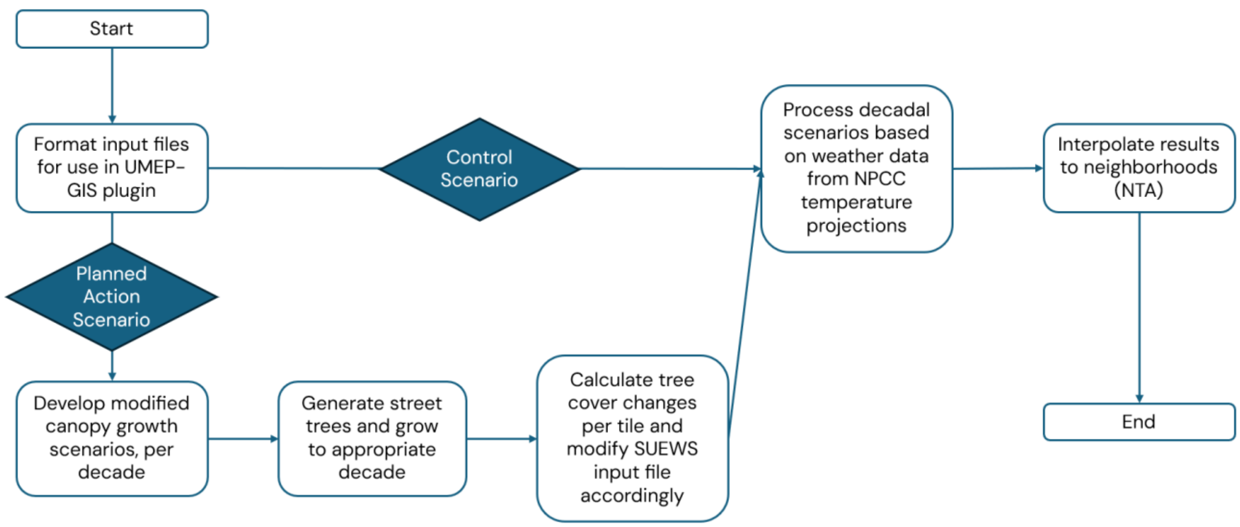
How does the forecast approach local outdoor heat?

The inventory (see previous sections) identifies baseline levels of adaptation measures in areas that face present levels of exposure to increasing temperatures. As highlighted in the inventory's results, heat-related risks and adaptation measures are unevenly distributed across neighborhoods. This necessitates spatially sensitive modeling approaches. The NYC Health Department has identified neighborhood environmental and social factors associated with increased risk to create the HVI, which has historically been used by the city to prioritize neighborhoods when implementing solutions to mitigate heat risk. This includes the NYC Parks Department's decisions on where street trees may be planted to maximize return on investment and reduce inequities.

The NPCC provides projections that identify how various greenhouse gas emissions scenarios are expected to impact the lived experiences of city residents by being able to use these data on warming temperatures to better understand factors of felt-heat on the ground, in buildings, and across populations. OMB's work takes a first step to translating projections to the neighborhood level for air temperature, and can be built on further in the future. For the scenarios described in this section, temperature change refers to the NPCC4 75th percentile projections from 2024 (month of July), to use the most recent projections. The 75th percentile is used because it is intermediate (rather than the more extreme 90th percentile) but still conveys serious risk.

This forecast is one step in aiding science-based decision making around heat-impactful activities in the city, including but not limited to tree planting. Conducting this forecast allows a view of the effects of actions added together and creates a basis for evaluating future actions and identifying data gaps where more information is needed for action.

FIGURE 22 | PROCESS FOR OUTDOOR HEAT FORECAST



See below sections for explanations related to UMEP and SUEWS; Figure Source: OMB

Planned Actions: Increasing Canopy Cover

- The tree canopy cover Planned Actions aligns with the city's commitment to achieve 30 percent canopy coverage outlined in *PlaNYC*, including actions to:
    - *Expand the Tree Risk Management Program*
    - *Maximize Tree Preservation and Planting Opportunities*
    - *Establish the Climber and Pruner Training Program Pilot*
    - *Ensure That All New Buildings Meet the City's Street Tree Planting Requirements*
    - *Incentivize New Yorkers to Steward Green Spaces*[237]

  This work toward achieving 30 percent canopy cover is being realized through the development and implementation of an Urban Forest Plan, as laid out in Local Law 148 of 2023.[238]

- Reaching a 30 percent canopy goal from the city's current level of coverage requires an additional 15,388 acres of canopy across public and private property that can be achieved in two primary ways:[239]

    1. Preserve, steward, and protect existing trees to reasonably maximize canopy growth
    2. Planting new trees

- Between 2010 and the most recent data capture year, 2017, the successful maintenance of existing street and park trees and continued protections of current trees in urban areas contributed to an overall 1.7 percent increase in canopy cover, totaling 3,252 additional acres. 87 percent of the canopy growth between these years is attributed to growth of existing trees, many of which exist on private property–the NYC Parks Department is responsible for just over half (53 percent) of existing city tree canopy.[240] Street trees account for just one component of the urban tree canopy. Growth and planting are expected to continue to aid the city in reaching its 30 percent canopy goal by 2050 and represent impactful strategies for alleviating outdoor heat. In this analysis, tree canopy change due to tree growth is assumed to continue at historical rates going forward across jurisdictions (public and private); assumptions are not based on specific level of maintenance.

Control Scenario

How hot will neighborhoods become in the absence of new adaptation actions?

To develop the scenarios used to forecast the effects of the Planned Actions, a **Control Scenario** is developed to provide a point of comparison. To do this, the key steps are:

1. Identify a model that could downscale citywide temperature projections to neighborhoods
2. Gather input data needed to model (which differ based on idiosyncratic neighborhood characteristics, such as vegetative cover and building height)
3. Run the model to determine how much heating is occurring and translate the local effects to NTAs

This Control Scenario is developed using the Surface Urban Energy and Water Balance Scheme (SUEWS) tool.[241] SUEWS has been tested in locations in the United Kingdom, United States, and Canada[242] and is based off longstanding models of urban water balance and urban evaporation-interception.[243] SUEWS is a physical-based model that utilizes commonly measured meteorological variables and information about area surface cover to simulate energy and water flux. SUEWS provides scalable results in various accessible platforms, such as free software namely QGIS. The version of SUEWS used in the forecast is from the Urban Multi-scale Environmental Predictor (UMEP) plugin available in QGIS.[244] The inputs used in this scheme are:

Meteorology

- The European Centre for Medium-Range Weather Forecast's (ECMWF) fifth generation reanalysis for global climate and weather (ERA5)[245]
    - Single Grid (40.75, -74)
- ERA5-Land Hourly[246]
    - Single Grid (40.75, -74.05)
    - Used for the following variable: Soil moisture deficit
- NPCC4 mean monthly temperature based on 75th percentile projection[247]
    - Decadal periods: 2030s, 2040s, 2050s

Surface Characteristics (from NYC Office of Technology and Innovation)

- 1-foot resolution Highest Hit LiDAR Digital Surface Model (DSM)[248]
- 1-foot resolution Highest Hit LiDAR Building Digital Surface Model (Building-DSM)[249]
- 1-foot resolution Vegetation Canopy Height Digital Surface Model (CDSM)[250]
- 1-foot resolution Hydrologically Enforced Digital Elevation Model (DEM)[251]
- 8-class 6-inch resolution Land Cover (LC)[252]
- 6-inch resolution Tree Canopy Change (2010-2017)[253]

Energy Use (Socioeconomic Data and Applications Center (SEDAC))

- Gridded Population of the World, Version 4 (GPWv4): Population Density, Revision 11[254]

SUEWS Input Preparation

To develop the spatial relationships for the model, New York City is divided into 1,052 hexagonal grids, each covering an area of 1 square kilometer. These sections are then mapped using a coordinate system specifically designed for the New York City region (EPSG:2263—NAD83 / New York Long Island). The total count of hexagons in the grid is then calculated by covering the full area of the city's DEM, excluding areas outside NYC's official boundaries as defined by the NYC Department of City Planning. To account for any potential incomplete values and reduce error, at least 85 percent of the polygon area has to be within city boundaries to be included. To reduce sample error with hexagons covered primarily by water, neighborhoods with hexagon area less than 15 percent within city boundaries are designated the mean temperature of the surrounding hexagons, using the Zonal Statistics tool in QGIS.

Population density is assigned to each hexagonal grid using the GPWv4 Revision 11 and then converted from square kilometers to hectares. SUEWS uses this to generate assumptions for anthropogenic heat. Note that population density is assumed to remain constant over time, given the city's projections of future population are at the borough level.[255] Extrapolating NTA-scale population based on these projections may be considered for future iterations to calibrate future heat.

Weather data is provided from ERA5-Hourly and ERA5-Land Hourly and condensed to a timeline of July 14, 2017 to July 22, 2017. This week represents a typical summertime week, typically within the hottest period, that matched the year of most recent city-run LiDAR flyover evaluation that provides data on city cover characteristics (2017). Future iterations of this work may use updated weather data to match the newest surface characteristic data available. The city will collect new LiDAR data every five years from 2025, according to Local Law 148 of 2023.[256] NPCC4 mean air temperature (75th percentile) data are converted to degrees Celsius for the following decadal periods: 2030s, 2040s, 2050s.

While incoming shortwave radiation is impacted by shadows, such as from tall buildings, and this may vary at different times of year, one week at the hottest time of year is selected to understand potential warming impacts in the warmest periods, with variation smoothed at the resolution used.

Once added, meteorological data are reformatted using the Metadata Processor tool in UMEP. The weather data observed are as follows:

- Incoming shortwave radiation (watts per meter squared)
- Wind speed (meters per second)
- Air temperature (degrees Celsius)
- Relative humidity (percent)
- Barometric pressure (kilopascal)
- Rainfall (millimeter)
- Observed soil moisture (water fraction by volume)
- Wind direction (degrees)

One version of these meteorological data is generated for each decadal period (2017, 2030s, 2040s, and 2050s). Each version contains the relevant air temperature projection applied to the input data.

Air temperature is the only projected meteorological variable used in this analysis—the city does not presently have widely used (e.g., NPCC) projections for other variables, such as humidity and wind. Thus, conditions developed in this model will only be influenced by a projected increase in air temperature. Future versions of this model may consider other projected meteorological variables as they become available. This is an important limitation, as surface temperatures and heat impacts depend heavily on humidity and wind, particularly for how urban heat islands manifest and how heat is felt on the ground. However, SUEWS, as a local surface energy balance model has the same uncertainty as most future climate projections, in which sensible heat flux is dependent on surface energy partitioning, and is still a good fit for use in this type of modeling.

Building morphology is generated using the Urban Morphology: Morphometric Calculator (Grid) tool in the UMEP settings. Listed below are the run settings:

- Vector polygon grid: Hexagon_grid.shp
- ID field: fid
- Search method: Throughout the grid extent
- Search distance from grid cell centroid: 0
- Wind direction search interval (degree): 5
- Raster DSM (only buildings or vegetation exist): No
- Raster DSM (3D objects + ground): Building-DSM
- Raster DEM (only ground): DEM

- Ignore NoData pixels: Yes
- Roughness calculation method: Kanda et al. 2013[257]
- Output folder: Building_Morphology

Vegetation morphology is generated using the Urban Morphology: Morphometric Calculator (Grid) tool in the UMEP settings. Listed below are the run settings:

- Vector polygon grid: Hexagon_grid.shp
- ID field: fid
- Search method: Throughout the grid extent
- Search distance from grid cell centroid: 0
- Wind direction search interval (degree): 5
- Raster DSM (only buildings or vegetation exist): Yes
- Raster DSM (3D objects + ground): Blank
- Raster DEM (only ground): Blank
- Raster DSM (only 3D objects): CDSM
- Ignore NoData pixels: Yes
- Roughness calculation method: Kanda et al. 2013[258]
- Output folder: Vegetation_Morphology

Land cover is reformatted to be suitable in UMEP-related applications. LC is converted using the Land Cover Reclassifier UMEP tool. The classes for such are below:

- Paved
- Buildings
- Evergreen trees
- Deciduous trees
- Grass
- Bare soil
- Water

Once reclassified, the Land Cover Fraction Grid tool in UMEP is applied to the data. Below are the run settings:

- Wind direction search interval (degrees): 5
- Search throughout the grid extent: Yes
- Search distance: 0
- Vector polygon grid: Hexagon_grid.shp
- ID field: fid
- UMEP land cover grid: LC_UMEP_FMT
- Ignore NoData pixels: Yes
- Output folder: LC_CNTRL

Once all required files and folders are calculated, SUEWS Prepare is used in the UMEP toolbox to generate all the needed files for SUEWS Advanced:

- Polygon grid: Hexagon_grid.shp
- Building morphology: build_IMPGrid_isotropic.txt
- Land cover fractions: LC_LCFG_isotropic.txt
- Tree morphology: veg_IMPGrid_isotropic.txt
- Meteorological data: July_2017
- Population density: Pop_ha calculated field in Hexagon_grid.shp
- Initial conditions: Leaf cycle: Summer (100 percent)
- Anthropogenic: # 771: Preset coefficients for NYC (Sailor et al. 2015)[259]
- Daylight savings and UTC: 87 and 304, -5

The previous step is subsequently repeated for all decadal periods, only changing the Meteorology data input to match the correct decade for the Control Scenario. These SUEWS model inputs are used for the baseline period.

Generating Temperature Projections

After each input folder is created using the inputs from the previous step, each SUEWS decadal period is processed in the SUEWS v2020a tool within UMEP. The run settings are set to default UMEP settings, including output time resolution in minutes, which is 60. See below for the keystroke settings for each:

- Input folder: requested SUEWS Prep folder
- Net radiation method: Ldown from Ta and RH (Jarvi et al. 2011)[260]
- Anthropogenic heat flux method: Modeled (Allen et al. 2010)[261]
- Storage heat flux method: Objective hysteresis model (OHM)
- OMH option: From Q*
- Roughness length for heat method: Kawai et al. 2009[262]
- Soil moisture deficit method: Modeled
- Atmospheric stability method: Campbell & Norman 1998 etc.[263]
- External water use method: Modeled data
- Aerodynamic properties: Observed data
- Output time resolution (minutes): 60
- Output folder: Same as input folder

Partitioning an output time resolution of 60 minutes for these scenarios grants maximum flexibility in visualizing and data extraction after the scenarios are developed. Having control of the runs after they are complete allows for outputs to be taken for the mean (e.g., diurnal, daytime, nighttime) but also for a specific time of day (e.g., 2pm, 3pm, and 4pm) without running the full suite of inputs into the model each time.

To generate and extract the spatial data from the scenario folders in the SUEWS Advanced process, the SUEWS Analyzer tool in the UMEP Post-Processor toolbox is used. Within the SUEWS v2020a scenario folder, there is a file called RunControl.nml. This file has text that directs the model to each generated text file per hexagon grid from the directory. After the correct RunControl.nml file is selected for the requested scenario, the following keystrokes are selected to generate GeoTIFF files of the requested variable, mean air temperature at 2 meters (2m) above the surface:

- Variable to analyze: Air temperature at 2m
- Year to investigate: 2017 (2030s, 2040s, 2050s)
- Time period (DOY) to aggregate: 195-203 (July 15th—22nd)
- Investigate specific time of day: 13:00, 14:00, and 15:00. (These are run separately and then averaged together)
- Average: Yes
- Vector polygon grid used in SUEWS model: Hexagon_grid.shp
- ID: fid
- Save as GeoTIFF: Yes
- Irregular grid (not squared): Yes
- Pixel resolution: 15m
- Output filename: July_20xx_mean_t2m

FIGURE 23 | EXAMPLE OF DIRECT EXPORT FROM SUEWS SPATIAL FOR 2017

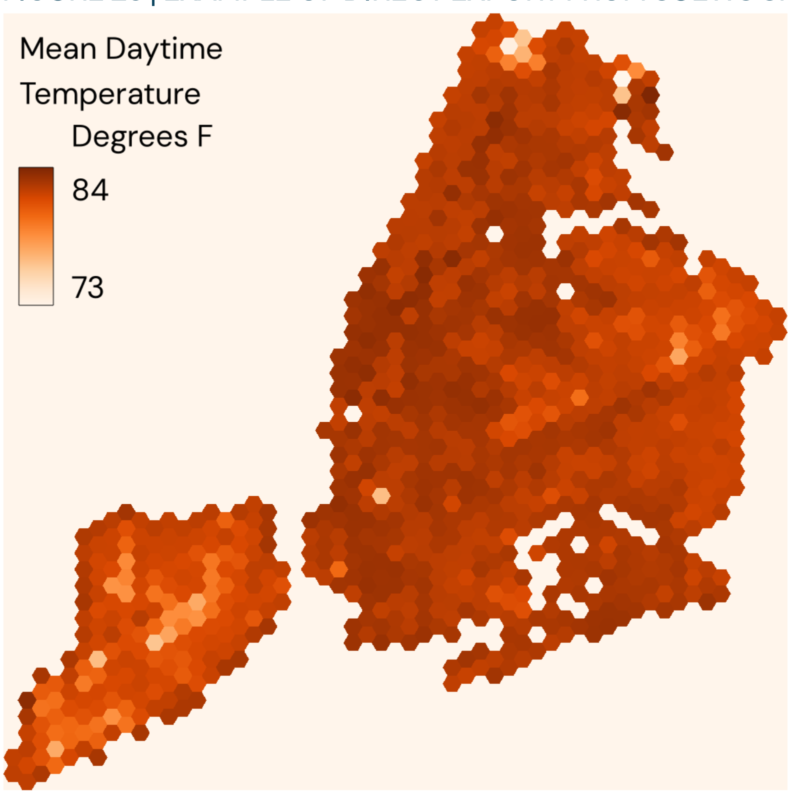


Figure Source: OMB

To translate these values from hexagon to NTA boundaries, the averages are calculated per NTA feature using the Zonal Statistics tool in QGIS. NTA averages are aggregated to be visualized by exporting them to other file types, such as shapefiles or Microsoft Excel spreadsheets. The figures below represent mean afternoon (1-3pm) temperature, aggregated by NTA. The decadal outputs indicate a gradual increase in summertime afternoon temperatures steady and consistent throughout the city. Compared to the Control Scenario, temperatures appear to increase upwards of 8-10 degrees Fahrenheit on average by 2050. This increase over time is quickly felt in more dense, urban communities and is in line with projections from NPCC4, which cites a citywide 6.4-degree Fahrenheit increase in mean monthly temperature for July.

FIGURE 24 | DECADAL OUTDOOR HEAT FORECAST CONTROL RESULTS

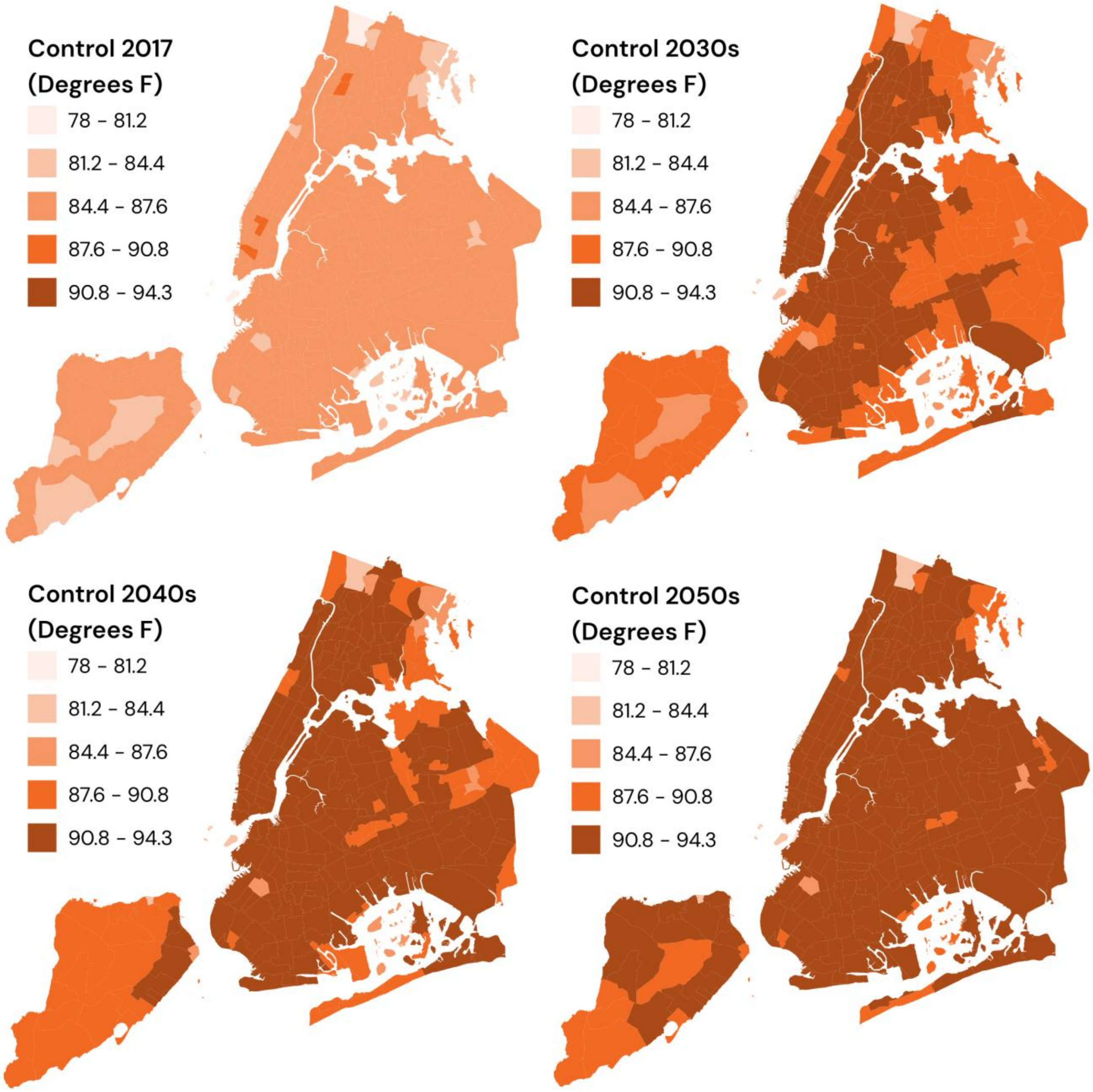


Figure Source: OMB

Planned Action Scenario

How hot will neighborhoods become if potential tree canopy expansion is realized?

On top of the Control Scenario, two considerations are included in a second scenario: growth of trees across private and public jurisdictions and planting of street trees by implanting the NYC Parks Department's Neighborhood Tree Planting Program. To do this, the key steps are:

1. Translate the planned actions to location-specific future changes per decade period
2. Input those changes into the model and run the results
3. Compare the Planned Actions results to the Control results to determine change over time based on action

Determining Decadal Canopy

Canopy growth and planting are considered part of the Planned Actions scenario. However, planting and growth are part of the NYC Parks Department's longstanding work and tree stewardship may happen regardless of the specific Neighborhood Tree Planting Program plans. However, these are concerted efforts and are deemed to be appropriate as Planned Actions.

According to the two most recent LiDAR surveys for which data are available at the time of analysis, between 2010 and 2017, the city's urban canopy—its total tree cover—grew by 1.7 percent. As information becomes available, these data can be updated to include the most recent LiDAR survey from 2021. The 1.7 percent increase in canopy cover is based on the proportion of canopy coverage over the city's entire area, which includes roads, buildings, and other land cover types, not just tree canopy area, represented as a canopy change rate. This calculation includes both gains in canopy cover and the loss of canopy from tree mortality, tree removal for development, and other effects. OMB refers to the net growth rate as the "growth rate" throughout and this accounts for loss and gain.

Additionally, the 1.7 percent increase can partially be attributed to the increase in citywide green roofs, but this iteration of the forecast does not include this growth. To understand how much the existing tree canopy has grown, OMB needs to compare the change only to the area that is covered by existing trees previously. To accurately project future changes, it is necessary to understand how much the canopy has expanded relative to is previous size, not just a citywide average. This provides a growth rate over time. This is calculated by the following formula:

((Canopy Gained - Canopy Lost) / Previous Canopy Area (i.e., for year 2010)) x 100

This provides the "percent canopy area" rate of growth, which is estimated to be 1.18 percent annually.

To estimate canopy growth for existing canopy to the appropriate decadal interval, growth is estimated using the Fixed Percentage Buffer tool in QGIS. Once the buffers are induced, the percent area coverage is calculated per individual hexagonal grid using the Overlap Analysis tool, one for each time interval:

- 2017 (benchmark)
- 2030
- 2040
- 2050

Once the overlap analyses are complete, the deltas between each decadal interval and the benchmark year are calculated and used as the growth rate to modify the land cover fraction in each SUEWS input file. The annual 1.18 percent buffer is applied for each interval, starting at the baseline year of 2017, then the year at which to start applying the plantings (according to the NYC Parks Department's Neighborhood Tree Planting Program) and then subsequently at the yearly periods matching the decadal projection periods. Growth is applied annually at 1.18 percent and added to match the appropriate interval year (i.e.; 2024-2017 = 7 years. 7 years x 1.18 percent = 8.26 percent, equating to a 108.26 percent increase in previous canopy area increase between 2017 and 2024). These projections apply to citywide canopy across jurisdictions (public and private property).

FIGURE 25 | GROWTH RATE FOR EACH SCENARIO

	2017 (Baseline)	2024	2030	2040	2050
Fixed Buffer (percent)	108.26	108.26	107.08	111.80	111.80

Figure Source: OMB

In addition to natural growth of existing canopy, canopy change is also driven by the strategic planting of street trees. To forecast tree planting, OMB followed these steps:

- **Data Source**: Analysis is based on information on planned implementation of the Neighborhood Tree Planting Program by the NYC Parks Department. The NYC Parks Department Department's Neighborhood Tree Planting program aims to plant the entire city on a 9-year cycle—prioritizing the most heat-vulnerable neighborhoods first.
- **Planting Zone Categorization**: Neighborhoods are divided into planting zones based on the NYC Parks Department's plans. Each zone is assigned 1) a "planting potential" total count (number of potential planting spots); and 2) a year for expected planting, scheduled between 2024 and 2035.
- **Tree Placement and Forecasting Approach**: Random points are assigned within each planting zone, with the number of points per zone (N) corresponding to the total potential planting spots identified by the NYC Parks Department. Tree planting potential is assessed by the NYC Parks Department through a combination of desktop and field analysis. OMB's forecasting relies on these assessments, using distribution within planting zones.
- **Limitations**: While trees may be clustered or planted strategically in reality, the analysis does not determine exact planting locations. Final locations will be decided in future years by Neighborhood Tree Planting Program staff, based on on-site suitability surveys.

To ensure that the randomly assigned street tree canopy would not be duplicative to existing canopy or buffers generated in the prior step (to account for annual existing-canopy growth), the spatial difference of each planting zone is taken of that which overlapped with the 2050 projected canopy coverage before assigning the points to each planting zone polygon.

To determine the size of canopy for newly planted trees, a standard new-tree canopy size is applied across all randomly distributed planting points. This size is determined in consultation with the NYC Parks Department using several resources:

- 2019 Street Tree ID Guide Top 24 List (24 most common street tree species)[264]
- Street Tree Approved Species Planting List (downloaded in February 2025)[265]
- McPherson et al. (2016) allometric equations for urban trees[266]
- NYC Tree Valuation Protocol[267]

The Top 24 list is cross referenced with the Approved Species Planting List to generate 17 species that are common and approved. One of these is removed (*Prunus virginiana)* and 11 added after consultation with the NYC Parks Department. Nine species are not matched for species-specific allometric equations using the sources above and are removed *(Quercus bicolor*, *Styphnolobium japonicum*, *Syringa reticulata*, *Quercus muehlenbergii*, *Quercus imbricaria*, *Quercus lyrata*, *Metasequoia glyptostroboides*, *Acer miyabe*, and *Aesculus glabra*), leaving 17 species in total for consideration (see the table below). Three of these species (*Celtis occidentalis*, *Quercus macrocarpa*, and *Gymnocladus dioicus*) do not have growth coefficients available in the Northeast region, so other regions (such as Midwest U.S.) are used.

All species are calculated for a standard planting size for the NYC Parks Department's street trees of approximately 3-inch caliper (7.62 centimeters). The NYC Parks Department indicates that this would likely result in trunk diameter at breast height for new plantings to be between 1.5 and 2 inches, so 1.5 inches is used as a conservative size. This corresponded to 3.81 centimeter diameter at breast height, which is the input into the species-specific equations, yielding the suggested new-planting canopy diameters for each species.

