The City of New York
Executive Budget
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Technical Appendices:
New York City Climate Budgeting

TABLE OF CONTENTS

GUIDELINES FOR IMPLEMENTING CLIMATE BUDGETING

To achieve the greatest benefit from Climate Budgeting, cities around the world will need to develop their own approaches that work within their specific budgets and political processes. In developing its Climate Budgeting initiative and inaugural publication, New York City benefited from the guidance and review of its counterparts in city government offices across the world. These appendices are intended to provide a reference for other cities as they develop or refine their own Climate Budgeting programs, providing an in-depth account of methodologies that support New York City's innovative approach to Climate Budgeting.

C40 CITIES CLIMATE BUDGETING GUIDELINES

New York City is a participant in a Climate Budgeting Program organized by C40 Cities. The program connects city governments that want to develop, implement, and improve Climate Budgeting processes that fit their governance structures and contribute to meeting their climate goals. Drawing on lessons learned from the cities participating in the program, C40 Cities has developed a step-by-step guide for cities looking to introduce Climate Budgeting, which outlines four overarching steps to setting up the process[1].

1. **Set the Foundation:** cities are advised to start by laying a strong foundation of commitment and collaboration across key stakeholders. This includes securing political commitment, establishing ownership by the city's chief financial officer or equivalent, and developing a climate-literate finance team. Early engagement with internal stakeholders fosters a collaborative environment and ensures broad understanding and support for Climate Budgeting across various departments.
2. **Mainstream Climate into the Budget Process:** this step involves the systematic integration of climate considerations into the budgeting process, using specifically designed instructions and templates. It includes establishing a methodology for quantifying greenhouse gas (GHG) emissions to assess the climate impact of budgetary proposals and actions. To assist cities with this step, C40 has developed a Handbook on GHG emissions quantification for Climate Budgeting[2].
3. **Undertake Climate Budgeting:** this is the active phase of climate budgeting, which puts the processes established in Step 2 into action. It includes issuing detailed instructions to all departments, collecting budget proposals, and developing a prioritization methodology to ensure that climate initiatives can be compared based on their potential impact and alignment with citywide targets. Evaluating gaps towards targets identifies areas where additional efforts or resources are required to ensure the city remains on track to meet its climate objectives.
4. **Expand, Improve, and Update:** the guidelines encourage cities to adopt a phased approach with annual improvements, allowing for refinement and expansion of the process over time. By using a continuous, iterative process, cities can progressively enhance their governance systems and improve technical analyses. Flexibility and adaptability allow cities to respond to new information, evolving best practices, and feedback from stakeholders, and ensure that Climate Budgeting remains a dynamic process capable of driving significant and sustained environmental impact over time.

NEW YORK CITY IMPLEMENTATION

New York City is implementing these broad steps in ways specific to its own budget process and needs. New York City's approach can serve as an example for other cities looking to do the same.

To lay a strong foundation, New York City's Budget Director established a team of dedicated staff with diverse technical skills and expertise within the Mayor's Office of Management and Budget (OMB). This team, called the Environmental Sustainability and Resiliency Task Force (ESR), has been instrumental in developing and implementing plans to initiate Climate Budgeting in New York City. Critical to this effort was early and regular engagement with the wider OMB team, counterparts at the Mayor's Office of Climate and Environmental Justice (MOCEJ) and city agencies, and external partners and subject-matter experts. To develop the most effective program and garner citywide support, ESR delivered a series of briefings and dialogue sessions with leadership and staff across teams within OMB and city government, aiming to communicate the objectives and proposed process improvements associated with Climate Budgeting and solicit insights and recommendations to design a workable and effective program.

A critical early step was to develop systems to better understand current city investments toward sustainability and resiliency. The city's budget is organized by agency, and because climate is cross-cutting, new approaches were needed to track and monitor relevant investments centrally. See Appendix 4 for detail on how ESR developed these new approaches.

In addition to tracking dedicated investments, ESR sought to analyze all spending for alignment and potential misalignment with sustainability and resiliency goals and needs. The decision was made to start with the capital plan because funding is organized into discrete projects, facilitating this type of analysis, and the long lifespan of capital projects means that decisions made today have potentially decades-long implications. Assessing all capital projects against climate objectives required the development of methods to manage the volume and variety of projects using standardized, uniform approaches. See Appendix 5 for detail on the development of the Climate Alignment Assessment.

Climate Budgeting requires OMB to collect new types of data to be able to consistently assess the costs and long-term benefits of planned and proposed actions. To collect new information on how proposed projects and programs impact sustainability, resiliency, and environmental justice, ESR developed a new Climate Budgeting Intake Form to be required with all relevant future funding requests. To estimate how planned capital projects will impact GHG emissions from city government operations, ESR implemented a new process for gathering capital project data on energy and fuel use. Implementing these new steps required thinking carefully about how to collect new information, what types of information to collect, how to validate and standardize submissions, and how to request the necessary data in a usable format without creating an overly burdensome requirement for agencies. See Appendix 2 for detail on the development of the Climate Budgeting Intake Form and Appendix 3 for detail on the process for collecting capital project emissions impact data.

To forecast citywide greenhouse gas emissions and associated air quality and health impacts, ESR considered several technical approaches and potential collaborators. Ultimately, the decision was made to collaborate directly with the U.S. Environmental Protection Agency (U.S. EPA), the New York City Department of Citywide Administrative Services, Division of Energy Management (DCAS DEM), and the NYC Health Department, as well as to seek broader support from MOCEJ, city agency partners, and external validators through the development of a Technical Advisory Group (TAG). See Appendix 6 for detail on the development of citywide and city government operations emissions forecasts.

Central to the development of this suite of tools, methodologies, and process improvements has been the commitment to a phased implementation and responsive and evolving process, so that Climate Budgeting is more impactful with each annual iteration.

CLIMATE BUDGETING INTAKE FORM

OVERVIEW

To inform the city’s Climate Budgeting process, 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 triage funding proposals, understand where additional information is needed, and support the assessment of impacts, cost effectiveness, and additional benefits and considerations.

During the 2025 plan cycle, agencies used the Climate Budgeting Intake Form to submit information on identified unfunded expense and capital projects and programs that may be necessary to meet the city's climate goals. When the city considers new needs in the future, a version of this Intake Form will be required for all relevant funding request submissions, including those that:

1. Increase or reduce GHG emissions from stationary energy, transportation, waste, or government operations as reported in the New York City GHG Inventory, or reduce the embodied emissions of construction materials, food, goods, or services; and/or
2. Positively or negatively impact climate resiliency to heat and/or flood risks as outlined by the New York City Panel on Climate Change (NPCC).

EXAMPLES

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

Projects or programs may increase or reduce GHG emissions by impacting:

- Building energy use (e.g., electrification, boiler replacement, Heating, Ventilation, and Air Conditioning (HVAC), lighting upgrades, window replacement, air sealing).
- Volume of waste sent to landfill, or the management and/or beneficial reuse of waste streams (e.g., recycling programs, compost programs, biogas capture and reuse).
- City-owned equipment with an emissions impact (e.g., conversion to hybrid or electric equipment, emissions controls).
- City fleet (e.g., electric vehicles (EVs), EV charging for city fleet).
- Citywide use of sustainable modes of transportation, including EVs, public transportation, cycling, and walking (e.g., public EV charging, bike lanes, bus lanes, priority bus signals, ferries, pedestrian infrastructure).
- Renewable energy generation, energy storage, or carbon capture (e.g., solar panels, offshore wind, hydropower, battery storage, carbon capture technology).
- Consumption-based emissions from sources such as food and consumer goods (e.g., procurement of low-carbon foods or goods).
- Consumption-based emissions from construction materials and/or processes (e.g., recycled or low-carbon construction materials or methods).

Projects or programs may influence the city's resiliency by impacting:

- Stormwater management, including permeable surfacing and green infrastructure (e.g., heavy downpour interventions, tanks/cisterns, restoration of streams, ponds, wetlands).
- Waterfront/shoreline infrastructure or natural waterfront areas, including construction or rehabilitation of infrastructure within the floodplain (e.g., beach protection or renourishment, dunes, groins, levees, flood walls/gates, building elevation, dry/wet floodproofing).
- Outdoor heat safety (e.g., expanding shade, cool roofs, water features, swimming pools).
- Indoor heat safety (e.g., air conditioning, increased access to cooling, cooling centers).
- Green and natural space (e.g., tree planting, vegetation, green streets, green roofs, parkland restoration).
- Community heat and flood resiliency, including engagement, education, outreach, monitoring, workforce development, or studies (e.g., outreach program for communities more susceptible to extreme heat, flood sensors).
- Heat and/or flood resiliency of building envelope (e.g., weatherproofing, waterproofing, equipment elevation/relocation).
- Continuation of services during extreme heat and/or flooding (e.g., emergency generators, interim flood protection measures).

INTAKE FORM QUESTIONS

The questions in the Intake Form are broken into three main sections: questions asked of all identified needs that may be necessary to meet the city's climate goals, followed by questions specific to needs impacting GHG emissions and questions specific to needs impacting climate resiliency.

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

- Briefly describe this need, including anticipated costs by year.
- Describe the timeline that would be needed to complete the capital project or put the program into operation.
- For new equipment or assets, what is the useful life (the extended service life, assuming regular maintenance)? For new programs, what is the expected duration (years)?
- Has this need been screened for competitive grant opportunities, including new programs out of the Bipartisan Infrastructure Law (BIL) or Inflation Reduction Act (IRA)? If so, which grant(s)?
- If emissions or resiliency components are part of a larger project, list those specific components and the associated estimated costs, as available.
- If emissions or resiliency components would result in any incremental operations and maintenance costs or savings, provide the expected amount per year (express savings as a negative).
- If this need would address environmental justice or equity, or directly benefit Disadvantaged Communities, describe how.
- If this need would support compliance with a local law or mandate, which?
- If this need would advance PlaNYC 2023 Initiatives, list which.

Identified relevant funding proposals that would impact emissions are required to include responses to the following requests:

- State the Emissions Sector and Emissions Source impacted and indicate the Anticipated Change to the Emissions Source (increase, decrease, eliminate, unknown).
- Describe the elements of the need expected to drive the anticipated change(s) and, as available, provide emissions details and quantified estimates.
- If the need would purchase new fossil-fuel-powered equipment or prolong the useful life of existing fossil-fuel-powered equipment, explain the purpose of the equipment.
- How were non-fossil-fuel alternatives considered and why are they not the preferred option?
- Note anything else that may be relevant, including any co-benefits, not captured elsewhere in the form.

Identified relevant funding proposals that impact climate resiliency are required to include responses to the following requests; where possible, respondents should quantify impacts (e.g., dollars of damages avoided, number of people protected or served, volume of water managed):

- If this is a capital project, will the New York City Climate Resiliency Design Guidelines (CRDG) be used during design[3]? If so, how (e.g., screen for risk using exposure screening tool)?
- If this need improves or detracts from resiliency to flood risk, explain how (note whether addressing current and/or future risk and quantify the impacts where possible).
- If this need improves or detracts from resiliency to heat risk, explain how (note whether addressing current and/or future risk and quantify the impacts where possible).
- If this need enables or disables continuation of operations or services during extreme weather/climate disasters, explain how.
- Note anything else that may be relevant, including any co-benefits, not captured elsewhere in the form.

CAPITAL PROJECT EMISSIONS IMPACT DATA GATHERING

Creating forward-looking GHG emissions forecasts for Climate Budgeting has required collecting new information from city agencies. OMB, in partnership with DCAS DEM has instituted a new process to collect information on how upcoming capital projects will impact GHG emissions. The responsibility for OMB to collect this information was established through Executive Order 89 of 2021 (EO89), and the process also supports the requirements of Local Law 101 of 2021 (LL101). Below is the relevant language from the Executive Order and Local Law that guide this new process.

EXECUTIVE ORDER 89 OF 2021 (EO89)

§ 5. Establishment of the Capital Plan Carbon Budget. Beginning in fiscal year 2023, agencies, offices, and other entities covered under Local Law 97 of 2019 (LL97) will be required to report to the Office of Management and Budget ("OMB") the emissions impacts of capital projects in City-owned buildings that are included in each year's September Capital Plan that are valued over $1,000,000 and involve the betterment, replacement, or installation of electrical, mechanical or plumbing equipment systems, or involve substantial reconstruction of a building envelope. Agencies will report whether each covered capital project increases, decreases, or has no effect on their overall emissions, and the magnitude of the change attributed to each project. OMB will provide DCAS with the carbon impact project information reported by agencies, to enable progress tracking toward the Agency Target Report [4].

LOCAL LAW 101 OF 2021 (LL101)

§ 24-803 Reduction of greenhouse gas emissions that contribute to global warming. c. (3) No later than 30 days after the publication of the report that, pursuant to paragraph 1 of subdivision d of section 219 of the charter, is required to be published no later than 90 days after the adoption of the capital budget, the office shall complete and post on its website a list of current and future capital projects intended to reduce greenhouse gas emissions from city government operations, and, for each such project, an estimate of the expected reductions of greenhouse gas emissions, a project timeline, the total projected budget, and the schedule of planned commitments, as such term is defined in such subdivision[5].

As outlined in EO89, data is now collected each year based on projects in the Adopted Capital Commitment Plan, also known as the September Capital Plan. To implement this process, OMB worked with DCAS DEM to develop a standard reporting template. The template includes the following fields:

- Project identifiers, including New York City Financial Management System (FMS) project ID (see Section 4), relevant funding and project managing agencies, and location.
- Whether a project falls under the purview of EO89, LL101, or both.
- Project information, including name, scope of work, Energy Conservation Measures (ECMs) to be implemented, the asset type, and whether the project involves constructing a new building.
- Whether the project is expected to increase, decrease, or have no impact on GHG emissions from government operations.
- Whether the project installs or prolongs the life of fossil fuel equipment or infrastructure.
- Project timeline, including anticipated date of substantial project completion.
- Fuel use, energy use, and direct emissions before and after project completion for any of the following that apply: electricity (kWh), natural gas (therms), fuel oil #2 (gallons), fuel oil #4 (gallons), steam (klbs), biofuel (gallons), diesel (gallons), gasoline (gallons), jet fuel (gallons), CH_4 - direct (metric tons), N_2O - direct (metric tons).
- Whether the data for the project derives from internal agency sources or calculations done by an external firm.
- Any additional comments or information the agency would like to provide.

Projects to construct new buildings are treated differently depending on whether the new building replaces an existing facility or not. If the new construction is replacing an existing building, the baseline annual energy consumption should be the consumption of the existing building. If the new construction is not replacing an existing building, the baseline annual energy consumption is zero and the change in annual energy consumption should be the estimated energy consumption at the facility after the project is complete.

The form uses the change in energy and direct emissions to auto-calculate the resulting GHG emissions using consistent emissions factors for each fuel type, aligned with the New York City GHG inventory. Data collected through this process is known as the Carbon Capital Budget (CCB) and informs the Climate Alignment Assessment (Appendix 5) and emissions forecasts (Appendix 6).

GREENHOUSE GAS EMISSIONS AND RESILIENCY BUDGET TRACKING

The OMB ESR Task Force now tracks capital and expense funding for investments planned to help the city advance its sustainability and 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 using the categorization of the city's GHG Inventory. For resiliency, funding is categorized based on the primary climate risks described by the NPCC, plus planning and preparedness work.

Sustainability Categories:

- Buildings & Facilities
- Transportation
- Energy
- Waste

Resiliency Categories:

- Coastal Flooding
- Inland Flooding
- Extreme Heat
- Planning & Preparedness

Tracking funding in a new way across agency budgets and city budget structures poses various challenges as described below and is continuously updated to reflect changes made during the city's financial and capital plans and advancements in the tracking process. Tracking reflects both city funds and non-city funding sources.

CAPITAL

The city's capital funding is organized in multiple ways. For the purpose of tracking climate-related funding, OMB looked at project IDs, which are unique project identifiers assigned in the city's centralized accounting and budgeting system, known as FMS. Each project was analyzed at the project ID level and assigned a category based on the below categorization.

A limitation to this tracking is that a capital project may include multiple scope elements. For example, a facility renovation project may include climate-related scope, such as heating system upgrades, alongside other scope such as bathroom renovations. FMS project IDs do not distinguish between scope elements. This tracking does not capture climate-related scope elements within larger projects and therefore is not meant to reflect the total sum of all climate-related capital investments. However, the positive impact of such projects is recognized in the Climate Alignment Assessment (see Appendix 5).

There are a few exceptions where this challenge can be overcome by tracking funding by budget lines within a project ID. Budget lines are identifiers of capital units of appropriation, which may 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 some circumstances, OMB found it necessary to only count certain budget lines toward climate investments. For example, there might be a capital project for street and utility reconstruction which has a mixed scope and includes several budget lines specific to sewer replacement, water main extensions, sidewalk construction, and street resurfacing. In this case, OMB would only track the funding allocated to the sewer replacement budget line as related to flood resiliency.

Within the main categories of climate investments, capital funds have been broken into sub-categories to better distinguish between different types of projects:

Capital Sustainability Sub-Categories:

- Buildings & Facilities: energy efficiency and electrification projects in city facilities
- Transportation: bike lanes, bus lanes, EV chargers, hybrid/electric ferries, hybrid/electric vehicles, and equipment
- Energy: solar, wind, hydroelectric, energy storage, and other renewable energy
- Waste: composting sites, and emissions-reducing projects from solid waste and wastewater resource recovery facilities

Capital Resiliency Sub-Categories:

- Coastal Flooding: large-scale neighborhood protection projects such as East Side Coastal Resiliency, United States Army Corps of Engineers projects, Raised Shorelines, and other capital projects impacting waterfront assets[6,7]
- Inland Flooding: cloudburst management projects, bluebelts, wetland restoration, flood protection for buildings, green infrastructure, Southeast Queens stormwater management, combined sewer overflow management, sewer construction and reconstruction projects, and other projects[8-11]
- Extreme Heat: tree planting and replacement, and pools
- Planning & Preparedness: emergency generators

EXPENSE

OMB has begun to track climate-related work in the expense budget using the same categories, but tracking is in a preliminary phase. When funding is added for a climate-related program, OMB will track funding for that program over time. However, in some instances, expense funding supports programs or operations that are a combination of climate-related work and other work, making the climate-specific work difficult to track. For example, funding in New York City Department of Transportation's (DOT) budget for roadway markings supports bike lanes, which would be considered a climate investment because they encourage alternative modes of transit, alongside other types of roadway markings such as traffic lane lines. Therefore, the expense programs tracked in the Climate Budgeting publication are not meant to reflect the total sum of all climate-related expense investments. In future Climate Budgeting publications, OMB hopes to refine its methodology and provide a more comprehensive look at expense investments.

CLIMATE ALIGNMENT ASSESSMENT

OVERVIEW AND METHODOLOGY

As part of the Climate Budgeting process, OMB conducted a Climate Alignment Assessment of New York City's capital plan, which will be updated on an annual basis as part of the Climate Budgeting publication released with the Executive Budget. Each capital project with more than $50,000 in the FY 2024-2028 Capital Commitment Plan was assigned color-coded tags based on its climate impacts. The purpose of the assessment is to understand whether capital projects and programs are aligned with the city's climate goals and guidelines. OMB will use the rating system to evaluate existing projects in addition to requests for new capital projects.

The OMB ESR Task Force, with input from MOCEJ, developed criteria based on:

- The city's commitment to net-zero emissions by 2050
- NPCC projections for future heat and flood risks[12]

The assessment also tracks impacts to the local environment and sustainable practices as "additional benefits" to these projects.

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. Projects' alignment with each of these priorities is considered separately. In some instances, the same project may be rated differently under each climate priority (see example ratings in Figure 5.1).

Each individual capital project is then screened to determine whether it can be rated, and if so, a rating is applied. This process is repeated for each potential climate impact. Projects are screened as follows:

EXAMPLE PROJECT ALIGNMENT WITH CLIMATE GOALS

Example Project	Net-Zero Emissions	Flood Resiliency	Extreme Heat Resiliency
Heat Electrification in City Facility	Rating: **Aligned** The project's main intent is switching to all-electric heating to reduce greenhouse gas emissions	Rating: **Aligned Component** A component of the project elevates critical infrastructure above the future flood level	**No Impact** If the facility already has cooling, the project does not impact extreme heat resiliency
Purchase of Emergency Generator	Rating: **Not Aligned** The generator will burn diesel for fuel	**Pending Rating** With current information, unable to determine whether equipment will be elevated above the future flood level	Rating: **Aligned** The project provides continuity of operations during extreme weather events, including extreme heat
City Contribution to the Metropolitan Transportation Authority (MTA) Capital Plan	Rating: **Aligned Component** All projects within the MTA capital plan contribute to mass transit services citywide	**Special Case** Further analysis is needed to determine how flood resiliency is considered in the MTA capital plan	**Special Case** Further analysis is needed to determine how extreme heat resiliency is considered in the MTA capital plan

FIGURE 5.1 | SOURCE: NYC OMB

DETERMINING A CAPITAL PROJECT'S CLIMATE ALIGNMENT

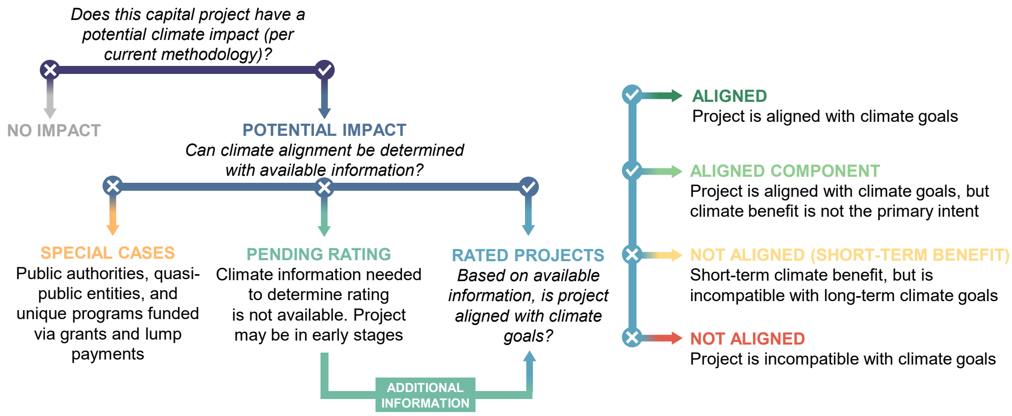


FIGURE 5.2 | SOURCE: NYC OMB

Projects with No Impact

Projects that do not have the potential to impact the climate priority, per the current methodology.

Projects with Potential Impact

Projects that do have the potential to impact the climate priority are further analyzed. This next level of analysis separates projects into three categories: rated projects, projects pending rating, and special cases.

Rated Projects

Projects that have been carefully analyzed and are rated as either aligned or not aligned with the given climate priority. Additional detail on how these categories apply to each climate priority is available under the corresponding heading (see Defining Alignment with Net-Zero Emissions, Defining Alignment with Climate Resiliency).

Projects Pending Rating

Projects for which a rating cannot be determined because the specific information needed to assess climate alignment is not yet available. Some of these projects are planned for future years, meaning design decisions that may influence how a project is rated have not yet been made. With additional information, such as the fuel type used or the resiliency standard followed, these projects could be rated in the future.

Special Cases

Projects for which a rating cannot be determined because funding is transferred to public authorities, quasi-public entities, and other unique programs that are funded through grants, loans, and lump payments.

For example, the Department of Housing Preservation and Development (HPD) provides loans and grants to housing developers, who are required to follow sustainability design guidelines that vary by proposed scope[13]. Many, but not all, of the resulting projects will be net-zero-emissions compatible, and outcomes will depend on each developer's unique set of needs. Another example of a special case is the School Construction Authority (SCA). Although the current methodology is able to capture some payments to the SCA such as the Leading the Charge initiative to electrify schools, other parts of SCA's budget support broader, more general work at schools[14]. Other examples include loans provided through the Economic Development Corporation (NYCEDC). OMB will continue to monitor these special cases and, where appropriate, tailor approaches to capture the impacts of these projects in future iterations of the assessment.

DEFINING ALIGNMENT WITH NET-ZERO EMISSIONS

Definition

Projects have an emissions scope if they impact emissions from either of the following sources:

- Scope 1 emissions: GHGs 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 EVs or sustainable modes of transit.
- Scope 2 emissions: GHGs 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 GHGs resulting from mining, harvesting, processing, manufacturing, transportation, and installation of goods, services, and materials consumed within New York City.

Determining Alignment

Projects with No Impact

The project does not contain scope that impacts emissions, as defined above. Examples of projects with no impact include upgrades to IT equipment, sewers and water mains, and accessibility upgrades.

Projects with Potential Impact

The project contains scope that impacts emissions, as defined above. Examples of projects with a potential impact include most upgrades in buildings and facilities, purchases of vehicles and equipment, and investments in energy infrastructure

Rating Breakdown

- **Aligned:** The project's primary intent is to reduce GHG emissions, and it is compatible with the city's net-zero goal. Scope that reduces emissions constitutes most or all of the project cost.
  - **Example:** Heat electrification in a city building.
- **Aligned Component:** The project reduces GHG 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 plus other scope.
  - **Example:** Street reconstruction project that includes new protected bike lanes.
- **Not Aligned (Short-Term Benefit):** The project offers short-term GHG emissions reduction benefits but is incompatible with the city's net-zero goal.
  - **Example:** Replacing inefficient oil boiler with efficient gas boiler.
- **Not Aligned:** The project does not have emissions or efficiency improvements and is incompatible with the net-zero goal.
  - **Example:** Purchasing a diesel-powered vehicle.

Projects Pending Rating

The project may have a favorable or unfavorable GHG emissions impact, but it cannot be determined with existing information. Examples of projects pending rating include future facility renovations and future vehicle purchases.

DEFINING ALIGNMENT WITH CLIMATE RESILIENCY

Definition

Projects have climate resiliency implications if they positively or negatively impact New York City's ability to withstand one or more of the following climate hazards:

- Coastal flooding from storm surges, high tides, and sea-level rise
- Increased or extreme precipitation and inland flooding
- Increased or extreme heat events (including indoor and outdoor heat)

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

Determining Alignment

Projects with No Impact

The project does not contain scope that impacts resiliency, as defined above. Examples of projects with no impact include upgrades to IT equipment, accessibility upgrades, and most vehicle purchases.

Projects with Potential Impact

The project contains scope that impacts resiliency, as defined above. Examples of projects with a potential impact include upgrades in buildings and facilities, green and natural spaces, and waterfront assets. These projects are evaluated separately for their alignment with both flood resiliency and heat resiliency.

Rated Projects

For **projects in buildings**, alignment is measured by determining if the agency is using a resiliency standard such as the CRDG that would protect the building from projected climate threats at the end of its useful life:

- **Aligned:** The project's primary intent is to further resiliency to extreme heat or flooding and is being designed to withstand climate risk at the end of its useful life, by following the CRDG or other equivalent resiliency standards[3]. Resiliency-related scope constitutes most or all of the project cost.
    - **Example (Flood Resiliency):** Renovations to protect a building from rising sea levels, following CRDG standards.
    - **Example (Heat Resiliency):** Installation of air conditioning to ensure thermal safety of city workers.
- **Aligned Component:** The project has resiliency benefits, but the primary intent is not resiliency. The project is being designed to withstand climate risk at the end of its useful life, by following the CRDG or other equivalent resiliency standards. The project cost could be a mix of resiliency scope plus other scope.
    - **Example (Flood Resiliency):** Construction of a new waterfront facility that follows CRDG standards.
    - **Example (Heat Resiliency):** Large-scale facility renovation, which also includes air conditioning upgrades.
- **Not Aligned (Short-Term Benefit):** The project is designed with resiliency benefits and may be designed to withstand extreme heat and flood risk but does not take into account future risk at the end of its useful life.
    - **Example (Flood Resiliency):** Renovations undertaken to protect a building from rising sea levels that do not account for long-term coastal flooding projections.

- **Not Aligned:** A risk exists but it is not being addressed, or the project makes the asset less resilient to extreme heat or flooding.
  - **Example (Flood Resiliency):** Construction of new facility in the floodplain with no flood protection.
  - **Example (Heat Resiliency):** Construction of new facility without air conditioning.

For **all other assets and projects**, alignment is measured by determining if the project contains one of the following components referenced in PlaNYC: Getting Sustainability Done (PlaNYC) or other resiliency plans as one of the city's resiliency goals[15]: Bluebelts, cloudburst management projects, raised shorelines, combined sewer overflow management, green infrastructure, wetland restoration, coastal protection infrastructure, cool roofs, indoor cooling, cool corridors, expanding and maintaining green space, greenstreets, outdoor cooling, shading canopy, tree planting and replacement, pools, Climate Strong Communities, resilience hubs.

- **Aligned:** The project's primary intent is to further resiliency to extreme heat or flooding and the project type is referenced as one of the resiliency goals in PlaNYC or other New York City resiliency plans (see list above). Resiliency-related scope constitutes most or all of the project cost.
  - **Example (Flood Resiliency):** Green infrastructure.
  - **Example (Heat Resiliency):** Construction of a public pool.
- **Aligned Component:** The project has resiliency benefits but the primary intent is not resiliency. The project type is referenced as one of the resiliency goals in PlaNYC or other New York City resiliency plans (see list above). The project cost could be a mix of resiliency scope plus other scope.
  - **Example (Flood Resiliency):** Street reconstruction that includes improved drainage.
  - **Example (Heat Resiliency):** Green infrastructure that contributes to reducing the urban heat island effect.
- **Not Aligned (Short-Term Benefit):** Project is designed with resiliency benefits, and may be designed to withstand flood risk, but does not take into account future risk at the end of the asset's useful life by using agency-wide or other equivalent resiliency standards. Note that current methodology does not differentiate between short- and long-term heat mitigation measures for non-building assets. Therefore, none of these assets will be rated Not Aligned (Short-Term Benefit) for heat resiliency.
  - **Example (Flood Resiliency):** Storm surge barriers that do not consider long-term coastal flood projections.
- **Not Aligned:** A risk exists but it is not being addressed, or the project makes the asset less resilient to extreme heat or flooding.
  - **Example (Flood Resiliency):** Street reconstruction that removes green space, reducing surface permeability.
  - **Example (Heat Resiliency):** Street reconstruction that removes green space, contributing to the urban heat island effect.

Projects Pending Rating

The project may have an impact on either flooding or extreme heat resiliency, but it cannot be determined with the existing information. Examples of projects pending rating include future facility renovations.

DEFINING ADDITIONAL BENEFITS

Projects that have scope supporting the following benefits are tagged to highlight these additional benefits beyond emissions reductions and resiliency to extreme weather:

- **Air Quality** - Projects that improve local air quality conditions from concentrations of particulate matter below 2.5 microns in size ($PM_{2.5}$), nitrogen dioxide, nitric oxide, sulfur dioxide, carbon monoxide, and ground-level ozone.
- **Circular Economy** - Projects that support the conservation of resources, beneficial reuse, recycling efforts, or reduction of waste from the city's waste stream.
- **Ecology** - Projects that support:
  - Green spaces in the public realm (e.g., parks, plazas, community gardens, playgrounds) and access to these areas.
  - Natural areas (examples of such projects include wetland restoration, bluebelts, conservation, daylighting, and soil maintenance).
  - The health and ecological function of New York City's ecosystems, waterways, and wildlife habitats (these efforts can affect local biodiversity, which provides essential ecosystem services, including nutrient recycling, pest regulation, erosion control, and pollination).
- **Sustainable Living** - Projects that support a more sustainable lifestyle for New Yorkers, such as those that encourage renewable energy production or electric or alternative forms of transportation, maintain public pedestrian spaces, or invest in urban agricultural efforts.

GREENHOUSE GAS EMISSIONS AND AIR QUALITY FORECASTING

OMB developed a forecast of GHG emissions and associated air quality impacts in New York City to evaluate the city's progress towards meeting its near- and long-term climate targets and to identify where additional action is needed. To develop this forecast, OMB implemented several phases of modeling and collaborated with a diverse group of stakeholders. Figure 6.1 illustrates the components of this forecast.

Sections 6.a. and 6.b. contain detailed results of the Citywide and City Government Forecasts, respectively.

Section 6.c. describes OMB's GHG emissions and air quality forecasting core model, developed to synthesize results from each of the components described below into an overall picture of the city's emission projections.

Section 6.d. describes OMB's analysis of city actions, a collection of policies and commitments the city is making to reduce citywide emissions. OMB analysts identified and modeled 13 city actions and worked with a Technical Advisory Group (TAG) to review the analyses.

Section 6.e. describes OMB's analysis of state actions, a collection of policies and commitments the state is making that will reduce citywide emissions.

Section 6.f. describes the forecast of emissions from city government operations. OMB developed this forecast in partnership with DCAS DEM.

Section 6.g. describes New York City's use of the U.S. EPA's City-based Optimization Model for Energy Technologies (COMET-NYC) to forecast a series of baseline scenarios that form the foundation for the emissions and air quality forecasts.

MODEL SUMMARY

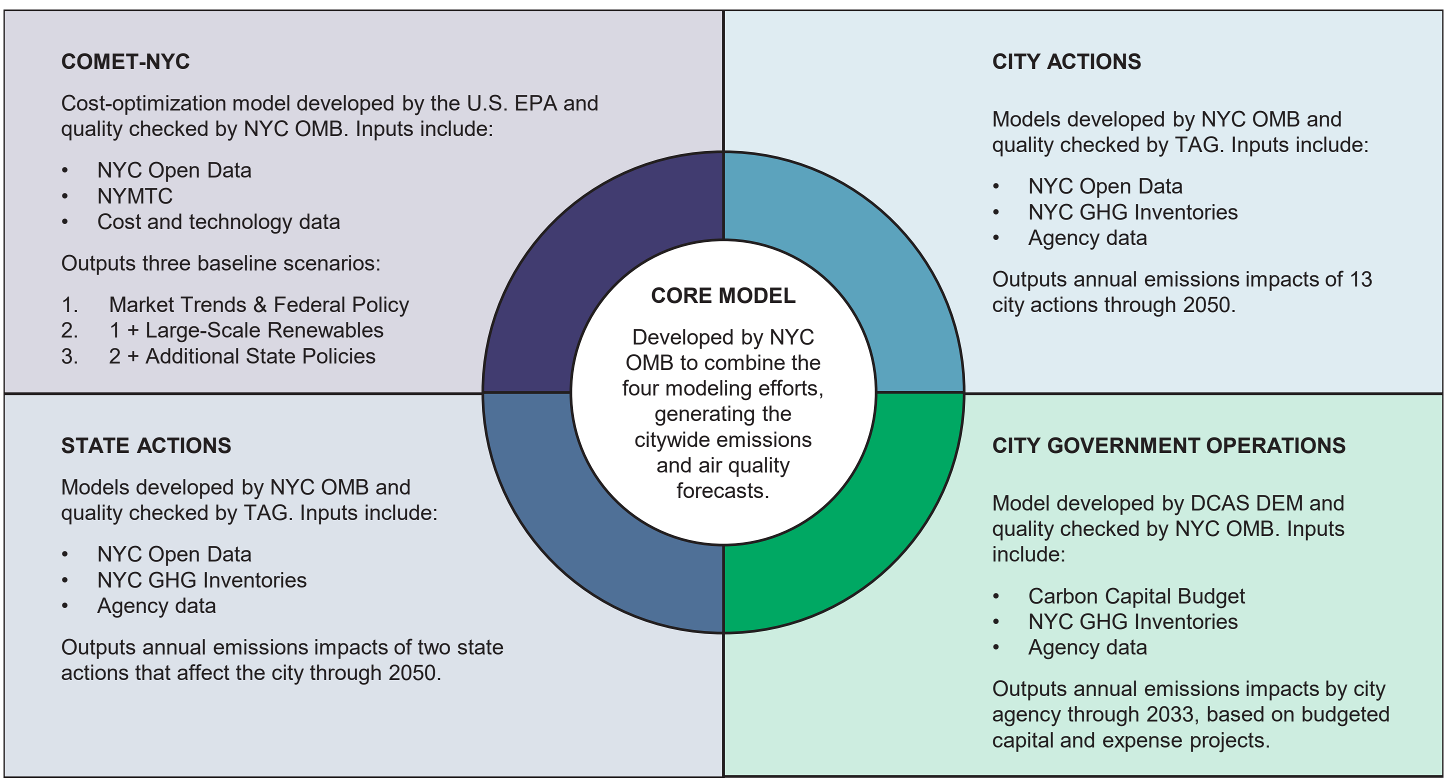


FIGURE 6.1 | SOURCE: NYC OMB[16-18]

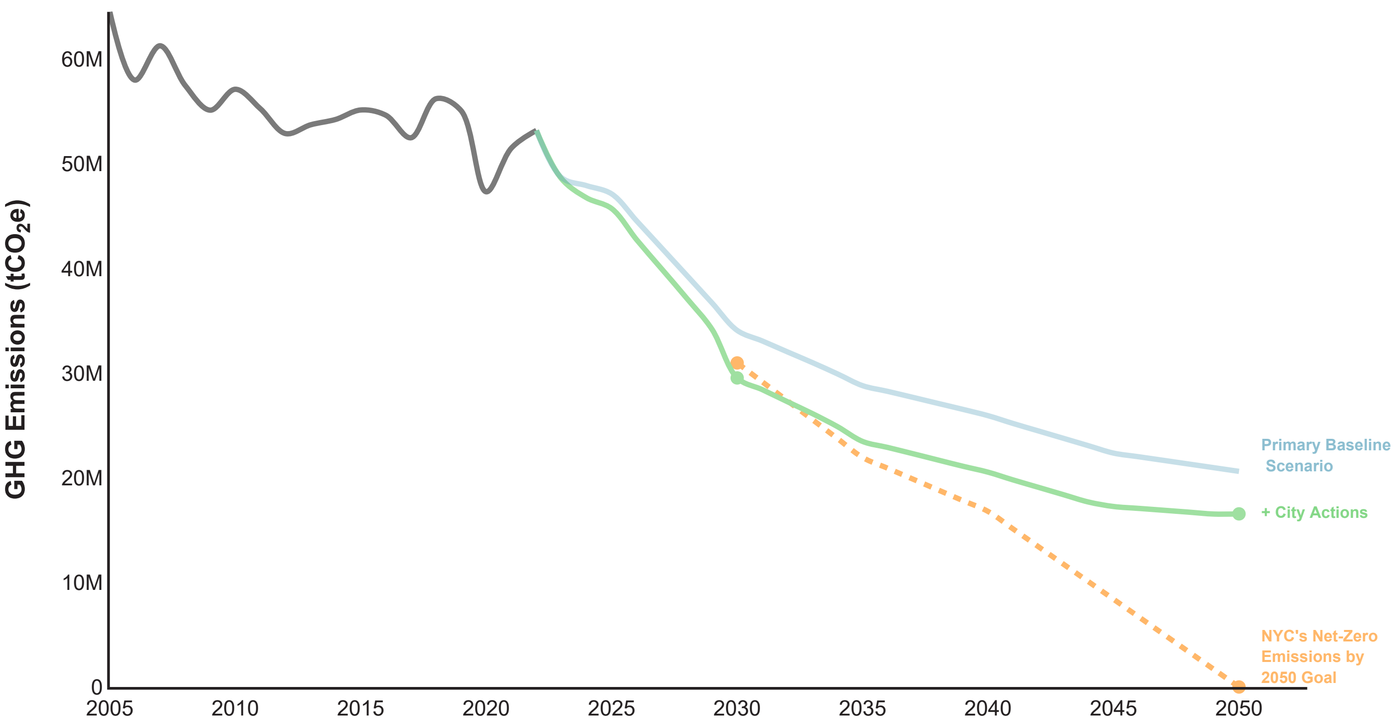
6.a. CITYWIDE GHG EMISSIONS FORECAST RESULTS

The Climate Budgeting publication includes several figures summarizing the results of the citywide GHG emissions and air quality emissions forecasts. In this section, these results are provided in tabular form.

The first group of tables summarizes the results from the GHG emissions forecast. All tables present GHG emissions in metric tons of carbon dioxide equivalent (tCO_2e). This measure includes emissions from multiple GHGs, although the main gases are CO_2 and CH_4, and follows the GHG Protocol for Cities (GPC) accounting protocol, which uses a 100-year time horizon to find the equivalent warming potential of CO_2 and CH_4. New York State's accounting protocol uses a shorter time horizon, which places more weight on CH_4 emissions because these lead to more warming in the near term.

Figure 6.2 shows the primary citywide GHG emissions forecast, the impact of city actions, and the remaining gap towards science-based emissions targets. To show how state policies contributed to this reduction, Figure 6.3 shows the projected emissions (after city actions) in the three baseline COMET-NYC scenarios. Figure 6.4 lists the projected GHG emissions reduction from each city action. Figure 6.5 summarizes the city action reductions by sector (buildings, transportation, and waste). Figures 6.6 and 6.7 show the composition of remaining GHG emissions in each year, in the primary citywide forecast.

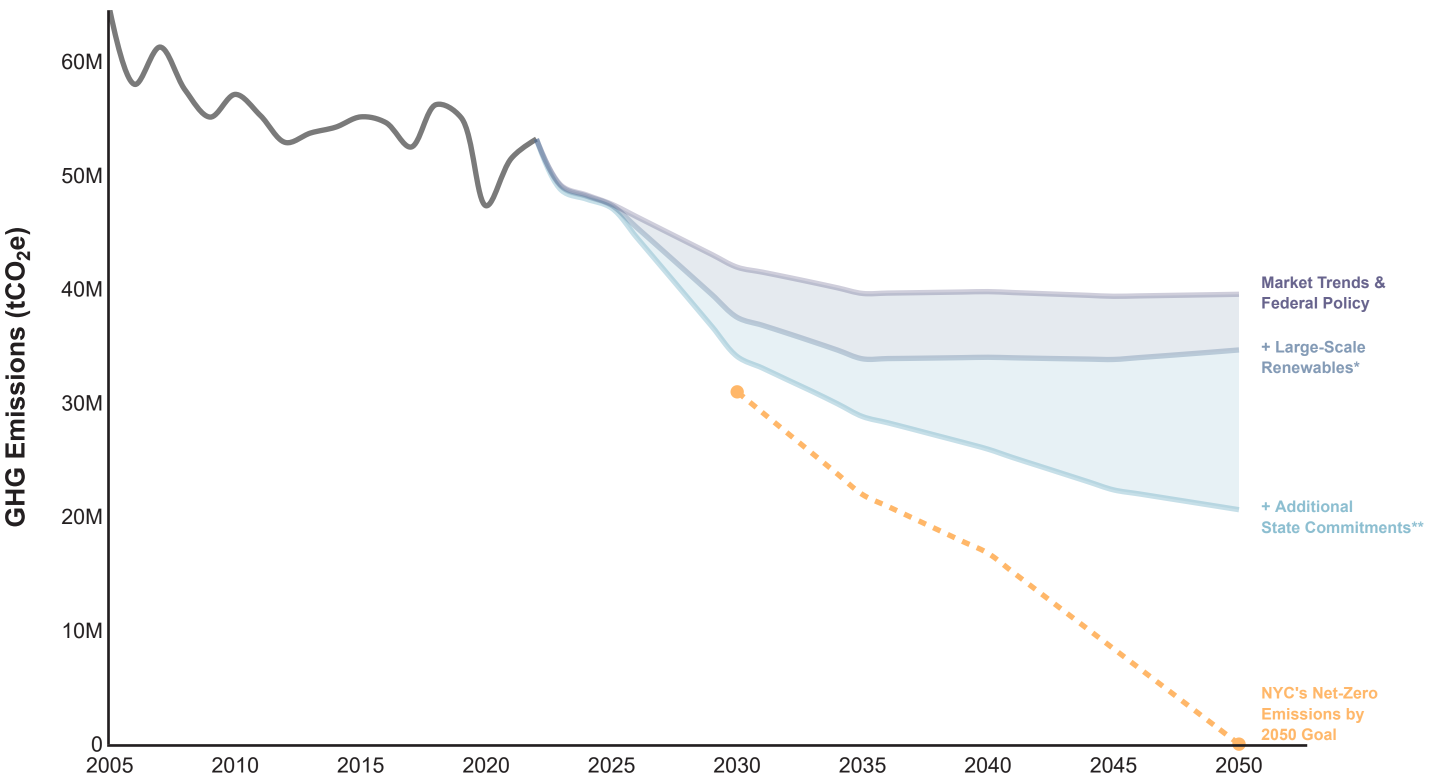
PRIMARY CITYWIDE FORECAST



Citywide GHG Forecast	(tCO_2e)					
	2025	2030	2035	2040	2045	2050
Primary Baseline Scenario	47,100,000	34,100,000	28,800,000	25,900,000	22,400,000	20,600,000
+ City Actions	(1,400,000)	(4,500,000)	(5,300,000)	(5,400,000)	(5,100,000)	(4,000,000)
NYC Forecasted Emissions	**45,700,000**	**29,600,000**	**23,500,000**	**20,500,000**	**17,300,000**	**16,600,000**
Gap from Science-Based Emissions Target	8,000,000	(1,400,000)	1,600,000	3,700,000	8,900,000	16,600,000
Interim Science-Based Emissions Target	**37,700,000**	**31,000,000**	**21,900,000**	**16,800,000**	**8,400,000**	**—**

FIGURE 6.2 | SOURCE: NYC OMB

BASELINE SCENARIO COMPARISON



**Includes Champlain Hudson Power Express & Clean Path New York transmission lines and 9 gigawatts of offshore wind.*

***Includes New York Clean Energy Standard, all electric passenger vehicle sales by 2035, congestion pricing, and Metropolitan Transportation Authority bus electrification.*

The orange line shows interim science-based emissions targets aligned with 1.5°C trajectory.