FIGURE 26 | ESTIMATED CANOPIES BY TREE SPECIES

Tree List	Canopy Diameter (Meters)
Acer rubrum	1.4081
Ginkgo biloba	1.4520
Liquidambar styraciflua	1.2823
Platanus x acerifolia	1.4237
Prunus cerasifera	1.5517
Quercus palustris	1.9704
Quercus rubra	2.1769
Tilia americana	1.1364
Tilia cordata	0.4783
Tilia tomentosa	1.0351

Ulmus americana	2.8805
Zelkova serrata	1.5055
Celtis occidentalis	1.4577
Quercus macrocarpa	0.9963
Betula nigra	3.2416
Gleditsia triacanthos	1.7719
Gymnocladus dioicus	1.5443

Figure Source: OMB

The average for all final species is taken to yield an average new-street-tree canopy diameter of 1.61 meters used for all modeled tree planting. Species are determined based on historical and presently approved planting lists in consultation with the NYC Parks Department. While species choices may change over time, the city considers future conditions when determining their planting pallet and so the species included here are a best estimate of average future planting considering climate change. Once the buffer totals for crown diameter are identified, the randomly assigned points are aggregated based on the year they are scheduled to be planted. Within the attribute table for the planting zones (which are carried onto the points layer when generated), there is a field that identifies the year in which the panting is slated to occur, from end-of-year 2024 to 2035. Each year is isolated from the planting group by attribute using the Select by Form tool in QGIS. The average crown diameter is applied via a buffer of the 17 tree species (1.61 meters) is applied to each point within the planting zones. Based on planting year, buffered trees are "grown" after they are "planted" using the Fixed Percentage Buffer tool in QGIS to simulate growth to the decadal intervals used in the analysis.

Projecting Neighborhood Heat

Once existing canopy growth and the area of new planting locations are projected and grown, the two parts are merged into one layer for each decadal interval. The merge is conducted using the Merge Vector Layer tool in QGIS and then geometries are fixed using the Structural method to ensure the use of buffered zones do not cause any linework inversions within the polygon.

The resulting shapefiles are then laid over the hexagon grid to calculate the percent area overlap. Using the Overlap Analysis tool in QGIS, the input layer is set to the Hexagon_grid.shp and the overlay layer is set to each of the decadal interval layers. The resulting shapefiles represent the canopy change over time per hexagonal grid, which will be crucial for modifying the SUEWS LC input files. These shapefiles are exported to Microsoft Excel and the percent change compared to the benchmark year (2017) is calculated.

After calculating the appropriate net canopy change between each decadal interval, the SUEWS LC input folder is cloned to a folder that represents the appropriate decade (e.g., 2030). Within the cloned LC folder, a .txt file called "LC_LCFG_isotropic" is opened in Microsoft Excel. The fields in this file represent the baseline land cover fractions of each tile within a SUEWS input. To estimate canopy cover, the class "DeciduousTrees" is increased to match the updated fraction calculated in the overlap analysis. These land class codes equate to a total value of one, so with every percentage increase to

DeciduousTrees, other land class features need to decrease equally. In most cases, “Paved” is subtracted first, with “Grass” subtracted from as a secondary option if paved area dropped to zero. For hexes with greater than 60 percent overlap with NTA-sized parks and greenspaces (e.g., Central Park, Green-wood Cemetery), “Grass” is subtracted first, then “Paved,” to account for the lack of paved surfaces and plethora of grassy area available. These use diminishing percentages to take from “Grass” first if available and then “Paved” for all remaining area that is required to be converted. See the above section on the inventory for a table of green NTAs. This approach assumes most new trees are planted over paved surfaces and grasses and will not account for attributes such as green roofs on top of buildings. This step is then repeated for each decadal interval.

After modifying the LC isotropic file for each of the decadal years, SUEWS Prepare is then run using these new LC values for the Planned Action Scenario. The rest of the run values per decadal years remain the same, only modifying the land cover fractions. Once the SUEWS Prepare folders are generated, the SUEWS v2020a tool and SUEWS Analyzer within UMEP is used to create the mean air temperature GeoTIFF files. Similarly to the benchmark runs, zonal statistics are used to calculate the mean air temperature across each NTA boundary. SUEWS Analyzer allows the user the same flexibility as before, so if granularity down to the hour is required, this is achievable within these settings.

The following maps show the differences between the Control Scenario for each decadal period and its related Planned Action Scenario, showing the effects of growth and tree planting. Cooling is displayed by quintile. Often dense, urban areas show the greatest amount of estimated cooling benefit.

FIGURE 27 | OUTDOOR HEAT FORECASTING RESULTS PER DECADE, BY SCENARIO

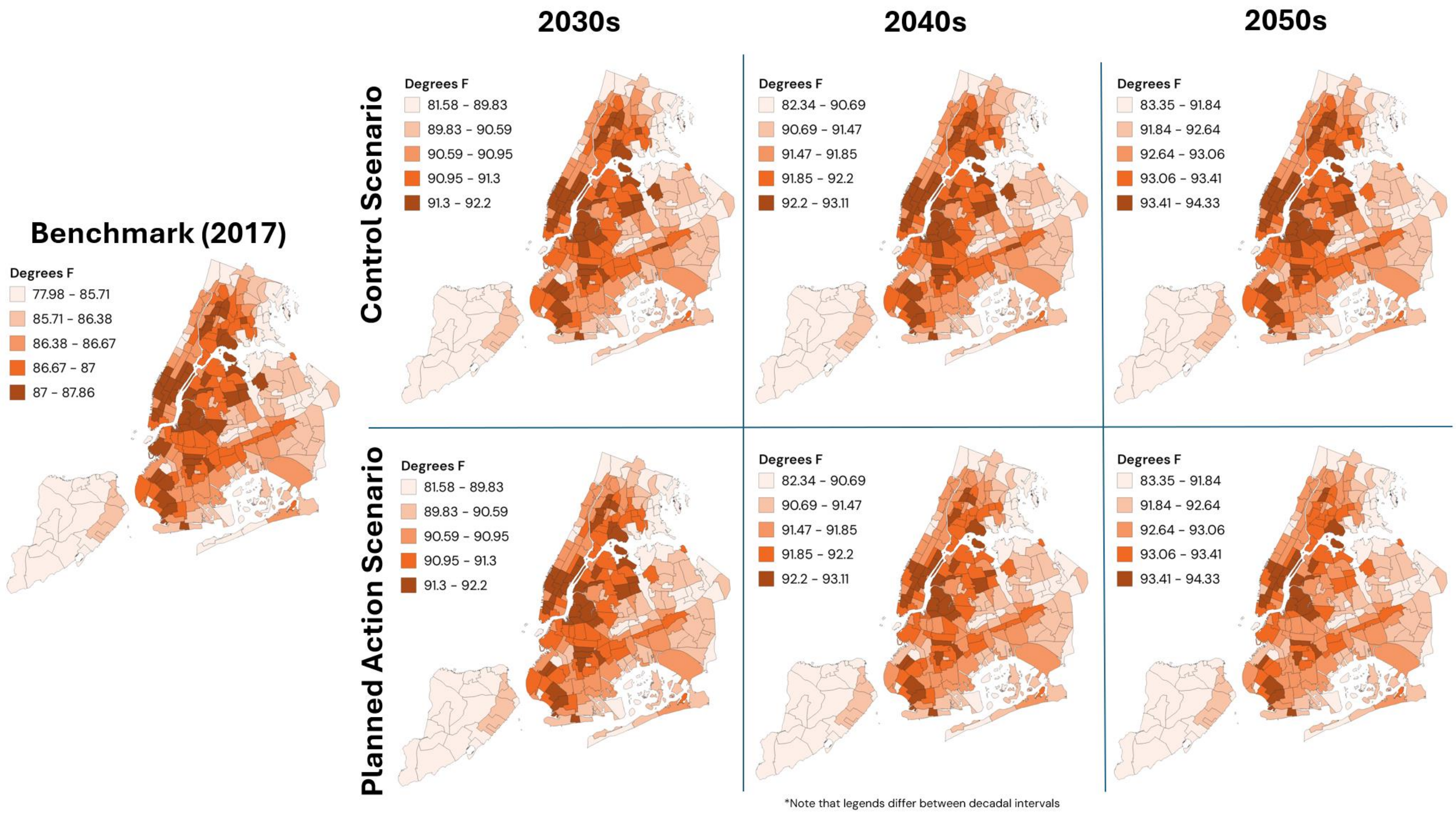


Figure Source: OMB

The table below presents average afternoon (1-3pm) temperature in degrees Fahrenheit, aggregated for each of the benchmark periods, per NTA.

FIGURE 28 | AVERAGE AFTERNOON TEMPERATURE RESULTS BY SCENARIO AND DECADE, BY NTA

NTA	Control 2017	Control 2030s	Control 2040s	Control 2050s	Planned Actions 2030s	Planned Actions 2040s	Planned Actions 2050s
BK0101	87.31	91.62	92.52	93.72	91.59	92.35	93.53
BK0102	87.37	91.68	92.58	93.79	91.53	92.40	93.59
BK0103	87.35	91.67	92.58	93.79	91.33	92.20	93.40
BK0104	87.36	91.67	92.57	93.78	91.53	92.40	93.58
BK0201	86.44	90.73	91.63	92.83	90.72	91.61	92.81
BK0202	86.90	91.21	92.11	93.32	91.18	92.02	93.22
BK0203	86.71	91.00	91.89	93.10	90.98	91.62	92.80
BK0204	86.69	90.98	91.88	93.09	90.98	91.63	92.74
BK0261	87.39	91.70	92.60	93.81	91.51	92.18	93.38
BK0301	86.99	91.30	92.21	93.42	91.28	91.84	93.02
BK0302	86.84	91.14	92.04	93.25	91.00	91.87	92.91
BK0401	87.47	91.79	92.69	93.90	91.74	92.61	93.77
BK0402	86.93	91.22	92.11	93.31	90.92	91.78	92.96
BK0471	85.94	90.03	90.88	92.02	90.04	90.86	92.03
BK0501	86.50	90.67	91.54	92.70	90.61	91.47	92.65
BK0502	86.99	91.29	92.19	93.40	91.09	91.95	93.12
BK0503	86.86	91.14	92.04	93.24	91.08	91.94	93.10
BK0504	86.27	90.49	91.37	92.55	90.47	91.35	92.52
BK0505	86.76	91.04	91.93	93.13	90.92	91.79	92.96
BK0571	85.53	89.49	90.31	91.40	89.53	90.43	91.62
BK0601	87.00	91.30	92.20	93.40	91.27	92.15	93.31
BK0602	86.64	90.89	91.78	92.96	90.87	91.68	92.76
BK0701	86.34	90.54	91.41	92.59	90.51	91.38	92.57
BK0702	86.42	90.64	91.52	92.71	90.63	91.39	92.56
BK0703	87.20	91.51	92.41	93.62	91.47	92.35	93.54
BK0771	82.41	85.70	86.38	87.37	85.80	86.67	88.02
BK0801	86.86	91.10	91.99	93.18	91.08	91.89	92.65
BK0802	86.78	91.09	91.99	93.20	91.06	91.94	92.96
BK0891	86.54	90.85	91.75	92.96	90.82	91.70	92.88
BK0901	87.06	91.36	92.26	93.47	91.32	92.22	93.41
BK0902	87.14	91.43	92.32	93.52	91.39	92.09	93.28
BK1001	86.80	91.09	91.99	93.20	91.08	91.72	92.84
BK1002	86.93	91.22	92.12	93.32	91.19	92.06	93.22
BK1061	86.64	90.92	91.81	93.01	90.91	91.75	92.84
BK1091	84.20	87.88	88.65	89.68	87.86	88.61	89.44
BK1101	87.40	91.71	92.62	93.83	91.67	92.54	93.70
BK1102	86.99	91.26	92.16	93.36	91.24	92.11	93.16
BK1103	87.28	91.59	92.49	93.70	91.54	92.42	93.59

BK1201	87.13	91.43	92.33	93.54	91.39	92.23	93.40
BK1202	87.12	91.43	92.33	93.54	91.27	92.11	93.25
BK1203	86.80	91.10	92.00	93.21	91.06	91.91	92.82
BK1204	86.62	90.87	91.76	92.95	90.78	91.66	92.84
BK1301	86.55	90.84	91.74	92.95	90.82	91.71	92.89
BK1302	86.19	90.41	91.30	92.48	90.39	91.22	92.39
BK1303	87.09	91.40	92.30	93.51	91.37	92.26	93.45
BK1391	87.21	91.49	92.38	93.58	91.47	92.36	93.55
BK1401	86.88	91.18	92.08	93.29	91.15	91.98	93.05
BK1402	86.65	90.94	91.84	93.04	90.83	91.70	92.87
BK1403	86.65	90.94	91.83	93.04	90.83	91.71	92.80
BK1501	86.83	91.13	92.04	93.24	91.00	91.88	93.04
BK1502	86.63	90.91	91.81	93.01	90.89	91.76	92.89
BK1503	86.22	90.47	91.36	92.55	90.39	91.20	92.38
BK1601	86.85	91.15	92.05	93.26	91.00	91.82	93.01
BK1602	86.82	91.12	92.03	93.23	91.05	91.76	92.94
BK1701	87.16	91.48	92.39	93.60	91.45	92.26	93.45
BK1702	86.89	91.17	92.07	93.28	91.13	92.01	93.09
BK1703	86.85	91.11	92.00	93.19	91.08	91.94	93.11
BK1704	87.24	91.55	92.45	93.66	91.50	92.35	93.51
BK1771	85.99	90.08	90.92	92.05	90.07	90.93	92.06
BK1801	86.54	90.83	91.72	92.93	90.70	91.57	92.74
BK1802	86.51	90.78	91.68	92.87	90.78	91.54	92.66
BK1803	86.55	90.81	91.70	92.89	90.75	91.54	92.72
BK1891	85.74	89.92	90.79	91.96	89.91	90.78	91.93
BK1892	86.53	90.73	91.61	92.79	90.71	91.47	92.62
BK1893	84.19	88.18	89.01	90.12	88.17	89.00	90.10
BK5591	86.62	90.55	91.37	92.47	90.52	91.37	92.58
BK5691	85.18	89.23	90.08	91.21	89.21	90.04	91.11
BK5692	81.92	85.79	86.60	87.69	85.79	86.61	87.70
BK5693	86.22	90.44	91.32	92.51	90.43	91.31	92.49
BX0101	86.80	91.11	92.01	93.22	91.09	91.97	93.16
BX0102	86.92	91.23	92.13	93.35	91.20	92.08	93.27
BX0201	87.28	91.57	92.47	93.68	91.55	92.43	93.62
BX0202	87.04	91.35	92.25	93.46	91.31	92.17	93.34
BX0291	86.90	91.18	92.07	93.27	91.10	91.98	93.16
BX0301	86.80	91.11	92.01	93.22	91.08	91.95	93.14
BX0302	86.53	90.83	91.72	92.93	90.81	91.62	92.80
BX0303	86.90	91.18	92.07	93.27	91.10	91.98	93.16
BX0391	86.36	90.60	91.48	92.67	90.58	91.46	92.59
BX0401	87.13	91.45	92.35	93.57	91.42	92.20	93.40
BX0402	86.59	90.89	91.80	93.00	90.88	91.77	92.96
BX0403	87.19	91.52	92.43	93.64	91.50	92.08	93.28
BX0491	87.01	91.33	92.23	93.44	91.29	92.16	93.36
BX0492	86.89	91.20	92.10	93.31	91.19	91.84	93.03
BX0501	86.65	90.96	91.86	93.07	90.94	91.83	93.03
BX0502	87.62	91.96	92.86	94.08	91.91	92.79	93.97

BX0503	87.86	92.20	93.11	94.33	92.02	92.89	94.06
BX0601	86.98	91.26	92.16	93.36	90.91	91.77	92.92
BX0602	87.09	91.40	92.30	93.51	91.34	92.21	93.12
BX0603	87.11	91.37	92.26	93.46	91.14	92.00	93.16
BX0701	86.81	91.12	92.02	93.23	90.93	91.81	93.00
BX0702	86.95	91.26	92.16	93.37	90.83	91.70	92.89
BX0703	86.36	90.55	91.42	92.58	90.51	91.36	92.53
BX0801	86.63	90.93	91.83	93.04	90.90	91.78	92.97
BX0802	86.62	90.90	91.80	93.00	90.71	91.59	92.78
BX0803	85.14	89.16	90.00	91.12	89.19	90.10	91.36
BX0901	86.85	91.14	92.04	93.24	91.10	91.92	93.09
BX0902	85.03	89.14	90.00	91.15	89.12	89.96	91.09
BX0903	86.74	91.00	91.89	93.08	90.98	91.68	92.85
BX0904	87.03	91.35	92.25	93.46	91.29	92.05	93.21
BX0991	86.38	90.45	91.30	92.44	90.41	91.22	92.34
BX1001	86.76	91.05	91.95	93.15	91.02	91.90	92.99
BX1002	84.88	88.99	89.85	91.00	88.97	89.75	90.88
BX1003	83.75	87.77	88.61	89.74	87.72	88.55	89.66
BX1004	86.35	90.55	91.43	92.61	90.53	91.39	92.51
BX1071	83.75	87.77	88.61	89.74	87.72	88.55	89.66
BX1091	85.02	89.10	89.95	91.10	89.09	89.95	91.09
BX1101	86.83	91.04	91.92	93.10	90.98	91.82	92.83
BX1102	86.41	90.60	91.47	92.64	90.57	91.43	92.50
BX1103	86.34	90.56	91.44	92.61	90.54	91.40	92.57
BX1104	86.66	90.84	91.72	92.89	90.80	91.65	92.80
BX1161	86.22	90.40	91.28	92.45	90.39	91.26	92.35
BX1201	86.49	90.68	91.56	92.73	90.58	91.46	92.66
BX1202	85.72	89.83	90.69	91.84	89.82	90.67	91.81
BX1203	86.28	90.50	91.38	92.56	90.41	91.31	92.51
BX1271	83.05	86.14	86.78	87.63	86.51	87.71	89.38
BX2691	79.26	82.59	83.27	84.19	82.71	83.67	84.95
BX2791	86.71	90.84	91.71	92.86	90.78	91.59	92.71
BX2891	83.17	86.49	87.19	88.15	86.47	87.42	88.77
MN0101	86.79	91.05	91.94	93.14	91.03	91.91	93.09
MN0102	87.49	91.80	92.71	93.92	91.77	92.64	93.81
MN0191	77.98	81.58	82.34	83.35	81.59	82.35	83.36
MN0201	87.73	92.05	92.96	94.17	92.03	92.90	94.08
MN0202	87.49	91.82	92.72	93.94	91.82	92.73	93.94
MN0203	86.57	90.82	91.70	92.90	90.80	91.68	92.35
MN0301	86.71	91.03	91.93	93.14	91.02	91.91	93.10
MN0302	86.61	90.92	91.82	93.03	90.91	91.80	93.00
MN0303	86.67	90.98	91.88	93.09	90.98	91.88	93.08
MN0401	87.09	91.36	92.26	93.45	91.33	92.20	93.36
MN0402	87.33	91.62	92.52	93.72	91.48	92.36	93.54
MN0501	87.66	91.98	92.89	94.10	91.95	92.82	94.00
MN0502	87.45	91.76	92.67	93.88	91.73	92.63	93.82
MN0601	86.53	90.84	91.74	92.95	90.84	91.74	92.94

MN0602	87.42	91.75	92.65	93.86	91.75	92.66	93.86
MN0603	87.23	91.55	92.46	93.67	91.51	92.40	93.61
MN0604	87.57	91.89	92.80	94.01	91.87	92.75	93.93
MN0661	86.39	90.69	91.59	92.79	90.69	91.58	92.79
MN0701	87.20	91.50	92.40	93.61	90.83	91.73	92.93
MN0702	86.58	90.89	91.79	93.00	90.81	91.69	92.89
MN0703	86.37	90.67	91.56	92.77	90.65	91.53	92.72
MN0801	87.48	91.81	92.71	93.93	91.80	92.54	93.75
MN0802	87.10	91.42	92.32	93.54	91.09	91.97	93.17
MN0803	87.35	91.69	92.59	93.81	91.49	92.36	93.56
MN0901	85.51	89.75	90.63	91.82	89.73	90.61	91.78
MN0902	83.87	87.97	88.83	89.98	87.95	88.79	89.92
MN0903	86.08	90.34	91.23	92.43	90.31	91.17	92.34
MN1001	86.62	90.93	91.83	93.04	90.74	91.63	92.82
MN1002	86.70	91.01	91.91	93.12	90.96	91.85	93.04
MN1101	86.51	90.80	91.70	92.90	90.77	91.66	92.85
MN1102	86.62	90.93	91.83	93.04	90.78	91.67	92.87
MN1191	86.93	91.22	92.12	93.32	91.22	92.12	93.06
MN1201	86.53	90.83	91.73	92.94	90.81	91.69	92.88
MN1202	86.51	90.82	91.72	92.93	90.80	91.69	92.88
MN1203	86.55	90.84	91.74	92.94	90.67	91.56	92.76
MN1291	86.46	90.76	91.66	92.86	90.75	91.64	92.83
MN1292	86.44	90.73	91.63	92.84	90.61	91.51	92.71
MN6491	86.40	90.68	91.57	92.77	90.64	91.53	92.74
QN0101	86.76	91.04	91.94	93.14	91.02	91.88	93.07
QN0102	86.53	90.83	91.73	92.94	90.82	91.71	92.91
QN0103	87.34	91.66	92.56	93.77	91.61	92.49	93.66
QN0104	86.93	91.22	92.12	93.33	91.20	91.90	93.08
QN0105	86.72	91.01	91.91	93.12	90.99	91.85	93.04
QN0151	87.45	91.78	92.69	93.89	91.78	92.68	93.89
QN0161	87.15	91.46	92.36	93.57	91.44	92.03	93.21
QN0171	86.29	90.51	91.39	92.57	90.50	91.32	92.50
QN0191	86.48	90.78	91.68	92.88	90.76	91.65	92.84
QN0201	87.43	91.73	92.63	93.83	91.69	92.52	93.70
QN0202	86.68	90.94	91.83	93.02	90.92	91.80	92.97
QN0203	86.86	91.15	92.05	93.26	91.16	91.92	93.00
QN0261	87.29	91.59	92.49	93.69	91.57	92.43	93.61
QN0271	86.07	90.27	91.15	92.32	90.34	91.22	92.40
QN0301	86.96	91.26	92.16	93.37	91.10	91.85	92.98
QN0302	86.78	91.07	91.97	93.18	91.05	91.73	92.92
QN0303	87.21	91.51	92.41	93.62	91.47	92.21	93.39
QN0401	87.26	91.58	92.48	93.69	91.43	92.28	93.39
QN0402	87.09	91.38	92.28	93.48	91.34	92.15	93.31
QN0501	86.78	91.04	91.93	93.12	91.03	91.88	93.06
QN0502	87.01	91.30	92.20	93.41	91.26	92.13	93.29
QN0503	86.10	90.22	91.08	92.22	90.21	91.07	92.24
QN0504	86.18	90.37	91.24	92.42	90.36	91.23	92.40

QN0571	85.97	90.11	90.97	92.12	90.11	90.97	92.12
QN0572	86.10	90.29	91.16	92.32	90.29	91.17	92.34
QN0573	85.78	89.84	90.68	91.81	89.84	90.69	91.83
QN0574	85.39	89.31	90.13	91.21	89.33	90.17	91.30
QN0601	86.61	90.86	91.75	92.94	90.83	91.70	92.87
QN0602	86.51	90.71	91.59	92.76	90.58	91.42	92.61
QN0701	85.28	89.42	90.29	91.45	89.41	90.26	91.42
QN0702	85.68	89.83	90.69	91.84	89.82	90.68	91.83
QN0703	85.93	90.01	90.86	92.00	90.01	90.85	91.99
QN0704	86.22	90.42	91.30	92.47	90.42	91.26	92.43
QN0705	86.06	90.20	91.06	92.22	90.19	91.01	92.18
QN0706	85.86	89.97	90.82	91.97	89.97	90.81	91.96
QN0707	87.01	91.30	92.20	93.40	91.28	92.04	93.22
QN0761	86.99	91.28	92.18	93.38	91.28	92.17	93.37
QN0791	85.26	89.12	89.93	91.00	89.14	89.98	91.12
QN0801	86.22	90.43	91.31	92.48	90.42	91.30	92.47
QN0802	86.16	90.34	91.21	92.37	90.33	91.20	92.35
QN0803	85.69	89.69	90.52	91.63	89.73	90.63	91.83
QN0804	85.25	89.10	89.90	90.97	89.14	90.05	91.28
QN0805	86.40	90.63	91.52	92.70	90.61	91.48	92.64
QN0871	85.23	89.33	90.18	91.34	89.30	89.74	90.81
QN0891	82.81	85.93	86.60	87.49	86.23	87.49	89.13
QN0901	86.24	90.35	91.21	92.36	90.41	91.30	92.47
QN0902	86.57	90.82	91.71	92.90	90.86	91.76	92.94
QN0903	87.00	91.30	92.21	93.41	91.27	92.15	93.33
QN0904	86.97	91.27	92.17	93.38	91.21	91.92	93.11
QN0905	86.36	90.47	91.32	92.46	90.26	91.13	92.33
QN1001	86.57	90.83	91.72	92.92	90.82	91.62	92.77
QN1002	86.46	90.68	91.57	92.75	90.66	91.49	92.65
QN1003	86.36	90.58	91.46	92.64	90.57	91.44	92.61
QN1091	86.52	90.74	91.62	92.81	90.74	91.62	92.81
QN1101	86.05	90.19	91.06	92.21	90.20	91.06	92.23
QN1102	86.04	90.16	91.02	92.16	90.15	91.01	92.17
QN1103	85.18	89.14	89.96	91.06	89.17	90.05	91.24
QN1104	85.46	89.32	90.12	91.19	89.38	90.28	91.50
QN1191	84.67	88.23	88.97	89.98	88.42	89.42	90.72
QN1201	86.85	91.14	92.03	93.24	91.10	91.96	93.13
QN1202	86.41	90.65	91.54	92.72	90.63	91.49	92.67
QN1203	86.21	90.41	91.29	92.46	90.40	91.27	92.43
QN1204	86.18	90.36	91.23	92.40	90.35	91.22	92.38
QN1205	86.09	90.26	91.14	92.30	90.26	91.13	92.29
QN1206	86.17	90.35	91.22	92.39	90.34	91.19	92.36
QN1301	85.74	89.85	90.70	91.85	89.86	90.73	91.89
QN1302	85.25	89.22	90.05	91.16	89.25	90.12	91.29
QN1303	86.20	90.40	91.28	92.45	90.39	91.26	92.41
QN1304	85.87	90.02	90.89	92.05	90.03	90.90	92.06
QN1305	86.08	90.24	91.10	92.26	90.24	91.11	92.26

QN1306	86.13	90.33	91.20	92.38	90.32	91.20	92.37
QN1307	85.50	89.65	90.52	91.67	89.65	90.51	91.67
QN1371	86.00	90.18	91.05	92.21	90.19	91.06	92.22
QN1401	86.17	90.36	91.24	92.41	90.35	91.22	92.33
QN1402	86.60	90.84	91.73	92.92	90.83	91.71	92.82
QN1403	85.69	89.85	90.73	91.89	89.85	90.71	91.87
QN1491	86.81	91.13	92.04	93.25	91.14	92.04	93.25
QN8081	87.03	91.34	92.23	93.44	91.32	92.18	93.37
QN8191	85.53	89.67	90.53	91.69	89.64	90.45	91.56
QN8291	85.14	88.49	89.16	90.06	89.28	90.39	91.53
QN8381	86.60	90.83	91.72	92.91	90.83	91.71	92.89
QN8491	86.37	90.57	91.45	92.62	90.55	91.43	92.61
QN8492	84.65	88.72	89.57	90.71	88.71	89.57	90.70
SI0101	85.30	89.35	90.19	91.33	89.36	90.24	91.43
SI0102	86.08	90.16	91.01	92.15	90.15	91.01	92.17
SI0103	86.21	90.40	91.27	92.44	90.39	91.25	92.42
SI0104	85.65	89.55	90.36	91.45	89.56	90.42	91.61
SI0105	85.30	89.12	89.92	90.99	89.09	89.91	91.03
SI0106	85.04	89.17	90.03	91.17	89.16	90.01	91.16
SI0107	85.71	89.77	90.62	91.75	89.74	90.58	91.72
SI0191	79.26	82.58	83.27	84.19	82.71	83.67	84.95
SI0201	85.90	89.99	90.84	91.98	89.98	90.83	91.96
SI0202	86.06	90.19	91.05	92.19	90.19	91.04	92.19
SI0203	83.98	87.28	87.96	88.87	87.96	89.23	90.64
SI0204	85.12	88.98	89.79	90.89	88.98	89.84	91.00
SI0291	85.34	89.30	90.15	91.30	89.31	90.18	91.41
SI0301	85.23	89.18	90.00	91.11	89.17	89.99	91.10
SI0302	85.30	89.28	90.11	91.22	89.28	90.13	91.24
SI0303	84.81	88.47	89.25	90.29	88.53	89.38	90.55
SI0304	84.22	87.53	88.22	89.17	87.69	88.68	90.02
SI0305	84.90	88.62	89.40	90.44	88.70	89.62	90.82
SI0391	84.37	88.15	88.95	90.04	88.20	89.07	90.21
SI9561	82.44	86.21	86.99	88.04	86.20	86.96	87.99
SI9591	84.57	88.59	89.43	90.56	88.58	89.41	90.53
SI9592	86.26	90.47	91.35	92.52	90.48	91.35	92.52
SI9593	84.57	88.59	89.43	90.56	88.58	89.41	90.53

Figure Source: OMB

The figure below shows mean afternoon temperature aggregated by scenario, rather than by NTA. This view provides a point of comparison between each scenario for their related decadal period. There is an observable decrease in temperature, by neighborhood, between The Control and Planned Action Scenarios.