Baseline Scenario	(tCO_2e)					
	2025	2030	2035	2040	2045	2050
Market Trends & Federal Policy	46,100,000	37,900,000	34,900,000	35,200,000	34,900,000	35,300,000
+ Planned Large-Scale Renewables	46,000,000	33,300,000	28,800,000	29,100,000	29,000,000	30,100,000
+ Additional State Policies	45,700,000	29,500,000	23,500,000	20,500,000	17,300,000	16,500,000
Interim Science-Based Emissions Target	**37,700,000**	**31,000,000**	**21,900,000**	**16,800,000**	**8,400,000**	**—**

FIGURE 6.3 | SOURCE: NYC OMB

NET GHG EMISSIONS IMPACT OF CITY ACTIONS

City Actions	(tCO_2e)					
	2025	2030	2035	2040	2045	2050
Building Emissions Limits (LL97-2019)	(937,900)	(2,749,100)	(3,062,400)	(3,088,400)	(3,095,900)	(2,883,100)
For-Hire-Vehicle Electrification	(49,700)	(871,200)	(936,100)	(954,000)	(722,700	0
City Government Operations	(161,100)	(351,600)	(396,900)	(398,900)	(371,700	(287,300)
NYCHA Clean Heat for All Challenge	(27,200)	(225,000)	(476,700)	(488,500)	(489,400)	(490,100)
Efficient & Electric New Builds (LL32-2018, LL154-2021)	(71,200)	(108,200)	(153,500)	(193,100)	(234,300)	(267,800)
Fuel Oil Phase-Out Mandates (LL43-2010, LL107-2013, LL119-2016, LL32-2023)	(71,800)	(92,700)	(133,300)	(103,000)	(45,800)	(50,500)
Electric Vehicle Vision	(24,900)	(53,400)	(67,700)	(68,900)	(52,200)	0
Bus Lanes (DOT Streets Plan, LL195-2019)	(32,100)	(29,400)	(15,700)	(14,700)	(3,100)	(700)
HPD Sustainability Design Guidelines	(6,900)	(28,400)	(40,000)	(36,800)	(36,900)	(30,700)
Bike Lanes (DOT Streets Plan, LL195-2019)	(15,400)	(14,500)	(7,700)	(7,200)	(1,500)	(400)
Mandatory Citywide Curbside Organics Collection (LL85-2023)	(1,400)	(5,900)	(7,200)	(8,600)	(10,000)	(11,400)
School Bus Electrification (LL120-2021, EO53)	(500)	(13,000)	(32,900)	(37,100)	(39,600)	(41,300)
NYCHA Solar Installations	(2,800)	(800)	(600)	(300)	(200)	(200)
NYCHA Permanent Affordability Commitment Together (PACT) Program	(300)	(200)	(200)	(200)	(200)	(200)

FIGURE 6.4 | SOURCE: NYC OMB

NET GHG EMISSIONS IMPACT OF CITY ACTIONS BY SECTOR

Sector	(tCO_2e)					
	2025	2030	2035	2040	2045	2050
Buildings	(1,262,000)	(3,413,000)	(4,085,000)	(4,097,000)	(4,087,000)	(3,905,000)
Transportation	(139,000)	(1,124,000)	(1,238,000)	(1,293,000)	(1,006,000)	(147,000)
Waste	(2,000)	(7,000)	(8,000)	(10,000)	(11,000)	(12,000)

FIGURE 6.5 | SOURCE: NYC OMB

REMAINING GHG EMISSIONS BREAKDOWN BY SOURCE

Source	(tCO_2e)					
	2025	2030	2035	2040	2045	2050
Electricity	14,210,000	4,063,000	3,270,000	1,571,000	1,519,000	1,478,000
Fuel Oil	1,935,000	1,567,000	1,270,000	1,136,000	919,000	897,000
Natural Gas	12,279,000	11,226,000	10,375,000	9,824,000	9,523,000	8,878,000
Steam	705,000	567,000	570,000	548,000	549,000	497,000
Transportation - Other	674,000	234,000	198,000	124,000	118,000	116,000
Vehicles - Compressed Natural Gas	74,000	56,000	46,000	9,000	4,000	600
Vehicles - Diesel	2,200,000	2,123,000	2,039,000	1,940,000	2,017,000	2,092,000
Vehicles - Electric	117,000	224,000	415,000	196,000	240,000	221,000
Vehicles - Gasoline	11,465,000	7,422,000	3,227,000	3,126,000	305,000	313,000
Vehicles - Hydrogen	—	—	—	—	—	—
Waste	2,067,000	2,062,000	2,061,000	2,059,000	2,058,000	2,057,000

FIGURE 6.6 | SOURCE: NYC OMB

REMAINING GHG EMISSIONS BREAKDOWN BY SECTOR

Sector	(tCO_2e)					
	2025	2030	2035	2040	2045	2050
Buildings	29,100,000	17,400,000	15,500,000	13,100,000	12,500,000	11,700,000
Transportation	14,500,000	10,100,000	5,900,000	5,400,000	2,700,000	2,700,000
Waste	2,100,000	2,100,000	2,100,000	2,100,000	2,100,000	2,100,000

FIGURE 6.7 | SOURCE: NYC OMB

The subsequent tables provide the air pollution emissions forecast. These forecasts are measured in metric tons of $PM_{2.5}$ ($tPM_{2.5}$), a potent form of local air pollution that research ties to numerous negative health consequences. Figure 6.8 lists the projected $PM_{2.5}$ emissions reduction from each city action. Figure 6.9 shows the projected level of $PM_{2.5}$ with market trends and federal policy, as well as the reductions due to state and city actions. Figure 6.10 shows the estimated health benefits from these $PM_{2.5}$ reductions. Section 6.c. describes how these benefits were calculated.

NET $PM_{2.5}$ EMISSIONS IMPACT OF CITY ACTIONS

City Action	*($tPM_{2.5}$)*					
	2025	2030	2035	2040	2045	2050
Building Emissions Limits (LL97-2019)	(75)	(176)	(194)	(187)	(187)	(173)
For-Hire-Vehicle Electrification	(1)	(12)	(11)	(11)	(8)	-
City Government Operations	(5)	(6)	(7)	(6)	(6)	(4)
NYCHA Clean Heat for All Challenge	(2)	(13)	(27)	(27)	(27)	(27)
Efficient & Electric New Builds (LL32-2018, LL154-2021)	(3)	(6)	(9)	(12)	(14)	(16)
Fuel Oil Phase-Out Mandates (LL43-2010, LL107-2013, LL119-2016, LL32-2023)	(11)	(18)	(16)	(14)	(11)	(11)
Electric Vehicle Vision	-	(1)	(1)	(1)	(1)	-
Bus Lanes (DOT Streets Plan, LL195-2019)	(1)	(1)	(1)	(1)	(1)	-
HPD Sustainability Design Guidelines	-	(2)	(2)	(2)	(2)	(2)
Bike Lanes (DOT Streets Plan, LL195-2019)	-	-	-	-	-	-
Mandatory Citywide Curbside Organics Collection (LL85-2023)	-	-	-	-	-	-
School Bus Electrification (LL120-2021, EO53)	-	(6)	(15)	(17)	(12)	(9)
NYCHA Solar Installations	-	-	-	-	-	-
NYCHA Permanent Affordability Commitment Together (PACT) Program	-	-	-	-	-	-

FIGURE 6.8 | SOURCE: NYC OMB, with DOHMH

ANNUAL $PM_{2.5}$ EMISSIONS FORECAST

Citywide $PM_{2.5}$ Forecast	(t$PM_{2.5}$)					
	2025	2030	2035	2040	2045	2050
Market Trends & Federal Policy	2,400	1,850	1,800	1,740	1,730	1,690
+ State Policies	-	(50)	(130)	(250)	(300)	(320)
+ City Actions	(100)	(240)	(280)	(280)	(270)	(240)
Forecast	**2,310**	**1,560**	**1,390**	**1,210**	**1,160**	**1,130**

FIGURE 6.9 | SOURCE: NYC OMB, with DOHMH

HEALTH IMPACTS OF FORECASTED $PM_{2.5}$ REDUCTIONS THROUGH 2050

Health Impact	Forecasted Events Avoided (Baseline + State + City Actions)	Potential Events Avoided (Net-Zero Target)
Premature Deaths	2,400	1,600
Emergency Department Visits for Asthma in Children	800	600
Emergency Department Visits for Asthma in Adults	1,400	1,000
Respiratory Hospital Admissions	400	200
Cardiovascular Hospital Admissions	200	200

FIGURE 6.10 | SOURCE: NYC OMB, with DOHMH

IMPACT OF $PM_{2.5}$ REDUCTIONS ON ASTHMA EMERGENCY DEPARTMENT VISITS, BY NTA

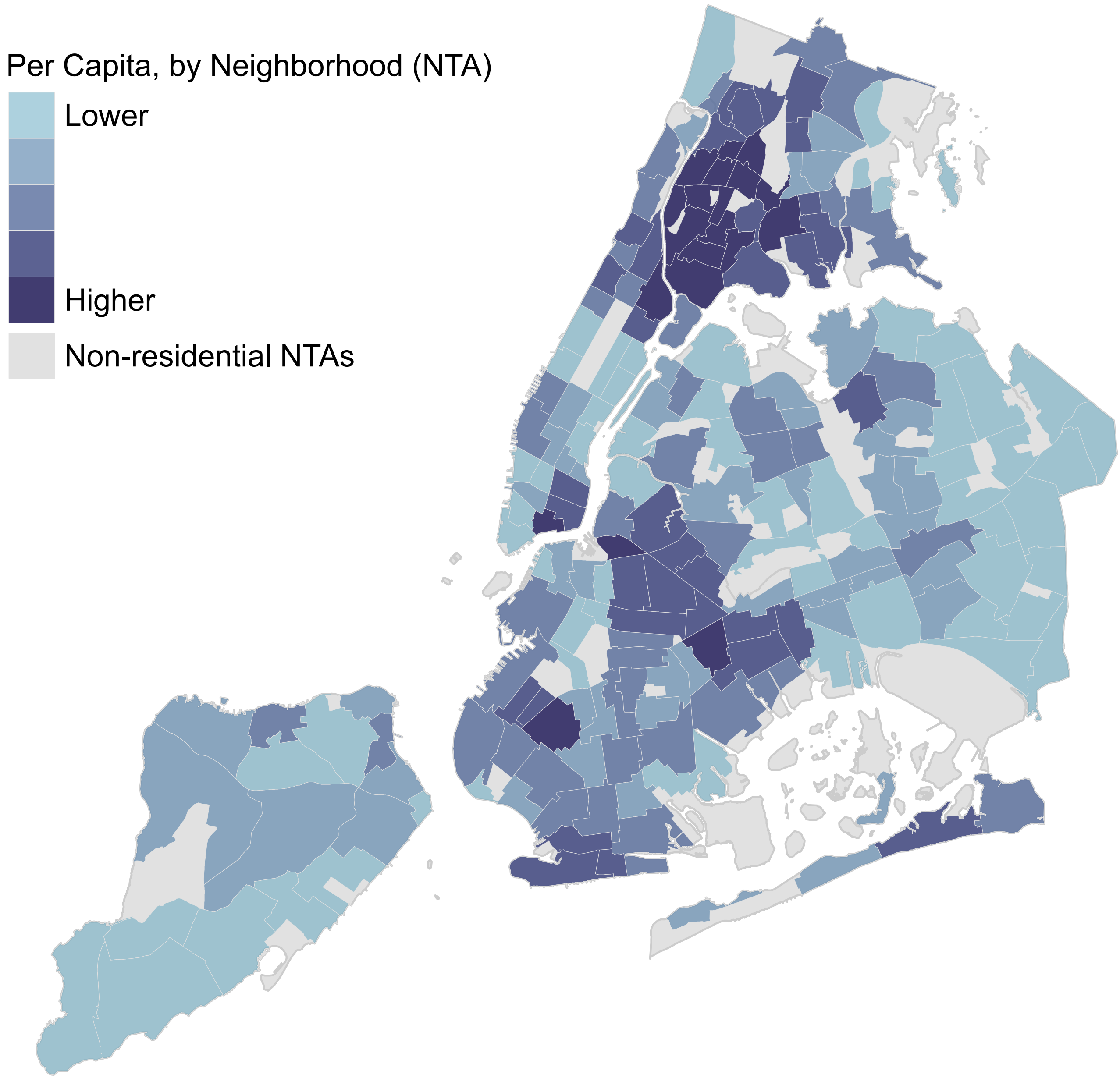


FIGURE 6.11 | SOURCE: NYC OMB, with DOHMH

IMPACT OF $PM_{2.5}$ REDUCTIONS ON RESPIRATORY & CARDIOVASCULAR HOSPITALIZATIONS, BY NTA

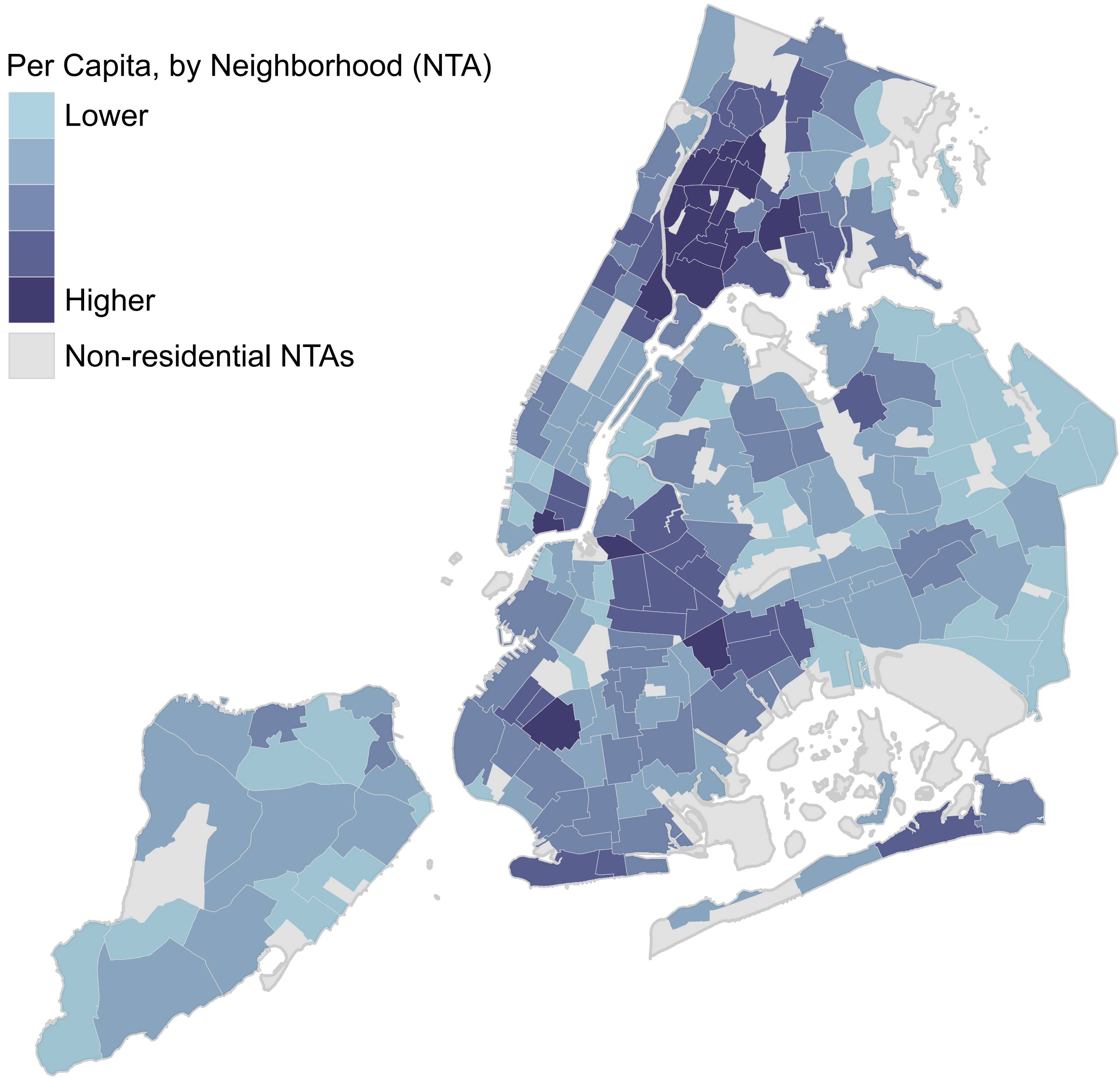
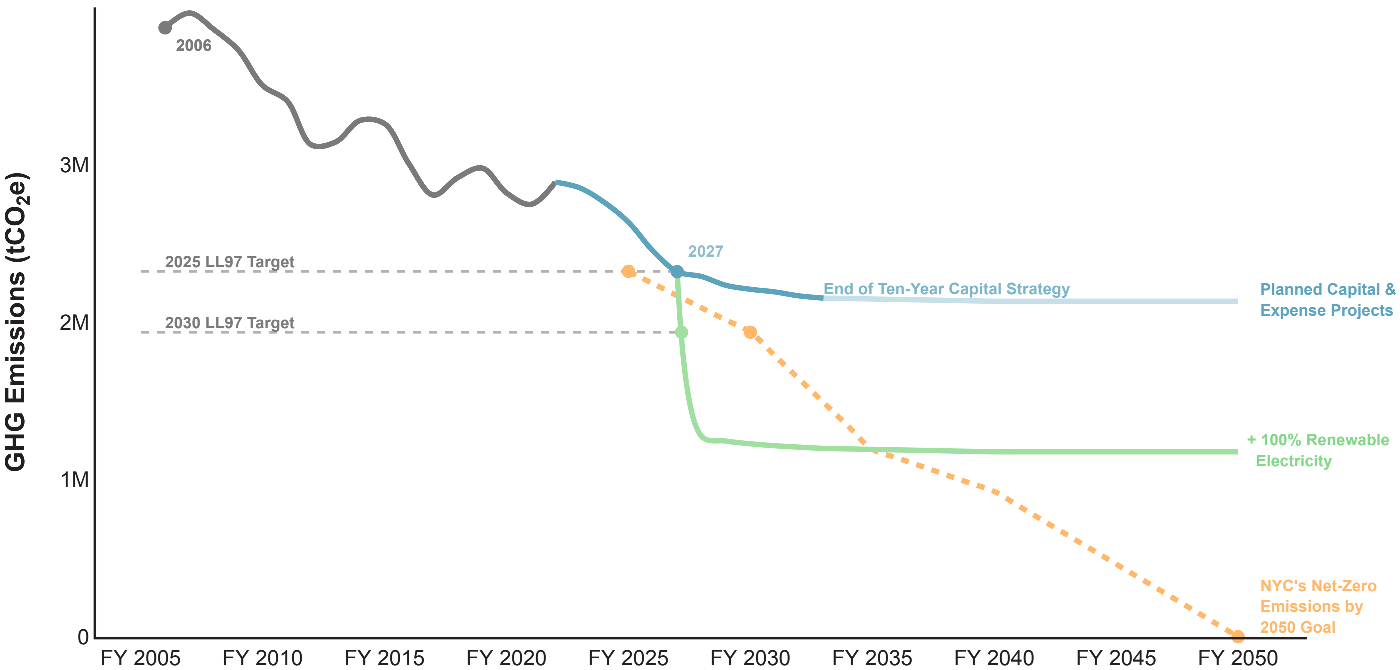


FIGURE 6.12 | SOURCE: NYC OMB, with DOHMH

6.b. CITY GOVERNMENT OPERATIONS GHG EMISSIONS FORECAST RESULTS

This section provides the results of the City Government Operations GHG Emissions Forecast in tabular form. Similar to in previous tables, these emissions are presented in tCO_2e using the GPC accounting protocol. Figure 6.13 shows the total emissions as a result of planned capital and expense projects, and the impact of the purchase of renewable energy certificates (RECs) from large-scale renewable (LSR) projects. Figure 6.14 breaks down the total GHG emissions reduction by sector, Figure 6.15 breaks down these reductions by agency, and Figure 6.16 breaks down these reductions by source.

CITY GOVERNMENT OPERATIONS EMISSIONS FORECAST



City Government Operations GHG Forecast	(tCO_2e)					
	2025	2030	2035	2040	2045	2050
Planned Capital and Expense Projects	2,600,000	2,200,000	2,100,000	2,100,000	2,100,000	2,100,000
+ 100% Renewable Electricity	—	(990,000)	(960,000)	(960,000)	(960,000)	(960,000)
Forecasted Emissions	**2,600,000**	**1,210,000**	**1,140,000**	**1,140,000**	**1,140,000**	**1,140,000**
Gap from Interim Science-Based Target	300,000	(690,000)	(60,000)	220,000	680,000	1,140,000
Interim Science-Based Emissions Target	**2,300,000**	**1,900,000**	**1,200,000**	**920,000**	**460,000**	

FIGURE 6.13 | SOURCE: NYC OMB, with DCAS

NET GHG REDUCTIONS BY SECTOR

Sector	(tCO$_2$e)					
	2025	2030	2035	2040	2045	2050
Buildings	(150,000)	(1,100,000)	(1,100,000)	(1,100,000)	(1,100,000)	(1,100,000)
Wastewater Treatment	(16,000)	(230,000)	(230,000)	(230,000)	(230,000)	(230,000)
Transportation	(13,000)	(170,000)	(190,000)	(200,000)	(220,000)	(230,000)
Waste	(74,000)	(89,000)	(89,000)	(89,000)	(89,000)	(89,000)
Other*	(2,000)	(81,000)	(81,000)	(81,000)	(81,000)	(81,000)

** Includes Water Supply, Fugitive and Process Emissions, and Streetlights and Traffic Signals*

FIGURE 6.14 | SOURCE: NYC OMB, with DCAS

NET GHG REDUCTIONS BY AGENCY

Agency	(tCO$_2$e)					
	2025	2030	2035	2040	2045	2050
DOE	(40,000)	(370,000)	(380,000)	(380,000)	(380,000)	(380,000)
DEP	(18,000)	(260,000)	(260,000)	(260,000)	(260,000)	(260,000)
DCAS Fleet	(13,000)	(170,000)	(190,000)	(200,000)	(220,000)	(230,000)
H + H	(3,000)	(130,000)	(130,000)	(130,000)	(130,000)	(130,000)
Other*	(170,000)	(730,000)	(740,000)	(740,000)	(740,000)	(740,000)

**Includes BPL, DCAS, DHS, DOC, DOHMH, DOT, Parks, DSNY, NYCEDC, FDNY, HRA, NYPD, NYPL, QPL, CIG, CUNY, and other city-owned assets.*

FIGURE 6.15 | SOURCE: NYC OMB, with DCAS

NET GHG REDUCTIONS BY SOURCE

Source	(tCO$_2$e)					
	2025	2030	2035	2040	2045	2050
Electricity	(97,000)	(1,300,000)	(1,300,000)	(1,300,000)	(1,300,000)	(1,300,000)
Fuel Oil	(71,000)	(110,000)	(120,000)	(120,000)	(120,000)	(120,000)
Natural Gas	22,000	(15,000)	(23,000)	(23,000)	(23,000)	(23,000)
Steam	(7,000)	(15,000)	(17,000)	(17,000)	(17,000)	(17,000)
Gasoline	(9,000)	(24,000)	(39,000)	(55,000)	(55,000)	(55,000)
Diesel	(4,000)	(150,000)	(150,000)	(150,000)	(150,000)	(150,000)
CH_4	(78,000)	(93,000)	(93,000)	(93,000)	(93,000)	(93,000)

FIGURE 6.16 | SOURCE: NYC OMB, with DCAS

6.c. OMB CORE MODEL: GHG AND AIR QUALITY FORECASTING

The Core Model is a python program that generates the New York City citywide emissions and associated air quality forecasts. The model integrates projections from 17 models (13 city actions models, two state action models, the City Government Operations GHG Emissions Forecast, and COMET-NYC), performs unit conversions for consistency, computes GHG emissions, particulate matter emissions, and associated health benefits, and outputs visualizations and summary tables.

The model uses the following external inputs:

- Historical emissions and activity data from the New York City 2022 GHG Inventory, developed by MOCEJ. These data are used to calibrate projections[18].
- Median-percentile global GHG emissions reduction targets to limit warming to 1.5°C with no or limited overshoot based on the Intergovernmental Panel on Climate Change's (IPCC) Sixth Assessment Report Synthesis Report[19]. These data are used to calculate science-based target emissions.
- Activity data for three baseline scenarios, developed by the U.S. EPA with COMET-NYC. These scenarios and COMET-NYC are described in Section 6.g.[16]
- Forecasted reductions in activity from city and state actions, either as an absolute or percent reduction, developed by OMB. These analyses are described in Section 6.d and 6.e.
- Forecasted reductions in emissions by city government, developed by DCAS DEM and OMB. These analyses are described in Section 6.f.
- Emissions factors for tCO_2e/kWh, tCH_4/kWh, tN_2O/kWh, $tPM_{2.5}$/kWh, $tPM_{2.5}/kg_{steam}$, $tPM_{2.5}/gal_{marine\ diesel}$ developed by the U.S. EPA with COMET-NYC.
    - Note that tCO_2e refers to metric tons of carbon dioxide equivalent, tCH_4 refers to metric tons of methane, tN_2O refers to metric tons of nitrous oxide, $tPM_{2.5}$ refers to metric tons of particulate matter of 2.5 micrometers in diameter. kWh refers to kilowatt hours, kg refers to kilograms, and gal refers to gallons.
- Emissions factors for tCO_2e, tCH_4, tN_2O, and $tPM_{2.5}$ from mobile sources, from the EPA's Motor Vehicle Emission Simulator (MOVES) model. MOVES creates emissions factors for on-road motor vehicles and gathers estimates of emissions from cars and trucks under a wide range of user-defined conditions (e.g., vehicle types, time periods, geographical areas, pollutants, and vehicle operating characteristics)[20].
- Emissions factors for $tPM_{2.5}$ from stationary sources, annual events avoided per ton, and distribution of health impacts to poverty groups, from the NYC Health Department[21].
- Emissions factor for $tPM_{2.5}$ from commuter rail from the National Emissions Inventory, developed by U.S. EPA[22].
- Population by Neighborhood Tabulation Area (NTA), from the 2020 U.S. Census developed by New York City Department of City Planning (DCP). These data are used to calculate geographic distribution of $PM_{2.5}$ emissions and health benefits[23].
- GeoJSON file with 2020 NTA boundaries, from DCP. This file is used to generate choropleth of $PM_{2.5}$ emissions and health benefits[24].

- The NYC Health Department Director of Air Quality and team have expressed full confidence in their methods and our application of them.
  - The methods are peer reviewed and were published in Environmental Science & Technology journal in 2020[25].
  - The methods are the same that were adopted for use by both National Grid and Con Edison in their Pathways to Carbon Neutral NYC report published in 2021.
  - To develop the methodology, the NYC Health Department:
    - Estimated $PM_{2.5}$, NO_x, SO_2, and CO emissions using building-level fuel type and energy use data reported under NYC Benchmarking Laws.
    - Adjusted emissions factors based on New York City and State regulatory sulfur limits. Applied air quality modeling using the U.S. EPA's Community Multiscale Air Quality (CMAQ) model across three nested grids centered over New York City.
    - Used meteorological inputs and emissions inventories for various base and future scenarios to predict $PM_{2.5}$ concentrations.
    - Used outputs from CMAQ modeling to estimate changes in $PM_{2.5}$ concentrations and health impacts. Used health benefit analysis tools, including U.S. EPA's BenMAP to estimate the reduction in adverse health outcomes, such as premature deaths and respiratory hospitalizations.
    - Analyzed the distribution of emissions reductions and health benefits across NYC neighborhoods and over time.
    - Analyzed variations in benefits by socioeconomic status, focusing on areas with different poverty levels.

The model takes the following assumptions:

- Outputs from COMET-NYC are provided in five-year increments. Data are linearly interpolated to fill in between years.
- There are some vehicle types that COMET-NYC does not separate. The following splits are applied to activity outputs, based on historical trends in the city's GHG inventory.
  - 7.2 percent of heavy-duty trucks are assumed to be solid-waste collection vehicles.
  - 22 percent of transit buses are assumed to be school buses.
    - An exception is compressed natural gas (CNG) transit buses, in which 0 percent are assumed to be school buses.
- Efficiency trends from MOVES are applied to project the emissions factors for vehicles. However, emissions factors for some vehicle types are not specified by MOVES. The following assumptions are applied to emissions factors.
  - 80 percent of the gasoline-vehicle GHG emissions factor is applied to the gasoline hybrid vehicles. For $PM_{2.5}$, 100 percent of the gasoline-vehicle emissions factor is applied.
  - 80 percent of the diesel-vehicle GHG emissions factor is applied to the diesel hybrid vehicles in the case of all emissions factors. For $PM_{2.5}$ emissions, 100 percent of the diesel-vehicle emissions factor is applied.
  - The CNG transit-bus emissions factor is applied to CNG heavy-duty trucks.
- MOVES provides different emissions factors for light-duty vehicles and pickups. A 75/25 percent split between their respective emissions factors is assumed.
- Emissions factors for the electricity grid for a projected year (tCO_2e/kWh) are applied to EVs and are multiplied by a vehicle's projected efficiency (kWh/vehicle mile traveled) for the corresponding year, unique to each vehicle type. This rectifies unit mismatches, giving tCO_2e/vehicle mile traveled.

- The $PM_{2.5}$ emissions factor for biofuel in buildings is assumed to be the same as fuel oil #2, and for biofuel in transportation is assumed to be the same as road diesel.
- The IPCC-aligned target takes the following reductions from 2005 GHG emission levels: 52 percent reduction by 2030, 66 percent reduction by 2035, 74 percent reduction by 2040, and 100 percent reduction by 2050[18,19].This target is determined by using the IPCC's median-percentile global reductions required to stay within 1.5°C[19]. These reductions are applied to New York City's 2005 emissions levels to produce the IPCC-aligned target line.

Note the following key variables and definitions:

- **Activity (indexed by *i*).** An activity is a type of emissions-producing activity within New York City, such as miles traveled by vehicles with internal combustion engines. Each activity has an associated GHG emissions factor and $PM_{2.5}$ emissions factor within each year. Emissions factors may change over time because of technological change, regulatory requirements, or modernization of the electric grid.
- **Baseline scenario (indexed by *b*):** Baseline scenarios are modeled in COMET-NYC. Each includes different sets of policy assumptions that influence the adoption of energy technologies. These scenarios and COMET-NYC are described in Section 6.g.
- **City action (indexed by *j*):** City actions are additional actions committed to by New York City that are expected to reduce emissions. These actions are described in Section 6.d.
- **State action (indexed by *s*):** State actions are additional actions enacted by New York State that are expected to reduce emissions in New York City. These actions are described in Section 6.e.
- **Years (indexed by *t*):** The model forecasts emissions from 2023 through 2050.

Note the following exclusions and limitations:

- This model does not capture the varying growth rates for solid waste collection vehicles, as it assumes a constant ratio of usage between this class and heavy-duty trucks.
- This model does not capture the varying growth rates for school buses, as it assumes a constant ratio of usage between this class and transit buses.
- All results of health impact calculations are rounded to account for uncertainties in the analysis.
- Reductions in $PM_{2.5}$ emissions have multiple positive health impacts, but for this analysis, only avoided premature deaths, emergency department visits, and hospital admissions are considered.
- Calculated health benefits are likely underestimated, as impacts due to increased physical activity or reduced noise exposure, both of which are co-benefits of transportation mode shifts, are not considered in this analysis. Similarly, impacts due to improved indoor environmental quality, a co-benefit of building efficiency upgrades, are not considered in this analysis.

Given the inputs and assumptions, the following steps are applied in python to generate the forecast:

1. <u>Calculate science-based GHG emissions targets.</u> Using the historical GHG Inventory and the IPCC targets, the science-based emissions-reductions targets are applied[19]. Targets are based on a 2005 baseline, so the 2005 historical emissions value is used as a starting point. They are set for the years 2030, 2035, 2040, and 2050. Targets for in-between years are linearly interpolated.

$$tCO_2e_{2030\_target} = tCO_2e_{2005} \times (1 - 52\%) = 31.0\ million\ tCO_2e$$
$$tCO_2e_{2035\_target} = tCO_2e_{2005} \times (1 - 66\%) = 21.9\ million\ tCO_2e$$
$$tCO_2e_{2040\_target} = tCO_2e_{2005} \times (1 - 74\%) = 16.8\ million\ tCO_2e$$
$$tCO_2e_{2050\_target} = tCO_2e_{2005} \times (1 - 100\%) = 0\ million\ tCO_2e$$

2. Calculate activity reductions from state actions. The impact of the two state actions, congestion pricing and Metropolitan Transportation Authority (MTA) bus electrification, are calculated[26,27]. They both are only applied to the third baseline scenario (Additional State Policies).

$$activity\_change_{ist} = \%\_change_{ist} \times activity_{baseline_{ibt}}$$

3. Calculate activity reductions from city actions. Calculate the activity reductions from each city action and adjust for possible interactions with the baseline scenario.
   a. Three city action models report changes in activity as a percentage of baseline activity (Bus Lanes, Bike Lanes, and School Bus Electrification)[28-30]. The reported percent change is multiplied by the baseline activity to give an absolute change in activity. The remainder of city action models report results as absolute change in activity.

$$activity\_change_{ijbt} = \begin{cases} \%\_change_{ijbt} \times activity_{baseline_{ibt}} & (if\ percent) \\ activity\_change_{ijbt} & (if\ absolute) \end{cases}$$

   b. One city action model, the Fuel Oil Phase-Out Mandates city action, applies to all fuel oil remaining in the baseline scenario after all other city actions are applied. The activity level must be calculated separately and last. Further documentation is in the City Actions Section 6.d.
   c. Additionally, some city actions could bring activity data below zero (e.g., reducing miles traveled by gas-powered passenger cars even though there are no more of that vehicle type on the road). To account for this, for each activity it is checked if the total impact of city actions would result in a negative activity in this baseline scenario. If so, the activity impact of each city action is scaled by a constant factor so that the activity level is zero after applying all city actions and the relative proportions of city actions remain the same.

$$adjusted\_activity\_change_{ijbt} = \begin{cases} activity\_change_{ijbt} \times \frac{activity_{baseline_{ibt}}}{\sum_j activity\_change_{ijbt}} & \left(if\ \sum_j activity\_change_{ijbt} > activity_{baseline_{ibt}}\right) \\ activity\_change_{ijbt} & (if\ otherwise) \end{cases}$$

4. Calculate GHG emissions.
   a. Given a selected baseline scenario, calculate the GHG emissions from activity data. Scenario outputs are in terms of activity, which are translated into tCO_2e using the COMET-NYC and MOVES emissions factors.

$$tCO_2e_{baseline_{bt}} = \sum_i activity_{baseline_{ibt}} \times GHG\_emission\_factor_{it}$$

   b. Given a selected baseline scenario and city action, calculate the GHG emissions change from the given city action. These impacts are translated into tCO_2e using the COMET-NYC and MOVES emissions factors.

$$\Delta tCO_2e_{ijbt} = activity_{ijbt} \times GHG\_emission\_factor_{it}$$

   c. Given a selected baseline scenario and city action, calculate the cumulative emissions impact from city actions.

$$\Delta tCO_2e_{bt} = \sum_i \sum_j \Delta tCO_2e_{ijbt}$$

d. Given a selected baseline scenario, calculate the annual GHG emissions forecast after all city actions are applied.

$$tCO_2e_{bt} = tCO_2e_{baseline_{bt}} - \Delta tCO_2e_{bt}$$

5. Calculate PM emissions.

a. Given a selected baseline scenario, calculate the $PM_{2.5}$ emissions from activity data. Scenario outputs are in terms of activity, which are translated into $tPM_{2.5}$ using the COMET-NYC, MOVES, and NYC Health Department emissions factors.

$$tPM_{2.5;\ baseline_{bt}} = \sum_i activity_{baseline_{ibt}} \times PM\_emission\_factor_{it}$$

b. Given a selected baseline scenario and city action, calculate the $PM_{2.5}$ emissions change from the given city action. These impacts are translated into $tPM_{2.5}$ using the COMET-NYC, MOVES, and NYC Health Department emissions factors.

$$\Delta tPM_{2.5;\ ijbt} = activity_{ijbt} \times PM\_emission\_factor_{it}$$

c. Given a selected baseline scenario and city action, calculate the cumulative emissions impact from city actions.

$$\Delta tPM_{2.5;\ bt} = \sum_i \sum_j \Delta tPM_{2.5;\ ijbt}$$

d. Given a selected baseline scenario, calculate the annual $PM_{2.5}$ emissions forecast after all city actions are applied.

$$tPM_{2.5;\ bt} = tPM_{2.5;\ baseline_{bt}} - \Delta tPM_{2.5;\ bt}$$

e. Health benefits, or negative health events avoided, due to air quality improvements are calculated using factors provided by the NYC Health Department.

$$events\_avoided_{kbt} = tPM_{2.5;\ bt} \times EA_k$$

where EA is the factor for events avoided per ton of $PM_{2.5}$ avoided, k indexes unique health metrics, and t indexes years. To apply the events avoided to different poverty groups,

$$events\_avoided_{gkbt} = events\_avoided_{kbt} \times dist_{gk}$$

where $dist$ is the percentage of events avoided to be applied to each poverty group, g indexes poverty group (numeric, 0-4), k indexes unique health metrics, and t indexes years.

f. To estimate per capita health impacts from $PM_{2.5}$ reductions across New York City's NTAs, citywide avoided health events are distributed to each NTA based on its population and poverty level. A weighted distribution formula is used to adjust for higher baseline health incidence rates in higher poverty areas. The number of avoided health events for each NTA is calculated by multiplying the citywide benefits by the proportion of the NTA population relative to the total city population and adjusting for poverty using a scaling factor. These results are then divided by the NTA population to derive per capita health benefits.

To find the per capita health benefits B in NTA n with population P:

$$B_i = \left(\frac{events\_avoided_{gkbt}}{P_i} \right)$$

DISTRIBUTION OF HEALTH IMPACTS FROM $PM_{2.5}$, BY PERCENTAGE OF HOUSEHOLDS BELOW FEDERAL POVERTY LEVEL

Health Impact	Very High Poverty (>30%)*	High Poverty (20–30%)*	Medium Poverty (10–20%)*	Low Poverty (<10%)*	No Poverty (0%)*
Premature Deaths	20%	26%	36%	17%	0%
Emergency Department Visits for Asthma in Children	48%	27%	22%	3%	0%
Emergency Department Visits for Asthma in Adults	43%	28%	25%	5%	0%
Respiratory Hospital Admissions	30%	27%	31%	13%	0%
Cardiovascular Hospital Admissions	23%	28%	35%	14%	0%

**Percent of households living below federal poverty level in neighborhood*

FIGURE 6.17 | SOURCE: OMB, with DOHMH

Discussion

The Core Model is a good tool to bring disparate data together and aggregate them. Goals for future development of the Core Model include:

1. Progress Tracking. Considering that this is the initial year of forecasting, there is a limited baseline for comparison. Moving forward, the model will undergo calibration against current conditions, facilitating accurate tracking of the city's progress towards its environmental goals.
2. City Operations Forecast Integration. The model currently takes the output of the City Government Operations Emissions Forecast as an input. DCAS DEM and OMB are collaborating to create a robust forecasting methodology for inclusion in the Core Model.
3. Air Quality Modeling. OMB is developing a methodology to provide more spatial detail on GHG and $PM_{2.5}$ emissions, with the goal of understanding where health impacts occur. Additionally, the first phase of mapping was performed externally in ArcGIS. In future iterations, this will be included within the Core Model itself.
4. Dashboard App Hosting. The Core Model also outputs a dashboard that is hosted locally on the computer running the program in python. Options to host the dashboard online to allow for public access will be explored. The app allows for further filtering and customization:
   - **GHG Emissions Calculation Methodology (select one):** GPC, Climate Leadership and Community Protection Act (CLCPA)
   - **Baseline Scenario (select one):** Market Trends & Federal Policy, + Planned Large-Scale Renewables, + Additional State Commitments
   - **City Actions Percent Included (set percent achieved, including over 100 percent):** Building Emissions Limits, For-Hire-Vehicle Electrification, City Government Operations, NYCHA Clean Heat for All Challenge, Efficient & Electric New Builds, Fuel Oil Phase-Out Mandates, Electric Vehicle Vision, Bus Lanes, HPD Sustainability Design Guidelines, Bike Lanes, Mandatory Citywide Curbside Organics Collection, School Bus Electrification, NYCHA Solar Installations, NYCHA Permanent Affordability Commitment Together Program
5. City Actions Tab. There is a placeholder in the app for a city actions tab, in which a deep dive into the impact of each of the city actions could be explored (in a similar manner to the city actions section of this appendix). Further development will be required to implement.

6.d. CITY ACTIONS

Policies and commitments made by the city are among the main drivers of forecasted GHG emissions reductions. OMB identified and modeled the impact of 13 of these city actions, which impact the three primary categories of emissions defined in the city's annual GHG Inventory: Stationary Energy (Buildings), Transportation, and Waste.

Three criteria were used to determine which city actions should be modeled and included in the citywide forecast:

1. GHG Impact: Impacts the scope of GHG emissions tracked in the city's GHG Inventory.
2. Commitment: Required by local legislation OR committed to by the current or a previous mayor.
3. Responsibility: Will be carried out by mayor-appointed leadership OR funded in the city's budget or capital plan.

RELATIVE GHG EMISSIONS REDUCTIONS FROM CITY ACTIONS

City Action	2030	2050	Description
BUILDINGS			
Building Emissions Limits (LL97-2019)	59.0%	59.7%	Places emissions caps on buildings over 25,000 square feet beginning in 2024, with caps tightening to net-zero by 2050.
NYCHA Clean Heat for All Challenge	4.2%	8.5%	Targets the installation of window heat pumps in 50,000 NYCHA units over 10 years beginning in 2022.
Efficient & Electric New Builds (LL32-2018, LL154-2021)	4.0%	3.9%	Limits the use of natural gas and fuel oil in new buildings beginning in 2024 and sets energy efficiency requirements.
Fuel Oil Phase-Out Mandates (LL43-2010, LL107-2013, LL119-2016, LL32-2023)	2.9%	1.8%	Bans the use of fuel oil #4 by 2027 and promotes biofuel mix.
HPD Sustainability Design Guidelines	0.8%	0.7%	Establishes design standards for HPD-financed properties to meet New York City's sustainability and resiliency goals.
NYCHA Solar Installations	0.1%	< 0.1%	Targets the installation of 30 megawatts of solar power on NYCHA campuses by 2026.
NYCHA Permanent Affordability Commitment Together (PACT) Program	< 0.1%	< 0.1%	Modernizes NYCHA developments while reducing energy use and emissions.
TRANSPORTATION			
For-Hire-Vehicle Electrification	12.5%	14.7%	Requires 100 percent of for-hire-vehicles be electric or wheelchair accessible vehicles by 2030.
Electric Vehicle Vision	1.6%	1.1%	Requires level 2 chargers in 20 percent of municipal parking spaces by 2025 and 40 percent by 2030.
Bus Lanes (DOT Streets Plan, LL195-2019)	1.5%	0.4%	Requires 150 miles of protected bus lanes by 2026.
Bike Lanes (DOT Streets Plan, LL195-2019)	0.7%	0.2%	Requires 250 miles of bike lanes by 2026.
School Bus Electrification (LL120-2021, EO53)	0.2%	0.6%	Requires 100 percent of the school bus fleet to be electric by 2035.
WASTE			
Mandatory Citywide Curbside Organics Collection (LL85-2023)	0.2%	0.2%	Mandates curbside residential organic waste collection citywide.

FIGURE 6.18 | SOURCE: NYC OMB[31-46]

OMB has developed methodology documentation for each of these city actions to provide transparency into this report's methods and to support other organizations aiming to develop similar forecasts. These methodologies are listed below. In order to estimate the impact of eligible city actions, OMB determined the level of compliance expected from each action. For city actions that are in control of the city, for instance mayoral commitments and actions funded in the city's budget, the current analysis assumes full implementation of these actions. Some examples include School Bus Electrification and Electric Vehicle Vision, where portions have been funded or are actively being carried out by city agencies. Alternatively, for city actions that depend on private actor compliance or participation, the current analysis does not assume full compliance. One example includes Mandatory Curbside Organics Collection, where the program will be available to all residents but not all residents will necessarily comply. Regardless, OMB acknowledges that full achievement of all city actions is not guaranteed, and depends on monitoring and support of those city actions.

6.d.i. BUILDINGS SECTOR

6.d.i.1. Building Emissions Limits (LL97-2019)

Criteria Screening

1. GHG Impact: 69,551,000 tCO_2e saved through 2050
2. Commitment: Required by local legislation
3. Responsibility: Funded in the city's budget or capital plan

Context

Local Law 97 of 2019 (LL97) imposes emissions limits for large buildings in New York City, with published emissions caps in 2024 and 2030. Emissions caps for the years 2035 and 2040 are an interpolation to zero tCO_2e in 2050[47]. Buildings whose emissions exceed these limits will pay penalties of $268 per tCO_2e above their emissions limit. For houses of worship or buildings with over 35 percent affordable housing units (i.e., the Article 321 pathway), less stringent requirements exist. Buildings in the Article 321 pathway may either reach the 2030 emissions target by the 2024 reporting year, or adopt a set of prescriptive energy conservation measures (PECMs)[48].

Buildings that do not fall under the Article 321 pathway are in the Article 320 pathway; within this pathway, some buildings with affordable housing units are granted either a two-year or 10-year extension before they are required to meet emissions reduction targets. For buildings where at least one unit is subject to rent regulation, but less than 35 percent of units are, they have until 2026 to meet the 2024 targets. For Mitchell-Lama buildings or buildings with no rent-regulated units but with at least one income-restricted unit, they are not required to meet the 2024 or 2030 emissions targets but are required to meet 2035 and subsequent targets.

Additional elements of the policy that are included in the model:

1. Good faith efforts: Buildings that are not in compliance with the 2024 emissions target can demonstrate good faith efforts and avoid paying penalties in 2024 and 2025, provided that they either reach their 2024 emissions target by 2026 and their 2030 emissions target by 2030, or that they prepare to electrify a substantial energy system in the building. Building owners that choose the good faith effort plan must hire professionals to audit their building energy use and help develop a compliance plan; OMB assumes that the cost of this audit will be five cents per square foot.
2. RECs: Buildings that are not in compliance can elect to purchase New York State Energy Research and Development Authority (NYSERDA) Tier IV RECs to offset emissions from building electricity use, up to the number of emissions above their limit. Note that Tier IV RECs are renewable energy certificates that fund the development of two large projects supplying renewable electricity to New York City—the Champlain-Hudson Power Express and Clean Path New York. These credits are only available starting in 2026 and are not available to buildings that have claimed a good faith effort[49].
3. Beneficial electrification credit: Buildings that electrify their energy systems (either space heating or hot water heating) in 2024-2035 may claim a beneficial electrification credit which reduces their emissions penalty by applying a negative coefficient to emissions from electricity use. This option is available regardless of whether building owners have claimed the RECs or good faith effort pathway.

Model Methodology

The Building Emissions Limits model generates a forecast through 2050 for GHG emissions reductions due to decarbonization of buildings greater than 25,000 square feet. The model is performed in python.