FIGURE 29 | MEAN AFTERNOON AIR TEMPERATURE, BY NTA (DEGREES FAHRENHEIT)

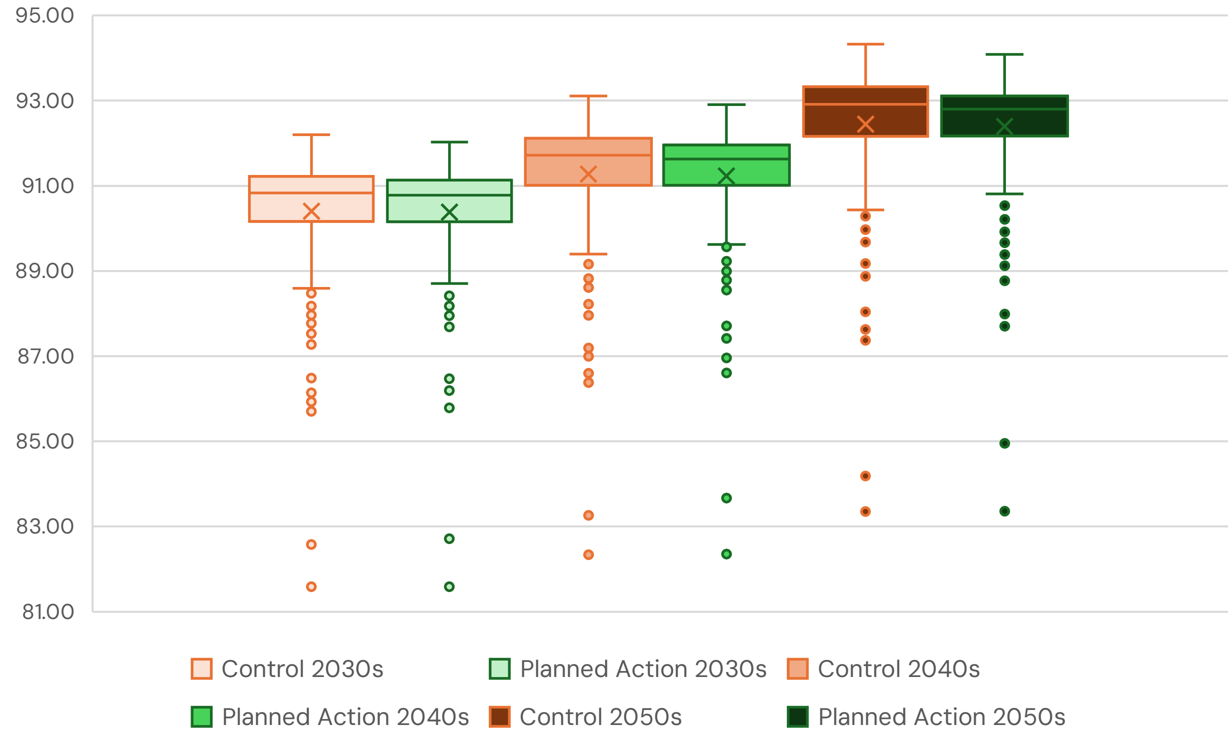


Figure Source: OMB

Note that temperature is represented in degrees Fahrenheit, which will depict temperature differentials on a relative scale. These can also be represented in Celsius, but this will change the proportional changes in degrees between scenarios. Absolute measures may be used. For the overall outputs of the model, "percent warming managed" is used as a universal and absolute measure. It represents the proportion of climate-change-induced temporal warming that is present in the Control Scenario but not the Planned Action Scenario. This reveals what proportion of heat intensification is estimated to be proactively ameliorated by the scenario parameters (tree canopy expansion).

A paired, one-tailed distribution t-test is used to test for statistical significance of the results by comparing the mean temperatures for each NTA for each decadal period except the baseline. This test reveals if the results of the Planned Action Scenario are different from the mean of the control. The p-values for the t-test are found below, with values for each decade less than 0.05, meaning that across neighborhoods the change in temperature from the Control Scenario to the modeled Planned Action Scenario is not likely due to chance (the null hypothesis).

2030s	0.000016*
2040s	0.000038*
2050s	0.001566*

** statistically significant at p<0.05*

To display results, the proportion of the heating effect from the Control at baseline (2017) is compared between the Control Scenario at each decade and the mitigation scenario. This represents the amount of heating effect managed between scenarios.

Evaluating Difference between Vulnerable Areas

To display and communicate the results, the proportion of the heating effect is compared between the Control Scenario at each decade and the Planned Action Scenario in 2050. This represents the amount of heating effect managed between scenarios.

The city's HVI is used to understand if changes in modeled temperature vary between more and less vulnerable locations. HVI 4 and 5 areas are considered "Higher Vulnerability" neighborhoods and HVI 1-3 are considered "Lower Vulnerability." This follows consultation with city agencies and considering the focus on HVI 4 and 5 areas in the NYC Parks Department's Neighborhood Tree Planting Program. While Higher HVI neighborhoods are considered a priority by the NYC Parks Department, the Neighborhood tree planting program considers planting in all city neighborhoods. The effects of strategic tree planting can help reduce proportional change in temperature. The NYC Parks Department's planting strategy is observed in this analysis to aid vulnerable communities more than neighborhoods with a HVI of 3 or lower. Presented below are the average proportional changes in temperature between Control and Planned Action Scenarios, based on HVI status, per neighborhood:

-2.246087572	Higher HVI
-1.348058671	Lower HVI*

**For the analysis included in the main results, two outliers are removed, these are two NTAs in a wide right tail of the data distribution. Both results are found in the Lower HVI group.*

FIGURE 30 | DISTRIBUTION OF NTA HEAT IMPACT PERCENTAGES BETWEEN SCENARIOS, IN 2050

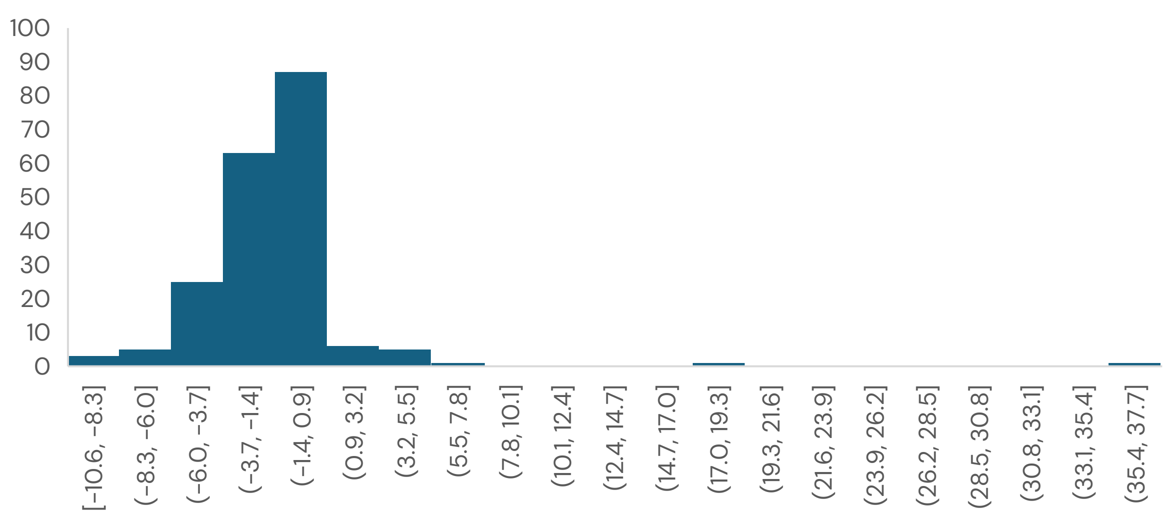


Figure Source: OMB

Observed above, Higher HVI neighborhoods see an increased proportion of climate-change warming managed by strategic planting of 0.898 percent, compared to Lower HVI communities. This represents a 67 percent difference in managed temperature. This begins to speak to the importance of targeted planting in neighborhoods that need it the most. The key observed characteristic contributing to the management of outdoor temperature increase is the availability to plant street trees and potential for canopy to expand. Previously verdant neighborhoods and neighborhoods with little area to expand street trees show less opportunity for growth between Control and Planned Action Scenarios. See the limitations sections for more about outliers and vegetation

The analysis is rerun as a test with using HVI 3-5 as a more inclusive cutoff for Higher HVI neighborhoods to determine if this is a driver of the difference in temperature differences between Higher and Lower HVI neighborhoods. However, the selection of Higher HVI as HVI 4 and 5 Areas do not result in changes to the overall trends found when using the previous cutoffs, so HVI 4 and 5 are kept for the definition of Higher HVI to keep consistent with other agency definitions of high vulnerability.
A heteroscedastic, two-tailed t-test is used to compare the temperature variation between Higher and lower HVI areas. p = 0.004109*, meaning the differences in Higher and Lower HVI Areas is likely not due to chance (the null hypothesis).

FIGURE 31 | ESTIMATED AVERAGE TEMPERATURE DIFFERENCE by HVI, 2050 (DEGREES FAHRENHEIT)

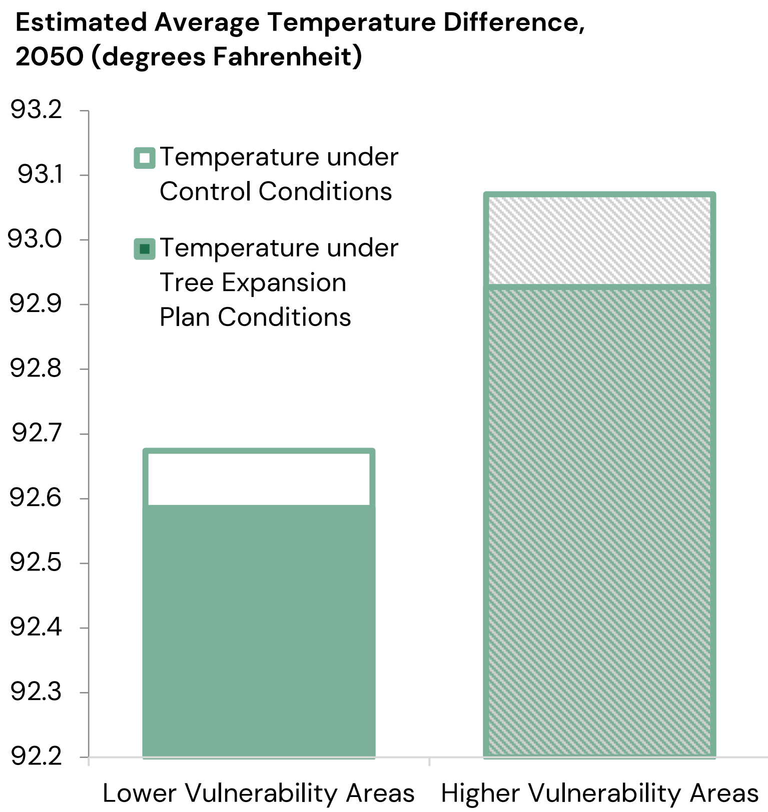


Figure Source: OMB

Validation

Results are validated by comparing SUEWS outputs to two other datasets supplied by collaborators, one another physics-based model and the other a mathematically modeled output.

For each of these comparative datasets, a Bland-Altman test is run to determine the agreement between results for each NTA across models. Results yielded no systematic difference in NTA trend when compared to the respective/individual means of both air temperature values per NTA, with few outliers (17 values out of 262 NTAs outside of the upper and lower limits for the physical model; 16 values out of 262 NTAs outside of the upper and lower limits for the mathematical model). SUEWS, however, does output a higher average temperature compared to other models. Because for OMB's analysis, the focus is on comparative warming managed between the Control and Planned Action Scenarios, it is determined that results are appropriate to use, though the difference in absolute temperatures revealed in validation will be investigated further.

Select neighborhoods are then spot checked, with help from partnering agencies and experts. Limitations for coastal neighborhoods and neighborhoods with high levels of vegetation exist—see *Limitations* section below.

FIGURE 32 | BLAND-ALTMAN PLOT COMPARISON OF SUEWS TO WRF-URBAN

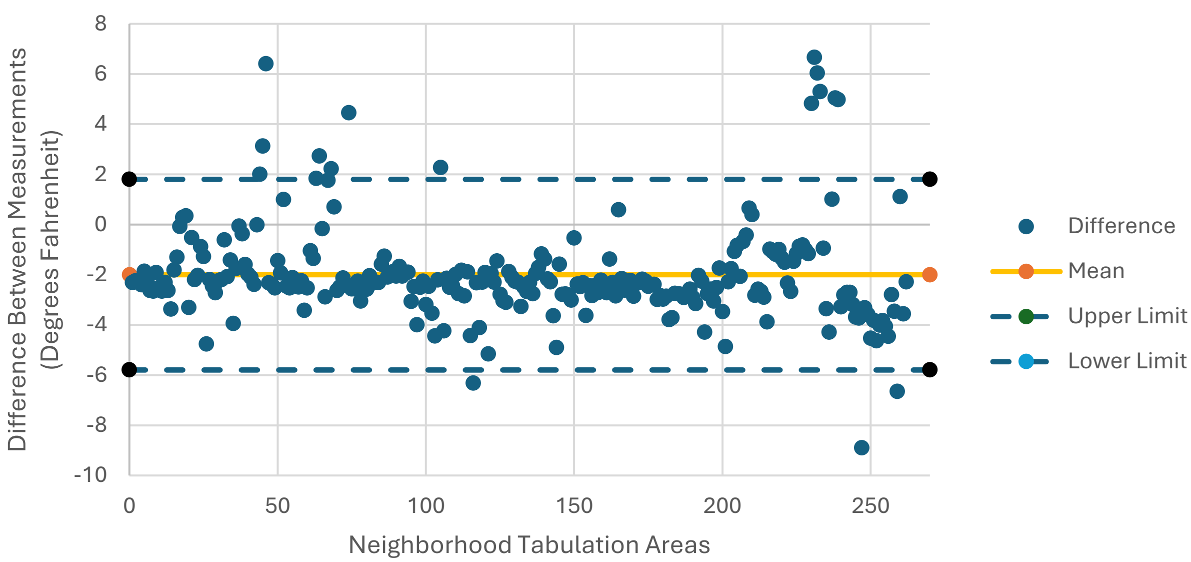


Figure Source: OMB; Source of Reference Dataset: Weather Research & Forecasting Model (WRF-Urban[268]) data provided by the Urban Systems Lab at The New School, led by Jain, M., Ortiz, L., and McPhearson, T.

FIGURE 33 | BLAND-ALTMAN PLOT COMPARIOSN OF SUEWS TO NYC URBAN HEAT PORTAL

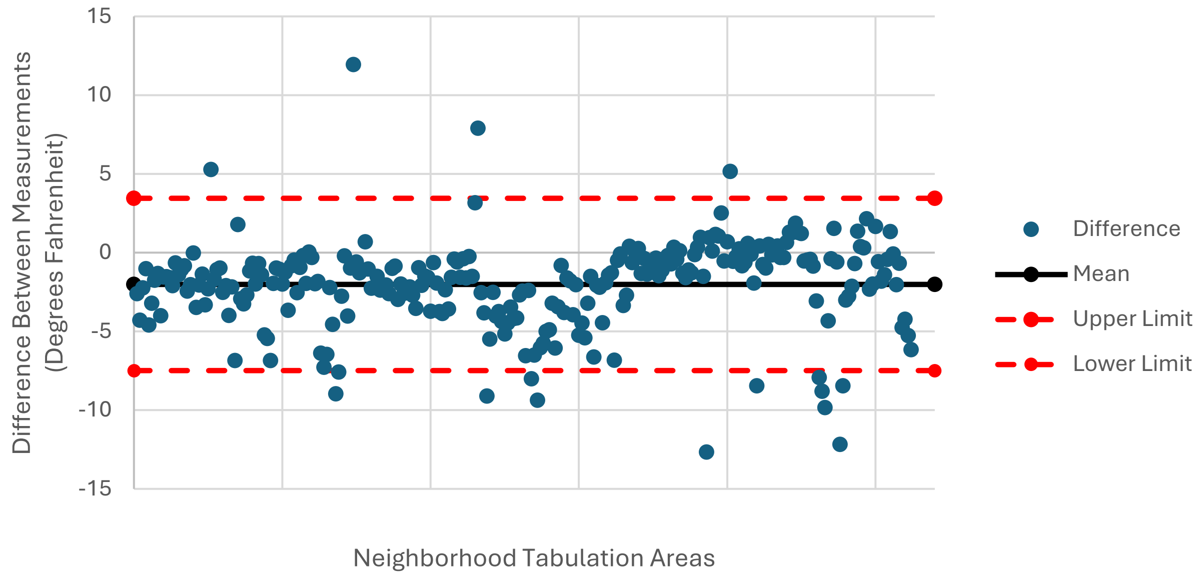


Figure Source: OMB; Source of Reference Dataset: Heris, M., Louie, A., Flohr, T., Haijing, L., Kittredge, A., Pankin, He, Z., Marcotullio, P., Fein, M. (2025). New York City Urban Heat Portal: Estimated Air Temperature.[269]

In the future, validation against empirical data, such as heat sensors, will be considered to bolster results further.

Limitations

Limitations include the lack of available data around some input variables. This work highlights where more information, such as on regional projections of humidity and wind, is needed to improve model results. However, SUEWS is an appropriate and well-tested choice for conducting this analysis and is a scalable model, used for simplified analysis in the absence of expensive computational power. The city currently has NPCC projections for citywide temperature, but not readily for humidity, wind, or other factors that influence heat profiles in various locations. Future changes in winds or humidity, such as stronger wind, higher humidity, or altered wind direction, are not captured in this modeling exercise, though they affect how temperature is felt on the ground by humans and are necessary factors to more accurately understand how climate change-induced effects to multiple variables will manifest in health and other impacts. These factors may be downscaled from global climate models in the future and, as new data inputs become available, the model runs can be updated. This analysis helps shed light on where more science and information are needed to improve the modeling and make it most useful for decision making. Coastal NTAs may be particularly susceptible to this limitation, given they may face greater heat attenuation from wind off waterbodies and the sample area may span land and water (see method above for how this is handled when a hex comprised both NYC land area and non-NYC area). However, given that days may experience greater or less wind, this model is still a representation of the heat profile that could be felt on some days, even along the coasts.

Modeling heat two meters above surface is a useful evaluation of city heat, as it captures more effective temperatures felt by individuals above various surfaces and accounts for cooling features such as baseline wind, compared to surface heat alone. However, there are other heat measurements that can be explored in the future, including mean radiant temperature, wet bulb globe temperature, physiological equivalent temperature, Universal Thermal Climate Index, and others, that may better capture how humans feel heat both outdoors and indoors, and in different locations (such as in shade or sun), implicating health outcomes more directly. Averaging temperatures at the NTA level can underestimate the value from tree canopy, as some of the most salient benefits may be to individuals directly in the shade underneath a tree. These hyperlocal effects are not included in this modeling and the influence of shade is underestimated. This can be investigated in the future.

There is an observed trend where the SUEWS model projects a counterintuitive increase in air temperature in highly vegetated neighborhoods, indicating a need to investigate some model assumptions. This relationship is likely caused by the conditions set in the SUEWS run input parameters, in which only air temperature can be forecasted into the future based on available projected inputs. Other dynamics that would impact air temperature modeling such as relative humidity, wind speed, and soil moisture (deficit) are not modeled into beyond baseline and thus can cause minor instability in edge cases in SUEWS. Preliminary thresholds for this event to occur is at or above a deciduous tree land cover fraction of 0.65 or higher. One proposed solution for this event is the modification of the OHM input, a coefficient that modifies the heat absorption capacity of various LC classes. Reducing the OHM coefficient of paved surfaces to one that represents the surfaces of New York City more accurately will stabilize the model. This will be explored in future iterations of work.
Tree canopy is just one adaptation measure for outdoor heat. In the future, other work could be considered, such as light-colored surfaces. Furthermore, only street tree planting plans (and all tree expansion) is included, though private property and non-street city trees' planting will be part of the cooling strategy.

COASTAL FLOODING FORECAST

How does the forecast evaluate local flooding from storm-surge and sea-level rise?

The inventory (described in previous sections) identifies baseline levels of risk in areas that face present levels of coastal flooding from both storm-surge and rising sea levels. Within the city's present floodplain maps (2007 FIRM and 2015 PFIRM, which for these analyses are considered the present-day baseline) for the 100-year storm, there are 67,253 buildings in the hazard area. There are 940 buildings in the 2020s projected high-tide flooding area (from the Department of City Planning's Flood Hazard Mapper).[270] While some of these buildings may have individual building-level protections such as floodproofing, they remain exposed at the neighborhood scale.

The forecast focuses on the potential for reducing flooding, or the *flood attenuation* potential, for present and future conditions. It specifically looks at select large-scale, neighborhood-level coastal flood protective projects under high-tide and storm-surge (with SLR) conditions given anticipated flood protection projects, both with and without the U.S. Army Corps of Engineers (USACE) New York and New Jersey Harbor and Tributaries Focus Area Feasibility Study (NYNJHATS) projects as per their 2022 Tentatively Selected Plan.[271] See the table below for the scenarios described in this section. These large-scale projects are just one form of protection, and this analysis is not a determination that these are the best option for coastal flood protections—the forms of these coastal protections do not show effects of individual building protections, Building Code Appendix G flood-resistant construction requirements, use of the CRDG, community resilience, or other protective options.

FIGURE 34 | FLOOD AREAS USED FOR DECADAL FORECAST

	100-Year Annual-Chance Floodplain (including High Estimate SLR)	High Tide (Middle-High Estimate SLR)
Present	Use the combined FIRM/PFIRM	Use the NPCC 2020s Middle-High Tide Projection (8-inch SLR)
2020s	Use the NPCC 2020s Future Floodplain (100-Year Event, 10-inch SLR)	Use the NPCC 2020s Middle-High Tide Projection (8-inch SLR)
2050s without NYNJHATS	Use the NPCC 2050s Future Floodplain (100-Year, 30-inch SLR)	Use the NPCC 2050s Middle-High Tide Projection (21-inch SLR)
2050s with NYNJHATS	Use the NPCC 2050s Future Floodplain (100-Year, 30-inch SLR)	Use the NPCC 2050s Middle-High Tide Projection (21-inch SLR)

Figure Source: OMB

The NYNJHATS project portfolio is evaluated in separate scenarios (one with it and one without) because it is a large-scale initiative that could impact the whole city but is tentative at this time. While NYNJHATS is not itself a Planned Action, it is a large-scale, federally led project suite that will likely involve city cost sharing and planning should it proceed. In 2022, USACE released a Tentatively Selected Plan (TSP), which is still subject to study, finalization, and congressional approval. The TSP is likely to change, given that it is subject to new parameters as laid out in the Water Resources Development Act, new agency specific procedures, and that public comments are still being considered.[272] Until these steps are completed, it is not possible to know the exact level of anticipated protection. Given the vast scope of this project set and the uncertainty, it is treated as a separate scenario in future coastal flood projections.

FIGURE 35 | PROCESS FOR COASTAL FLOODING FORECAST

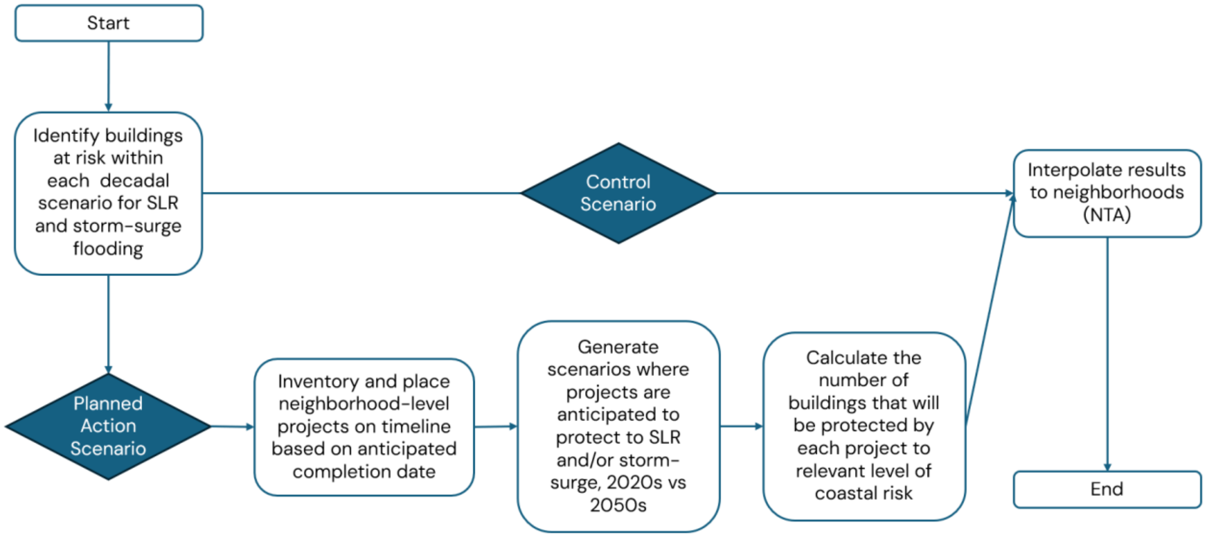


Figure Source: OMB

Parameters

- **Decadal Flood Areas:** The 100-year floodplain in this case describes the 1 percent annual-chance coastal flood for the specified decadal period (e.g., present-day 1 percent annual-chance flood; 2050s 1 percent chance flood). The city's Flood Hazard Mapper uses high estimates of SLR (90th percentile) to generate these storm-surge projections.[273] This is used in these analyses for consistency. For tidal flooding on its own (chronic flooding without storm-surge), a middle-high SLR estimate (75th percentile) is used to be conservative and consistent with the projection choices for outdoor heat (see previous sections). Note that this may be inconsistent with other guidance, such as the CRDG, but for the purpose of these illustrative projections is still appropriate for conducting comparable adaptation assessments, where as the CRDG are for proactive project development. However, this does shed light on the need for consistent guidance across the city on which projections to use and under what circumstances. This will be investigated further in the future

- **Sources of Projections**:
  - Present Day: The present-day tidal flood area uses the 2020s high-tide flood area (provided by NPCC) because no present-day, widely accepted flood map exists for tidal flooding in the city. Note that the same map is used for present-day and 2020s flooding. Present-day storm-surge uses the combined FEMA FIRMs and PFIRMs, since they are not reconciled to one predominant map[274] This is consistent with guidance from the DOB that uses both maps to determine flood areas (most inclusive) in Appendix G of the city's codes.[275]
  - Future: NPCC provides projections to estimate changes in tidal and storm-surge floodplains. The analysis described below relies on the 100-year floodplain (1 percent annual-chance flood) and high-tide flooding areas.[276]

- **Projections Used**: All current coastal flooding projections are based on NPCC3 (2019) estimates. NPCC4 (2024) is released with updated flooding projections, but:
    - NPCC4 projections are currently citywide and have not yet been downscaled to localized flood areas
    - NPCC4 SLR projections differ for some percentiles from NPCC3 (see the table below)
    - NPCC4 uses different decades of analysis (including 2030s period)

As localized NPCC4 projections become available, they may be incorporated into analysis. OMB aims to use the most up-to-date NPCC projections. NPCC3 reaffirmed the projections from NPCC2 (2015).

FIGURE 36 | DIFFERENCES BETWEEN PROJECTIONS (10TH, 25TH, 75TH, 90TH PERCENTILES)

(inches)	2020s	2030s	2050s	2080s	2100
NPCC2/3[277]	2, 4, 8, 10	--	8, 11, 21, 30	13, 18, 39, 58	15, 22, 50, 75
NPCC4[278]	--	6, 7, 11, 13	12, 14, 19, 23	21, 25, 39, 45	25, 30, 50, 65

Figure Source: OMB

Planned Actions: Construction of Neighborhood-Scale Coastal Flood Barriers

- PlaNYC outlines several priorities for coastal flood protections, specifically, targeted action to continue to design and construct world-class neighborhood-scale coastal protection projects and partner with the NYNJHATS process.
- The city has many flood protection projects underway at various stages and design levels. These are developed by several agencies across the city, including the Department of Design and Construction (DDC), NYCEDC, the NYC Parks Department, and others. Few projects have been completed, but several are in design and construction. OMB's decision of which projects to include in this analysis is based on agency consultation, level of project certainty, and meeting the Planned Actions criteria described earlier in this document. More information on project selection and projects not included in analysis at this time is detailed in following sections.