The model uses the following external inputs:

- Energy use and property type data among large buildings from the 2012-2022 Local Law 84 of 2019 (LL84) building energy benchmark datasets, from the New York City Open Data portal. These data are used to characterize existing buildings[50-60].
- Energy audit data for buildings over 50,000 square feet from the Local Law 87 of 2009 (LL87) 2019 dataset, from the New York City Open Data portal. These data are used to characterize energy consumption types and building energy technology[61].
- The Primary Land Use Tax Lot Output (PLUTO) dataset data, from the New York City Department of Finance are used to define property information such as building area, primary property classification, number of housing units, number of floors, and building age[17].
- The covered buildings list, from the New York City Department of Buildings (DOB), lists all buildings covered by LL97, and whether they are covered under the Article 320 pathway, the Article 321 pathway, or an Article 320 pathway with an extension[62].
- State-level fuel oil and natural gas rates from the U.S. Energy Information Administration (EIA), used to project costs and savings[63].
- Electricity tariff rates and steam tariff rates from Consolidated Edison, used to project costs and savings[64,65].
- ECM cost and efficacy data for multi-family buildings, from Cadence OneFive. These data are used to characterize residential building upgrades.
- The 2021 Carbon Trading for New York City's Building Sector study, developed with The Brattle Group, provides a list of ECMs for large commercial and residential buildings, with the estimated cost and emissions reduction from each. These data are used to characterize commercial building upgrades[66].
- The 2014 One City, Built to Last study, developed by the Mayor's Office of Long-Term Planning and Sustainability, contains an extensive list of ECMs, although the cost data behind these measures are outdated. These data are used to find the energy reductions from adopting PECMs, as specified for the Article 321 pathway[67].
- Building energy use intensity (EUI) trends for each fuel type, from COMET-NYC. COMET-NYC projects that residential building energy use by 2050 will decline because climate change reduces the need for heating, and buildings will replace heating, cooling, lighting, and other appliances with more efficient technologies. The trends in EUI are used to adjust the ECMs' energy reductions, so that reductions are proportional to the buildings' energy use after the energy efficiency improvements modeled in COMET-NYC[68].
- Incentive programs from various sources, outlined in Figure 6.19.

DESCRIPTION OF INCENTIVE PROGRAMS

Program Name	Incentivizing Agency	Applicability	Incentive Limit
Commercial and Industrial Energy Efficiency Program	Consolidated Edison	Commercial and Industrial	Lesser of $1M/project or 50% of project costs
Multifamily Clean Heat Program	Consolidated Edison	Multi-family	Lesser of $1M/project or 50% of project costs
Multifamily Energy Efficiency Program	Consolidated Edison	Multi-family	100% of project cost
Retrofit Electrification Pilot	HPD	HPD Portfolio ≤ seven stories	$1M
Multifamily Buildings Low-Carbon Pathways Program	NYSERDA	Multi-family	Lesser of $3M or 50% per market rate project OR 75% for low- or medium-income projects
179D Tax Deduction for Energy Efficient Buildings	Internal Revenue Service (IRS)	Commercial	Varies
Weatherization Assistance Program	New York State Homes and Community Renewal (HCR)	Multi-family (Low Income)	Varies
New York State Affordable Multifamily Energy Efficiency Program	NYSERDA	Multi-family	Lesser of $1M/project or 85% of project costs
Industrial & Commercial Abatement Program	New York City Department of Finance	Commercial and Industrial	Varies
Clean Heating Fuel Credit	New York State Taxation	Commercial/Residential	Varies
Clean Energy Initiative Program	HCR	Multi-family (Low Income)	$12.5M
Commercial and Industrial Clean Heat Program	Consolidated Edison	Commercial and Industrial	Lesser of $1M/project or 50% of project costs
Real-Time Energy Management (RTEM)	Consolidated Edison	Commercial and Industrial	50% of the total cost of the RTEM system

FIGURE 6.19 | SOURCE: NYC OMB

The model takes the following assumptions:

- Building owners are rational and will choose the least-cost option among paying fines, purchasing RECs (when eligible), and making upgrades to their buildings. They calculate the net present value of each option using a 15-year decision horizon with a 6.5 percent annual discount rate.
    - The cost includes the up-front cost of technology (minus any applicable incentives), the energy savings over the next 15 years, and the penalties from failing to meet current-period and future LL97 targets.
- Costs of energy, technologies, and decisions are modeled at the building level. There is no distinction between which measures are paid for by the owner versus tenants; it is assumed that decisions will minimize costs at the building level.
- All Article 321 pathway properties that are not currently in compliance with their 2030 emissions targets will adopt PECMs, rather than attempting to achieve the 2030 emissions target in the 2024 reporting year.

- Building owners will consider renovations in each period that they are above the building-specific emissions target from LL97, rather than waiting to align work with regularly scheduled building capital lifecycles. This assumes that the large penalties will be adequate incentive for buildings to refinance existing commitments, if necessary.
- All eligible incentives will be applied to reduce the cost of energy efficiency upgrades and electrification work.
- Incentive programs will remain in their currently published form through 2050, unless otherwise specified.
- Building owners, when making a decision in a given time period, do not consider how the decision impacts their choices in future time periods.
- Following a DOB brief, it is assumed that RECs will be available at a rate of $32.01 per megawatt hour (MWh) starting in 2026 and will be more expensive than paying LL97 penalties starting in 2030.
- Building owners are price takers; they do not anticipate that the price of RECs or energy commodities will change depending on their levels of consumption.

Note the following exclusions and limitations:

- This model only studies the impacts of LL97 on privately owned buildings. LL97 also imposes emissions limits on city-owned buildings, but these are accounted for in the City Government Operations Forecast Model.

Given the inputs and assumptions, the following steps are applied to generate the forecast:

1. Calculate building-level emissions caps. This is done using emissions caps by use type, for the square footage in each building with that use type, following the formula below. These emissions caps are provided for each use type in the US EPA's Energy Star Portfolio Manager tool.

$$bldg\_emissions\_limit_{year} = \sum_{use \in use\_types} emissions\_limit_{use,\ year} \times bldg\_square\_footage_{use}$$

   For buildings in the covered buildings list without energy benchmarking data, building energy use and primary property type are inferred by building a prediction model for these fields based on the building age, location, and tax classification data (from PLUTO) from buildings with the energy data and applying that prediction model to the remaining buildings.

2. Calculate energy use types and the cost and energy savings from ECMs. This is done by following the formulas of cost and energy savings for each ECM from the Carbon Trading Study.
   a. For some buildings, energy use data (e.g., the amount of natural gas consumed for space heating) and features that determine ECM suitability (e.g., window R value) are available. For others, these features are imputed using data on building use, age, location, size, and fuel types used.
   b. Energy savings from ECMs are calculated using formulas from the Carbon Trading Study (for ECMs in commercial buildings), from Cadence OneFive (for ECMs in residential buildings), and from the One City, Built to Last study (for PECMs). The energy savings from the Carbon Trading Study and Cadence OneFive are summarized in Figure 6.20.
   c. Cost savings are calculated by multiplying these energy savings by the average energy cost per thousand British thermal units (Btu).

DISTRIBUTION OF THE UP-FRONT COSTS OF INSTALLING ECMS

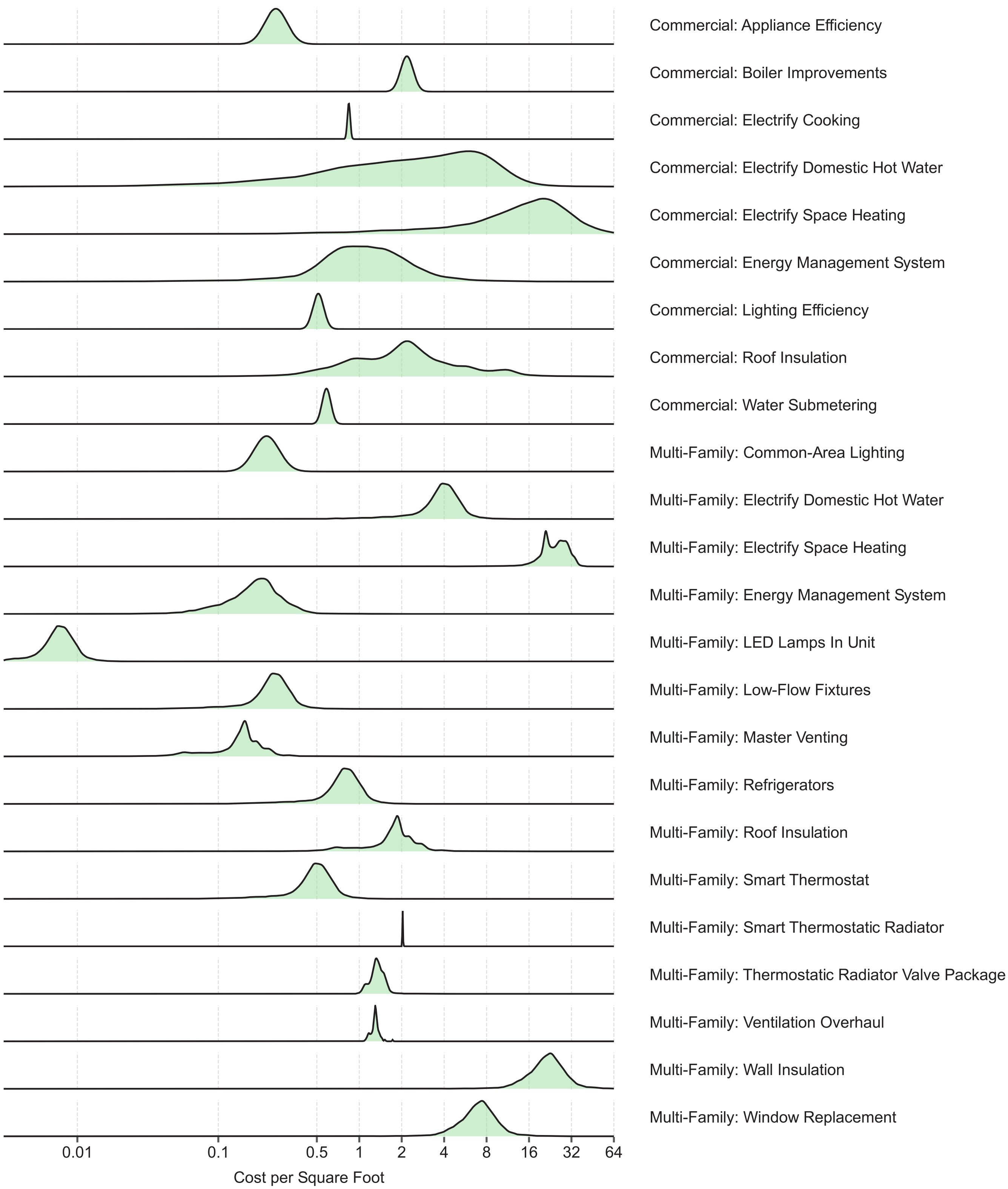


FIGURE 6.20 | SOURCE: NYC OMB, with Cadence OneFive and One City, Built to Last

3. Simulate each building's decisions through 2050.
   a. For buildings on the Article 321 pathway, this requires adopting PECMs if the building is above its 2030 emissions limits or doing nothing otherwise.
      i. Find the energy use reductions from PECMs. For each fuel type, multiply each building's energy use by the percent of energy use reduction from adopting all PECMs. This is the sum of energy reductions identified in the One City, Built to Last study, multiplied by the percentage of buildings where that PECM can be applied.
      ii. Adjust the energy use reduction by the EUI trend from COMET-NYC. The following formula describes how to calculate the adjusted reduction:

$$adjusted\_reduction_{fuel\_type,\ year} = reduction_{fuel\_type} \times \frac{building\_EUI_{fuel\_type,\ base\_year}}{building\_EUI_{fuel\_type,\ base\_year}}$$

   b. For Article 320 pathway properties, this involves the following steps:
      i. Calculate the cost of adopting ECMs, paying penalties for emissions exceeding emissions limits, or taking other measures (good faith efforts, RECs, or beneficial electrification credits).
      ii. Assume that each building adopts the bundle of ECMs that results in the lowest cost, after all penalties, incentives, and energy costs. To find the least-cost bundle of ECMs:
         1. A cost-optimizing building manager will consider adding ECMs in order from least cost per ton of emissions abated to greatest cost per ton of emissions abated.
         2. The least-cost bundle is the set of ECMs that has the lowest net present value of cost (up-front cost of ECMs in the bundle, less any incentives, less the discounted energy savings over the next 15 years, plus the discounted penalties over the next 15 years). A 6.5 percent discount rate is used throughout the analysis.
      iii. Proceed to the next time period (keeping track of which ECMs are adopted).
      iv. To avoid double counting energy use reductions from COMET-NYC, building energy use is adjusted to match the changing rates of energy use from existing buildings in COMET-NYC (in each fuel type).

CHANGE IN ENERGY USE FROM LOCAL LAW 97

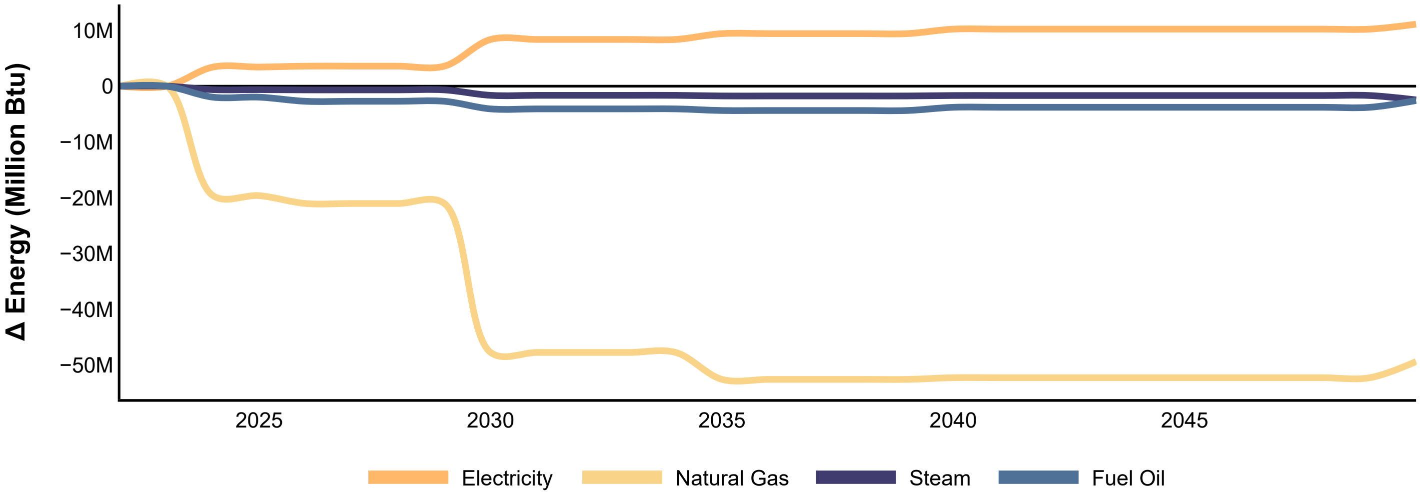


FIGURE 6.21 | SOURCE: NYC OMB

Discussion

While LL97 is not expected to eliminate fossil fuel use in large buildings, fossil fuel use declines dramatically over the duration of the law. This impact is more pronounced in buildings on the Article 320 pathway, which face mandates to reduce emissions rather than to implement sets of prescriptive ECMs.

Figure 6.22 shows the total emissions from all Article 320 pathway properties, in each compliance period. The emissions from electricity are calculated with the emissions factors used to generate the LL97 emissions caps rather than the COMET-NYC emissions factors, to ensure that emissions calculations are comparable between the emissions caps and building energy use. From left to right, each group of columns shows the emissions from covered buildings without any changes to energy use (and only changes to the emissions intensity of electricity), the changes to building energy use from baseline efficiency improvements modeled in the state-and-federal-policies COMET-NYC scenario, the additional improvements after building owners implement ECMs to avoid penalties, and the additional improvements enabled by state, federal, and city incentive programs.

On average, buildings are expected to meet the 2030, 2035, and 2040 targets through energy conservation measures. Incentive programs help enable deeper emissions reductions. Some emissions remain in 2050, due to continued use of fossil fuels for heating, cooking, and some industrial uses.

ARTICLE 320 PATHWAY PROPERTIES' EMISSIONS AND EMISSIONS LIMITS OVER TIME

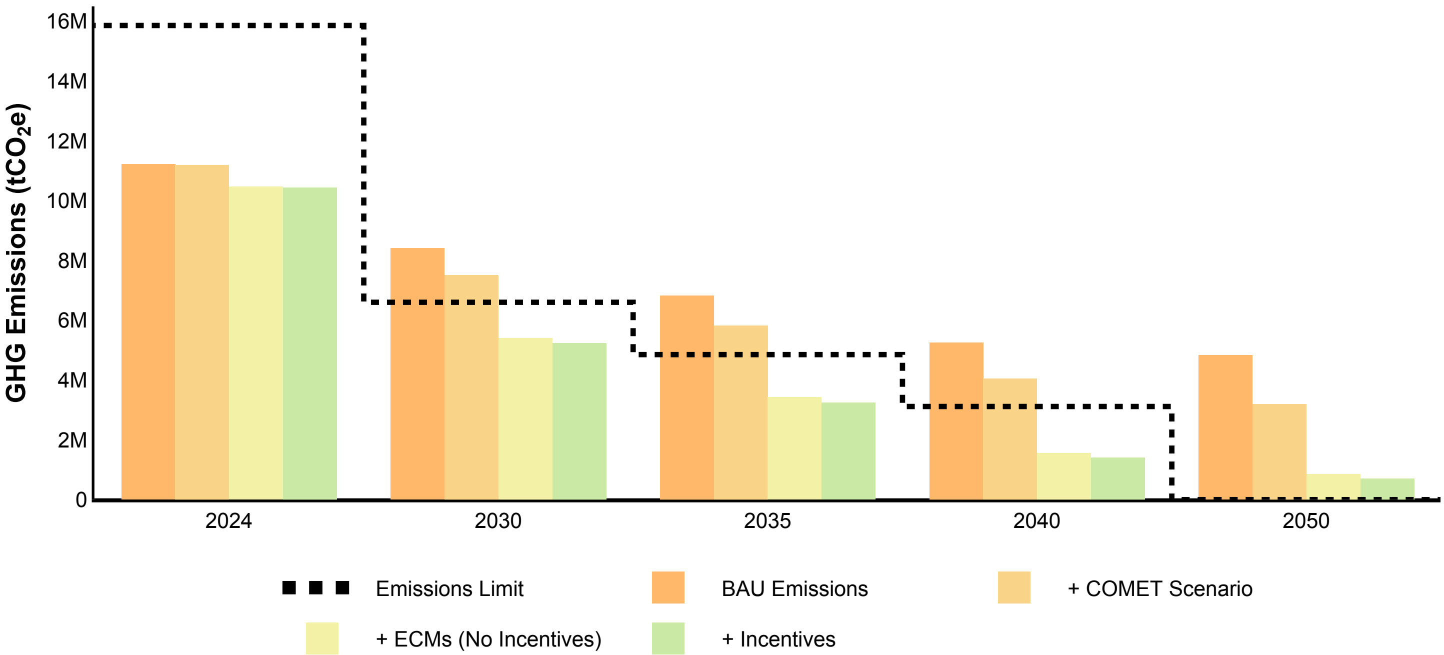


FIGURE 6.22 : SOURCE: NYC OMB

6.d.i.2. NYCHA Clean Heat for All Challenge

Criteria Screening

1. GHG Impact: 9,967,000 tCO_2e saved through 2050
2. Commitment: Install 30,000 window unit heat pumps in NYCHA facilities (~10,000 dwelling units), followed by additional heat pump installations until 50,000 dwelling units are equipped with window unit heat pumps
3. Responsibility: Will be carried out by mayor-appointed leadership

Context

In December 2021, NYCHA, New York Power Authority, and NYSERDA announced the Clean Heat for All Challenge, a $250 million effort to convert NYCHA residences to electric heating with window-unit heat pumps[69]. In August 2022, the city and state announced a $70 million, seven-year investment in window-unit heat pumps for NYCHA facilities, marking the first installments of the Clean Heat for All Challenge. The $70 million will pay for development and production of 30,000 window-unit heat pumps. NYCHA's longer-term goal is to install window-unit heat pumps in 50,000 dwelling units (DUs) over the 10 years after the announcement.

Model Methodology

The NYCHA Clean Heat for All Challenge model generates a forecast through 2050 for GHG emissions reductions by shifting heating from oil and gas to electricity due to the installation of electric heat pumps. The model is performed in Microsoft Excel.

The model uses the following external inputs:

- NYCHA campuses' energy consumption data by fuel type for 2019-2021, obtained from New York City Open Data portal[70].
- Information regarding the implementation and timeline of heat pump installations, information on site selection, and anticipated heat pump energy consumption was obtained from interviews with NYCHA staff.

The model takes the following assumptions:

- Baseline energy consumption (dwelling units without heat pump installations) is assumed to remain constant over time.
- Heat pump conversions will include conversion of space heating and Domestic Hot Water (DHW) heating systems to electric heat pumps.
- All baseline fuel oil consumption is assumed to be fuel oil #2.
- Based on the average number of rooms in NYCHA dwelling units, an average of 2.9 heat pumps are assumed to be installed in each NYCHA dwelling unit. This assumption was developed through correspondence with NYCHA staff, based on the assumption that one window unit will be installed in the living room and in each bedroom.
- The average annual energy consumption of heat pumps for space heating per 1,000-square-foot dwelling unit ($SH\ electricity$) is 10 million Btu, obtained from NYCHA.
    - The average NYCHA dwelling unit is 1,000 square-feet, obtained from NYCHA.
- Existing DHW systems are assumed to have 70 percent efficiency. This is based on the performance of low-efficiency, direct-fired water heaters, as provided by engineers at Cadence OneFive.

- Window heat pumps are assumed to have a Coefficient of Performance (COP) of 2.5. As this is a new technology, it is unclear how well these units will perform. A COP of 2.5 was selected based on the average COP of cold-climate heat pumps, from a 2017 study in New England homes[71].
- Per the Clean Heat for All press release Clean Heat for All Challenge press release and information obtained from NYCHA, heat pump installations are modeled as follows:
  - 30,000 heat pumps are assumed to be installed by the end of 2028 (~10,000 dwelling units). This is based on the press release referring to seven-year contracts covering the first 30,000 heat pump installations.
  - Per conversations with NYCHA, NYCHA plans to achieve a total of 50,000 dwelling units electrified by 2035. After the initial set of 30,000 heat pumps are installed by 2028, the remaining heat pump installations are assumed to occur at a constant rate of 6,638 dwelling units per year until a total of 50,000 dwelling units are converted by 2035.
  - Per conversations with NYCHA, heat pump conversions will take place in phases. A total of 10 NYCHA campuses have been selected for the first two phases. In the first phase, conversion of five campuses (totaling 7,500 units) will begin in 2024 and finish in 2027. For the second phase, five additional campuses (totaling 3,300 units) will begin in 2027 and complete in 2029. For each of the first two phases, the model calculations are based on the historical average energy consumption from the campuses identified for each phase. After phase two is complete, the model calculations are based on historical average energy consumption for all remaining campuses. Phases will be completed in sequence; however, the model assumes that heat pump installations will occur at a constant rate. Therefore, the model shows installations occurring for multiple phases in the same year when one phase ends and another begins.

Note the following exclusions and limitations:

- The initiative assumes a smooth rollout and maintenance of 30,000 window-unit heat pumps, which could be hindered by logistical, technical, or financial barriers. Issues such as delays in production, installation challenges in older buildings, and higher-than-anticipated maintenance costs are potential exclusions.
- Assumptions regarding the reduction in GHG emissions may not account for variability in resident usage patterns, which could affect the overall energy consumption and efficiency of heat pumps. Changes in behavior or preferences that lead to increased energy use could limit the effectiveness of this initiative.
- The initiative assumes that all NYCHA dwelling units are suitable candidates for the installation of window-unit heat pumps. However, structural limitations, building codes, or historical preservation constraints may exclude certain buildings or dwelling units from participation.
- The modeling assumes that, without this intervention, there will be no changes in the energy usage of NYCHA buildings. This is distinct from the assumptions in the COMET-NYC model, which projects that building owners will upgrade building energy systems periodically and that building energy use declines over time. Given that upgrades in NYCHA buildings are unlikely to occur without interventions such as this program, we adjust the building energy-use forecasts in COMET-NYC to avoid counting a reduction in energy use from these programs.