Determining Neighborhood-Scale Projects

- The first step to calculating the anticipated protection incurred from future coastal protection projects is to determine which flood protection projects to include for analysis. This is determined in collaboration with NYCEDC and DEP's Bureau of Coastal Resilience (BCR), alongside other agencies and non-city entities, such as MOCEJ, Battery Park City Authority, NYCEM, New York State, and USACE.
- There are two main varieties of flood protection projects:
    - First, there are neighborhood-level flood protection projects, that typically create stationary or deployable barriers to protect an area upland of the barriers from flood waters. These focus on stopping water from reaching land, via methods such as levees,

berms, and floodwalls. These typically ameliorate the entire floodplain area behind them (to a particular design storm, described in more detail later in this section). These are included in the forecast analysis.
    - Second, there are projects that protect assets only, without affecting the larger neighborhood behind the protections, such as wet and dry floodproofing and building elevation. For the purposes of these analyses, this latter type of project is not included in current evaluations, but it is intended to incorporate them in the future to get a more holistic sense of what is protected in the present and future.
- These varieties are not clearly defined and there may be grey areas, such as for coastal parks, where protections may benefit solely the park asset or individual building/campus, but this constitutes the majority of what exists in that area's coastal floodplain.
- The definition of neighborhood-level flood protections may be defined more clearly in the future, but at this time a limitation of this analysis is possible subjectivity of projects and the lack of a full inventory of large-asset or infrastructure protections. The focus of this analysis on neighborhood-level flood protections is not to suggest that asset protections are not important. All types of physical protections must be tailored appropriately to their locations and redundant protections are often prudent. These include both hardscape measures and natural measures. Community measures and other alternatives are also being investigated.
- Furthermore, asset level protections can offer protections on their own but also in the meantime while neighborhood-level projects are built, often with long time horizons. The CRDG, being piloted as part of Local Law 41 by MOCEJ is an example of using climate projections to influence asset-level protections for capital projects.

Control Scenario

How many buildings will be at risk of flooding in the absence of large-scale infrastructure projects?

To develop the scenarios used to forecast the effects of the Planned Actions, a **Control Scenario** is developed to provide a point of comparison. To do this, the key steps are:

1. Identify which locations are at risk to be flooded in the present and future, using current and estimated floodplain maps
2. Overlay project and flood maps with city building locations to understand what properties will be at risk

Present Conditions

To understand the flood attenuation potential of flood protections, the baseline level of flooding is considered using the 2007 FIRM and 2015 PFIRM floodplains for the present-day 100-year storm—either area is considered eligible for analysis (if in the PFIRM, FIRM, or both). Few neighborhood-level coastal protections have been completed to-date. Due to this gap, the Control Scenario for the present and future is a view of the city without neighborhood-level protections in general. The only neighborhood-level projects included in analysis that are complete at this time is the Old Howard Beach Raised Shorelines and Phase One of East Side Coastal Resiliency, but they were still considered to be future protection rather than present protection as they are finished in 2024 while analysis was ongoing. Protections are included in the Planned Action Scenario, not the Control Scenario.

The count of building polygons overlapping with the flood areas are calculated using the DOB Building Footprints Feature Layer to determine how many buildings (by Building Identification Number, BIN) fall within the projected floodplains. This is the baseline level at risk. Any amount of overlap between the building footprint and floodplain leads to the inclusion of that building in the analysis even if the overlap is minor. This helps show the proportion of any affected buildings protected, but it should be noted that buildings will experience varying levels of impact (from partial to full flooding to destruction by wave action). This analysis does not compute levels of damage.

Future Decades

For analysis of future decades, NPCC flood maps for the 2020s and 2050s decadal periods are used and the DOB Building Footprints Feature Layer is overlaid on these flood hazard maps to determine how many buildings (by BIN) fall within the projected floodplains. This assumes no change in building count and location into the future. Projecting these changes can be investigated in the future.

The table below shows the number of buildings located within the flood area for the present and future high tide and 100-year storm for each NTA, without neighborhood-level protections. This is what is considered the "buildings at-risk." NTAs without any floodplain overlap or any buildings are excluded from this list. This is not a comprehensive list of every neighborhood in the city—it only includes NTAs that have at least one building at risk of either storm-surge or tidal inundation.

FIGURE 37 | BUILDING COUNT LOCATED IN FLOOD AREAS BY NTA

NTA	NTA Name	Buildings in Present 100-Year Storm Area	Buildings in Present High-Tide Area	Buildings in 2050s 100-Year Storm Area	Buildings in 2050s High-Tide Area
BK0101	Greenpoint	528	3	2127	5
BK0102	Williamsburg	25	2	420	5
BK0103	South Williamsburg	27	0	617	0
BK0104	East Williamsburg	84	9	307	11
BK0201	Brooklyn Heights	20	0	32	0
BK0202	Downtown Brooklyn-DUMBO-Boerum Hill	51	1	85	2
BK0203	Fort Greene	7	0	45	0
BK0261	Brooklyn Navy Yard	93	3	118	3

BK0301	Bedford-Stuyvesant (West)	0	0	51	0
BK0503	East New York-New Lots	0	0	391	0
BK0504	Spring Creek-Starrett City	9	0	38	0
BK0505	East New York-City Line	2	1	458	1
BK0601	Carroll Gardens-Cobble Hill-Gowanus-Red Hook	1186	12	1965	23
BK0702	Sunset Park (West)	150	4	284	19
BK1001	Bay Ridge	8	0	38	0
BK1101	Bensonhurst	0	0	1	0
BK1102	Bath Beach	1	0	153	0
BK1103	Gravesend (West)	1261	1	2676	4
BK1301	Gravesend (South)	2338	1	3155	3
BK1302	Coney Island-Sea Gate	3161	9	3327	13
BK1303	Brighton Beach	2009	0	2072	0
BK1391	Calvert Vaux Park	1	0	2	0
BK1501	Gravesend (East)-Homecrest	411	0	1814	0
BK1502	Madison	0	0	2092	0
BK1503	Sheepshead Bay-Manhattan Beach-Gerritsen Beach	7321	22	10392	58
BK1801	Flatlands	0	0	2190	0
BK1802	Marine Park-Mill Basin-Bergen Beach	2332	9	8626	14
BK1803	Canarsie	4989	1	8213	1
BK1891	Marine Park-Plumb Island	10	1	21	2
BK1892	McGuire Fields	8	0	8	0
BK1893	Canarsie Park & Pier	2	0	2	0
BK5691	Barren Island-Floyd Bennett Field	22	5	68	4
BK5693	Shirley Chisholm State Park	0	0	5	0
BX0101	Mott Haven-Port Morris	264	3	417	5
BX0102	Melrose	0	0	2	0
BX0201	Hunts Point	109	0	269	2
BX0291	North & South Brother Islands	11	0	11	0
BX0303	Crotona Park East	12	5	31	4
BX0401	Concourse-Concourse Village	17	0	23	0
BX0402	Highbridge	3	0	8	0
BX0501	University Heights (South)-Morris Heights	12	0	12	0
BX0601	West Farms	3	0	6	0
BX0701	University Heights (North)-Fordham	7	1	10	1
BX0802	Kingsbridge-Marble Hill	25	0	34	1

BX0803	Riverdale-Spuyten Duyvil	7	0	9	1
BX0901	Soundview-Bruckner-Bronx River	8	5	167	5
BX0902	Soundview-Clason Point	236	2	1279	2
BX0903	Castle Hill-Unionport	40	0	205	1
BX1001	Westchester Square	33	4	49	4
BX1002	Throgs Neck-Schuylerville	1806	16	2883	27
BX1003	Pelham Bay-Country Club-City Island	598	20	1151	36
BX1004	Co-op City	5	0	197	0
BX1071	Hart Island	7	0	14	0
BX1091	Ferry Point Park-St. Raymond Cemetery	5	0	5	0
BX1103	Pelham Gardens	0	0	226	0
BX1161	Hutchinson Metro Center	58	0	100	0
BX1202	Eastchester-Edenwald-Baychester	30	1	81	1
BX2891	Pelham Bay Park	80	0	85	0
MN0101	Financial District-Battery Park City	312	4	400	13
MN0102	Tribeca-Civic Center	127	0	348	3
MN0191	The Battery-Governors Island-Ellis Island-Liberty Island	90	5	121	13
MN0201	SoHo-Little Italy-Hudson Square	204	0	374	0
MN0203	West Village	111	0	339	1
MN0301	Chinatown-Two Bridges	44	0	78	1
MN0302	Lower East Side	31	1	47	2
MN0303	East Village	390	1	804	1
MN0401	Chelsea-Hudson Yards	316	3	541	7
MN0402	Hell's Kitchen	23	2	57	12
MN0601	Stuyvesant Town-Peter Cooper Village	45	0	66	0
MN0602	Gramercy	0	0	38	0
MN0603	Murray Hill-Kips Bay	59	2	95	3
MN0604	East Midtown-Turtle Bay	7	2	11	2
MN0661	United Nations	1	0	2	0
MN0701	Upper West Side-Lincoln Square	8	1	8	1
MN0702	Upper West Side (Central)	5	0	5	2
MN0801	Upper East Side-Lenox Hill-Roosevelt Island	58	2	107	3
MN0803	Upper East Side-Yorkville	69	1	174	1
MN0901	Morningside Heights	0	0	1	0
MN0902	Manhattanville-West Harlem	13	1	24	3

MN0903	Hamilton Heights-Sugar Hill	12	1	16	12
MN1002	Harlem (North)	24	0	165	0
MN1101	East Harlem (South)	416	0	681	0
MN1102	East Harlem (North)	423	0	930	0
MN1191	Randall's Island	24	0	49	2
MN1201	Washington Heights (South)	0	0	3	0
MN1202	Washington Heights (North)	4	0	27	1
MN1203	Inwood	24	0	210	1
MN1292	Inwood Hill Park	5	0	6	1
QN0101	Astoria (North)-Ditmars-Steinway	155	2	351	4
QN0102	Old Astoria-Hallets Point	486	0	772	0
QN0103	Astoria (Central)	15	0	74	0
QN0105	Queensbridge-Ravenswood-Dutch Kills	68	0	721	0
QN0151	Rikers Island	17	0	66	0
QN0191	Astoria Park	0	0	3	0
QN0201	Long Island City-Hunters Point	330	6	983	11
QN0202	Sunnyside	36	1	84	1
QN0261	Sunnyside Yards (South)	1	0	3	0
QN0302	East Elmhurst	2	0	7	0
QN0303	North Corona	0	0	3	0
QN0402	Corona	0	0	3	0
QN0501	Maspeth	35	0	59	4
QN0502	Ridgewood	4	0	14	0
QN0602	Forest Hills	6	0	80	0
QN0701	College Point	392	10	1345	12
QN0702	Whitestone-Beechhurst	105	0	185	0
QN0703	Bay Terrace-Clearview	3	0	65	2
QN0704	Murray Hill-Broadway Flushing	8	0	45	0
QN0706	Queensboro Hill	0	0	84	0
QN0707	Flushing-Willets Point	195	4	515	5
QN0761	Fort Totten	15	1	35	4
QN0871	Mount Hebron & Cedar Grove Cemeteries	0	0	1	0
QN1003	Howard Beach-Lindenwood	5170	243	6608	566
QN1102	Bayside	0	0	3	0
QN1103	Douglaston-Little Neck	188	2	356	2
QN1191	Alley Pond Park	2	0	5	0
QN1306	Springfield Gardens (South)-Brookville	215	26	2763	66
QN1307	Rosedale	794	71	2853	121

QN1401	Far Rockaway-Bayswater	2663	0	3518	237
QN1402	Rockaway Beach-Arverne-Edgemere	4019	22	4422	1092
QN1403	Breezy Point-Belle Harbor-Rockaway Park-Broad Channel	9154	314	9423	837
QN1491	Rockaway Community Park	3	0	5	0
QN8081	LaGuardia Airport	36	0	40	3
QN8191	Flushing Meadows-Corona Park	70	2	100	0
QN8381	John F. Kennedy International Airport	8	0	230	0
QN8491	Jamaica Bay (East)	6	0	6	0
QN8492	Jacob Riis Park-Fort Tilden-Breezy Point Tip	116	0	164	4
SI0101	St. George-New Brighton	25	4	33	6
SI0102	Tompkinsville-Stapleton-Clifton-Fox Hills	146	0	229	1
SI0103	Rosebank-Shore Acres-Park Hill	67	1	155	2
SI0104	West New Brighton-Silver Lake-Grymes Hill	80	1	144	2
SI0106	Port Richmond	192	1	304	0
SI0107	Mariner's Harbor-Arlington-Graniteville	399	4	847	4
SI0191	Snug Harbor	0	0	2	0
SI0201	Grasmere-Arrochar-South Beach-Dongan Hills	1700	0	2887	0
SI0202	New Dorp-Midland Beach	4958	0	5924	0
SI0203	Todt Hill-Emerson Hill-Lighthouse Hill-Manor Heights	14	0	29	0
SI0204	New Springville-Willowbrook-Bulls Head-Travis	262	7	481	17
SI0291	Freshkills Park (North)	13	1	23	1
SI0301	Oakwood-Richmondtown	1617	31	2215	32
SI0302	Great Kills-Eltingville	649	5	1241	6
SI0303	Arden Heights-Rossville	6	0	52	0
SI0304	Annadale-Huguenot-Prince's Bay-Woodrow	127	3	313	7
SI0305	Tottenville-Charleston	351	3	578	7
SI0391	Freshkills Park (South)	20	0	25	1
SI9561	Fort Wadsworth	3	0	3	0
SI9592	Miller Field	12	0	24	0
SI9593	Great Kills Park	4	0	8	0

Figure Source: OMB. Updated June 6th, 2025

Planned Action Scenario

How many buildings will remain at risk of flooding if large-scale infrastructure projects are built?

The Planned Action Scenario builds on the Control Scenario, adding in levels of protection for selected coastal resiliency projects. To do this, the key steps are:

1. Identify which city projects may reduce risks from tidal flooding and the 100-year storm
2. Gather data for each project, including design storm level (see below), project extent maps, and corresponding floodplain reductions
3. Join all project data and overlay with city building locations to understand what properties may be protected after interventions are implemented

Coastal Project Delineation

Flood resiliency projects are built to different levels of protection, such as present-day SLR, 2050s 100-year storm, 2030s 10-year storm, and others. The intensity, duration, and frequency of storm event an asset is designed to withstand is known as the "design storm."[279] To build to a particular design storm, and based on the conditions of a given site (e.g., elevation), the height of a large flood protective measure are typically referred to be the "design flood elevation." The choice to build protections at varying levels is made by the project design teams, which consider factors like site conditions, available funding, specific needs, and other relevant information. Only the scenarios included in the beginning of this section (1 percent storm-surge (with SLR) and high tide for present, 2020s, and 2050s) are included in analysis for several reasons:

- Why only high tide and the 100-year storm?
  - **Data availability:** Floodplain maps are only available for these scenarios, compared to other lesser storm levels (e.g., 10-year storm).
  - **Design variability:** Projects are conducted by various entities (e.g., city, state, federal), which introduces variability from project teams that are designing based on varied protocols, models, and needs. Using the supplementary data provided from agencies on each of the projects, the 100-year storm and high tide are the most common threats projects are designed to protect against.
  - **Scientific variability:** Flood protection projects are designed at different points in time and may use various NPCC projections (e.g., NPCC2, NPCC3, NPCC4) and probabilities, varying their estimates of SLR. Furthermore, different project design teams may use different scientific models to determine flood areas, Additionally, NYNJHATS is tentatively designed to a separate SLR projection curve corresponding to the USACE estimated 1 percent annual exceedance probability. To account for differences in projection levels across built projects, OMB included NPCC3 moderate projections as a catch-all, particularly since NPCC4 values revised SLR estimates from NPCC3. The goal is to include projects that are built to similar standards even if they are not identical, given the variability inherent in projections used over time and

    - the lack of a citywide and cross-jurisdictional standard for projection percentiles to use in project design.
    - **Practicality:** Few projects are built to standards higher than the 100-year storm (even though 500-year floodplain maps are available), so these conditions are not used.
- Why Present, 2020s, and 2050s?
    - **Data availability:** The only local floodplain maps available for the future decadal periods up to mid-century are from NPCC3 (2019) for the 2020s and 2050s. In the future, additional decadal periods could be added.
    - **Practicality:** Few projects address flooding beyond the 2050s projection level, although projects are occasionally built to 2100s level.

Coastal Project Selection

OMB worked with DEP BCR, NYCEDC, and MOCEJ to identify neighborhood-level resiliency projects that should be included in the analysis, as well as DDC, Battery Park City Authority, NYS Department of Housing and Community Renewal, USACE, and the NYC Parks Department regarding projects under their management and control. Project managers and teams are asked to complete a table asking for the following details:

- Project name
- Mapping available (Line of Protection and/or Area of Protection)
- Design flood elevation
- Storm/SLR projection
- Project status
- Anticipated completion date
- Level of protection for each under the scenarios described in the previous table above:
    - Present SLR
    - Present 100-year storm
    - 2050s SLR
    - 2050s 100-year storm
- Additional Notes or Comments: including
    - The NPCC future projections used for the protection levels (e.g., NPCC3 2019 75th percentile projections)

Following the information collection process, projects are winnowed to select only those that fit the scenario conditions and have enough data for analysis, including spatial data on project areas for mapping. See the table below for the final project list for the 15 projects that are modeled.

FIGURE 38 | LIST OF COASTAL PROTECTION PROJECTS CONSIDERED IN FORECAST

East Side Coastal Resiliency	Seaport Coastal Resilience	East Midtown Coastal Resiliency
Brooklyn Bridge-Montgomery Coastal Resilience	FiDi-Seaport Climate Resilience Plan	Mott Basin Raised Shoreline

Battery Park City Coastal Resilience North/West	Red Hook Coastal Resiliency	Rockaways Atlantic Shorefront (USACE)
Battery Park City Coastal Resilience South	Travis Avenue Raised Shoreline	Old Howard Beach Raised Shoreline
The Battery Coastal Resilience	South Shore of Staten Island Coastal Storm Risk Management (USACE)	NYNJHATS (USACE)

Figure Source: OMB

The list below represents projects that were evaluated but do not meet the selection criteria for this first iteration of analysis (e.g., protecting assets rather than neighborhoods, data availability at present project stage):

- Manhattan Waterfront Greenway—Inwood
- Mayberry Raised Shoreline
- Tottenville Shoreline Protection Project
- Coney Island Creek Raised Shoreline
- Fresh Creek Tide Gates
- Hunts Point Energy Resilience
- LaGuardia Airport Berms
- Living Breakwaters
- Rockaway Boardwalk (see Rockaways Atlantic Shorefront instead)
- Rockaways Back Bay—Hammels, Arverne, Edgemere (USACE)
- Beach 88th Street Park
- Thursby Basin Park
- Rockaway Community Park
- Bayswater Park Shoreline Berm and Restoration
- Sea Gate T-Groins
- Coney Island Boardwalk (see NYNJHATS instead)
- Lower Concourse Park
- Utopia Parkway
- Academy Street
- North Cove

This list is not exhaustive of all climate resilience projects, but those large projects that are identified during the discovery process.

Coastal Project Processing

Input data sources included:

- DOB Buildings Footprints by BIN
- NYCEDC, DEP, and other agency project maps
- NPCC 2050s storm floodplain (100-year) and high tide flood area

- FEMA FIRM and PFIRM shapefiles

QGIS is used to find the attenuation extents for each coastal project (the area of floodplain behind each project that would see reduced flooding due to the project) and buildings protected during analysis (the number of buildings in the previously at-risk area that would now be in an area of managed risk from the flood project). For most projects, maps with flood attenuation areas are shared with OMB from project teams and shapefiles are included directly in the combined shapefile of project attenuation extents (output). Spatial data for some projects provided to OMB are only available as lines, not polygons. For these projects, OMB assumed attenuation areas for the project (looking at the area behind/upland of the barrier lines) for each of the scenarios separately (present tidal, future tidal without NYNJHATS, future tidal with NYNJHATS, present storm, future storm without NYNJHATS, and future tidal with NYNJHATS). This is only the case for the Raised Shoreline projects (Mott Basin, Old Howard Beach, Travis Avenue) and East Midtown Coastal Resiliency.

For the case of the Raised Shoreline projects, tidal flooding areas are assumed to be the extents upland of the proposed project lines, with flooded areas choked off by the barriers. For East Midtown Coastal Resiliency, the 100-year floodplain and tidal inundation areas are assumed to be entirely mitigated behind the barrier lines parallel to the tie-ins mapped.

Projects are phased in based on their completion year and the year of projection based on available NPCC projections (2020s and 2050s). For example, projects completed in the 2030s would not be included in the protected areas to the 2020s storm since they would not yet be built. Dates are estimations of completion dates and may differ as projects progress, including if projects are completed in phases. NYNJHATS is still tentative, as well. The latest dates are used to be conservative

Due to variations in flood modeling by various project teams and at different time points, projects that are listed as being built to withstand the 100-year storm in the present or the future are matched up to the utilized floodplains (FIRM/PFIRM and NPCC) and all appropriate areas considered to be attenuated. Where shared mapped attenuation areas vary slightly compared to the used floodplains, these are adjusted after consultation with project teams to allow for direct comparison between baseline flood maps and attenuated areas.

The same exercise is conducted for tidal flooding areas, but due to the lack of mapped tidal flooding attenuation areas available, tidal attenuation areas are largely extrapolated based on the storm attenuation area if applicable in the tidal zone. See the table below for information on each project's scenario inclusion. For example, if a project's design storm is the present-day 10-year storm and 2100 SLR flooding, this would have been incorporated into the protection area analyses as such:

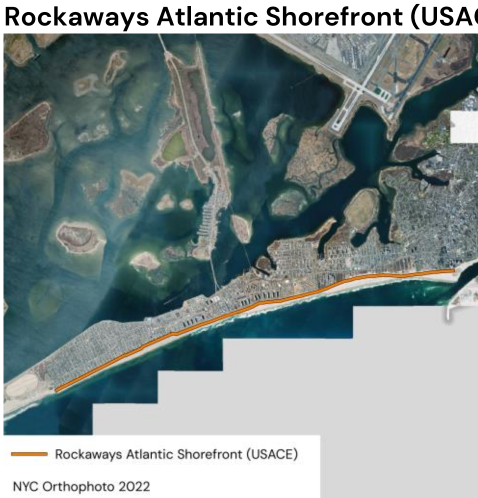
- Present Tidal: yes
- Present Storm: no (not built to a high-enough standard to protect fully against the 100-year storm)
- Future Tidal: yes

- Future Storm: no (not built to a high-enough standard to protect fully against the 100-year storm)

FIGURE 39 | COASTAL FLOOD PROTECTION PROJECT FORECASTING ATTRIBUTES

Project Name	Current 100yr Storm	2050s 100yr Storm	Current Tidal	2050s Tidal	Earliest Modeled Decade
Mott Basin Raised Shorelines 	N	N	Y	Y	2050s
Old Howard Beach Raised Shorelines 	N	N	Y	Y	2020s
Travis Avenue Raised Shorelines 	N	N	Y	Y	2020s

East Side Coastal Resiliency 	Y	Y	Y	Y	2020s
Red Hook Coastal Resiliency 	N	N	Y	Y	2020s
The Battery Coastal Resilience 	N	N	Y	Y	2020s

Seaport Coastal Resilience 	N	N	Y	Y	2020s
Brooklyn Bridge-Montgomery Coastal Resilience 	Y	Y	Y	Y	2020s
Rockaways Atlantic Shorefront (USACE) 	Y*	Y*	Y	Y	2050s+ NYNJ HATS

South Shore Staten Island Coastal Storm Risk Management (USACE) 	Y	Y	Y	Y	2050s
Battery Park City Coastal Resilience North/West 	Y	Y	Y	N	2020s
Battery Park City Coastal Resilience South 	Y	Y	Y	N	2020s

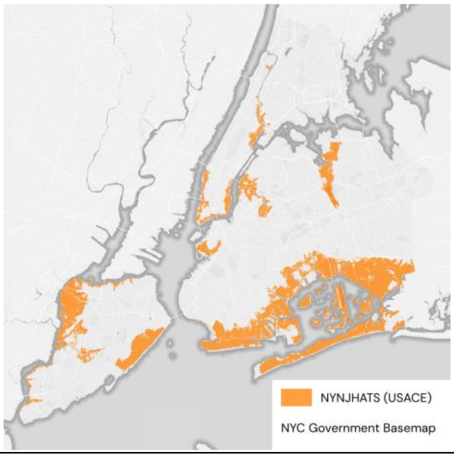
NYNJHATS (USACE) 	Y	Y	Y*	Y*	2050s+ NYNJHATS
East Midtown Coastal Resiliency 	Y	Y	Y	Y	2050s
FiDi-Seaport Climate Resilience Plan 	Y	Y	Y	Y	2050s

Figure Source: OMB

**Project extents and locations are subject to change and based on design storm at the time of analysis. "Y" means that the design storm covers the scenario described in the column (e.g., 2050s 100-year storm) and "N" means it is not designed to that level of protection. Rockaways Atlantic Shorefront is built to 100-year standard for 2050 but will not see attenuation in the absence of NYNJHATS due to bidirectional flooding from Jamaica Bay, in addition to the Atlantic Ocean. See below for an explanation of NYNJHATS protections for tidal flooding and High Frequency Flood Risk Reduction Features.*

Notably, partial protections are not considered in these analyses due to complexity. While it may be the case that a barrier for the 10-year design storm provides some protection to the 100-year storm (though not full protection), these partial protections are not included for consideration due to the limitations of flood map and project attenuation areas described earlier in this section. For these purposes, and noting the limitations, only full protections for each scenario are included.

Additionally, though a year's storm-surge (including SLR) is greater than tidal flooding alone, not all storm-surge projects are protective to tidal flooding. For example, some projects use deployable barriers that are only deployed when a threshold storm event is reached—these would not be deployed during high tides alone and would thus remain exposed unless other complementary measures are included in the project. The one exception for this evaluation is NYNJHATS—NYNJHATS includes some High Frequency Flood Risk Reduction Features that are used to ameliorate risk for lesser events when storm-surge deployables are undeployed. For this reason and due to the uncertainty of the project at this stage, NYNJHATS-inclusive scenarios consider all protected areas for storms to be protected for tidal flooding, as well, though this may not always be the case in practice.

After project areas are corrected, the count of buildings in the floodplain per NTA are generated using QGIS Count Points within Polygons function. This is based off attenuated areas behind the flood barriers, where flooding would occur without the barrier and would likely not occur to that design level with the barrier installed. The count of buildings in the attenuation floodplain area are generated and these values compared to the total number of at-risk (in the floodplain) buildings to generate a proportion of potentially protected buildings for each scenario per NTA. See the table below for the share of buildings in each scenario that would be protected from the proposed projects. Note that only the NTAs that overlap the floodplain are eligible for analysis and the results are a simple proportion—if the neighborhood expects a flood wall for example that will protect 100 percent of buildings in two NTAs behind it, the pertinent NTAs would see 100-percent protection. This is equal for an NTA with five out of five protected properties and an NTA with 100 out of 100 protected properties, since showing proportions of protection. This is not a comprehensive list of every neighborhood in the city—it only includes NTAs that have at least one building protected by a neighborhood-scale project from either storm-surge or tidal inundation.