Given the inputs and assumptions, the following steps are applied to generate the forecast:

1. Combine datasets. NYCHA publishes building-by-building energy consumption data with a separate dataset for each fuel type. Data are compiled into a building-level GHG Inventory from the energy consumption data sets. All buildings that reported no electricity use in 2019-2021 were excluded.
2. Compute current average energy consumption per unit. NYCHA campuses are then divided into three groups representing the current understanding of the phases of heat pump conversions. The first two phases each include five NYCHA campuses, referred to as “First-Five Campuses” and “Second-Five Campuses” respectively; all other campuses are labeled as “Remaining Campuses,” The model reflects the impact of heat pump conversions occurring sequentially at the “First-Five Campuses”, then the “Second-Five Campuses,” and finally the “Remaining Campuses.” Given that heat pump installations are assumed to occur at constant rates, installations for multiple phases are modeled to occur in the same the same year. In 2027 the final “First-Five Campus” dwelling unit installations and the initial “Second-Five Campus” dwelling units installations will occur; in 2029 the final “Second-Five Campus” dwelling unit installations and the initial “Remaining Campus” dwelling unit installations will occur.
3. Compute increased electricity demand for DHW. The electricity demand for DHW is calculated individually for each of the three sets of campuses. First, the consumption dedicated to DHW is found by relating a percentage of heating fuel used for DHW to each campus’ average heating fuel consumption per dwelling unit, per fuel type. The model assumes that 28 percent of heating fuel consumption goes to DHW.

$$DHW\_consumption_{fuel\_type} = avg\_heating\_fuel\_consumption\_per\_DU_{fuel\_type} \times \%\_heating\_fuel\_for\_DHW$$

Then, for each set of campuses, the effective DHW output per DU is found by multiplying consumption for DHW by an assumed efficiency for the existing DHW system.

$$effective\_DHW\_output_{fuel\_type} = DHW\_consumption_{fuel\_type} \times DHW\_effective$$

Finally, the increased electricity consumption for DHW per DU is calculated for each set of campuses. To find the electricity consumption for DHW, the effective DHW output is divided by an assumed heat pump COP for each energy source. Consumption for each fuel type is then summed to achieve the total DHW electricity consumption for each set of campuses.

$$DHW\_electricity = \sum_{fuel\_type} \frac{effective\_DHW\_output_{fuel\_type}}{COP_{heat\_pump}}$$

4. Compute new average energy consumption per DU. After heat pump installation, DUs will no longer consume fossil fuels for heating. Some fossil fuel use will remain, because cooking is not electrified. Electricity consumption will increase as electric heat pumps replace fossil-fuel-powered heating and DHW. The per-dwelling-unit energy consumption after converting to a heat pump is projected as follows:

   a. Cooking gas per DU: No change; use average consumption for each set of campuses
   b. Electricity per DU:

   $$new\_electricity\_consumption = baseline\_electricity + DHW\_electricity + SH\_electricity$$

   c. Heating gas per DU: consumption drops to 0 million Btu
   d. Heating oil per DU: consumption drops to 0 million Btu
   e. Steam use per DU: consumption drops to 0 million Btu

WEIGHTED AVERAGE CONSUMPTION PER DWELLING UNIT, 2019-2021

Development Type	Number of Current DUs	*(million Btu per DU)*					
		Cooking Gas	Electricity	Heating Gas	Heating Oil	Steam	All Fuel
First-Five Campuses	7,539	4.0	25.4	147.8	41.2	-	**218.4**
Second-Five Campuses	3,334	5.3	35.8	95.3	0.1	-	**136.5**
Remaining Campuses	162,209	6.0	22.7	120.7	10.8	3.8	**164.1**
All Campuses	173,082	5.2	25.3	125.2	13.5	3.2	**172.4**

FIGURE 6.23 | SOURCE: NYC OMB, with NYCHA

5. Compute the reduction in energy consumption. First, for each year, baseline energy consumption values (DUs before heat pump installation) are found by multiplying the number of DUs by the baseline average consumption per DU for each fuel type and summing the consumption values for each fuel type.

$$baseline\_electricity\_consumption = \sum_{fuel\_type} \#\_of\_DUs \times baseline\_avg\_consumption\_per\_DU_{fuel\_type}$$

Then for each year, the electrification-scenario (DUs after heat pump installation) consumption value is found by multiplying the number of DUs with heat pump installations by the new (electrification scenario) average consumption per DU for each fuel type, and summing the consumption values for each fuel type.

$$electrification\_scenario\_electricity\_consumption = \\ \#\_of\_DUs_{heat\_pump} \times new\_avg\_consumption\_per\_DU_{electricity}$$

The modeled annual consumption is then found, for each year, by summing the consumption from DU without heat pump installations (baseline scenario) and consumption from DU with heat pump installations (electrification scenario). Note: overtime the total number of DU remains constant; as more dwelling units receive heat pump installations, few DUs are without heat pump installations.

$$modeled\_energy\_consumption_{fuel\_type} = \\ \#\_of\_DUs_{no\_heat\_pumps} \times baseline\_avg\_consumption\_per\_DU_{fuel\_type} + \\ \#\_of\_DUs_{heat\_pumps} \times avg\_consumption\_per\_DU_{heat\_pumps;\ fuel\_type}$$

Finally, the annual reduction in energy consumption is found by subtracting the modeled energy consumption from the baseline energy consumption for each year.

$$\Delta energy\_consumption = baseline\_energy\_consumption - modeled\_energy\_consumption$$

Discussion

By electrifying heating in 50,000 dwelling units, the NYCHA Clean Heat for All Challenge is expected to result in large decreases in fossil fuel use. This will be accompanied by an increase in electricity, although the magnitude of energy required will be significantly less because the heat pump heating systems are more efficient than current fossil fuel heating systems.

CHANGE IN ENERGY USE FROM NYCHA CLEAN HEAT FOR ALL CHALLENGE

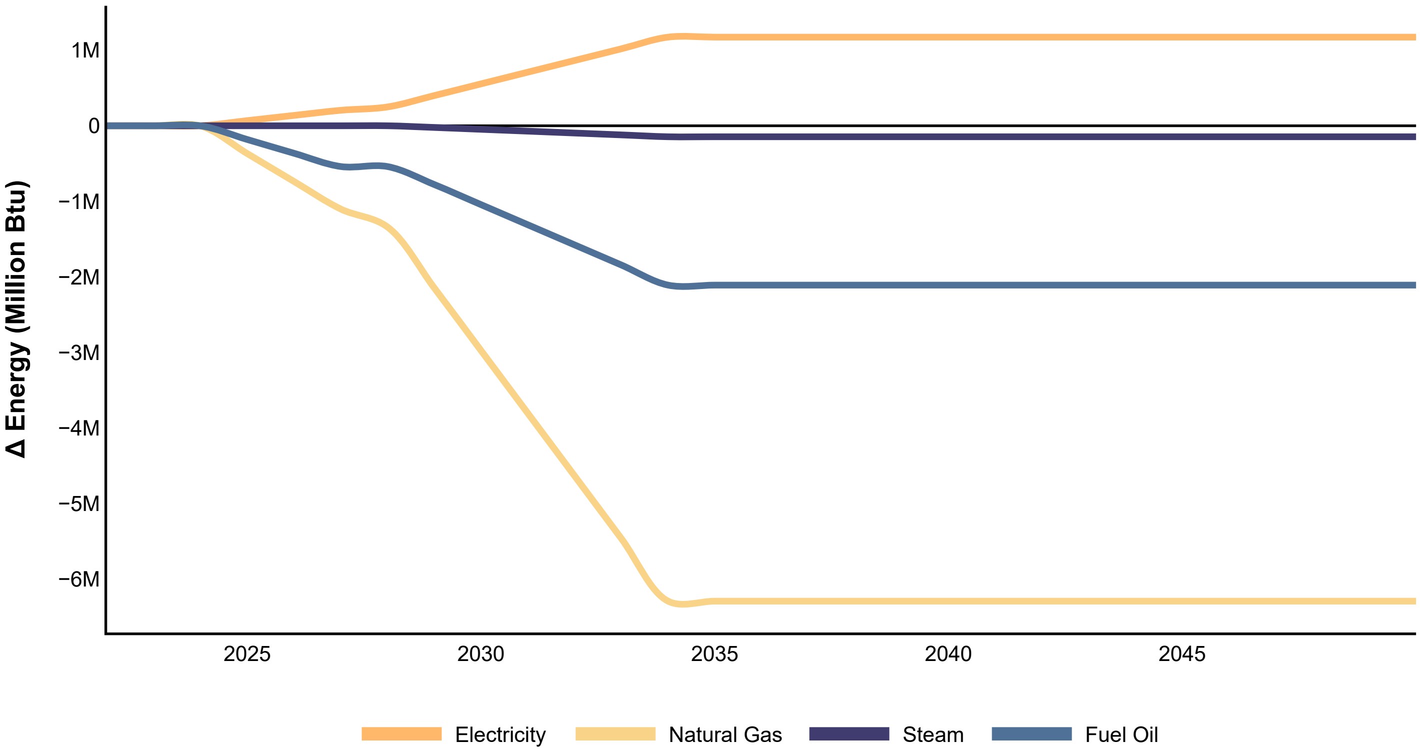


FIGURE 6.24 | SOURCE: NYC OMB, with NYCHA

6.d.i.3. Efficient & Electric New Builds (LL32-2018, LL154-2021)

Criteria Screening

1. GHG Impact: 4,544,000 tCO_2e saved through 2050
2. Commitment: Required by local legislation
3. Responsibility: Will be carried out by mayor-appointed leadership

Context

Two local laws establish guidelines for energy use in newly constructed buildings or buildings with substantial renovations. Note that buildings undergoing substantial renovations are those in which more than 50 percent of a building subsystem is replaced within 12 months; these projects are identified in DOB's dataset as “Alt-CO New Building with Existing Elements to Remain.”

Local Law 32 of 2018 (LL32) updates the New York City Energy Conservation Code (ECC), which defines minimum energy efficiency standards for technologies in new buildings[72]. New York State also has an energy code for buildings, although the ECC has stricter standards for energy efficiency. New York State also developed a Stretch energy code (NYStretch) which municipalities have the option to adopt[73]. The average energy use of buildings following the NYStretch energy code is expected to form the basis for the performance-based energy targets in LL32. Beginning in 2025, the predicted energy use of buildings designed and constructed in compliance with this code is, on average, expected to be no greater than 80 percent of the predicted energy use of such buildings if such buildings were designed and constructed in minimum compliance with the American Society of Heating, Refrigerating and Air-Conditioning Engineers standard 90.1-2013 or the New York State Energy Code, as such term was defined on December 1, 2017.

Local Law 154 of 2021 (LL154) prohibits the combustion of substances that emit 25 kilograms or more of carbon dioxide per million Btu of energy in new buildings[74]. In effect, this bans all fossil fuels and requires new buildings to use only electricity. This law is rolled out to different building categories at different times, summarized in the Figure 6.25. Some exemptions are made for certain uses such as manufacturing, lab space, hospitals, emergency power generation, and commercial kitchens.

TIMELINE OF LL154 LEGISLATION

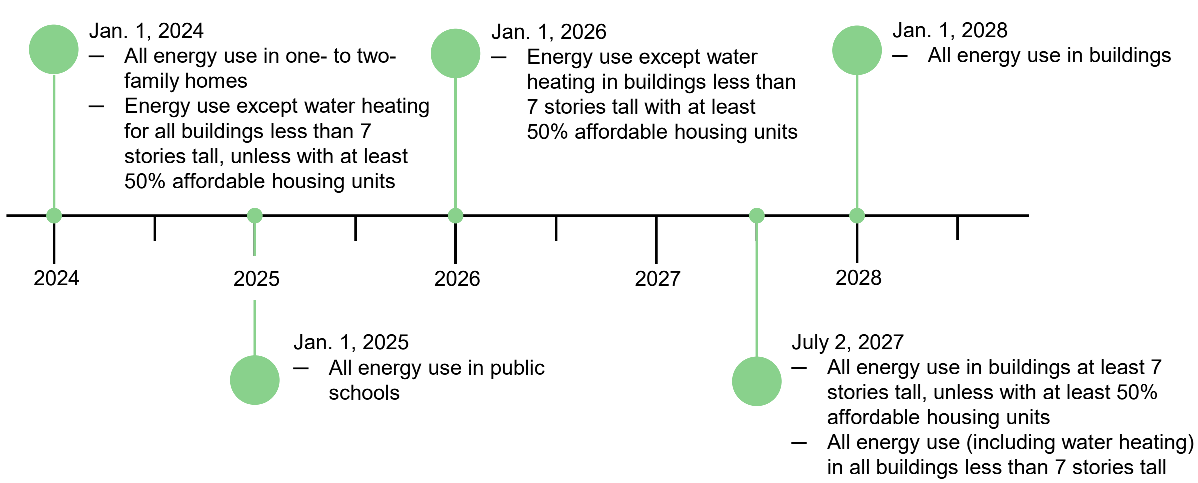


FIGURE 6.25 | SOURCE: NYC OMB

Model Methodology

This model forecasts GHG emissions reductions due to increasing energy efficiency standards for new buildings and replacement of fossil fuels with electricity. The model is performed in Microsoft Excel, after some data processing in python.

The model uses the following external inputs:

- The DOB NOW Job Application Filing Dataset, which contains records of approved permits (either Permit Issued or Permit Entire) for all new buildings and Alt-CO New Building with Existing Elements to Remain. Information such as number of proposed units, total square footage of construction project, and number of stories is used to characterize buildings[75].
- The PLUTO dataset, which includes square footage from previous projects. These data are used to find the average area of multi-family units in current projects, and the building sizes prior to building alterations for substantial renovation projects. 2023 PLUTO data are used for the average area of multi-family units, and 2020 PLUTO data for the pre-alteration building sizes[17].
- The New York Metropolitan Transportation Council (NYMTC) Socioeconomic and Demographic (SED) 2055 Forecast, which contains projections of employment and population through 2050. These data are used to predict the number of residential units and commercial area required through 2050[76].
- NYSERDA analyses and calculations of average EUI under different energy codes for commercial, single family, and multi-family homes are leveraged to inform energy savings expected[77,78].
- Energy use among large buildings from the 2012-2022 LL84 building energy benchmarking dataset, from the New York City Open Data portal. These data are used to find the expected mix of fuels in multi-family or commercial properties[50-60].
- The list of Article 321 pathway properties, which includes buildings with greater than 35 percent of rent-regulated (or otherwise affordable) properties and houses of worship. This list is used to estimate the percentage of recent multi-family construction with an alternate LL154 compliance pathway (for buildings with over 50 percent affordable units)[48].

The model takes the following assumptions:

- Significant renovation rates (for both commercial and residential buildings) will continue at the same average rate as was recorded in 2021-2023 through the DOB-NOW Job Application Filing dataset. This dataset includes completed permit applications from over 2,500 unique buildings, with 1,993 from new buildings and 625 for substantial renovations.
- Population will grow to levels projected in the SED Forecast from NYMTC.
- The number of housing units per capita is constant. With this assumption, the projected amount of new construction is calculated using only the projected population (from NYMTC) and the current building stock (from PLUTO). This calculation is included below.
- There is considerable uncertainty about the demand for new commercial real estate given the rise of hybrid and remote work, making it challenging to forecast the amount of new construction needed. This model assumes that the amount of square footage needed per person remains constant, using population growth estimates from NYMTC.
- New construction will be in the same proportion of building typologies (i.e., one- to two-family homes, multi-family buildings less than seven stories tall, multi-family buildings seven stories or taller, commercial buildings less than seven stories tall, and commercial buildings seven stories or taller) as in new construction permits from the DOB-NOW dataset.

Note the following exclusions and limitations:

- The DOB-NOW Job Application Filings dataset does not indicate the square footage of a project dedicated to residential or commercial use, as would be necessary to calculate the building-level energy use targets. There are also no data about the use type of new construction, such as would be needed to determine whether the use type is exempt from emissions limits.
- This analysis only includes the relative emissions reduction in new housing stock and substantial retrofits due to the related legislation. The total emissions from this building stock are not calculated, as they are included in baseline scenarios.
- The modeling only considers five building typologies: one- to two-family homes, multi-family buildings less than seven stories tall, multi-family buildings seven stories or taller, commercial buildings less than seven stories tall, and commercial buildings seven stories or taller. While energy conservation codes include a greater level of detail, this is the minimum level necessary to capture the timeline of fossil fuel phaseouts from LL154.
- LL154 also applies to public schools; these are considered in the City Government Operations Emissions Forecast and are not duplicated here.
- LL154 has some exceptions, including laboratories and commercial kitchens. These exceptions are not modeled because they represent a very small amount of New York City's building stock, and because filing data do not include information on use types for new construction.
- Changes to fuel oil use are not considered, as the baseline for new construction with fuel oil is already close to zero, and counting a reduction in fuel use from this measure would overlap with the Fuel Oil Phase-Out Mandates.

Given the inputs and assumptions, the following steps are applied to generate the forecast:

1. Process datasets to get average energy use and building characteristics. All characteristics are determined within the following building classifications: one- to two-family homes, multi-family buildings less than seven stories tall, multi-family buildings seven stories or taller, commercial buildings less than seven stories tall, and commercial buildings seven stories or taller. The steps to process the data are:
   a. Find the average amount of building alterations (ALT-CO entries in DOB-NOW) per month, and the total new dwelling units. Calculate the estimated commercial area of these developments by multiplying the number of proposed dwelling units by the average size of a dwelling unit and subtracting this from the total construction floor area.
   b. Find the average size of a residential unit built in each year, from the PLUTO dataset.
   c. Find average electricity use and natural gas use per square foot in 2022, from the Local Law 84 of 2009 (LL84) dataset.

2. Project quantity of new area constructed. Scale 2023 levels of commercial area and residential units (from PLUTO) by the population projections from NYMTC's SED to forecast new construction.

$$Projected\_New\_Res\_Units_{target\_year} = \frac{projected\_population_{target\_year} - projected\_population_{base\_year}}{projected\_population_{base\_year}} \times num\_res\_units_{base\_year}$$

$$Projected\_New\_Commercial\_Area_{target\_year} = \frac{projected\_population_{target\_year} - projected\_population_{base\_year}}{projected\_population_{base\_year}} \times commercial\_area_{base\_year}$$

3. Compute energy consumption. For each new housing unit and each square foot of commercial real estate, find the energy use under baseline scenario construction and the updated building energy codes. To do so, find the building EUI of natural gas and electricity, or the amount of energy used per square foot of commercial real estate or per residential unit. Then multiply by the total square footage of commercial real estate or the total number of residential units to get the total energy demand.
    a. EUI from commercial real estate and residential real estate are from NYSERDA analyses of energy codes: Residential NYStretch Energy Code of 2020, Commercial NYStretch Energy Code of 2020. These studies evaluate the average building energy use from buildings constructed according to the NYStretch energy code and New York City ECC.
    b. For the baseline scenario, it is assumed that residential buildings follow the 2016 New York City ECC. For buildings constructed from 2020-2024, buildings follow the NYStretch energy code. Following 2025, guidance has not been published, but it is assumed that building performance standards will be 70 percent of the 2016 New York City ECC values.
    c. Buildings are assumed to electrify space and water heating following the schedule above. It is assumed that electrified buildings have the same EUI as buildings with fossil fuel use, because NYSERDA's analysis does not provide alternate energy use assumptions for electrified buildings.

Discussion

The laws mandating efficient and electric new buildings are expected to result in significant fossil fuel use reductions. As Figure 6.26 shows, both natural gas use and electricity use decline immediately, as a result of the more efficient energy codes. From 2027 through 2050, the fossil fuel ban applies to all new construction. In this period, the amount of natural gas use declines considerably but the electricity use increases to meet heating demand.

ENERGY-USE IMPACTS FROM EFFICIENT & ELECTRIC NEW BUILDS

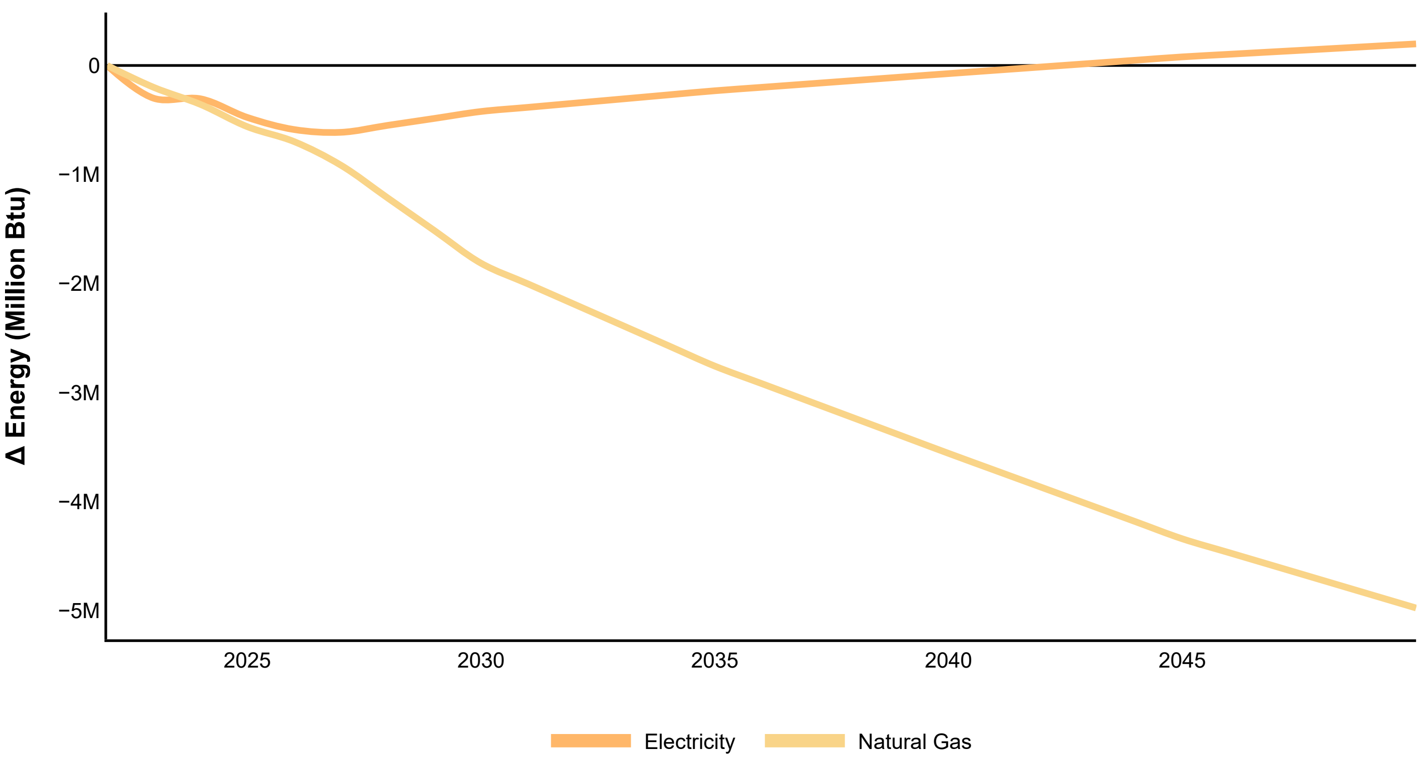


FIGURE 6.26 | SOURCE: NYC OMB

These two measures complement each other to result in considerable GHG reductions. Figure 6.27 shows the emissions impact of the two policies. Emissions from electricity in each year were calculated by multiplying the electricity use by the projected COMET-NYC emissions factors. The fossil fuel ban alone may increase emissions in the near term because fossil-fuel-powered electric generators produce significant GHG emissions. However, when combined with energy efficiency improvements, emissions are expected to decrease substantially in the near term. Once the electric grid delivers zero-carbon electricity, electrification of building energy systems in new buildings will deliver large GHG reductions.