FIGURE 40 | PROPORTION OF AT-RISK BUILDINGS PROTECTED, BY SCOPE, DECADE, AND NTA

NTA	Buildings in Present 100-Year Storm Area Protected (percent)	Buildings in Present High-Tide Area Protected (percent)	Buildings in Future 100-Year Storm Area w/o NYNJHATS Protected (percent)	Buildings in Future High-Tide Area w/o Protected (percent)	Buildings in Future 100-Year Storm Area w/ NYNJHATS Protected (percent)	Buildings in Future High-Tide Area w/ NYNJHATS Protected (percent)
BK0101	0.00	0.00	0.00	0.00	72.92	80.00
BK0104	0.00	0.00	0.00	0.00	71.99	100.00
BK0503	0.00	0.00	0.00	0.00	100.00	0.00
BK0504	0.00	0.00	0.00	0.00	100.00	0.00
BK0505	0.00	0.00	0.00	0.00	100.00	100.00
BK0601	0.00	0.00	0.00	0.00	89.01	78.26
BK0702	0.00	0.00	0.00	0.00	0.35	0.00
BK1101	0.00	0.00	0.00	0.00	100.00	0.00
BK1102	0.00	0.00	0.00	0.00	98.69	0.00
BK1103	0.00	0.00	0.00	0.00	98.77	0.00
BK1301	0.00	0.00	0.00	0.00	99.49	0.00
BK1302	0.00	0.00	0.00	0.00	99.55	76.92
BK1303	0.00	0.00	0.00	0.00	99.95	0.00
BK1501	0.00	0.00	0.00	0.00	100.00	0.00
BK1502	0.00	0.00	0.00	0.00	100.00	0.00
BK1503	0.00	0.00	0.00	0.00	99.93	91.38
BK1801	0.00	0.00	0.00	0.00	100.00	0.00
BK1802	0.00	0.00	0.00	0.00	99.85	92.86
BK1803	0.00	0.00	0.00	0.00	100.00	0.00
BK1891	0.00	0.00	0.00	0.00	33.33	0.00
BK1892	0.00	0.00	0.00	0.00	100.00	0.00
BK1893	0.00	0.00	0.00	0.00	100.00	0.00
BK5691	0.00	0.00	0.00	0.00	64.71	75.00
BK5693	0.00	0.00	0.00	0.00	100.00	0.00
BX0101	0.00	0.00	0.00	0.00	58.99	20.00
BX0102	0.00	0.00	0.00	0.00	100.00	0.00
BX0401	0.00	0.00	0.00	0.00	56.52	0.00
MN0101	23.22	0.00	98.25	69.23	98.25	46.15
MN0102	45.45	0.00	40.80	0.00	100.00	0.00
MN0191	0.00	0.00	2.48	7.69	0.83	7.69
MN0201	0.00	0.00	0.00	0.00	99.73	0.00
MN0203	0.00	0.00	0.00	0.00	98.82	0.00
MN0301	100.00	0.00	100.00	100.00	100.00	100.00
MN0302	100.00	100.00	100.00	50.00	100.00	100.00
MN0303	100.00	100.00	100.00	100.00	100.00	100.00

MN0401	0.00	0.00	0.00	0.00	95.38	0.00
MN0601	100.00	0.00	100.00	0.00	100.00	0.00
MN0602	0.00	0.00	100.00	0.00	100.00	0.00
MN0603	4.49	0.00	14.74	0.00	98.95	66.67
MN0803	0.00	0.00	0.00	0.00	97.13	0.00
MN1002	0.00	0.00	0.00	0.00	100.00	0.00
MN1101	0.00	0.00	0.00	0.00	100.00	0.00
MN1102	0.00	0.00	0.00	0.00	100.00	0.00
MN1191	0.00	0.00	0.00	0.00	2.04	0.00
MN1202	0.00	0.00	0.00	0.00	81.48	0.00
MN1203	0.00	0.00	0.00	0.00	80.00	0.00
QN0105	0.00	0.00	0.00	0.00	0.14	0.00
QN0201	0.00	0.00	0.00	0.00	100.00	81.82
QN0202	0.00	0.00	0.00	0.00	100.00	100.00
QN0261	0.00	0.00	0.00	0.00	100.00	0.00
QN0303	0.00	0.00	0.00	0.00	100.00	0.00
QN0402	0.00	0.00	0.00	0.00	100.00	0.00
QN0501	0.00	0.00	0.00	0.00	100.00	100.00
QN0502	0.00	0.00	0.00	0.00	100.00	0.00
QN0602	0.00	0.00	0.00	0.00	100.00	0.00
QN0701	0.00	0.00	0.00	0.00	15.84	0.00
QN0702	0.00	0.00	0.00	0.00	0.54	0.00
QN0704	0.00	0.00	0.00	0.00	100.00	0.00
QN0706	0.00	0.00	0.00	0.00	100.00	0.00
QN0707	0.00	0.00	0.00	0.00	100.00	60.00
QN0871	0.00	0.00	0.00	0.00	100.00	0.00
QN1003	0.00	0.41	0.00	3.36	100.00	98.76
QN1306	0.00	0.00	0.00	0.00	100.00	89.39
QN1307	0.00	0.00	0.00	0.00	100.00	100.00
QN1401	0.00	0.00	0.00	12.24	72.77	81.01
QN1402	0.00	0.00	0.00	0.00	99.98	100.00
QN1403	0.00	0.00	0.00	0.00	100.00	96.65
QN1491	0.00	0.00	0.00	0.00	100.00	0.00
QN8191	0.00	0.00	0.00	0.00	97.00	0.00
QN8381	0.00	0.00	0.00	0.00	100.00	0.00
QN8491	0.00	0.00	0.00	0.00	100.00	0.00
QN8492	0.00	0.00	0.00	0.00	100.00	100.00
SI0101	0.00	0.00	0.00	0.00	15.15	16.67
SI0104	0.00	0.00	0.00	0.00	100.00	100.00
SI0106	0.00	0.00	0.00	0.00	100.00	0.00
SI0107	0.00	0.00	0.00	0.00	100.00	100.00
SI0191	0.00	0.00	0.00	0.00	100.00	0.00
SI0201	0.00	0.00	100.00	0.00	100.00	0.00
SI0202	0.00	0.00	100.00	0.00	100.00	0.00
SI0203	0.00	0.00	0.00	0.00	100.00	0.00
SI0204	0.00	0.00	0.00	0.00	100.00	100.00
SI0291	0.00	0.00	0.00	0.00	100.00	100.00

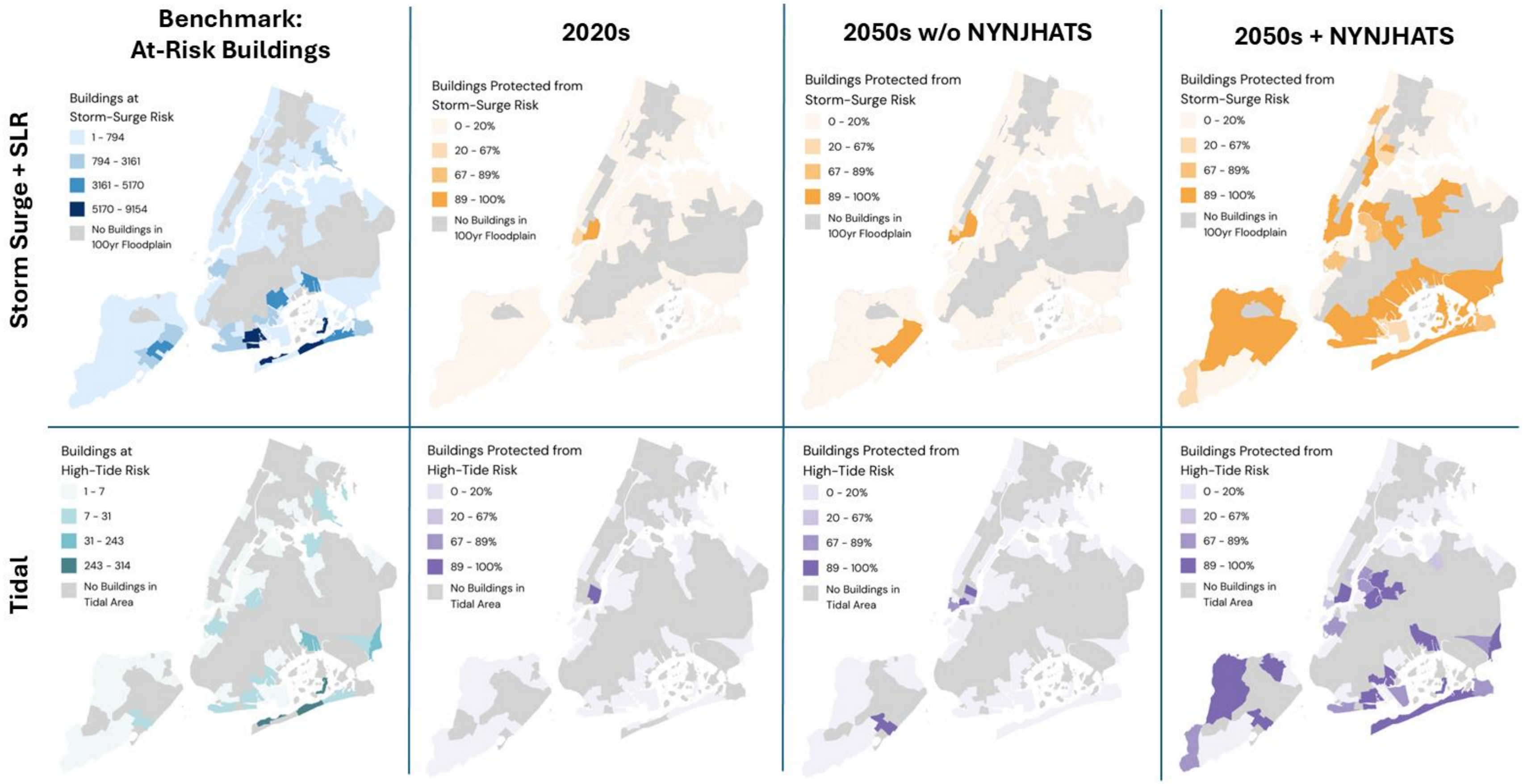
SI0301	0.00	0.00	98.87	100.00	98.92	100.00
SI0302	0.00	0.00	0.00	0.00	16.12	0.00
SI0303	0.00	0.00	0.00	0.00	100.00	0.00
SI0304	0.00	0.00	0.00	0.00	0.32	0.00
SI0305	0.00	0.00	0.00	0.00	36.68	85.71
SI0391	0.00	0.00	0.00	0.00	100.00	100.00
SI9592	0.00	0.00	100.00	0.00	100.00	0.00

Figure Source: OMB

The total share of buildings protected per total for storm-surge risk citywide is 1.02 percent in the 2020s, 10.8 percent in the 2050s (without NYNJHATS), and 85.3 percent in the 2050s (with NYNJHATS).

The total share of buildings protected per total for tidal risk citywide is negligible in the 2020s. In the 2050s, this share grows to 2.7 percent without NYNJHATS, and 89.5 percent with NYNJHATS.

FIGURE 41 | SHARE OF AT-RISK BUILDINGS AT BASELINE AND AFTER PROJECTED PROTECTIONS, BY SCENARIO AND NTA



The figure shows the count of buildings at-risk at the benchmark and shows the proportion (share) of at-risk buildings protected for future. Scenarios; Figure Source: OMB

Assessing Vulnerable Areas

Using the city's EJ Areas Mapping tool,[280] census tracts in EJ Areas are extracted and the forecast is reprocessed. The scenarios are split into two groups, one where buildings are exposed/protected in EJ Areas, and another in non-EJ Areas. Counts and proportions are reevaluated using the aforementioned groups and results show that approximately 25 percent of buildings at risk in EJ Areas will be unprotected by the evaluated protective measures (including NYNJHATS) to a 2050s 100-year storm, compared to only 7 percent of non-EJ Areas.

Using the city's Flood Vulnerability Index (specifically the Flood Susceptibility to Harm and Recovery Index, FSHRI), census tracts that are determined to be of "higher vulnerability" (FSHRI four and five) are extracted and the analysis is run.[281] The scenarios are split into two groups, similar to the EJ Areas analysis. These two groups, Higher FSHRI and Lower FSHRI, shared similar results between area types.

Additional Limitations

Projects will come online incrementally, with levels of protection adding up over time, though the gulf of time between the 2020s and 2050s scenarios may make the onset of protections seem sudden in forecast results for these two decadal periods. Furthermore, project design levels are only as good as their scientific design criteria. If climate change progresses more rapidly, events such as tidal flooding and any 100-year storm are likely to become more frequent and extensive, which can lead to underperformance of protective measures.

While neighborhood-level protective measures are important, redundant protections and community and social measures can provide higher levels of protection, such as during the event of failure of a large flood protection project (e.g., a breach or damage). These analyses provide a foundation to build on to consider more varieties and levels of protection in the future, including individual asset protections and social measures. Analysis in the future will attempt to add these in a standardized way to existing efforts and update with projects that are cancelled or newly planned. Additionally, projects in this list mainly include large hardscape designs, though may include some nature-based solutions within larger projects. These and other natural features such as wetlands will be investigated more in the future. The evaluation of hardscape measures such as floodwalls currently does not include analysis of induced flooding (flooding in a place that results from or worsens due to flood protections in a nearby place. Some project designs may include induced flooding-reduction features, but these are not separately captured in this analysis and may be investigated in the future.

Projects that are included on this list are likely to be completed and some are already complete or almost complete. Projects may be added, altered, or removed from the forecasting list and analyses will be updated in the future to account for project status and design changes and should be considered a potential view of protection, not a certainty.

Only building counts are included in this first analysis, but more could be assessed, such as number of residential units, number of buildings of different types (e.g., critical facilities), infrastructure, property value, demographic populations, and others. These would be more important for understanding the nuanced impacts of different at-risk populations and assets. Furthermore, the number of buildings will vary in the future, but due to the lack of a granular buildings count forecast citywide, baseline building counts are projected forward into the future for the purposes of assessing levels of adaptation to buildings.

INDOOR HEAT

How does the forecast approach indoor heat adaptation strategies?

The city's A/C and indoor cooling goals are somewhat more nascent than those for other hazards. PlaNYC includes an initiative, "maximize access to indoor cooling" that involves developing a maximum summer indoor temperature policy, including mandatory cooling requirements for new construction, and reforming the Home Energy Assistance Program.[282] However, the development of these programs is still underway. At this time, it is not possible to forecast indoor cooling for residences. However, this may be assessed in the future.

For this iteration of analysis, OMB forecasted future A/C prevalence in schools, using the Leading the Charge initiative parameters.[283] Leading the Charge is an effort to begin converting 100 existing schools to all-electric heating by 2030.[284]

Electrification of schools promotes indoor cooling, because electric school buildings will have dedicated or central heating and cooling systems, which will enable A/C across the whole building. The forecast for indoor heat examines how uptake of electrification in line with the Leading the Charge initiative could increase rates of A/C in schools. It is important to note that, due to a 2017 mayoral announcement targeting full attainment of A/C for school classrooms by 2022, most school classrooms already have A/C. [285] However, public assembly spaces, such as gymnasiums, have lower levels of attainment. The effects on students in these spaces, compared to traditional classrooms, may be more unclear, given the activities in these spaces may be multipurpose and extend beyond traditional classroom learning.[286]

Exact locations and timelines for these school conversions are in ongoing formulation, allowing this analysis to compare what is currently planned versus potential future expansions of cooling capacity. Some key assumptions must be considered, particularly that A/C estimates for school retrofits at as-yet-undetermined locations are assumed based on average school characteristics. Additionally, due to as-yet-undetermined timing of retrofits for many Leading the Charge locations, coarse timeline estimates are assumed. At this time, the number of projects with added A/C are based on assuming even roll-out over the next five years, for simplicity in this analysis.

Understanding these patterns is crucial for assessing the extent to which school electrification can mitigate indoor heat exposure, but this is just one measure of indoor cooling attainment across the city. Future work will examine expanding this analysis.

FIGURE 42 | PROCESS FOR INDOOR HEAT ESTIMATION

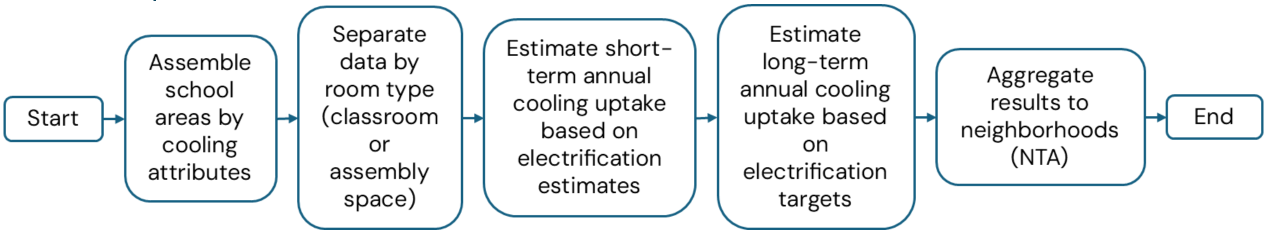


Figure Source: OMB

School Room Analysis

School areas are separated into two groups:

1. **Classrooms**: spaces that include regular instruction of students, considered "traditional" classrooms (as opposed to other instructional spaces such as auditoriums). These are spaces that are prioritized for achieving comprehensive A/C by 2022 by former Mayor de Blasio in 2017.[287] Most classroom spaces already have A/C (see analyses below), though the adequacy of these units may be variable.
2. **Public assembly**: spaces for students to congregate for group activities that are not typical classrooms—these are often spaces such as gymnasiums, auditoriums, or cafeterias. They may serve multiple purposes and are often difficult to cool, given their large sizes. They have lower baseline A/C rates (see below analyses), as they largely cannot be sufficiently cooled by removable (largely in-window) A/C units and require central A/C in many cases.

OMB used the classification scheme for the inventory (see previous sections) as well as the forecasting work described below. The forecast is conducted separately due to the disparate levels of cooling between these space types.

Inputs:

- NYC School Construction Authority (SCA) data on Leading the Charge plans—information on which schools may be electrified in upcoming years based on funding allocation
- NYC Public Schools Building Space Usage (Open Data)—list of all school classrooms as of 2024, based on the Principle Annual Space Survey, self-reported[288]
- NYC Public Schools' 2024 Air Conditioning Survey—a survey conducted annually to determine which classrooms have functional A/C systems

Process steps:

- A comprehensive list of school rooms are taken from the NYC Public Schools Building Space Usage dataset. Only those data as of 2024 (the most recent year of data) are used. Rooms are classified in the dataset by Room Function. In order to determine which rooms fit under "classrooms" vs "assembly" spaces, NYC Public Schools' Building Space Usage room functions are mapped heuristically onto A/C Survey classroom classifications.

- The annual A/C survey includes several categories of room types that are not the same as the NYC Public Schools Building Space Usage dataset because the surveys are conducted in the field and judgements may vary
- Generally for the A/C survey, rooms considered for these analysis purposes as classrooms are those categorized as:
    - *Regular Classrooms* functioning for *Instructional Space* or *Under Construction*
    - *Other* room spaces with area greater than 500 square feet functioning as I*nstructional Space* or *Under Construction*
- Generally for the A/C survey, rooms considered for these analysis purposes as assembly spaces are those not for the function of *Facility Operations* that are categorized as:
    - *Auditorium*
    - *Cafeteria*
    - *Library*
    - *Multipurpose*
    - *Gym*
- Rooms classifications from the A/C Survey are used when available (even if they are inconsistent with the room type indicated in the NYC Public Schools Building Space Usage dataset).
- When rooms in the NYC Public Schools Building Space Usage dataset are not part of the A/C Survey, any room types from the NYC Public Schools Building Space Usage dataset that clearly mapped onto the categories above are used and labeled as classroom or assembly accordingly. Other NYC Public Schools Building Space Usage room types are classified by inferring room purpose from other context or from checking individual cases from the A/C survey for guidance, though inconsistencies existed that are idiosyncratic to individual A/C surveyors or the layouts of different school buildings that may use room types for different purposes. For more information on the A/C survey, see previous sections.
- See below for a table of room type mapping for those rooms only identified in the NYC Public Schools Building Space Usage dataset (no A/C Survey conducted) considered for this analysis to be classrooms or public spaces. Other room types are not included as they may be service spaces, facility areas, or others that may not need A/C (e.g., facility closets).

FIGURE 43 | SCHOOL ROOM CLASSIFICATIONS

ART ROOM	Classroom	NEST SIXTH-EIGHTH GRADE	Classroom
AUTOMOTIVE SHOP	Classroom	NON-D75 SPED CLASSROOM	Classroom
COMPUTER LAB	Classroom	PRE-K FULL DAY	Classroom
D75 SPED CLASSROOM	Classroom	PRE-K HALF DAY	Classroom
DANCE ROOM	Classroom	REGULAR CLASSROOM	Classroom
ELECTRONICS SHOP	Classroom	REGULAR CLASSROOM—HS GRADES	Classroom
FIFTH GRADE	Classroom	REGULAR CLASSROOM—MS GRADES	Classroom
FIRST GRADE	Classroom	RESOURCE ROOM	Classroom
FOURTH GRADE	Classroom	SCIENCE CLASSROOM FOR PS	Classroom
FUNDED—ESL	Classroom	SCIENCE DEMO ROOM	Classroom
FUNDED—LITERACY	Classroom	SCIENCE LAB	Classroom
FUNDED—MATH	Classroom	SECOND GRADE	Classroom
FUNDED—OTHER	Classroom	SETSS	Classroom
FUNDED—READING	Classroom	THEATRE ARTS/DRAMA	Classroom
HOME ECONOMICS	Classroom	THIRD GRADE	Classroom
HORIZON KINDERGARTEN-FIRST GRADE	Classroom	WOOD/CARPENTRY SHOP	Classroom
HORIZON SECOND-TWELFTH GRADE	Classroom	ADAPTIVE PHYSICAL EDUCATION	Assembly
ICT—ELEMENTARY SCHOOL GRADES	Classroom	AUD/CAFETERIA	Assembly
ICT—HIGH SCHOOL GRADES	Classroom	AUDITORIUM	Assembly
ICT—MIDDLE SCHOOL GRADES	Classroom	GYM/AUD/CAFETERIA	Assembly
INDIVIDUALIZED EDUCATION PLAN	Classroom	GYM/AUDITORIUM	Assembly
KINDERGARTEN	Classroom	GYM/CAFETERIA	Assembly
MEDIA CENTER	Classroom	GYMNASIUM	Assembly
MULTI-PURPOSE CLASSROOM	Classroom	LIBRARY	Assembly
MUSIC ROOM	Classroom	MULTI-PURPOSE ROOM	Assembly
NEST FIRST-THIRD GRADE	Classroom	STUDENT CAFETERIA	Assembly
NEST FOURTH-FIFTH GRADE	Classroom	SWIMMING POOL	Assembly
NEST KINDERGARTEN	Classroom	WEIGHT ROOM	Assembly
NEST NINTH-TWELFTH GRADE	Classroom	UNDER CONSTRUCTION	Depends on room size (see above re: 500 ft^2)

Figure Source: OMB

- All building rooms from the NYC Public Schools Building Space Usage dataset are included and classified according to the above. Not all buildings in this list have baseline data on A/C prevalence from the NYC Public Schools A/C Survey, so these un-surveyed rooms are assigned a weighted random value of either having or not having A/C to compensate for lack of data at baseline. The random values are based on weighted probabilities of A/C prevalence based on the A/C survey results at baseline (e.g., if 95 percent of classrooms surveyed had A/C, a 95 percent weighted probability of "yes" is randomly assigned to un-surveyed classrooms, with a 5 percent random assignment of "no."). This allowed for the application of A/C turnover from electrification to be applied across schools for later steps of the analysis.
- Only the NYC Public Schools Building Space Usage list of buildings and rooms is included—spaces part of the A/C Survey but not on this list are excluded from this analysis. One

building listed for Leading the Charge upcoming projects do not have A/C survey results, so this building is excluded from analysis for the time being. This was done to allow a consistent baseline number of rooms to determine proportions of A/C over time.

Future Projections

- Any schools with a forecasted construction end date (provided by SCA based on current funding and plans for Leading the Charge) are assigned that year for all rooms in the building to have A/C. This is applied incrementally for construction dates until the final date in 2030.
- Additional schools without construction dates (e.g., if in design process) are assumed to come online by 2035 to allow time for design, planning, and construction, informed by consultation with SCA on average construction timelines, and taking the most conservative timeline.
- The number of rooms with A/C is annualized to show incremental change year on year until 2035. Note that if school rooms in Leading the Charge buildings are already surveyed as having A/C, these would show no turnover in the analysis (even if now a different form and energy source, such as a window A/C unit to central A/C). This may underplay the importance of additional cooling benefits gained from dedicated or central A/C versus window units, but that could not be assessed at this time for effectiveness, just A/C presence.
- Due to the Leading the Charge goal of 100 schools, the anticipated schools over the next five years based on funding are subtracted from 100 to get the remaining number of unspecified schools to be electrified. The average number of classrooms and assembly rooms per building are generated from the total buildings list from NYC Public Schools and the remaining “electrified” schools are selected randomly from the list of schools (checking that their average number of classrooms and assembly spaces is similar to the overall average for all buildings). These are then ”electrified" in the simulation, converting any unairconditioned spaces to A/C.
- These are all applied by 2050 as the end year for all electrification through Leading the Charge. This date is assumed to give enough time for the full portfolio to be electrified, though it is conservative and may give more time than is needed, particularly since all Leading the Charge projects must be initiated by 2030. These uptake rates are annualized between 2036 and 2050 to get a trend of uptake.

Results from the analysis indicate an increase in A/C uptake over time as buildings are electrified. Leading the Charge school electrification projects alone could increase the proportion of school assembly spaces that are air conditioned by approximately 5 percent. This is meaningful for these spaces as they are less likely to already be air conditioned at baseline compared to traditional classrooms.

Classrooms will also receive more A/C over time as electrification projects come to fruition, but due to relatively higher levels of classroom A/C at baseline compared to assembly spaces, the effects are less pronounced. This work is an initial step in investigating the many efforts that ensure cooling for students.

Limitations

Other factors, such as insulation, may be important for understanding indoor heat, and this could be explored in the future. Furthermore, this dataset only accounts for public schools, not private or other schools. It also relies heavily on data from the NYC Public Schools A/C Survey, which does not include all schools. While not all A/C is created equal (e.g., differences in efficiency), school electrification results in dedicated or central A/C, often where there was none before or where there were previously window units. Central air is often highly effective at cooling spaces compared to window units, so it is assumed that effective A/C is being rolled out as part of Leading the Charge.[289]

Because A/C prevalence is already high in traditional classrooms, the impacts of school electrification on A/C seem relatively meager, since most classrooms are turning over from already having window A/Cs to continuing to have A/Cs (though now certainly dedicated or central). However, this does not account for the fact that having functional window A/Cs may not provide sufficient cooling even when A/C is technically present and functional (though some schools may already have central or dedicated A/C at baseline, but this is less likely compared to simply having any A/C type). This could be an area for future investigation, particularly examining how striated effects on education are seen in schools. Though research has established how students with and without A/C are impacted in their learning outcomes, more information can be collected on how sufficient A/C is and how gradations of A/C effectiveness and space/activity types affect learning outcomes and thus if there is an additional effect of switching window A/Cs to dedicated or central A/C in terms of learning ability in schools, and how assembly spaces are affected as they may not be solely spaces of traditional instruction and learning.
Note that this only compares the existing stock of schools and does not consider newly built schools, which will also have cooling.[290] Cooling can also be provided through other sources outside of Leading the Charge, but only Leading the Charge as a program is considered at this time in analysis.

Room usage can change with school needs and priorities and these values are a snapshot in time. Additionally, other rooms such as offices are excluded and some room types may have varying usages across schools even if they are labeled as the same “type” or “function.”

GLOSSARY

Term	Definition
A/C	Air Conditioning
Appendix G	Appendix G of the NYC Building Code for Flood-Resistant Construction
BBL	Borough Block Lot
BCR	NYC Department of Environmental Protection's Bureau of Coastal Resilience
BIN	Building Identification Number
CRDG	Climate Resiliency Design Guidelines
DCP	NYC Department of City Planning
DDC	NYC Department of Design and Construction
DEM	Digital Elevation Model
DEP	NYC Department of Environmental Protection
DOB	NYC Department of Buildings
DSM	Digital Surface Model
ERA5	European Centre for Medium-Range Weather Forecast's 5th generation reanalysis for global climate
FEMA	Federal Emergency Management Agency
FIRM/PFIRM	Flood Insurance Rate Map/Preliminary Flood Insurance Rate Map
FSHRI	Flood Susceptibility to Harm and Recovery Index
GIS	Geographic Information Systems
HPD	NYC Department of Housing Preservation and Development
HVI	Heat Vulnerability Index
KPI	Key Performance Indicator
LiDAR	Light Detection and Ranging
LC	Land Cover
MOCEJ	New York City Mayor's Office of Climate and Environmental Justice
MS4	Municipal Separate Storm Sewer System
NFIP	National Flood Insurance Program
NPCC	New York City Panel on Climate Change
NYCEDC	NYC Economic Development Corporation
NYCEM	NYC Department of Emergency Management
NYCHA	New York City Housing Authority
NYNJHATS	USACE New York & New Jersey Harbor and Tributaries Focus Area Feasibility Study
NTA	Neighborhood Tabulation Area
OMB	NYC Mayor's Office of Management and Budget
ROW	Right of Way
SCA	NYC School Construction Authority
SLR	Sea-Level Rise
SUEWS	Surface Urban Energy and Water Balance Scheme
TSP	NYNJHATS Tentatively Selected Plan
UMEP	Urban Multi-scale Environmental Predictor
USACE	United States Army Corps of Engineers

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The City of New York
Executive Budget
Fiscal Year 2026

Eric Adams, Mayor

Mayor's Office of Management and Budget
Jacques Jiha, Ph.D., Director

Technical Appendix C: Greenhouse Gas Emissions and Air Quality Forecasting

New York City Climate Budgeting

CONTENTS

EMISSIONS FORECASTS

For the Fiscal Year (FY) 2026 Climate Budgeting publication, the New York City Mayor's Office of Management and Budget (OMB) refined its initial greenhouse gas (GHG) emissions and air quality forecasts with improved methodologies, new data sources, and policy updates. For detailed methodologies of the forecasts on which this work is built, refer to the Technical Appendices to the FY 2025 Climate Budgeting publication.[1]

The sections below summarize the policy updates that were captured, methodology updates that were implemented, and results of those updates.

OMB developed four emissions forecast scenarios. These scenarios build cumulatively to capture the impact of State and City Actions to reduce emissions.

1. **Market Trends & Federal Policy**: GHG emissions are influenced by population and weather changes and market trends, as well as federal policies including the Inflation Reduction Act, the Bipartisan Infrastructure Law, and fuel economy standards.
2. **Large-Scale Renewable Projects**: Scenario 1 + planned transmission projects and large-scale renewable energy developments.
3. **Additional State Actions:** Scenario 2 + state commitments to decarbonize, including the Clean Energy Standard (CES) and zero-emissions vehicle requirements.
4. **City Actions:** Scenario 3 + 16 City Actions (including City Government Operations GHG reductions) committed to through mayoral or legislative action.

Fig. 1 shows the projected emissions in each scenario, along with emissions reductions targets for New York City. These targets include New York City's goal to reach net-zero emissions by 2050 and interim reduction targets from the Intergovernmental Panel on Climate Change.[2] This figure shows that by 2030, the introduction of large-scale renewables is expected to greatly reduce New York City's GHG emissions. City Actions are the second-largest source of reductions in 2030. By 2050, additional State Actions are expected to become the largest contributor to GHG reductions. However, the collective impact of planned climate actions at the city and state levels is currently insufficient to reach interim GHG reduction targets or net-zero GHG emissions by 2050.

FIG. 1 | CITYWIDE GHG EMISSIONS FORECAST SCENARIOS

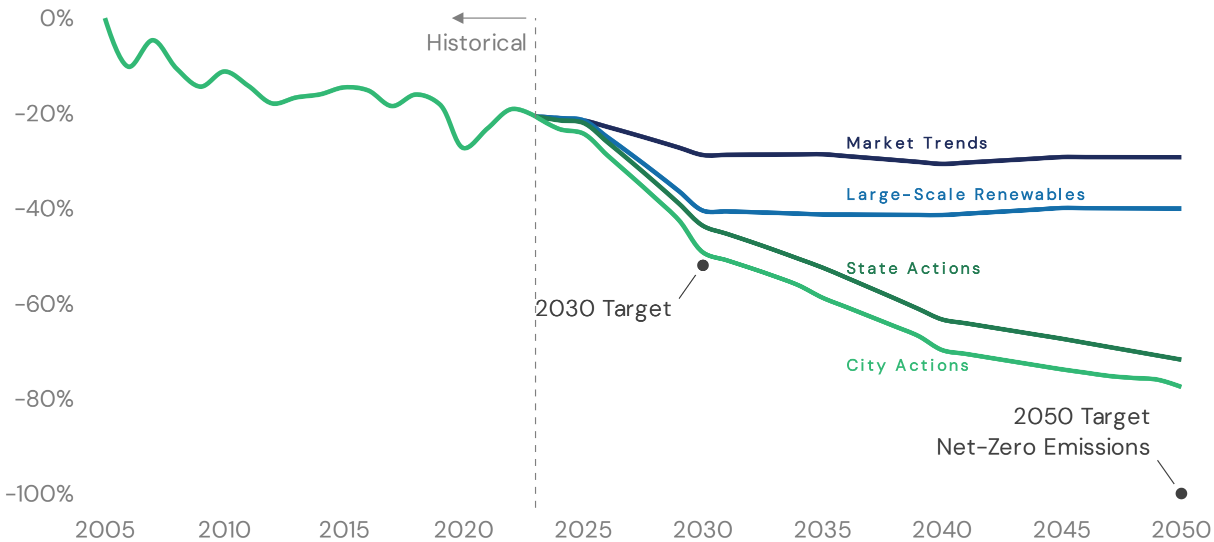

Figure Source: OMB

Fig. 2 summarizes the key policy updates and methodological updates for each scenario. The updates for the first three scenarios were implemented using the U.S. Environmental Protection Agency (EPA)'s City-based Optimization Model for Energy Technologies (COMET).[3] The updates for the City Actions scenario were implemented using action-specific analysis developed in Python and Microsoft Excel.

FIG. 2 | SUMMARY OF MODEL UPDATES

Scenario	Policy Updates	Methodological Updates
Market Trends & Federal Policy	• Significant policy uncertainty, including tariffs and risks to climate policies[4] • Executive order barring development of new offshore wind projects[5]	• Integrated new datasets on current inventory, costs, efficiency, and projections • Added medium- and heavy-duty electric vehicle (EV) technologies
Large-Scale Renewable Projects	• Delays and cancellations of large-scale renewable projects[6]	• Updated interconnection zone of Sunrise Wind development
Additional State Actions	• State forecasts 2030 state Clean Energy Standard (CES) to be achieved in 2033[7] • New CES rules prohibit imports of fossil-fuel-generated electricity after 2040[8] • Revised Central Business District tolling program began in January 2025[9]	• Implemented the New York State Advanced Clean Truck Rule[10]
City Actions	• City adopted the J-51 Reform program, which incentivizes additional Local Law 97 of 2019 retrofits in some properties[11] • City adopted Public Solar NYC program[12]	• Revised methodologies for some City Actions • Integrated new datasets on current inventory, costs, and population projections • Incorporated new accounting procedure for GHG emissions from City Government Operations

Figure Source: OMB

MARKET TRENDS AND FEDERAL POLICY

Policy Updates

Given the significant uncertainty surrounding federal climate policy and market trends, the 2025 forecast does not reflect all potential policy changes since the 2024 forecast. A series of executive orders and administrative actions have targeted existing federal policies,[13] many of which have resulted in legal challenges.[14] Without clarity on which actions will survive legal challenges, this analysis assumes that the federal policies modeled in the 2024 forecast will remain unchanged. Those policies are the clean energy investment tax credit, the nuclear production tax credit, the clean electricity production tax credit, and the residential clean energy credit.

As a result of the new federal position, any new offshore wind developments are delayed in the model. An executive action barring new offshore wind leases or permits was issued on January 20, 2025.[15] As all offshore wind development requires extensive federal permitting, this order effectively halts offshore wind development. The forecasts assume that, except for projects with current federal leases and permits, there will be no new offshore wind capacity added in New York State until 2035. The Large-Scale Renewables section describes the status of existing projects.

The most significant impact of federal policy changes may be on energy technology costs and availability. Tariffs imposed on imports of clean energy technology will likely raise costs,[16] and reducing research funding and subsidies for clean technologies may impact costs and reduce availability of new technologies. OMB continues to monitor the long-term market trends in energy technology but given the current degree of uncertainty around these changes, the updated forecasts do not integrate related developments.

Methodology Updates

The 2025 forecast integrated new and revised datasets to reflect updated forecasts and to improve the calibration to historical energy use. Population forecasts and energy use data are widely used across each energy sector modeled in COMET. These were updated with population growth forecasts from the New York Metropolitan Transportation Council (NYMTC)[17] and historical energy use data from the New York City Greenhouse Gas Inventories.[18]

Modules were updated within each of the three general COMET sectors: energy supply, transportation demand, and stationary energy demand.

Energy Supply

The electricity module was updated to incorporate data on the projected costs and capacity of new electricity generators and the historical mix of electricity sources. Average costs of installing and operating new electric generators were drawn from the U.S. Energy Information Agency (EIA)'s Annual Energy Outlook (AEO)'s regional cost data for New York City and upstate New York.[19] For renewable energy sources, a supply curve analysis from the New York State Energy Research Development Authority (NYSERDA)[20] was used to find the capacity and relative costs of renewable resources. To update the historical mix of electricity sources, data from the EIA's Historical State Data[21] and the U.S. Department of Energy's combined heat and power plant database were used.[22]

The fossil fuel supply modules were updated to reflect commodity price forecasts from the AEO. The AEO forecasts end-use residential, commercial, and industrial prices for natural gas and petroleum products including fuel oil and gasoline.[23] These prices were incorporated directly into the model, removing the sub-models representing refineries.

The hydrogen supply module was updated to align with the 2024 update to the National Renewable Energy Laboratory's Annual Technology Baseline. Two sources of hydrogen were removed: hydrogen from high temperature electrolysis and hydrogen from biomass gasification. Costs for the remaining sources—hydrogen from low temperature electrolysis and hydrogen from steam methane reforming—were updated.

Transportation Demand

The light-duty vehicle demand module was updated using the vehicle turnover model from the EPA's Motor Vehicle Emission Simulator (MOVES).[24] This model requires an inventory of current vehicles, including their age and drive train. New York State Department of Motor Vehicles registration data were used to construct this inventory,[25] then vehicle turnover rates from MOVES were used to find how many vehicles will need to be replaced.[26] The demand for new vehicles was calculated by assuming that vehicle miles traveled (VMT) per capita remains constant and multiplying the historical VMT per capita by the projected population growth from NYMTC.[27] The demand for new vehicles plus replacements was then translated into demand by fuel source (gasoline, diesel, electric, or hybrid) using projected vehicle sales by fuel source from the AEO.[28]

The 2025 forecast added technologies for medium- and heavy-duty electric vehicles (EVs) into COMET. These vehicle types were not modeled in the 2024 forecast, due to the negligible current use of such vehicle types in New York City. These vehicle types were included in the 2025 forecast to project the impacts of state policies to promote electrification of medium- and heavy-duty vehicles. The average fleet efficiency of EVs was modeled using forecasts from the AEO.[29]

Stationary Energy Demand

Stationary energy demand in COMET consists of three modules: residential, commercial, and industrial. All three modules were updated with historical building stock area, historical consumption data from the Greenhouse Gas Inventories, and population forecasts from NYMTC. Floor area data from the 2015 and 2020 Primary Land Use Tax Lot Output datasets were used to set building stock area for the 2015 and 2020 calibration years within the model.[30]

COMET's residential module was also updated to reflect changes in household size and residential energy use technology. The average household size for 2015 and 2020 was revised using U.S. Census Bureau data,[31] allowing for more accurate per-household energy service demand projections. The distribution of lighting technologies in the residential sector was updated to reflect improved market penetration of LEDs, using data from EIA.[32] Unit energy consumption and equipment stock data were updated by technology class using the EIA's National Energy Modeling System Residential Demand Module.[33]

The industrial module was updated to reflect forecasts of energy demand in two industrial sectors: paper and nonmanufacturing sector industrial demand. Demand forecasts from the AEO were used for each sector.[34]

Discussion

Fig. 3-4 show the impact on emissions due to the updated methodology. The 2025 forecast predicts lower emissions reductions due to market trends and federal policies. This is largely due to efforts to better match the Greenhouse Gas Inventories and to model the lifetime of existing technologies. By more closely matching the technologies in use in 2023 (the last year with Greenhouse Gas Inventories data), the 2025 model finds less rapid technological change and lower emissions declines through 2025. Through 2050, the projections differ largely because the 2025 forecast predicts higher fuel oil use and lower uptake of light-duty EVs.

FIG. 3 | YEAR-OVER-YEAR MARKET TRENDS SCENARIO COMPARISON

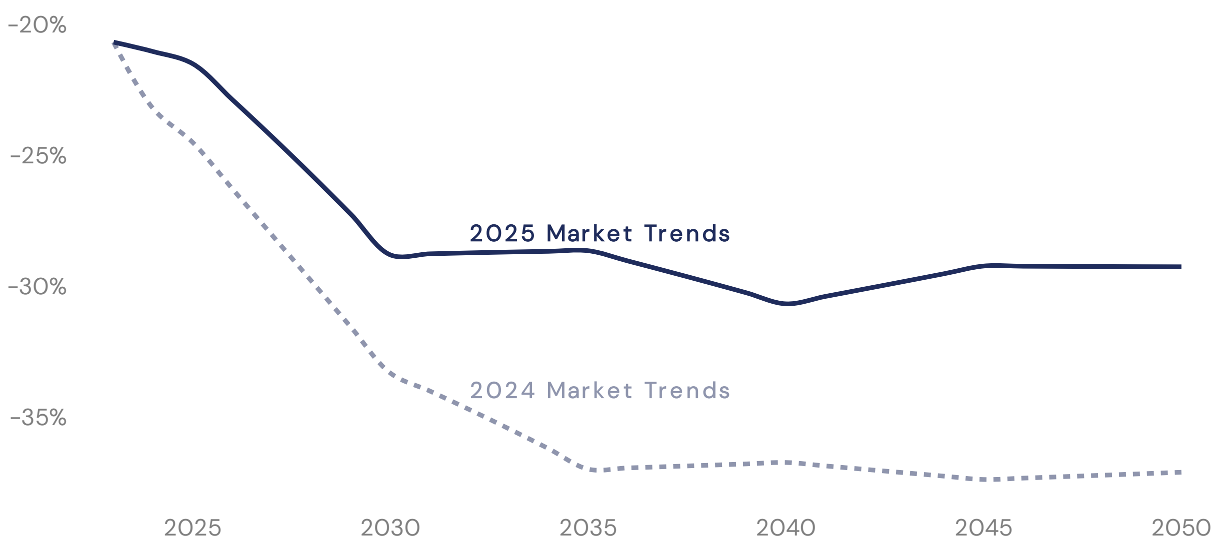

Figure Source: OMB

FIG. 4 | YEAR-OVER-YEAR MARKET TRENDS SCENARIO COMPARISON (TONS CO_2E)

	2025	2030	2035	2040	2045	2050
2024 Model	47,474,500	41,933,400	39,627,700	39,787,800	39,379,300	39,553,800
2025 Model	49,364,000	44,773,400	44,873,500	43,598,500	44,505,800	44,488,400

Figure Source: OMB

LARGE-SCALE RENEWABLE PROJECTS

Policy Updates

As described in the FY 2026 Climate Budgeting publication, several large-scale renewable projects have been canceled or delayed, jeopardizing the state's ability to meet its goal of providing 70 percent renewable electricity by 2030. Of the offshore wind projects in the 2024 forecast, only the Sunrise Wind and Empire Wind 1 projects have necessary permits to proceed.[35] Empire Wind 1 was able to secure all necessary federal and state permits and begin construction in the summer of 2024, in part because of the city's funding. Despite this progress, a halt work order was issued in April 2025 by the federal government introducing additional risk to this project.[36]

In December of 2024, the state terminated contracts for Clean Path NY,[37] although it appears likely that components of the project will be developed.[38] To model these developments in COMET, transmission capacity from Clean Path is now modeled starting in 2030 (a three-year delay) and only 1.7 gigawatts (GW) of offshore wind capacity are modeled. Of that capacity, Empire Wind 1 (0.8 GW) is serving New York City while the Sunrise Wind development (0.9 GW) serves the rest of the state.

FIG. 5 | LARGE-SCALE RENEWABLE PROJECTS ASSUMPTIONS

Project Name	Status	Year Online	Capacity (GW)	Connection Point
Clean Path New York	Cancelled	~~2027~~ 2030	1.8GW Solar, 2GW Wind, 1.3GW transmission line	Manhattan
Champlain Hudson Power Express	In Progress	2026	1.25	Queens
Sunrise Wind	In Progress	2027	0.924	Long Island
Empire Wind 1	In Progress*	2027	0.816	Brooklyn
Empire Wind 2	Cancelled	2029	1.26	Long Island
Beacon Wind 1	Cancelled	2028	1.23	Queens
Attentive Energy One	Cancelled	2035	1.275	Brooklyn
Community Offshore Wind	Cancelled	2034	1.3	Brooklyn
Excelsior Wind	Cancelled	2031	1.35	Long Island

Figure Source: OMB

** Despite obtaining all relevant federal permits, a halt work order was issued in April 2025 by the federal government introducing additional risk to this project.*

Methodology Updates

There were no substantial updates to the large-scale renewable methodology since the 2024 forecast.

Discussion

The delays and cancellations in offshore wind substantially lowered the GHG reductions from the Large-Scale Renewables scenario. As Fig. 6 shows, GHG emissions are roughly 5 percent lower (relative to the 2005 baseline) from 2035 through 2050 in the 2024 scenario. Fig. 7 shows that in 2030, the canceled projects would have lowered emissions by roughly 1 million tons of carbon-dioxide-equivalent GHG emissions (CO_2e). By 2050, that gap grows to over 3.4 million tons.

FIG. 6 | YEAR-OVER-YEAR LARGE-SCALE RENEWABLES SCENARIO COMPARISON

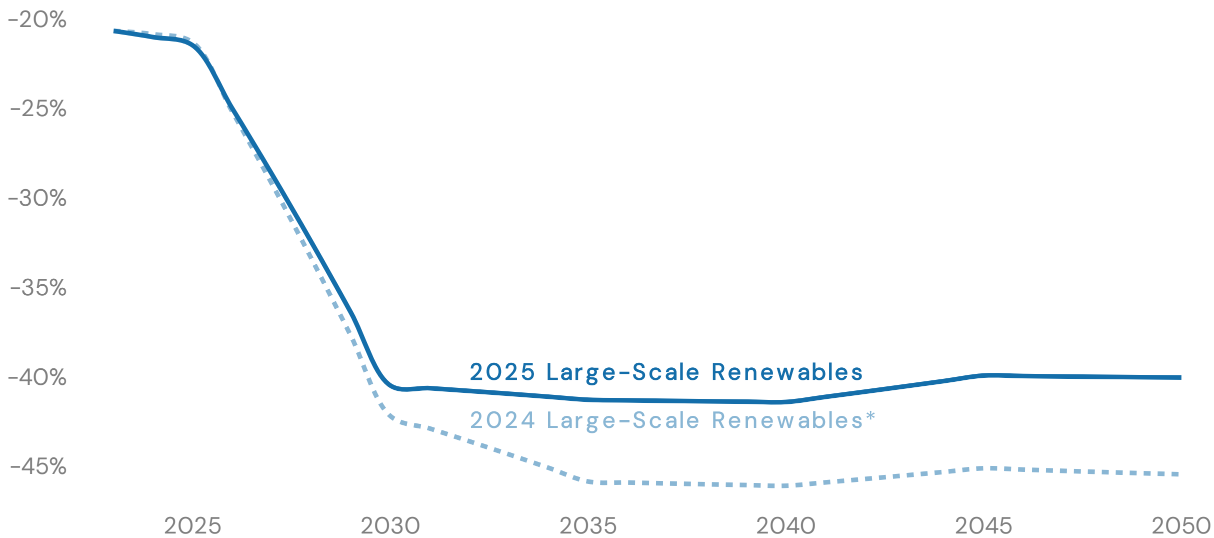

Figure Source: OMB

* *2024 data are forecasted using updated 2025 methodology, which improves calibration to the city's Greenhouse Gas Inventories, integrates revised energy data and projections, and models electric options for medium- and heavy-duty vehicles.*

FIG. 7 | YEAR-OVER-YEAR LARGE-SCALE RENEWABLES SCENARIO COMPARISON (TONS CO_2E)

	2025	2030	2035	2040	2045	2050
2024* Model	49,477,600	36,341,600	34,040,700	33,892,500	34,506,500	34,293,700
2025 Model	49,374,000	37,415,600	36,915,500	36,837,000	37,766,600	37,698,300

Figure Source: OMB

ADDITIONAL STATE ACTIONS

Policy Updates

The 2025 State Actions scenario was updated to reflect delays and cancellations in renewable energy, incorporate the proposed definition of zero-emissions electricity, and revise the impact of congestion pricing given the version implemented in January 2025.

Delays in renewable energy increase the difficulty of meeting the state's CES targets of providing 70 percent renewable electricity by 2030 and 100 percent emissions-free electricity by 2040. Following analysis from the New York State Department of Public Service (DPS) and NYSERDA, the forecasts assume that the state will meet the 2030 CES target in 2033.[39] Renewable energy project delays also increase the uncertainty that the state will be able to meet its target of providing 100 percent carbon-free electricity by 2040, although the model continues to assume the on-time achievement of this 2040 target.

Following a proposed definition from DPS, the model's zero-emissions grid target was updated. In 2019 the Climate Leadership and Community Protection Act (CLCPA) established a state target to achieve a zero-emissions electric grid by 2040, but did not define zero emissions at the time. DPS proposed a definition for zero-emissions grid in November 2024 that clarifies that the zero-emissions requirement would also apply to imported electricity.[40] To implement this definition, the COMET model prohibits electricity imports from PJM Interconnection or ISO New England after 2040.

The central business district tolling program, or congestion pricing, began in January 2025 after delays and policy changes in 2024.[41] There is some uncertainty regarding the future of the congestion pricing program, as U.S. Department of Transportation moved to shut down the program, but this action was challenged in federal court.[42] The forecast assumes that the current iteration of congestion pricing will remain in effect. The Congestion Pricing model was updated using percent change values in VMT from the November 2024 Reevaluation.[43] Specifically, Appendix 4A2-2 (2023) and Appendix 4A2-10 (2045) report VMT changes under the adopted toll structure compared to the No Action scenario. These tables provide percent reductions in VMT by area (e.g., Manhattan Central Business District (CBD), New York City non-CBD, regional subareas), which were used to scale vehicle activity inputs in the model. Updates were applied by vehicle class and time period, consistent with the adopted toll structure's anticipated effects on traffic patterns.

MTA Bus Electrification was included, but there was no change from the 2024 forecast.

Methodology Updates

The 2025 forecast models the state's Advanced Clean Truck Rule to require sales of electric medium- and heavy-duty vehicles. The Advanced Clean Truck Rule adopts California's standards for sales of zero-emissions medium- and heavy-duty vehicles, which grow over time to require 55 percent of all medium-duty trucks and 40 percent of heavy-duty vehicles sold to be emissions-free.[44] This rule was implemented in COMET by imposing a minimum percentage of electric medium- and heavy-duty vehicles, following the timeline from the state's rule.[45]

Discussion

As Fig. 8 shows, changes to State Actions decrease emissions reductions in the near term but somewhat increase emissions reductions in the long term. Fig. 9 shows that in 2030, the 2025 forecast finds that emissions are over 2.5 million tons CO_2e greater than the 2024 forecast. This is primarily due to delays in achieving the 2030 CES. Starting in 2040, Fig. 9 shows that emissions in the 2025 forecast are roughly 1 million tons CO_2e less than in the 2024 forecast. This is due to changes in the rules of the 2040 CES, clarifying that no imports of fossil-fuel-generated electricity are allowed.

FIG. 8 | YEAR-OVER-YEAR STATE ACTIONS SCENARIO COMPARISON

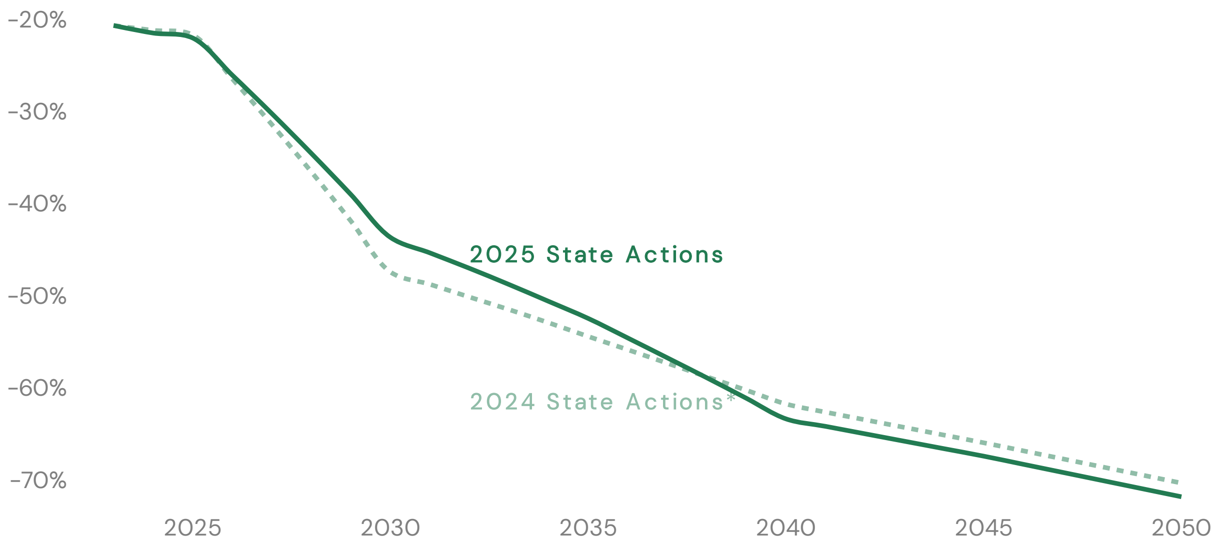

Figure Source: OMB

* *2024 data forecasted using updated 2025 methodology.*

FIG. 9 | YEAR-OVER-YEAR STATE ACTIONS SCENARIO COMPARISON (TONS CO_2E)

	2025	2030	2035	2040	2045	2050
2024* Model	49,240,100	33,051,400	28,650,800	24,042,400	21,391,300	18,640,500
2025 Model	49,029,500	35,414,200	29,882,000	23,023,300	20,477,100	17,703,800

Figure Source: OMB

CITY ACTIONS

OMB identified and modeled two additional City Actions to reduce GHG emissions and updated its 14 existing models. The two new City Actions are J-51 Reform and Public Solar NYC.

FIG. 10 | RELATIVE GHG EMISSIONS REDUCTIONS FROM CITY ACTIONS

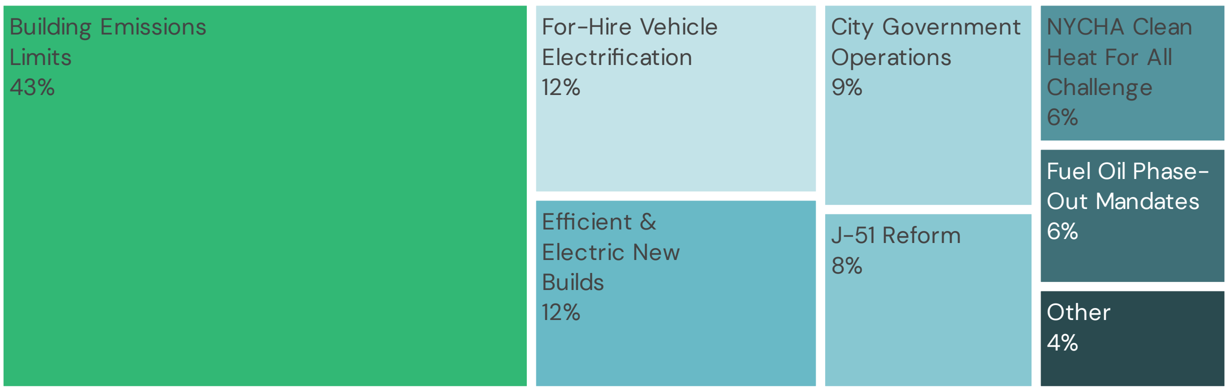

Figure Source: OMB

FIG. 11 | NET GHG EMISSIONS IMPACT OF CITY ACTIONS (TONS CO_2E)

	2025	2030	2035	2040	2045	2050
J-51 Reform (New Action)	(4,650)	(94,180)	(155,570)	(211,190)	(211,250)	(294,070)
Public Solar NYC (New Action)	-	(1,150)	(560)	(60)	(60)	(50)
Building Emissions Limits	(850,830)	(1,695,390)	(1,666,930)	(1,577,690)	(1,473,920)	(1,561,880)
NYCHA Clean Heat For All Challenge	(19,510)	(95,790)	(200,710)	(209,090)	(209,160)	(209,190)
Efficient & Electric New Builds	(17,830)	(52,900)	(182,230)	(278,080)	(353,650)	(423,580)
Fuel Oil Phase-Out Mandates	(103,490)	(192,060)	(271,430)	(264,060)	(282,110)	(205,290)
HPD Sustainability Design Guidelines	(1,860)	(11,330)	(17,800)	(18,220)	(18,220)	(17,780)
NYCHA Solar Installations	(1,990)	(2,060)	(1,020)	(110)	(100)	(100)
NYCHA PACT Program	(70)	(60)	(30)	(10)	20	60
For-Hire Vehicle Electrification	(104,690)	(842,510)	(931,430)	(957,140)	(954,370)	(424,260)
Electric Vehicle Vision	(20,800)	(53,700)	(67,470)	(69,330)	(69,130)	(30,730)
Bus Lanes	(4,330)	(6,210)	(4,960)	(2,740)	(1,230)	(220)
Bike Lanes	(11,460)	(13,610)	(10,870)	(6,010)	(2,690)	(480)
School Bus Electrification	1,910	(40,080)	(81,340)	(88,020)	(89,580)	(90,790)
Mandatory Citywide Curbside Organics Collection	(1,710)	(6,170)	(7,430)	(8,690)	(9,950)	(11,210)
City Government Operations	(275,800)	(413,060)	(386,380)	(359,090)	(377,350)	(338,270)

Figure Source: OMB

J-51 Reform

Criteria Screening for New City Actions

1. GHG Impact: 3,720,000 tCO_2e saved cumulatively through 2050
2. Commitment: Enabled by New York City Council in December 2024,[46] after state legislation from October 2023.[47] Current program covers retrofits through June 30, 2026, but state and local legislature have opportunities to extend the program
3. Responsibility: Carried out by New York City Housing Preservation & Development (HPD)

Context

OMB estimated the GHG impact of the J-51 Reform (J-51 R) program by modeling how the program incentivizes efficiency retrofits for eligible condo and co-op buildings. In December 2024, New York City Council passed legislation adopting the most recent version of J-51,[48] which has existed in some form since 1955.[49] J-51 R provides a tax abatement to defray the costs of certain retrofits for eligible residential properties.[50] Covered work includes some necessary components of long-term Local Law 97 of 2019 (LL97) compliance, including electrical wiring, heat pumps for space and water heating, and building envelope improvements.[51] The tax incentive covers up to 70 percent of the certified reasonable cost (CRC) of eligible retrofit work, paid out over 12-20 years through a tax abatement.[52]

The analysis does not consider the impacts of J-51 R on emissions from rental properties. The program covers rental properties where a majority of units are regulated at an affordable rental rate,[53] but these properties are not subject to the emissions limits under LL97.[54] Instead, these properties comply with the law by demonstrating low emissions in 2024 or undertaking a set of prescriptive retrofits.[55] The model assumes that without a financial incentive to reduce emissions, there will be no additional emissions impact from J-51 R in these properties.