GHG IMPACTS DUE TO EFFICIENT & ELECTRIC NEW BUILDS MEASURES

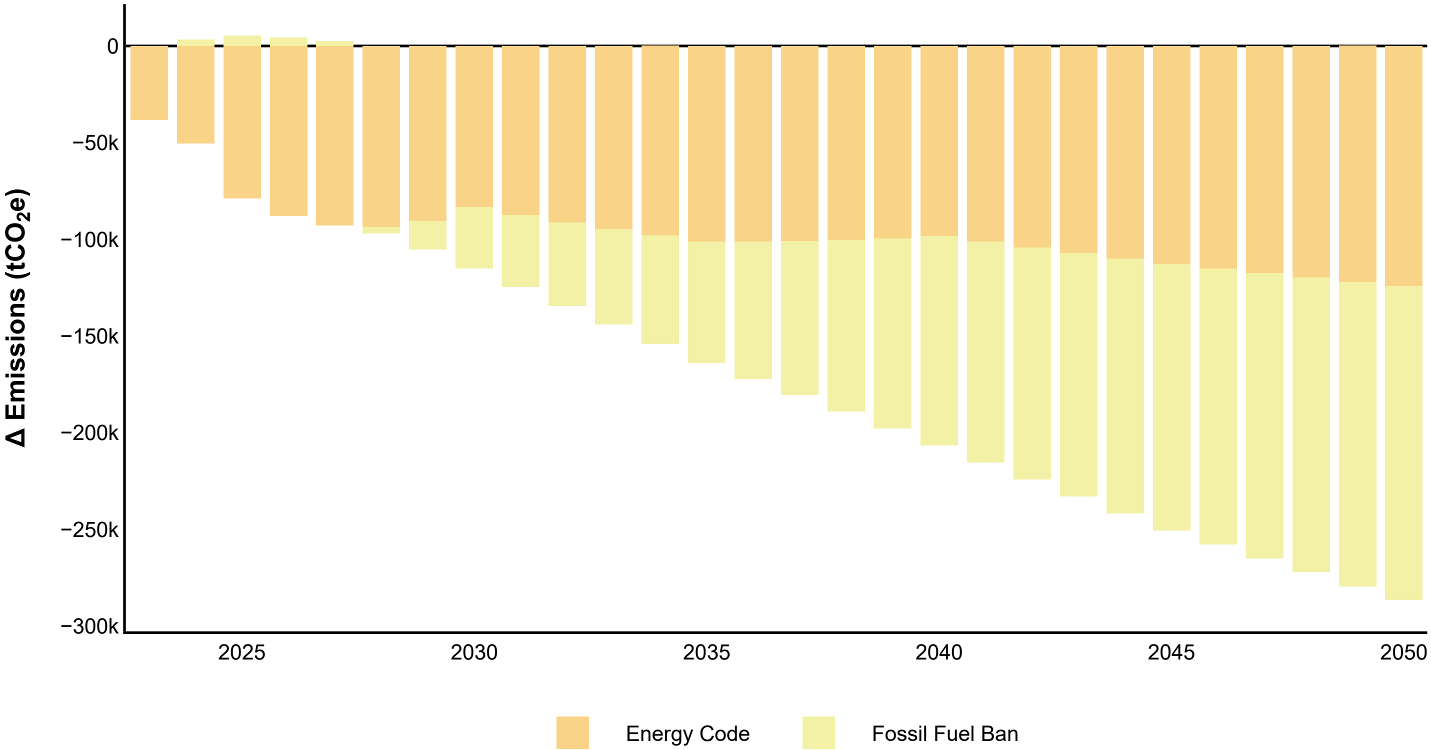


FIGURE 6.27 | SOURCE: NYC OMB

6.d.i.4. Fuel Oil Phase-Out Mandates (LL43-2010, LL107-2013, LL119-2016, LL32-2023)

Criteria Screening

1. GHG Impact: 1,137,000 tCO_2e saved through 2050
2. Commitment: Required by local legislation, mayoral commitment
3. Responsibility: Will be carried out by mayor-appointed leadership

Context

Since 2010, the city has passed four local laws to regulate fuel oil consumption in buildings. The laws define two distinct schedules—the phase-out of fuel oil #4, and the phase-in of biodiesel. There are two levers for regulation, both of which are managed by the New York City Department of Environmental Protection (DEP) – (1) Certification of boiler installations: DEP will only allow installations that meet the fuel oil requirements outlined in administrative code; and (2) Fuel oil market restrictions: DEP requires that all fuel oil sold in the city be blended with biofuel according to the schedule outlined in administrative code.

Local Law 43 of 2010 (LL43) states that after October 1, 2012, all fuel oil #2, fuel oil #4, and fuel oil #6 delivered to and used in the city must contain no less than 2 percent biodiesel by volume, with some exceptions for emergency generators. Rules were amended in 2011 such that by 2015, existing boilers must switch from fuel oil #6 to fuel at least as clean as low -ulfur fuel oil #4. The law also requires that newly installed boilers only burn fuel oil #2, and that existing boilers must be modified to meet the equivalent emissions of burning fuel oil #2 by 2030[34].

Local Law 107 of 2013 (LL107) states that after October 1, 2014, all fuel oil #2, fuel oil #4, and fuel oil #6 delivered to and used in any city-owned building must contain no less than 5 percent biodiesel by volume. The law includes provisions to pilot 10 percent biodiesel no less than 5 percent of city-owned buildings, and to study the feasibility of a city-wide requirement to use no less than 5 percent biodiesel by volume[35].

Local Law 119 of 2016 (LL119) states that after October 1, 2012, all fuel oil #2, fuel oil #4, and fuel oil #6 delivered to and used in the city must contain no less than 2 percent biodiesel by volume. After October 1, 2017, it must contain no less than 5 percent biodiesel by volume, with some exceptions for emergency generators. Fuel oil #2 must contain no less than 10 percent biodiesel by October 1, 2025, 15 percent by October 1, 2030, and 20 percent by October 1, 2034[36].

Local Law 32 of 2023 (LL32) states that after June 30, 2024, no work permit, certificate of operation, or registration may be issued or renewed for a boiler to burn fuel oil #4. After January 1, 2025, no boilers used to generate electricity and/or steam in an electric-, steam-, or combined-electric-and-steam-generation facility may burn fuel oil #4. After July 1, 2025, no boilers in a city-owned building or a Department of Education – operated public school may burn fuel oil #4. After July 1, 2027, no boilers may burn fuel oil #4[37].

Model Methodology

The Fuel Oil Phase-Out Mandates model forecasts GHG emissions reductions due to the phase out of fuel oil #4 and the phase in of biodiesel into the fuel mix. The model is performed in python for integration into the Core Model and re-implemented in Microsoft Excel for quality checking by agency partners.

The model uses the following external inputs:

- Energy use among large buildings from the 2012-2022 building energy benchmarking dataset, from the New York City Open Data portal. These data are used to find which fuels replace fuel oil #6 following ban in 2015[50-60].
- Mix of fuel oil types (biofuel and fuel oil #2, fuel oil #4, and fuel oil #6) in 2005-2022 from the New York City 2022 GHG Inventory, developed by MOCEJ. These data are used to find the share of fuel oil types and the trend in biofuel generation[18].
- The Furnace and Boiler guide, developed by the U.S. Department of Energy, is used to find the typical efficiency of fuel oil and natural gas boilers[79].
- The New York City 2020 ECC is used to find the typical efficiency of new electric heating[80].

The model takes the following assumptions:

- Replaced oil burners have a COP of 0.8, based on the low estimate for “mid-efficiency” heating systems from the Furnace and Boiler Guide.
- New natural gas burners have a COP of 0.8, new oil burners have a COP of 0.81, and new electric heating (which can be several varieties of heat pump) have a COP of 3.0, based on the New York City 2020 ECC. To find the COP of electric heating, this analysis used the median of air-source-heat-pump efficiencies with a reported COP in the 2020 ECC.
- Burning a mix of biofuel and heating oil does not impact the efficiency of burners.
- The amount of fuel oil #4 will decrease following the same proportions that fuel oil #6 decreased (in LL84-reporting buildings) following its ban. Figure 6.28 below shows the historical and projected portion of fuel oil #4 among all building fuel oil consumption.
- The fuel mix replacing fuel oil #4 will follow the same proportions that replaced fuel oil #6 in LL84-reporting buildings following its ban.
- The amount of energy consumed for heating will remain constant (to avoid double counting energy efficiency improvements from other city action models).
- Fuel oil #2 will be converted to B10 (10 percent biofuel blend), B15 (15 percent biofuel blend), and B20 (20 percent biofuel blend) at the same rate as when complying with the B2 (2 percent biofuel blend) and B5 (5 percent biofuel blend) regulation—that is, starting three years prior to compliance, their share of biofuel will increase proportionally up to the target at the same rate as biofuel use grew historically. Figure 6.28 below shows the historical and projected portion of biofuel among all building fuel oil consumption.
- Fuel oil consumption in the manufacturing and construction sectors are included in the analysis, but if the fuel oil is not used for heating, then it may not be subject to the ban.
- Whenever fuel oil #6 is referenced, it accounts for both fuel oils #5 and #6.

Note the following exclusions and limitations:

- The focus of the model is on the fuels used to heat private buildings in New York City. It does not attempt to model energy efficiency improvements or climate change (including change in heating degree days (HDD)), which may adjust the baseline heating demand. These considerations are factored into COMET-NYC’s baseline scenarios, as they impact baseline emissions forecasts and emissions reductions from other city actions.
- For buildings covered under LL97, building owners may replace fuel oil #4 with either natural gas burners or electric heating to comply with emissions-reduction targets. These reductions are accounted for in the LL97 city action. The fuel oil phase-out mandates are only applied to remaining fuel oil #4 where building owners do not electrify their home heating system.

HISTORICAL AND PROJECTED COMPOSITION OF BUILDING FUEL OIL

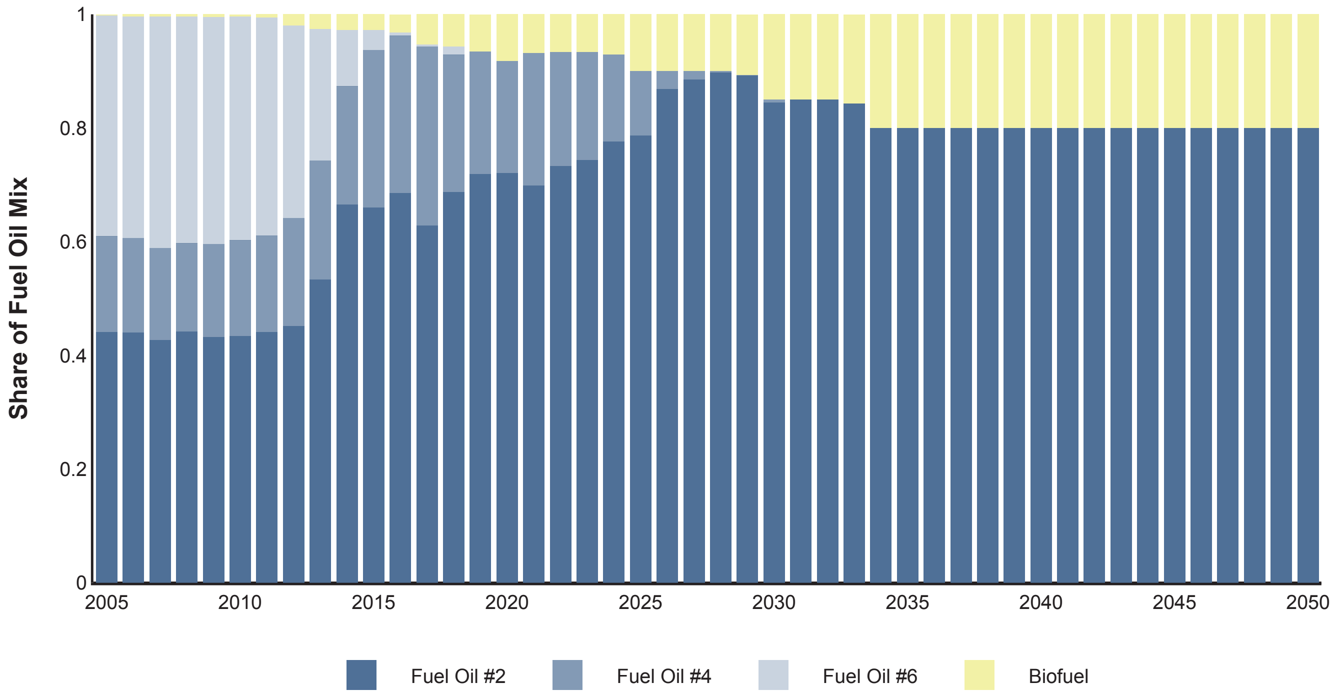


FIGURE 6.28 | SOURCE: NYC OMB

Given the inputs and assumptions, the following steps are applied to generate the forecast:

1. Find the fuel mix that historically replaced one unit of fuel oil #6. For robustness, two empirical strategies are considered. Method A (linear regression) is the preferred estimation method, as it better accounts for building-specific and time-period-specific effects through the inclusion of fixed-effects terms.

   a. Method A – Linear regression strategy. For each fuel type in fuel oil #2, fuel oil #4, natural gas, electricity, district steam, and other, the regression equation is estimated where i indexes buildings and t indexes years.

$$\boldsymbol{Fuel_{it} = \beta FO6_{it} + \alpha_i + \alpha_t}$$

   For each fuel type, β is the correlation between fuel oil #6 ($FO6$) and the outcome fuel type. A negative value indicates that increasing fuel oil #6 is correlated with a decrease in that fuel type, which is the direction expected if a fuel is used to replace fuel oil #6. Looking only at significant (p-value < 0.05) β values, the estimated share of fuel use will be the β coefficient for that fuel divided by the sum of β coefficients for all fuels.

   b. Method B – Differences strategy. First, the average composition of fuel types in a period before the fuel oil #6 ban (2012-2014) and after the ban (2017-2022) is found, for buildings that did or did not ever record using fuel oil #6. Let $\Delta Fuel_{Has\_FO6}$ be the change in the share of a given fuel type from buildings that had fuel oil #6, and $\Delta Fuel_{No\_FO6}$ be the change among buildings that did not have any fuel oil #6. The estimated share of each fuel type that will result from a one-unit decrease in fuel oil #6 is found to be

$$\boldsymbol{Fuel\_Replacing\_FO6 = \frac{\Delta Fuel_{Has\_FO6} - \Delta Fuel_{No\_FO6}}{\Delta FO6}}$$

   Both methods predict that fuel oil #4 will be primarily replaced by natural gas (74 percent using Method A, and 81 percent using Method B), with fuel oil #2 as the second-most common (26 percent using method A, and 12 percent using Method B). Method A finds that electricity use decreases slightly (by 1.4 percent) in buildings that replace fuel oil #4, which could be due to reduced venting or circulation while replacing outdated boilers. Method B finds that electricity use increases (by 6.4 percent), although many building-level factors could explain this change, as the method does not include building-level fixed effects.

2. Project the fuel mix that would replace one unit of fuel oil #4. Scale the replacement fuel types so that one unit of energy decrease from fuel oil #4 is replaced by the mix of significant fuel types—natural gas (NG), fuel oil #2 ($FO2$) and electricity (E)—proportional to the amounts that historically replaced fuel oil #6.

$$substitution\_rate_{FO4\_to\_FO2} = \frac{COP_{oil\_boiler} \times \frac{MMBtu}{gal_{FO4}}}{COP_{new\_oil\_boiler} \times \frac{MMBtu}{gal_{FO2}}}$$

$$substitution\_rate_{FO4\_to\_NG} = \frac{COP_{oil\_boiler} \times \frac{MMBtu}{gal_{FO4}}}{COP_{new\_gas\_boiler} \times \frac{MMBtu}{SCF_{NG}}}$$

$$substitution\_rate_{FO4\_to\_E} = \frac{COP_{oil\_boiler} \times \frac{MMBtu}{gal_{FO4}}}{COP_{e\_heating} \times \frac{MMBtu}{kWh_e}}$$

3. Incorporate biofuel phase-in rate: Beginning three years before the regulation takes effect (at share R, in year y), the blend will be a function of the average blend of biofuel (BF) before regulation (share P) and the percentage of the previous goal that was met in year $t - t_0$. Note that the percentage can have a maximum value of 1.

$$share_{BF} = (R - P) \times (\%\_of\_goal\_met) \times (t - t_0) + P$$

$$gal_{BF} = share_{BF} \times \frac{gal_{FO2} + gal_{FO4}}{1 - share_{BF}}$$

4. Project decline in biofuel consumption: Similarly, the amount that biofuel use will decline as fuel oil #2 or #4 declines are calculated (without changing the share of biofuel blend).

$$\Delta gal_{BF} = share_{BF} \times \frac{\Delta gal_{FO2} + \Delta gal_{FO4}}{1 - share_{BF}}$$

5. Calculate the energy consumption after biofuel decline. To find the resulting amount of a particular fuel type after the share of biofuel changes, use:

$$energy\_consumption_{post} = energy\_consumption_{pre} \times \frac{1 - share_{BF\_post}}{1 - share_{BF\_pre}}$$

Discussion

Figure 6.29 shows how fuel oil use is expected to decrease (as a consequence of both the ban on fuel oil #4 and the higher proportion of biofuel), and the corresponding increases in natural gas and biofuel use. The magnitude of impact from this measure declines over time. This is because fuel oil use is expected to decline in the baseline scenario and due to other measures such as Building Emissions Limits (LL97) and City Government Operations. A decrease in fuel oil #4 is expected in the baseline scenario because buildings replace old oil-powered boilers with less expensive gas or electric heating systems. New York City also plans to replace fuel oil #4 in city-owned buildings with fuel oil #2 and biofuel, which is modeled in the City Government Operations Emissions Forecast section.

CHANGE IN FUELS OVER TIME DUE TO FUEL OIL MANDATES

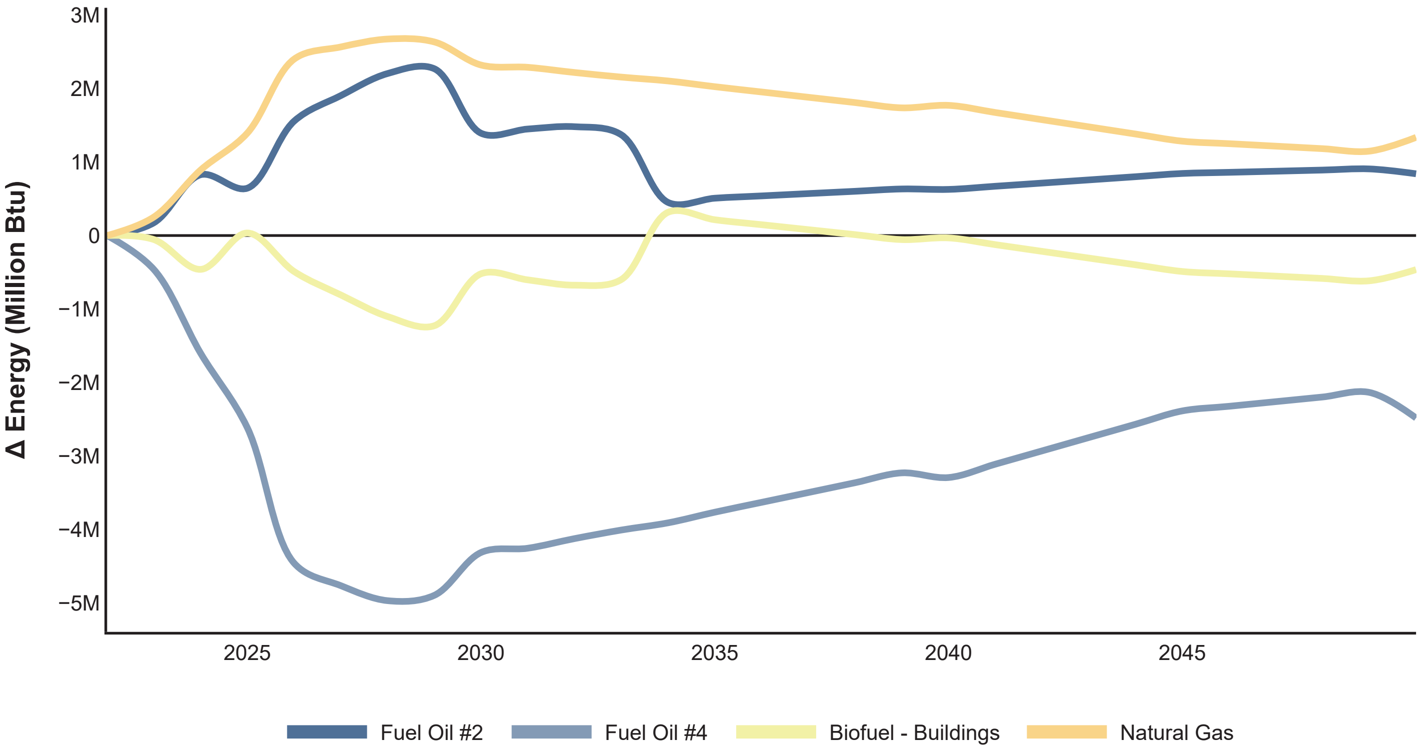


FIGURE 6.29 | SOURCE: NYC OMB

6.d.i.5. HPD Sustainability Design Guidelines

Criteria Screening

1. GHG Impact: 78,000 tCO_2e saved through 2050
2. Commitment: Required by local legislation
3. Responsibility: Will be carried out by mayor-appointed leadership

Context

HPD released updated design guidelines, effective March 2023, detailing requirements for the work done under HPD-sponsored programs. These include Sustainability Design Guidelines (SDGs), which aim to ensure that all buildings undergoing HPD-sponsored work comply with LL97, and that those buildings doing more extensive work (substantial or gut rehabilitations) reduce GHG emissions through envelope improvements and by replacing inefficient, fossil-fuel-based heating and hot water systems with heat pumps in many cases[38].

Model Methodology

The HPD SDG model generates a forecast through 2050 for GHG emissions reductions due to energy efficiency requirements. The model is performed in python. Many of the data processing steps are performed within the Building Emissions Limits model.

The model uses the following external inputs:

- List of buildings where SDGs are applicable, as well as the energy use within each building, provided by HPD.
- The building-level energy use dataset generated within the Building Emissions Limits model.
- Number of planned conversions dwelling unit conversions from 2024-2026 and type of each conversion, as well as the total budgeted number of conversions by 2033. Type of conversion includes whether the unit will only undergo PECMs, or will additionally pursue DHW electrification, space heating electrification, or full electrification. The number of planned conversions was provided by HPD, and number of total budgeted conversions was provided by OMB's Housing and Economic Development Task Force. The number of conversions is summarized in the Figure 6.30.
- The 2014 One City, Built to Last study, developed by the Mayor's Office of Long-Term Planning and Sustainability, contains an extensive list of ECMs, although the cost data behind these measures are outdated. These data are used to find the energy reductions from adopting PECMs, as specified for the Article 321 pathway[48].
- ECM cost and efficacy data for multi-family buildings, from Cadence OneFive. These data are used to characterize the building energy impacts from space heating and water heating electrification.
- Building EUI trends for each fuel type, from COMET-NYC. COMET-NYC projects that residential building energy use by 2050 will decline because climate change reduces the need for heating, and buildings will replace heating, cooling, lighting, and other appliances with more efficient technologies. The trends in EUI are used to adjust the PECMs' energy reductions, so that reductions are proportional to the buildings' energy use after the energy efficiency improvements modeled in COMET-NYC.
- PLUTO data, from the New York City Department of Finance, are used to find the number of housing units.