The analysis found that 1,670 condo and co-op properties subject to LL97 emissions limits are eligible for J-51 R, out of 4,266 total condo and co-op properties subject to LL97 emissions limits. Condo and co-op buildings are eligible for this program if the average assessed value (AV) of dwelling units is $45,000 or below.[56] Eligible properties were identified by merging the list of properties subject to LL97 and property assessment data.[57]

Of these eligible properties, 1,155 (69 percent) currently exceed their 2030 LL97 emissions limits and 136 eligible properties (8 percent) currently exceed their 2024 emissions limits. Fig. 12 shows the location of properties exceeding their 2030 emissions limits, colored by J-51 R eligibility. Eligible properties are concentrated in northern Manhattan, northwest Bronx, central and eastern Queens, and southern Brooklyn. Among higher-AV condo and co-ops, 1,792 (42 percent) currently exceed their 2030 emissions limits and 205 (5 percent) exceed their 2024 emissions limits.

FIG. 12 | CONDO AND CO-OP BUILDINGS THAT EXCEED 2030 LL97 LIMITS

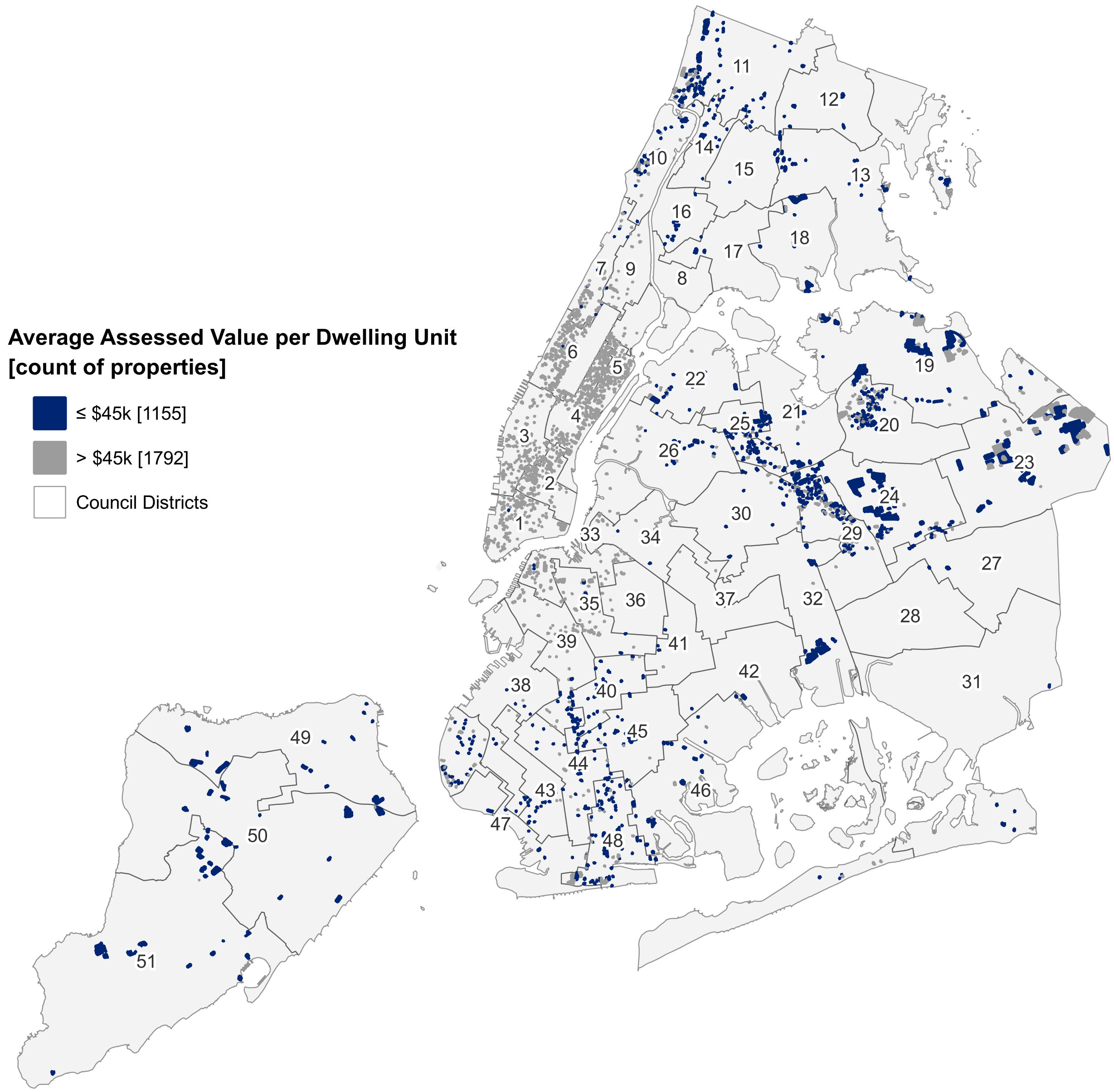

Figure Source: OMB

Condos and co-ops that are eligible for J-51 R are further from meeting their LL97 targets relative to other multifamily properties. Fig. 13 shows the average 2030 compliance rates among four categories of multifamily properties facing LL97 emissions limits: eligible condos and co-ops, higher-AV condos and co-ops, rental properties with some rent-regulated units, and rental properties where all units are market-rate rentals. In the 2023 reporting data (the most recent available), 69 percent of eligible condos and co-ops exceeded their 2030 LL97 emissions limits. This was the highest rate among the four property categories. Eligible condos and co-ops also had a low rate of improvement—8 percent more properties reached emissions limits in 2023 data versus 2022 data, compared to the 12 percent improvement among higher-AV condos and co-ops and market-rate rentals. While eligible condos and co-ops make up only 28 percent of condos and co-ops subject to LL97 emissions limits, they make up 39 percent of condos and co-ops that exceed their 2030 LL97 emissions limits.

FIG. 13 | MULTIFAMILY PROGRESS TOWARDS 2030 LL97 TARGETS

	Count Properties Exceeding 2030 Targets (2023 data)	Percent Properties Meeting 2030 Targets (2023 data)	Percent Properties Meeting 2030 Targets (2022 data)	Percent Improvement from 2022 to 2023
J-51 R Eligible Condos/Co-ops	1,155	31%	23%	8%
Higher-Assessed Value Condos/Co-ops	1,792	58%	46%	12%
Rentals (Some Rent-Regulated)	529	43%	31%	12%
Rentals (Market Rate)	1,894	37%	30%	7%
All Multifamily Properties	5,370	46%	36%	10%

Figure Source: OMB

Model Methodology

J-51 R was modeled as an extension of OMB's LL97 model. OMB's LL97 model is an agent-based financial decision model. For each building subject to LL97, the model finds the optimal amount of energy efficiency retrofits given the up-front cost of investments, energy savings, and any potential penalties for exceeding LL97 emissions limits. Within the LL97 decision framework (further described in the Technical Appendices to the FY 2025 Climate Budgeting publication[58]), J-51 R partially offsets the upfront cost of certain retrofits, for eligible properties. The analysis assumes that J-51 R will be continued in its existing form through 2050.

J-51 R abates up to 70 percent of the CRC of a retrofit by providing an annual abatement of up to 8.33 percent of the CRC, subject to certain limitations: the annual abatement cannot exceed 50 percent of the property tax bill, and the CRC of retrofits must be greater than $1,500 per dwelling unit to receive a program benefit.[59] If the standard annual abatement (8.33 percent of the CRC) does not exceed 50 percent of the annual tax bill, the amount will be paid out over 12 years. However, if 8.33 percent of the CRC exceeds 50 percent of the tax bill (which could occur if the property has other tax exemptions in place and/or the cost of the retrofit is sufficiently high), a lesser annual amount is paid out and the program benefits will be paid out over a longer period. If any unclaimed portion of the J-51 R abatement remains at the end of 20 years, that amount is lost.

The LL97 analysis was updated since the 2024 forecast to integrate new cost data from HPD,[60] retrofit efficacy estimates from DPS,[61] a revised list of covered buildings from the New York City Department of Buildings (DOB),[62] 2023 building energy use data from the LL84 dataset,[63] and new utility cost information from Consolidated Edison and National Grid.[64] The HPD cost data is contained in the CRC list, which also specifies which measures are covered under J-51 R.

Below, an illustration of the decision process for a sample building shows how J-51 R can incentivize building energy upgrades. An illustrative property was selected from eligible properties that are on-track to meet 2024 emissions, but to exceed 2030 emissions limits. The sample property has roughly

90 residential units and 90,000 square feet of residential area. Fig. 14 shows the projected emissions of this property with no action, with LL97 retrofits predicted by the model but without J-51 R, and with LL97 retrofits incentivized by J-51 R. Without any retrofits, the property faces annual penalties starting at $16,000 in 2030 and growing to $78,000 by 2050.

FIG. 14 | PROJECTED PROPERTY EMISSIONS, INCLUDING WITH RETROFITS AND J-51

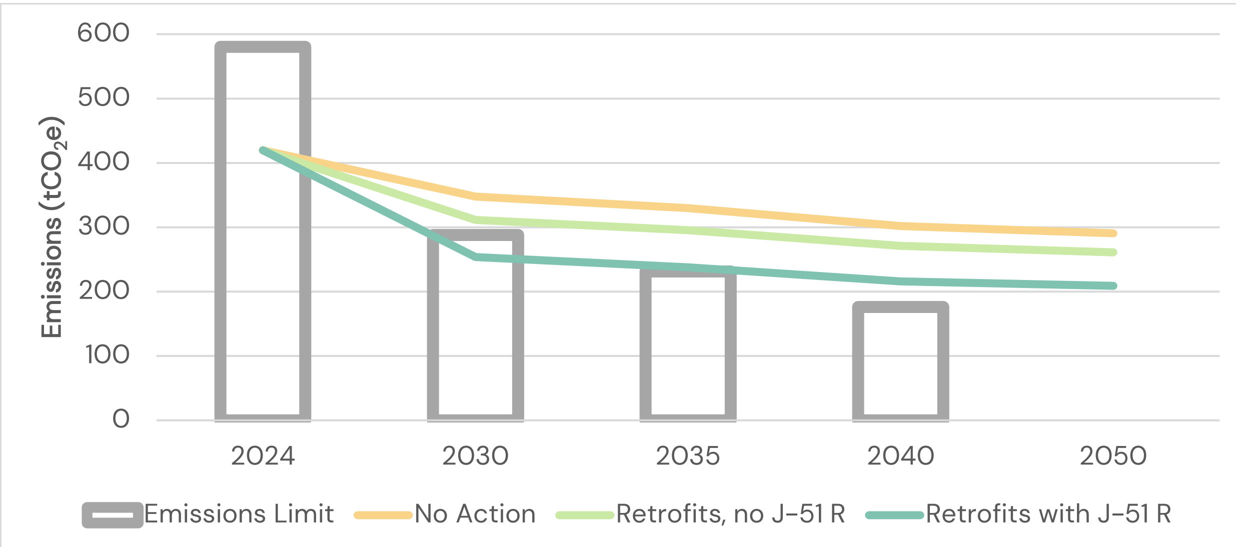

Figure Source: OMB

Without J-51 R, the property's optimal compliance pathway is to do some work to reduce emissions but not enough to meet LL97 emissions targets. Fig. 15 illustrates the components of this decision in 2030. Each row shows a potential retrofit, ordered in ascending net cost. The property will do work that results in the least cumulative net cost. Columns show the up-front cost of the retrofit, the net present value (NPV) of energy savings, any utility or state rebates to defray the cost, the NPV of the penalty if all retrofits up to that row are adopted, and the cumulative net cost if all retrofits up to that row are adopted. NPV is calculated using a 15-year time horizon and a 6.5 percent discount rate. Some measures are consolidated for readability in Fig. 15. *Short-Payback Measures* include boiler controls, ENERGY STAR refrigerators, thermostatic radiator valves, and low-flow fixtures; *Wall & Window Envelope Work* includes high-efficiency windows and external wall insulation. The building's optimal decision is to do short-payback measures but no envelope work.

FIG. 15 | EXAMPLE LL97 DECISIONS WITHOUT J-51 R

	Upfront Cost	Energy Savings NPV	Rebates	Penalty NPV	Cumulative Net Cost
No Work	--	--	--	$238,942	$238,942
Short-Payback Measures	$113,885	$135,876	--	$146,933	$124,941
Wall & Window Envelope Work	$496,376	$119,859	$50,951	$35,366	$338,938
Roof Envelope Work	$427,464	$7,488	$43,517	$30,069	$710,100

Figure Source: OMB

With J-51 R, the property is incentivized to upgrade its building envelope and exceed its 2030 LL97 emissions targets. Fig. 16 illustrates the components of this decision in 2030, with the additional J-51 R Abatement column showing the NPV of the J-51 R tax abatement. With the tax incentive in place, it is optimal for the property to improve its building envelope with high-efficiency windows and external wall insulation. Building envelope improvements are an important step towards building decarbonization because they can reduce the upfront cost and increase the energy savings from space heating electrification. As Fig. 14 shows, J-51 R enables this property to reach emissions targets through 2035 but not in 2040 or 2050.

FIG. 16 | EXAMPLE LL97 DECISIONS WITH J-51 R

	Upfront Cost	Energy Savings NPV	Rebates	NPV of J-51 R Abatement	Penalty NPV	Cumulative Net Cost
No Work	--	--	--	--	$238,942	$238,942
Short-Payback Measures	$113,885	$135,876	--	--	$146,933	$124,941
Wall & Window Envelope Work	$496,376	$119,859	$50,951	$256,548	$35,366	$82,389
Roof Envelope Work	$427,464	$7,488	$43,517	$216,634	$30,069	$236,916

Figure Source: OMB

Discussion

The J-51 R program has the potential to substantially reduce carbon emissions, if extended through 2050. The total emissions benefit is approximately 300,000 tons annually in 2050, or roughly 8 percent of total emissions reductions from City Actions in 2050.

J-51 R is also expected to increase compliance with LL97 and reduce penalties. Fig. 17 summarizes the 2030 expected compliance rates, penalties, and emissions reductions for eligible condos and co-ops with and without J-51 R. J-51 R enables an additional 229 properties (or 14 percent) to reach their 2030 LL97 targets, reduces total annual penalties by 45 percent, and results in 50 percent additional emissions reductions.

FIG. 17 | J-51 R IMPACTS FOR ELIGIBLE CONDOS AND CO-OPS IN 2030

	Count of Eligible Properties (Percent) Meeting 2030 Targets	Penalties In 2030 (Million $)	Percent Emissions Reduction
Without J-51 R	1,036 (64%)	16	18%
With J-51 R	1,265 (78%)	8.8	27%

Figure Source: OMB

J-51 R can also fund necessary steps on the way towards building decarbonization, such as building envelope upgrades and electrical work. Replacing a building heating system is expensive and invasive, and many properties may not be able to finance or schedule such retrofits immediately. As a financial model, this analysis does not account for these frictions that can delay energy retrofits. By funding incremental steps that enable efficient decarbonization, the J-51 R program can support owners preparing for extensive building decarbonization retrofits even if properties are not prepared to replace their existing heating system.

Public Solar NYC

Criteria Screening for New City Actions

1. GHG Impact: 10,900 tCO_2e saved through 2050
2. Commitment: New York City committed to developing public solar in the PlaNYC and PowerUp reports. [65] The program was funded in 2024 by a joint New York State/New York City initiative. [66]
3. Responsibility: Will be carried out by New York City Mayor's office and Comptroller's office.[67]

Context

New York City was awarded a grant to support the development of public solar. This program provides solar power in underserved communities, including 1-4 family homes in disadvantaged communities and community solar projects that serve low-income New Yorkers. The program is assumed to launch by the end of year 2025.

Methodology

Estimates by the Mayor's Office of Climate and Environmental Justice (MOCEJ) indicate that this project is expected to install 1.6 MW of rooftop solar within New York City each year between 2026 and 2031, for a total of 8.0 MW of installed solar. OMB modeled the impact of this measure by reducing grid electricity demand by the amount produced by the existing solar capacity in each year.

Discussion

This program is expected to have a modest impact on New York City's GHG emissions. The emissions reductions from the program depend on the grid electricity factor, which is expected to decline to near zero by 2040 due to the CES targets. Public solar has other important benefits, including reducing electricity costs for program participants and reducing electric grid congestion.

Building Emissions Limits (LL97)

Policy Updates

No policy updates related to LL97 changed the forecasted emissions reduction. DOB clarified rules regarding the option to purchase offsets for some GHG emissions.[68] Under this program, the price of one ton of emissions offset is equal to the price per ton of the penalty and the revenue collected from offsets is used to fund energy efficiency retrofits in affordable housing. Because the costs of these options are equal, the model of LL97 decisions cannot distinguish between the options and this policy update has no impact on the emissions reductions within properties facing LL97 emissions. There may be additional emissions benefits not captured by this model due to energy efficiency improvements funded by the offsets.

Methodology Updates

The model was updated since the 2024 forecast to integrate new retrofit cost data from HPD,[69] retrofit efficacy estimates from DPS,[70] a revised list of covered buildings from DOB,[71] 2023 building energy use data,[72] and new utility cost information.[73] Additionally, an update from the 2024 model improved the utility cost data used in some financial decisions.

Updated data reveal that more buildings are reaching LL97 emissions targets. As Fig. 18 shows, over 90% of properties now meet their 2024 emissions targets (have emissions at or below the emissions limit) and over 40% of properties now meet their 2030 emissions targets. This progress is encouraging, although some emissions reductions in 2023 were due to relatively mild winter and summer temperatures.[74]

FIG. 18 | PERCENT OF BUILDINGS MEETING LL97 EMISSIONS LIMITS

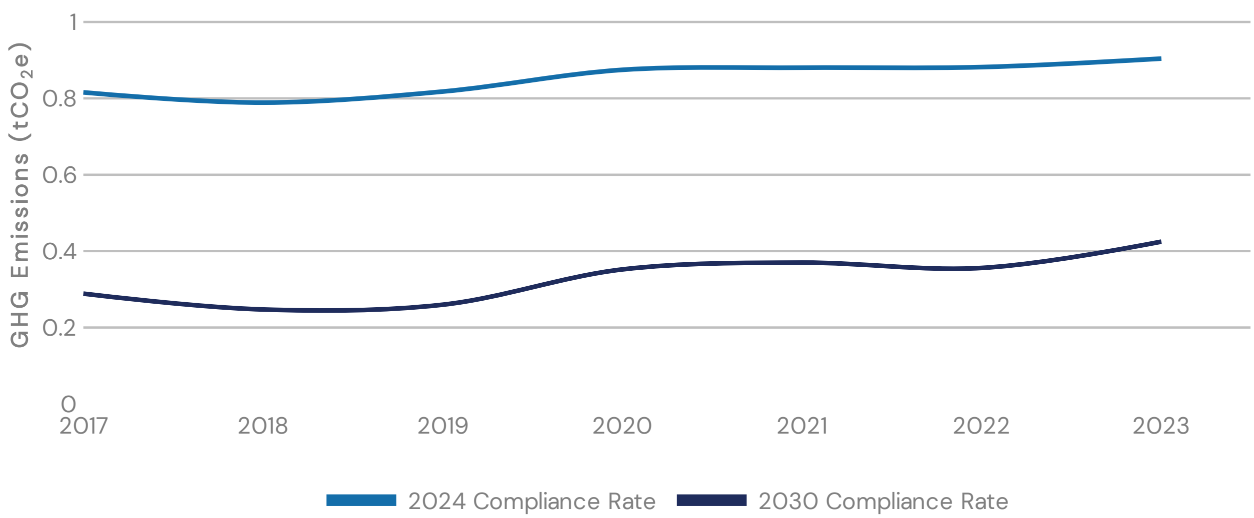

Figure Source: OMB

Additionally, OMB revised the LL97 methodology so that retrofits to comply with the law apply *instead of* the energy reductions COMET projects, rather than *in addition to* those reductions as in the 2024 model. In the 2024 model, the COMET energy reductions were first applied to LL97-covered properties and then the relative energy savings from retrofits were applied on the remaining energy use. In the 2025 methodology, retrofit emissions reductions apply only to properties' base energy use. The absolute energy reduction from LL97 is then the reduction after applying the LL97 retrofits, less the energy reduction that COMET would project.

Discussion

The 2025 analysis finds that the impact of LL97 is lower than the estimates from the 2024 analysis. The difference is primarily due to the impact of refined and updated datasets on energy and retrofit costs. Costs of retrofits were updated to align with the J-51 R CRC list. Because the CRC determines the maximum benefit amount for J-51 R retrofits, the CRC makes somewhat conservative cost assumptions to cover retrofit costs in most cases. These updates increased the relative price of electricity and electrification, resulting in lower modeled uptake of electrification measures and lower emissions reductions than the 2024 analysis.

Fig. 19 shows the total emissions and emissions limits over time for properties subject to emissions limits. In the 2025 forecast, total emissions slightly exceed the 2030, 2035, and 2040 emissions limits and substantially exceed the 2050 emissions limit.

FIG. 19 | PROJECTED TOTAL EMISSIONS AND EMISSIONS LIMITS, FOR PROPERTIES WITH LL97 EMISSIONS LIMITS

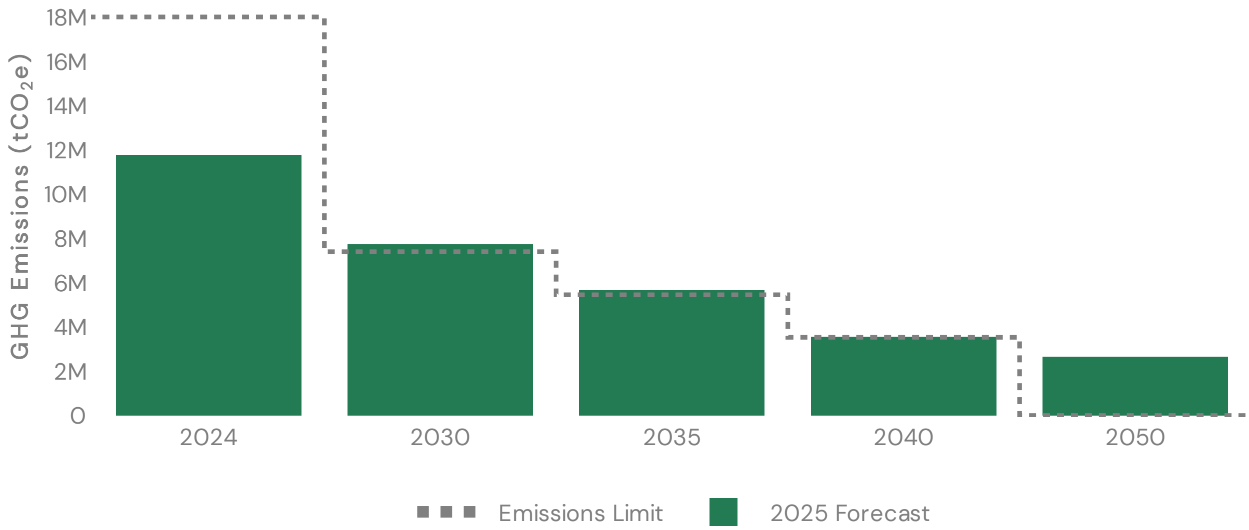

Figure Source: OMB

NYCHA Clean Heat For All Challenge

Policy Updates

In fall 2024, the demonstration pilot successfully installed 72 window heat pumps across 24 New York City Housing Authority (NYCHA) apartment units.[75] The next phase of the program is to install heat pumps in 10,000 apartment units by 2028, and with a further goal to reach 50,000 units by 2035.

Methodology Updates

To enhance large-data processing capabilities, the model was transitioned from Microsoft Excel to Python while retaining its original calculation methodologies.

Updates to NYCHA campus energy consumption data and portfolio characteristics were incorporated, ensuring the model reflects the most current information.[76]

Discussion

The differences between the 2025 and 2024 models stem from two main factors. The first is a slight delay in the program schedule, delaying the emissions reductions. Second is the updated baseline building consumption data, revealing that buildings were more efficient than expected, limiting the potential emissions savings.

Further updates will aim to refine the methodology to calculate energy and emissions impacts on a building-by-building basis, instead of using aggregated averages. This would enhance accuracy of the results but requires a plan specifying which buildings are to be included.

Efficient and Electric New Builds

Policy Updates

There were no policy updates that influenced OMB's analysis of the Efficient and Electric New Builds City Action. A legal challenge had been lodged against New York City's law restricting the emissions intensity of fuels used in new construction, but was dismissed by a federal judge in March 2025.[77]

Methodology Updates

The 2024 methodology was updated to incorporate adjusted population forecasts from NYMTC.[78] A comparison of these two population forecasts is shown in Fig. 20. The population forecasts used in the 2024 analysis found that the New York City population increases continuously through 2050. NYMTC's adjusted population forecasts follow the historical population decline due to COVID, and project that population will increase through 2050 when the adjusted population matches NYMTC's original projection from 2020.[79]

FIG. 20 | ADJUSTED AND ORIGINAL POPULATION PROJECTIONS

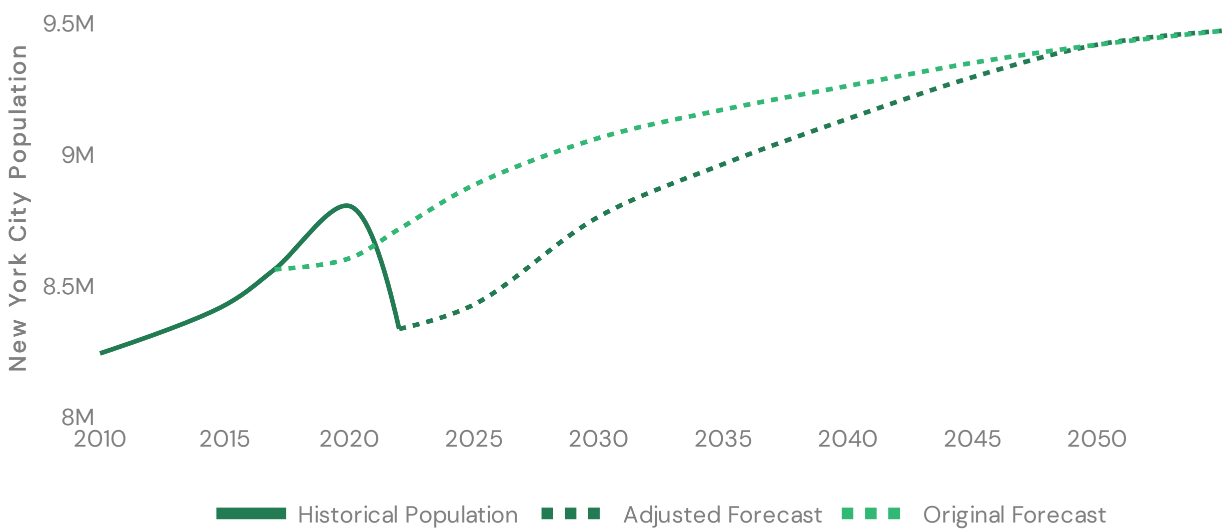

Figure Source: NYMTC

Discussion

The emissions reductions from this law are expected to increase relative to the 2024 projection. While there is population decline between 2020 and 2022 in the updated population forecast, the rapid growth in population between 2022 and 2050 will require a greater degree of construction than in the original forecast. Additionally, this construction will largely occur after the requirements for efficient and electric new buildings apply to all types of new construction, increasing the emissions reductions from new construction relative to a status quo without these ordinances.

Fuel Oil Phase-Out Mandates

Policy Updates

There were no substantial policy updates related to fuel oil phase-out mandates.

Methodology Updates

The current share of biofuel blend in building fuel oil was updated using the Greenhouse Gas Inventories.[80] No change was made to the Fuel Oil #4 replacement assumptions from the 2024 model because this analysis relied on historical data surrounding the phaseout of Fuel Oil #6.

Discussion

The emissions reductions from fossil fuel phase-out mandates are virtually unchanged from last year.

HPD Sustainability Design Guidelines

Policy Updates

There were no substantial policy updates related to HPD's sustainability design guidelines (SDGs).

Methodology Updates

Because the analysis is built on top of the LL97 analysis, data updates to that model also influenced this model. Additionally, OMB changed the procedure to avoid double counting emissions reductions between this model, LL97, and building energy use projections from COMET. In the 2025 forecast, the impact of HPD SDGs is only reported as the additional energy reduction relative to the LL97 model, which accounts for building energy use projections from COMET.

Discussion

The 2025 analysis projects a lower impact from HPD SDGs, although the analysis does not reflect the full impact of HPD SDGs because some reductions have already been achieved. This estimate should be interpreted as the future expected impact of HPD SDGs, rather than the total impact. The reduced impact is primarily due to updated energy consumption data from the LL84 dataset,[81] which show that energy efficiency among HPD properties is already improving. Among HPD properties, natural gas use declined roughly 26 percent from 2022 data to 2023 data. This reduction is likely due to implementation of the SDGs, along with milder heating and cooling needs in 2023 and other operational efficiencies. Because the baseline energy use has improved since last year's model, there is less room for emissions reductions in the future.

NYCHA Solar Installations

Policy Updates

There were no substantial policy updates related to NYCHA solar installations.

Methodology Updates

There were no major methodology updates to this model, other than updated solar installation project characteristics and timelines provided by NYCHA.

Discussion

This year's model is slightly more impactful than last year's. A small variation in emissions reductions year-over-year stems from updated project characteristics. Last year, 9.68 MW of solar installations were projected through 2025. This year expected installations rose to 14.95 MW through 2027.

NYCHA PACT Program

Policy Updates

There were no substantial policy updates to the NYCHA Permanent Affordability Commitment Together (PACT) conversion program.

Methodology Updates

In the 2025 analysis, OMB revised the NYCHA PACT methodology so that retrofits from the conversions apply *instead of* the energy reductions COMET projects, rather than *in addition to* those reductions as in the 2024 model. In the 2024 model, the COMET energy reductions were first applied to NYCHA properties and then the relative energy savings from PACT conversions were applied on the remaining energy use. In the 2025 methodology, PACT conversion emissions reductions apply only to properties' base energy use. The absolute energy reduction of the NYCHA PACT program is then the reduction after applying the PACT program, less the energy reduction that COMET would project. Additionally, because this model is built on top of the LL97 model, data updates to that model apply to this program as well.

Discussion

The modeled impact of the NYCHA PACT program is lower than in the 2024 forecast, and by 2050 the program is projected to slightly increase emissions relative to the baseline energy reductions projected in COMET. This is due to the updated methodology to account for interactions with COMET energy reductions. COMET projects that multifamily buildings will replace energy technologies with more efficient versions over time. In the long run, energy efficiency measures in PACT conversions achieve a lower energy reduction than the average reductions COMET projects for multifamily buildings. This makes the emissions trajectory of the PACT program appear to increase towards the end of the modeled period, because emissions increase relative to the COMET baseline energy reductions for multifamily buildings.

For-Hire Vehicle Electrification

Policy Updates

New Yorkers take over 600,000 rides per day in Uber or Lyft vehicles.[82] Cars driving for these two rideshare services constitute NYC's high-volume for-hire vehicle (HVFHV) fleet. The New York City Taxi and Limousine Commission (TLC) regulates HVFHVs, and in 2023 it announced the Green Rides Initiative, which requires that all HVFHVs be either EVs or wheelchair-accessible vehicles (WAVs) by 2030.[83] The intermediate targets are as found in Fig. 21.

FIG. 21 | GREEN RIDES INITIATIVE TARGETS FOR FRACTION OF HVFHV TRIPS TAKEN IN EVS OR WAVS

Year	2024	2025	2026	2027	2028	2029	2030
EV + WAV target	5%	15%	25%	40%	60%	80%	100%

Figure Source: OMB

The past year saw a sharp increase in the number of EV HVFHVs, due largely to a brief window in October 2023 when the TLC lifted its freeze on new HVFHV medallions, but only for EVs.[84] At the beginning of 2023, less than 1 percent of HVFHV trips were in EVs; by the end of 2024, over 11 percent were.

The HVFHV fleet already exceeds both the 2024 and 2025 targets for EV and WAV rides, but the growth in EVs is expected to slow in coming years, absent additional incentives to convert from internal combustion engine (ICE) vehicles to EVs.

Methodology Updates

The modeling methodology was updated in coordination with researchers at TLC.

The model projects the shift in annual VMT from ICE vehicles to EVs, assuming the Green Rides Initiative is fully implemented. 2024 data are used as the baseline.

For each year, the gap between the target percentage of EV and WAV trips and the actual percentage is calculated as:

$$\text{Gap} = \text{Target EV \& WAV \%} - \text{Actual EV \& WAV \%}$$

If the gap is greater than zero, the model assumes that 90 percent of the gap will be met by replacing ICEs with EVs, while 10 percent of the gap will be met by WAVs. Thus, for any year, the projected fraction of trips that are taken in EVs is:

$$\text{Projected EV \%} = \text{2024 Actual EV Trip \%} + 0.9 * \text{Gap}$$

Total yearly HVFHV VMT, which is not directly reported by riders to the TLC, is calculated by dividing the total 2024 trip VMT by the HVFHV utilization rate (the average percentage of time that drivers spend with passengers, relative to the total amount of time the driver spends logged into the rideshare app).

$$\text{Total VMT} = \frac{\text{2024 Trip VMT}}{\text{Utilization Rate}}$$

Total annual EV VMT is calculated by multiplying the total HVFHV VMT by the expected percentage of trips that are in EVs in a given year. ICE VMT is assumed to decrease by an equal amount.

$$\text{EV VMT} = \text{Total VMT} * \text{Projected EV \%}$$

$$\text{ICE VMT Change from Baseline} = \ -\text{EV VMT}$$

Assumptions

The model takes the following assumptions:

- EV and WAV percentages will not decrease from current percentages
- EV and ICE HVFHVs have similar usage patterns (number and length of trips per vehicle per day, and similar distance driven between passengers)
- Based on recent trends, total HVFHV mileage will remain flat
- Each new EV or WAV replaces a non-WAV ICE vehicle, 1:1
- Of standard ICE vehicles that are replaced due to this policy, 90 percent will be replaced with EVs while 10 percent will be replaced with WAVs

Data

TLC provided monthly trip VMT data for 2023 and 2024 for HVFHVs overall, as well as for EV and WAV HVFHVs.

TLC reports that the utilization rate (the percentage of time drivers spend driving a passenger, relative to total time logged into the Uber or Lyft apps) for HVFHVs is 53.4 percent.[85]

Discussion

The emissions reductions from FHV electrification are virtually unchanged from last year.

Electric Vehicle Vision

No substantial changes to modeled policy or methodology.

Discussion

The emissions reductions from Electric Vehicle Vision are virtually unchanged from last year.

Bus Lanes

Policy Updates

Protected bus lane installations lag targets, reducing the expected impact of this policy. The city has targeted 30 miles per year of protected bus lane installations from 2022-2026, but it installed 5.2 miles in 2023 and 13.5 in 2024.[86] No policy changes have shifted the targets for future bus lane installations, so the projected bus lane installations remain unchanged.

Methodology Updates

The methodology was updated in collaboration with researchers at the New York City Department of Transportation (DOT).[87] Using data from the 21st Street bus lane improvement project in Queens and from the citywide mobility survey,[88] DOT found that:

- Each additional mile of dedicated bus lanes results in 663 new bus trips per day
- About 43 percent of these trips replace vehicle trips
- Replaced vehicle trips have an average length of 2.2 miles

Multiplying by 250 weekdays per year, DOT found that the annual reduction in VMT per additional bus lane mile was 154,238 miles per year.

VMT change is multiplied by the actual or expected number of lane-miles installed and divided by the total private VMT in 2023 as reported in the NYC Greenhouse Gas Inventory, to determine the percent change in VMT due to protected bus lane installations.[89]

Discussion

The methodological update relative to the 2024 forecast resulted in a decrease in modeled emissions impact from bus lanes.

Bike Lanes

Policy Updates

Protected bike lane installations lag targets, reducing the expected impact of this policy. The city installed 31.9 miles of protected bike lanes in 2023 and 29.3 in 2024, relative to a target 50 miles per year of installations.[90]

Methodology Updates

There were no major methodology updates to this model.

Discussion

The delayed pace of bike lane installations resulted in slightly reduced GHG reductions from bike lanes, although the 2025 forecast is not substantially different from the 2024 forecast.

School Bus Electrification

Policy Updates

There are currently approximately 30 EV school buses operating in New York City, out of a fleet of approximately 10,500 buses. New York City school bus vendors have been awarded a total of $174 million for 533 EV school buses, across five different grants, which are expected to enter service in the next several years. Despite the slow initial pace of bus electrification, the state's school bus electrification policy has not changed.

Methodology Updates

There were no major methodology updates to this model. However, a small change is made in how the results are incorporated into the City Actions forecast. Rather than calculating the impact of the policy as a percentage reduction of VMT by fossil fuel school buses, the impact is calculated by forcing the share of school bus VMT served by EVs or fossil fuels to reflect the model output. The results are equivalent.

Discussion

The projected emissions reductions from school bus electrification are unchanged relative to the 2024 forecast.

Mandatory Citywide Curbside Organics Collection

Policy Updates

As of April 1, 2025, separation of organics (leaf and yard waste, food waste, and food-soiled paper) from trash is mandatory citywide.[91] While this is anticipated to increase the amount of organic material diverted from landfills, there is insufficient data available at the time of publication to project the impact of this mandate on waste diversion levels.

Methodology Updates

Since the last publication, the New York City Department of Sanitation (DSNY) conducted and published the results of the 2023 Waste Characterization Study (WCS),[92] which documents the composition of the city's waste streams. These data replace the previous WCS from 2017.

New waste tonnage data is used in this year's model, as data are collected monthly.[93]

The format of the WCS changed to aggregate all borough data, so the model is simplified to align with this. Other than this, all calculation methodologies remain the same.

Discussion

The results of the model are very similar to the previous year.

City Government Operations

The City Government Operations GHG Emissions Forecast summarizes the impact of the city's current planned capital and expense commitments on emissions. The forecast includes GHG reductions from capital and expense projects planned through FY 2027, after which emissions from electricity fall to zero due to the city's commitment to purchasing 100 percent clean electricity.[94] Beyond FY 2027, the forecast reflects emissions reductions from capital and expense projects already in progress. The model estimates reductions based on a combination of reported project-level data, required under Local Law 101 of 2021 or Executive Order 89 of 2021,[95] and projected implementation timelines from the city's Ten-Year Capital Strategy.

Methodology Updates

The methodology to forecast City Government Operations emissions reductions is largely unchanged since the FY 2025 Climate Budgeting publication. The model has been migrated from a Microsoft Excel workbook to a Python script, but continues to use the same data sources, assumptions, and formulas. The boundaries of the Greenhouse Gas Inventories, published by MOCEJ and the NYC Department of Citywide Administrative Services (DCAS), have been updated to exclude City University of New York senior colleges, which are not under city operational control. In addition, the electrical grid emissions factors were updated and found to be higher than previously recognized.

The updated 2025 forecast reflects 34 percent emissions reductions by 2025, compared to 27 percent in last year's projection. This improvement is largely attributable to updated inventory data and a reduction in city energy consumption between FY 2022 and FY 2023. Emissions from electricity are projected to drop to zero beginning in FY 2027, consistent with the city's plan to purchase 100 percent clean electricity.

FIG. 22 | CITY GOVERNMENT OPERATIONS GHG FORECAST

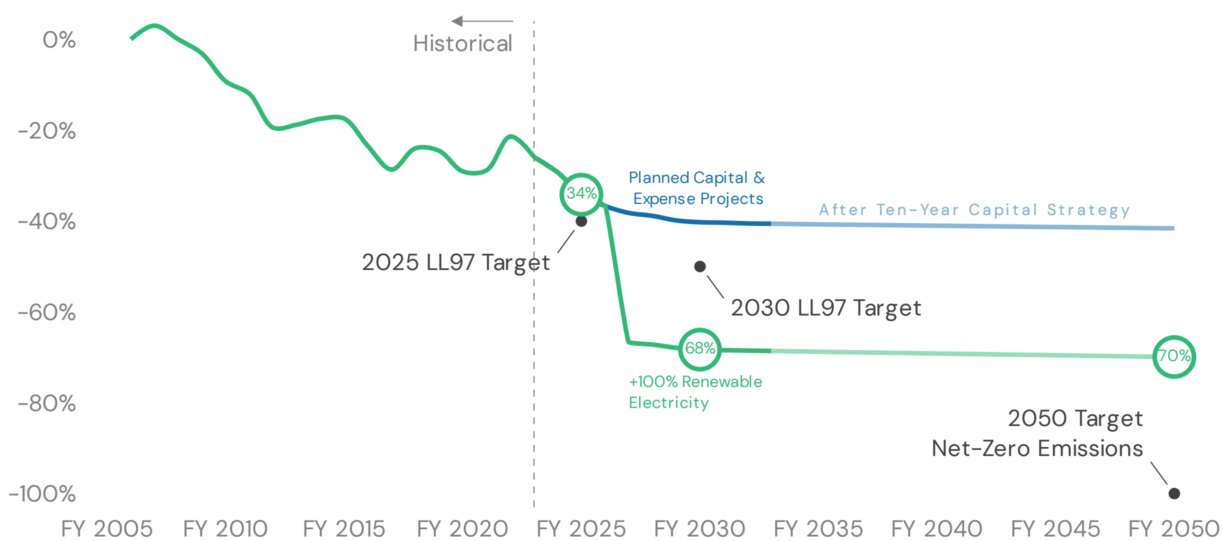

Figure Source: OMB, with DCAS

Discussion

The city government's forecasted emissions in the near term are similar to last year's projection, but cumulative reductions through 2050 are slightly lower. This is due primarily to project delays. Updated inventory values, which reflect higher electricity emissions factors, also contribute to a slower apparent pace of decarbonization, even as near-term reductions have improved.

FIG. 23 | YEAR-OVER-YEAR CITY GOVERNMENT FORECAST COMPARISON (TONS CO_2E)

	2025	2030	2035	2040	2045	2050
2024 Model	2,671,300	2,207,800	2,185,600	2,173,100	2,160,700	2,148,200
2024 + RECs	-	1,404,300	1,405,500	1,404,000	1,402,500	1,401,000
2025 Model	2,415,100	2,192,600	2,175,300	2,164,500	2,153,700	2,143,000
2025 + RECs	-	1,238,300	1,238,300	1,235,000	1,231,600	1,228,300

Figure Source: OMB, with DCAS Energy Management

FIG. 24 | REMAINING CITY GOVERNMENT GHG EMISSIONS BY SOURCE (TONS CO_2E)

	2025	2030	2035	2040	2045	2050
Electricity	1,181,200	-	-	-	-	-
Biofuel	100	100	100	100	100	100
Fuel Oil	182,100	153,900	151,900	151,900	151,900	151,900
Natural Gas	617,900	590,300	589,200	589,200	589,200	589,200
Steam	49,100	29,300	29,300	29,300	29,300	29,300
Vehicles-Biodiesel / Renewable Diesel	100	100	100	-	-	-
Vehicles-Diesel	27,300	500	500	500	500	500
Vehicles-Electric	1,900	-	-	-	-	-
Vehicles-Gasoline	72,500	58,400	44,300	30,200	16,100	2,000
Waste & Wastewater	259,500	250,500	250,500	250,500	250,500	250,500

Figure Source: OMB, with DCAS Energy Management

As Fig. 25 shows, buildings remain the largest contributor to GHG emissions, driven by fossil-fuel-based heating systems. Emissions from waste and wastewater infrastructure also contribute substantially.

As Fig. 26 shows, emissions are concentrated among a small number of agencies, with the New York City Department of Education, DSNY, and New York City Department of Environmental Protection accounting for the majority of city government operational emissions.

FIG. 25 | REMAINING GHG EMISSIONS BREAKDOWN BY SECTOR IN 2050

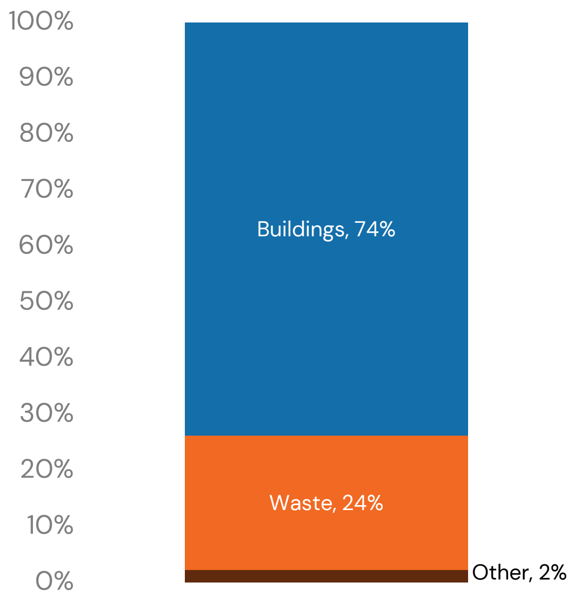

Figure Source: OMB, with DCAS Energy Management

FIG. 26 | REMAINING GHG EMISSIONS BREAKDOWN BY AGENCY IN 2050

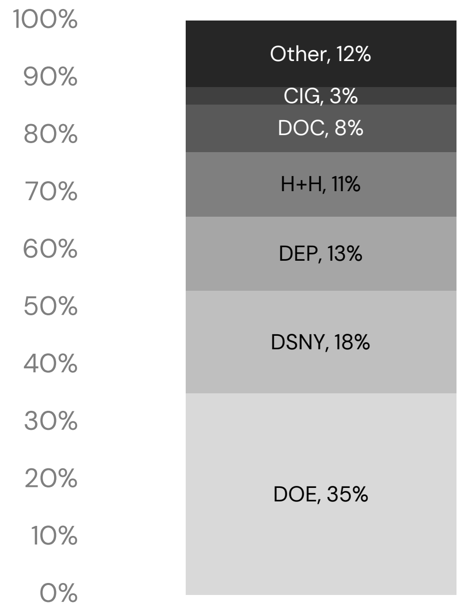

Figure Source: OMB, with DCAS Energy Management

This forecast helps track progress toward the city's long-term climate targets, including achieving net-zero emissions by 2050 and LL97 targets. As new capital and expense projects are funded and implemented, the model will be updated to reflect their impact on operational emissions.

GREENHOUSE GAS EMISSIONS FORECAST RESULTS

This section shows the results of the GHG emissions forecast in the City Actions scenario, which includes all market trends, federal policies, and state policies modeled in other scenarios. This is the primary scenario used in the FY 2026 Climate Budgeting forecast.

Fig. 27 and 28 compare the 2025 and 2024 forecasts. To highlight the impact of policy changes, the 2024 forecast was rerun using the 2025 methodology updates but preserving the 2024 model's policy scenarios. The emissions forecasts diverge between 2030 and 2040 because of 2030 CES and large-scale renewables delays, but the forecasts are largely similar after 2040 because both assume the state reaches the 2040 CES target.

FIG. 27 | YEAR-OVER-YEAR CITY ACTIONS SCENARIO COMPARISON

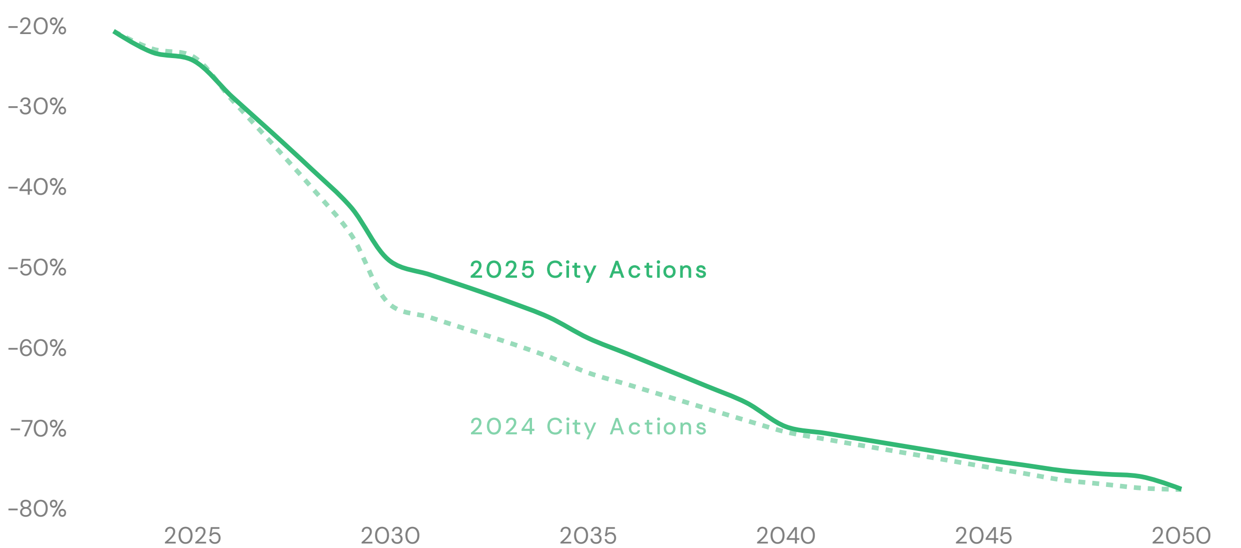

Figure Source: OMB

FIG. 28 | YEAR-OVER-YEAR CITY ACTIONS SCENARIO COMPARISON (TONS CO_2E)

	2025	2030	2035	2040	2045	2050
2024 Model	47,912,700	28,491,100	23,186,300	18,564,500	15,864,800	14,060,600
2025 Model	47,612,300	31,894,000	25,895,800	18,973,800	16,424,400	14,095,900

Figure Source: OMB

Fig. 29 shows the breakdown of remaining GHG emissions in the 2025 City Actions scenario. Natural gas is the largest remaining source of emissions, followed by landfills and diesel vehicles. State Actions dramatically reduce the emissions contribution from electricity and gasoline-powered vehicles, and City Actions reduce the natural gas use from large buildings.

FIG. 29 | REMAINING GHG EMISSIONS BREAKDOWN BY SOURCE (TONS CO_2E)

	2025	2030	2035	2040	2045	2050
Electricity	14,500,900	5,074,900	2,603,100	305,900	298,500	284,900
Fuel Oil	1,905,800	1,448,000	1,333,900	1,277,500	1,337,900	944,100
Natural Gas	14,217,400	12,331,300	11,316,400	10,498,500	10,159,400	9,148,400
Steam	402,600	340,800	331,800	310,100	310,100	269,900
Vehicles - Diesel	2,106,200	2,407,800	2,076,700	1,758,700	1,683,600	1,373,900
Vehicles - Electric	125,100	269,300	258,100	45,600	53,300	56,300
Vehicles - Gasoline	11,431,700	7,728,200	5,821,600	2,781,800	596,500	37,800
Vehicles – Other*	963,900	436,900	298,500	141,300	132,000	128,600
Landfills	1,862,200	1,764,800	1,764,800	1,764,800	1,764,800	1,764,800
Wastewater	98,300	98,300	98,300	98,300	98,300	98,300

Figure Source: OMB

**Vehicles-Other includes vehicles powered by compressed natural gas and hydrogen.*

$PM_{2.5}$ EMISSIONS FORECAST RESULTS

The subsequent tables show the results of the air pollution emissions forecast. Most changes in the air pollution emissions forecast are based on the policy updates outlined above, although there were additional methodology changes to represent uncertainty in the health impacts of forecasted emissions reductions and to account for medium- and heavy-duty EV fine particulate matter ($PM_{2.5}$) emissions in the net-zero forecast. $PM_{2.5}$ is a potent form of local air pollution that research ties to numerous negative health consequences. Fig. 30 lists the projected metric tons of $PM_{2.5}$ emissions from each scenario, and Fig. 31 shows the estimated health benefits from $PM_{2.5}$ reductions.

The 2025 methodology for air pollution was updated to include $PM_{2.5}$ emissions factors for medium- and heavy-duty EVs. These technologies were introduced in the 2025 COMET forecast to model the state's electrification commitments in this sector. To translate the activity in these sectors into $PM_{2.5}$ emissions, the analysis assumes that heavy-duty EVs have the same $PM_{2.5}$ emissions factor as EV buses (the only heavy-duty EV included in the MOVES output used) and that $PM_{2.5}$ emissions from medium-duty EVs are the average of $PM_{2.5}$ emissions from light-duty and heavy-duty EVs.

FIG. 30 | $PM_{2.5}$ EMISSIONS FORECAST (METRIC TONS)

	2025	2030	2035	2040	2045	2050
Market Trends & Federal Policy	2,610	1,850	1,780	1,640	1,630	1,580
Planned Large-Scale Renewables	2,610	1,770	1,700	1,640	1,630	1,580
Additional State Actions	2,600	1,740	1,640	1,540	1,500	1,410
City Actions	2,520	1,570	1,430	1,320	1,280	1,180

Figure Source: OMB, with NYC Health Department

The 2025 health impacts methodology was also updated to show uncertainty in the health impacts and to change the calculation of $PM_{2.5}$ emissions in the net-zero scenario. Low and high health impacts from DOHMH research are used to convey the range of possible health impacts as a result of air quality improvements.[96] The net-zero achievement scenario was updated to assume that the only remaining $PM_{2.5}$ emissions are from fully electrified light-, medium-, and heavy-duty EVs.

FIG. 31 | FORECASTED HEALTH EVENTS (CAUSED BY $PM_{2.5}$ EMISSIONS) AVOIDED ANNUALLY IN 2050

	Forecasted Events Avoided			Potential Additional Events Avoided with Net-Zero Achievement		
	Low-end	Average	High-end	Low-end	Average	High-end
Premature Deaths	45	90	135	155	300	450
Emergency Department Visits for Asthma	45	90	125	145	290	410
Respiratory & Cardiovascular Hospital Admissions	5	25	45	20	85	150

Figure Source: OMB, with NYC Health Department

GLOSSARY

Term	Definition
AEO	Annual Energy Outlook
AV	Assessed Value
CBD	Central Business District
CES	Clean Energy Standard
CLCPA	Climate Leadership and Community Protection Act
COMET	City-based Optimization Model for Energy Technologies
CRC	Certified Reasonable Cost
DCAS	NYC Department of Citywide Administrative Services
DOB	New York City Department of Buildings
DOT	New York City Department of Transportation
DPS	New York State Department of Public Service
DSNY	New York City Department of Sanitation
EIA	U.S. Energy Information Agency
EPA	U.S. Environmental Protection Agency
EV	Electric Vehicle
FY	Fiscal Year
GHG	Greenhouse Gas
HPD	New York City Department of Housing Preservation and Development
HVFHV	High-Volume For-Fire Vehicle
ICE	Internal Combustion Engine
J-51 R	J-51 Reform
LL97	Local Law 97 of 2019
MOCEJ	New York City Mayor's Office of Climate and Environmental Justice
MOVES	EPA Motor Vehicle Emission Simulator
NPV	Net Present Value
NYCHA	New York City Housing Authority
NYMTC	New York Metropolitan Transportation Council
NYSERDA	New York State Energy Research and Development Authority
OMB	New York City Mayor's Office of Management and Budget
PACT	NYCHA Permanent Affordability Commitment Together
$PM_{2.5}$	Fine Particulate Matter
SDG	HPD Sustainability Design Guidelines
TLC	New York City Taxi and Limousine Commission
VMT	Vehicle Miles Traveled
WAV	Wheelchair-Accessible Vehicle
WCS	Waste Characterization Study

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