NUMBER OF PLANNED DWELLING UNIT CONVERSIONS THROUGH HPD'S SUSTAINABLE DESIGN GUIDELINES

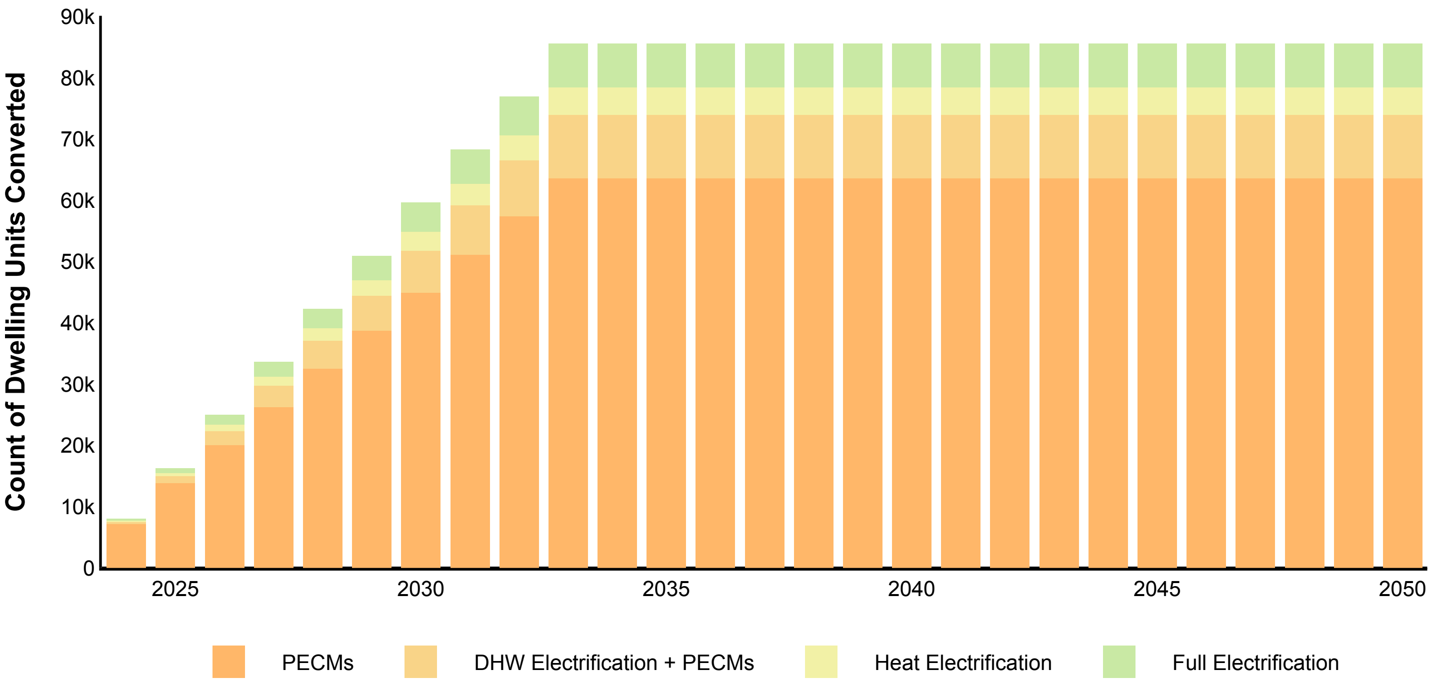


FIGURE 6.30 | SOURCE: NYC OMB

The model takes the following assumptions:

- The same proportion of apartments will undergo space heating electrification, DHW electrification, and full electrification in the 2027-2033 period as in the 2024-2026 period. HPD only provided plans for the type of conversions through 2026.
- The impact of each residential unit conversion will equal the average impact across all residential units in the list of HPD properties. HPD did not specify which buildings would undergo conversions.

Note the following exclusions and limitations:

- Some properties in the HPD list overlapped with properties in the covered-buildings list for LL97; to avoid double counting, the emissions reductions from these properties only include the work additional to the baseline needed to comply with Article 321 of LL97.

Given the inputs and assumptions, the following steps are applied to generate the forecast:

1. Find the energy-use reductions from PECMs and electrification at each building. The HPD SDGs are aligned with the LL97 PECMs. Therefore, to model the impact of these PECMs, these properties are modeled in the same manner as Article 321 pathway properties in the Building Emissions Limits analysis, also through 2050. For each fuel type, multiply each building's energy use by the percent of energy use reduction from adopting all PECMs. This is the sum of energy reductions identified in the One City, Built to Last study, multiplied by the percentage of buildings where that PECM can be applied.
   - For DHW, space heating, or full electrification (both DHW and space heating), the methods from Cadence OneFive are applied to find the energy-use reductions. These reductions are summarized in the Building Emissions Limits analysis section.

2. Find the energy-use reduction per dwelling unit, for each type of conversion.
    - Divide the building-level-energy-use reduction by the number of dwelling units per building.
    - If the building is included in the Article 321 pathway, subtract the energy-use reduction already included in the Building Emissions Limits model. This is the energy-use reduction from applying PECMs if the building's emissions exceeds its 2030 emissions target.
3. Multiply the energy-use reduction by the number of anticipated unit conversions. This is the weighted average of the per-dwelling-unit energy reduction, based on the number of units per building, multiplied by the total number of converted dwelling units with that type of conversion. The following formula shows the calculation:

$$reduction_{fuel\_type;\ year} =$$

$$\sum_{c \in conversion\_types} \left(\#\_conversions_{year;\ c} \times \sum_{b \in buildings} reduction_{fuel\_type;cb} \times \frac{dwelling\_units_b}{total\_dwelling\_units} \right)$$

4. Adjust the energy use reduction by the EUI trend from COMET-NYC. The following formula describes how to calculate the adjusted reduction:

$$adjusted\_reduction_{fuel\_type,\ year} = reduction_{fuel\_type} \times \frac{building\_EUI_{fuel\_type,\ base\_year}}{building\_EUI_{fuel\_type,\ base\_year}}$$

Discussion

The HPD design guidelines are expected to reduce fossil fuel use among converted residential units, particularly for those that electrify heating systems. This reduction is much smaller than the reductions from LL97, because the HPD housing stock anticipating residential unit conversions is much smaller than the number of private buildings subject to emissions standards from LL97.

CHANGE IN ENERGY USE FROM HPD SUSTAINABILITY DESIGN GUIDELINES

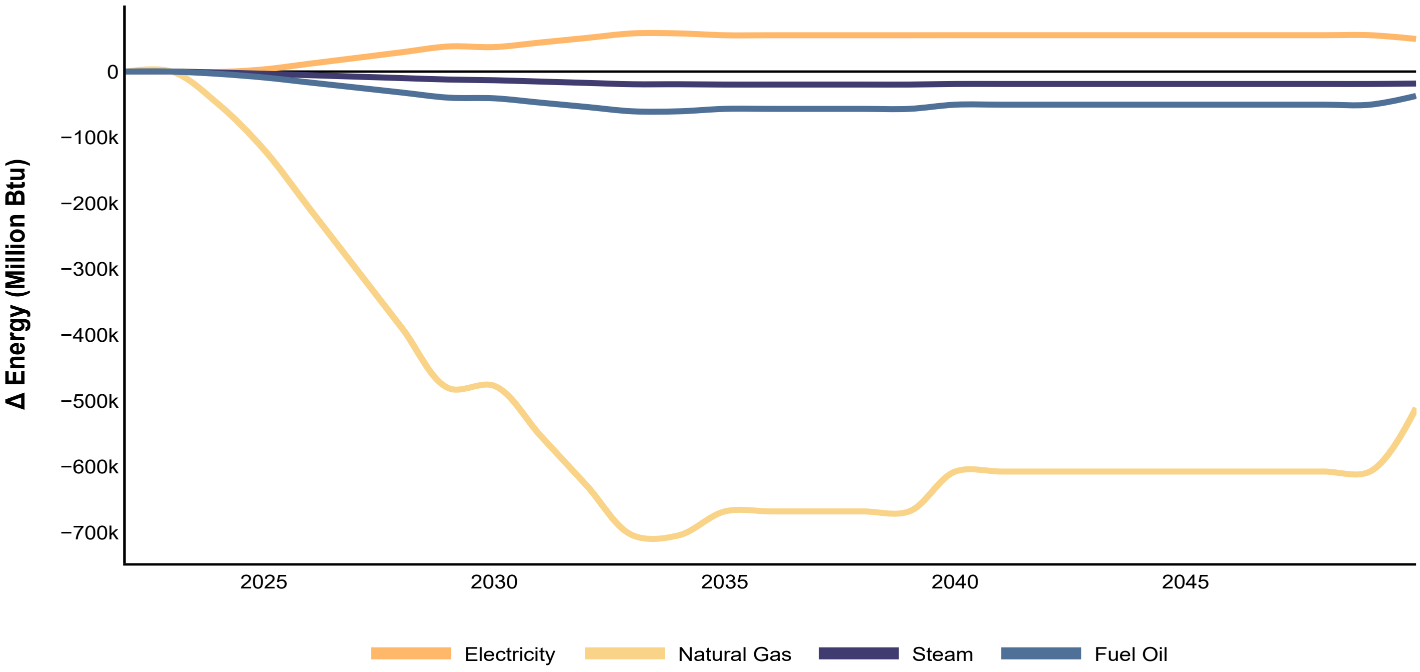


FIGURE 6.31 | SOURCE: NYC OMB

6.d.i.6. NYCHA Solar Installations

Criteria Screening

1. GHG Impact: 23,000 tCO_2e saved through 2050
2. Commitment: Mayoral commitment
3. Responsibility: Will be carried out by mayor-appointed leadership

Context

As part of the U.S. Department of Housing and Urban Development Renew300 program and their 2021 Sustainability Agenda, NYCHA committed to hosting 25 megawatts (MW) of renewable energy on its property by 2025[81,82]. In 2021, NYCHA increased the goal to 30 MW by 2026. This analysis estimates the kWh electric generation anticipated from solar panels installed on NYCHA developments—this includes projects that are already completed as well as projects that are expected in the future. All solar installations at NYCHA are included in the analysis, regardless of the program employed for solar procurement (e.g., ACCESSolar, PACT, etc.).

Model Methodology

The NYCHA Solar Installations model generates a forecast through 2026 for GHG emissions reductions due to the generation of electricity from solar panels. The model is performed in Microsoft Excel.

The model uses the following external inputs:

- Past and upcoming solar installations, provided by NYCHA. These show that currently, NYCHA has 3.0 MW of solar installed on their properties, with plans to install an additional 4.7 MW by 2026.

The model takes the following assumptions:

- All kWh generated by solar are offsetting electricity that would have otherwise been used from the grid.
- A capacity factor of 12.6 percent, in alignment with DCAS assumptions. This is approximately equal to 1104 kWh generated annually for each kilowatt (kW) of installed capacity.

Note the following exclusions and limitations:

- The model only includes solar installations that have already occurred and upcoming installations where NYCHA has identified a developer. Therefore, the model does not include solar installations that are expected to occur but are still pending agreements with developers.

Given the inputs and assumptions, the following steps are applied to generate the forecast:

1. Calculate the installed capacity. Given the list of past and upcoming NYCHA solar installations, the capacity in each year is the sum of the capacity installed that year and the amount already installed by the start of that year. If $kW\_Installed_{it}$ is the amount installed and kW_t is the total capacity, this is:

$$kW_t = kW_{t-1} + kW\_Installed_t$$

2. Calculate the annual generation. Multiply the total annual capacity by the capacity factor (CF) and by the annual hours (8,760).

$$kWh_t = kW_t \times 12.6\% \times 8,760$$

3. Calculate the emissions reduction. As the generated electricity offsets electricity that would have come from the grid, the annual reductions are assumed to be:

$$annual\_reductions_t = kWh_t \times electricity\_emissions\_factor_t$$

Discussion

With the assumed generation rate, the 7.7 MW of solar panels on NYCHA campuses will provide 8.4 GWh of electricity annually, starting in 2026. This is approximately .06 percent of total electricity consumed in residential buildings in New York City, according to the 2022 New York City GHG Inventory.

6.d.i.7. NYCHA PACT Program

Criteria Screening

1. GHG Impact: 7,000 tCO_2e saved through 2050
2. Commitment: Required by local legislation
3. Responsibility: Will be carried out by mayor appointed leadership

Context

The NYCHA Permanent Affordability Commitment Together (PACT) program connects NYCHA developments to funding to enhance property management and encourage comprehensive renovations and provides design standards to help projects improve energy efficiency. Since the developments undergo deep renovations, an opportunity arises to make the homes more energy efficient. NYCHA PACT Program is a part of NYCHA's Sustainability Agenda, which sets goals for sustainability across all NYCHA programs[83]. NYCHA PACT Program has developed design standards that provide options for building projects to improve building energy efficiency.

Model Methodology

The NYCHA PACT Program model generates a forecast through 2050 for GHG emissions reductions due to energy efficiency requirements. The model is performed in python, within the Building Emissions Limits model. The model uses the following external inputs:

- List of buildings where NYCHA PACT Program conversions are scheduled, as well as the energy use within each building, provided by NYCHA[84].
- The building-level energy use dataset generated within the Building Emissions Limits model.
- The 2014 One City, Built to Last study, developed by the Mayor's Office of Long-Term Planning and Sustainability, contains an extensive list of ECMs, although the cost data behind these measures are outdated. These data are used to find the energy reductions from adopting PECMs, as specified for the Article 321 pathway.
- Building EUI trends for each fuel type, from COMET-NYC. COMET-NYC projects that residential building energy use by 2050 will decline because climate change reduces the need for heating, and buildings will replace heating, cooling, lighting, and other appliances with more efficient technologies. The trends in EUI are used to adjust the PECMs' energy reductions, so that reductions are proportional to the buildings' energy use after the energy efficiency improvements modeled in COMET-NYC.

The model takes the following assumptions:

- All buildings will take PECMs, and their emissions reductions will be equal to emissions reductions among Article 321 pathway properties.

Note the following exclusions and limitations:

- Some properties in the NYCHA PACT Program list overlapped with properties in the covered buildings list for LL97; to avoid double-counting, the emissions reductions from these properties are only accounted for in the Building Emissions Limits city action.

Given the inputs and assumptions, the following steps are applied to generate the forecast:

1. Find the energy-use reductions from PECMs. Through interviews with NYCHA staff, OMB learned that many of the projects being implemented are similar to the LL97 PECMs, as described above. Therefore, to model the impact of these PECMs, these properties are modeled in the same manner as Article 321 pathway properties in the Building Emissions Limits analysis, also through 2050. For each fuel type, multiply each building's energy use by the percent of energy use reduction from adopting all PECMs. This is the sum of energy reductions identified in the One City, Built to Last study, multiplied by the percentage of buildings where that PECMs can be applied.
2. Adjust the energy-use reduction by the EUI trend from COMET-NYC. The following formula describes how to calculate the adjusted reduction:

$$adjusted\_reduction_{fuel\_type,\ year} = reduction_{fuel\_type} \times \frac{building\_EUI_{fuel\_type,\ base\_year}}{building\_EUI_{fuel\_type,\ base\_year}}$$

Discussion

NYCHA PACT Program conversions are not expected to have a very significant impact on citywide energy use. NYCHA PACT properties not covered by LL97 represent a very small portion of the overall building stock, and without commitments to electrify building heating systems, the reductions from this measure are much smaller than reductions from HPD Sustainability Design Guidelines.

ENERGY-USE REDUCTIONS DUE TO NYCHA PACT CONVERSIONS

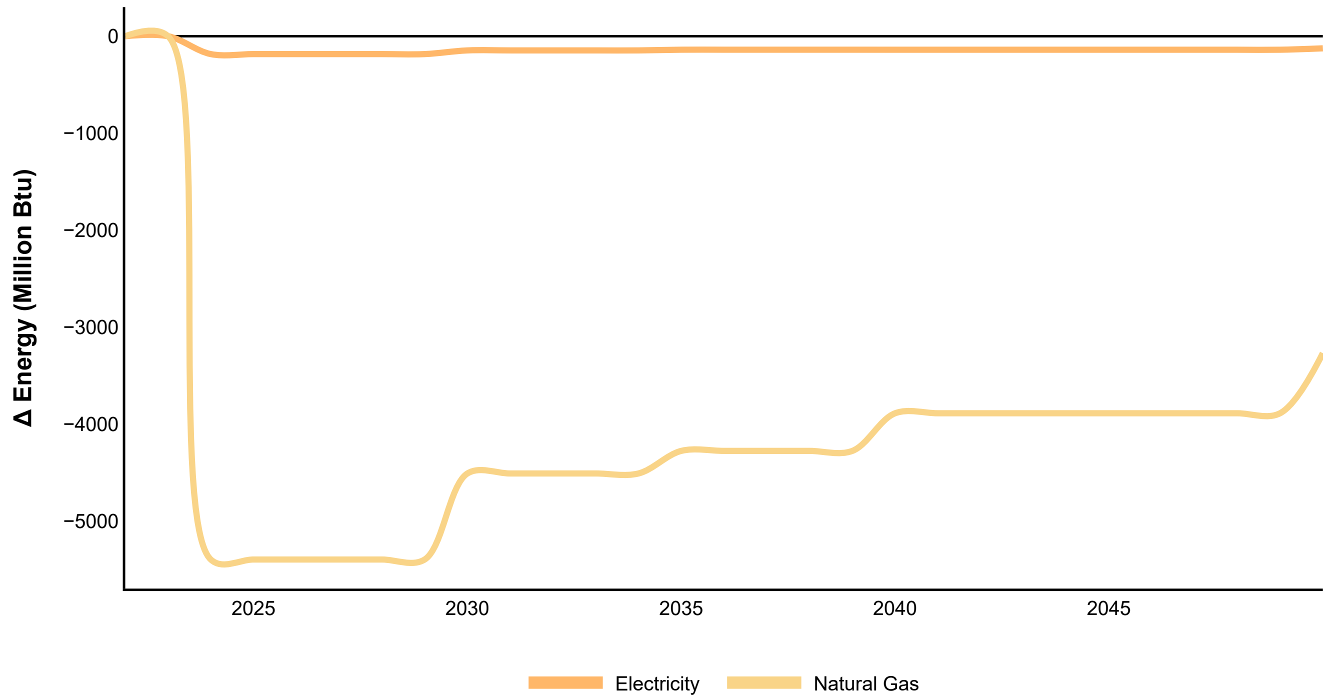


FIGURE 6.32 | SOURCE: NYC OMB, with NYCHA

6.d.ii. TRANSPORTATION SECTOR

6.d.ii.1. For-Hire-Vehicle Electrification

Criteria Screening

1. GHG Impact: 17,422,000 tCO_2e saved through 2050
2. Commitment: Mayoral commitment
3. Responsibility: Will be carried out by mayor-appointed leadership

Context

In his 2023 State of the City address, Mayor Adams committed to build upon vehicle fleet electrification efforts by requiring the 100,000-plus high-volume for-hire-vehicles (HVFHVs) serving New York City to be zero-emissions by 2030, with support from Uber and Lyft. Uber and Lyft make up the majority of vehicles covered by HVFHV licenses[85].

In August 2023, Mayor Adams along with the Commissioner of the Taxi & Limousine Commission (TLC) announced the Green Rides Initiative. This builds upon Mayor Adams's 2023 State of the City commitment requiring HVFHVs to become wheelchair-accessible vehicles or zero-emission vehicles by 2030, with interim targets starting in 2024[86].

Model Methodology

The For-Hire-Vehicle (FHV) Electrification model generates a forecast through 2035 for GHG emissions reductions due to electrification of the HVFHV fleet (Uber and Lyft). The model is performed in Microsoft Excel.

The model uses the following external inputs:

- The Green Rides Compliance Pathway, which includes the anticipated turnover of HVFHVs using the average retirement age of HVFHVs, developed by TLC. These data are used to forecast the replacement of fossil-fuel vehicles and purchasing of electric vehicles.
- Charged Up! Pathway for FHV Electrification, developed by TLC. These data are used to estimate average mileage per trip of HVFHVs[87].
- TLC HVFHV trip data. These data are used to estimate driving patterns of HVFHVs. Examples of the data include average mileage per trip, average day on the road, and number of unique vehicles.
- Congestion Pricing's assumed effect on HVFHVs vehicle miles traveled (VMT), an output from the Congestion Pricing model (see State Actions Section 6.f.). These data are used to estimate the mileage of HVFHVs given the implementation of congestion pricing.
- EIA's Annual Energy Outlook (AEO) 2022 projected fuel economies. These data are used to estimate the change in fuel consumption over time due to improvements in fuel economy over time[88].

The model takes the following assumptions:

- HVFHVs will follow the outlined pathways set forth by TLC, the entity that approves HVFHV licenses.
- Given that the wheelchair-accessible vehicles and EV requirement deadlines are both scheduled for 2030, their respective trajectories are combined.
- HVFHVs are assumed to transition to EVs instead of other alternative fuel types due the current market of alternative fuel types.
- HVFHVs are assumed to be on the road 233 days per year, equivalent to the historical average number of days on the road from 2015-2023.
- TLC reports the average daily mileage for HVFHVs as 72 per day, whereas Charged Up reports an average mileage of 96 miles per day. This analysis uses 96 miles per day to account for miles outside the trip (i.e., vehicle used for personal use or driving to high-demand area to look for trips).

Note the following exclusions and limitations:

- Trip data do not account for miles accumulated outside of serving a customer. This underestimates the impact of the commitment, missing emissions from idling and from driving in between trips.
- There is potential for delays due to cost, supply chains, and limited charger networks.

Given the inputs and assumptions, the following steps are applied to generate the forecast:

1. Collect HVFHV fleet data. To determine the quantity of vehicles expected to electrify, the existing fleet data are obtained from TLC records. The associated fuel types of the fleet are added to the dataset after consultation with TLC.
2. Develop an adoption pathway. An adoption pathway for electrification is constructed using the average “useful life” of a HVFHV, which is based on the average turnover of licenses. There are two causes of turnover considered–end of life retirement and early retirement. TLC provided the expected annual percentage of vehicles that electrify after reaching end of life, scaling up to 100 percent in 2030. The early-retirement group have a slower electrification trajectory that accelerates rapidly in 2029 and 2030.
3. Incorporate future fuel economy. To account for increased mileage and efficiencies of future vehicle models, data from the AEO are used to project improving fuel economy. Since the AEO reports multiple fuel economies for battery-electric vehicles, an average is used.
4. Compute the expected transition. Using the developed adoption pathway, vehicles transitioning from gasoline to electric are calculated.

$$\%\_of\_EVs\_in\_HVFHV\_Fleet = \%\_of\_EVs\_from\_Early\_Retirement + \%\_of\_EVs\_from\_EOL\_Retirement$$

Discussion

Based on Figure 6.33, in the years up to 2026, the EV transition will mostly come from HVFHVs reaching EOL. From 2027, the demand for HVFHVs to transition to EVs before their EOL increases significantly. COMET-NYC projects that EVs ownership will start to increase after 2025 with the state's EV mandate on new car sales, current incentives, and price decreases for EVs. There is a possibility that these policies and trends considered in COMET-NYC will help to facilitate this rapid increase in EVs in the for-hire vehicle market. Further analysis will assess the changing EV market and the progress towards this goal.

HVFHV ADOPTION SCENARIO

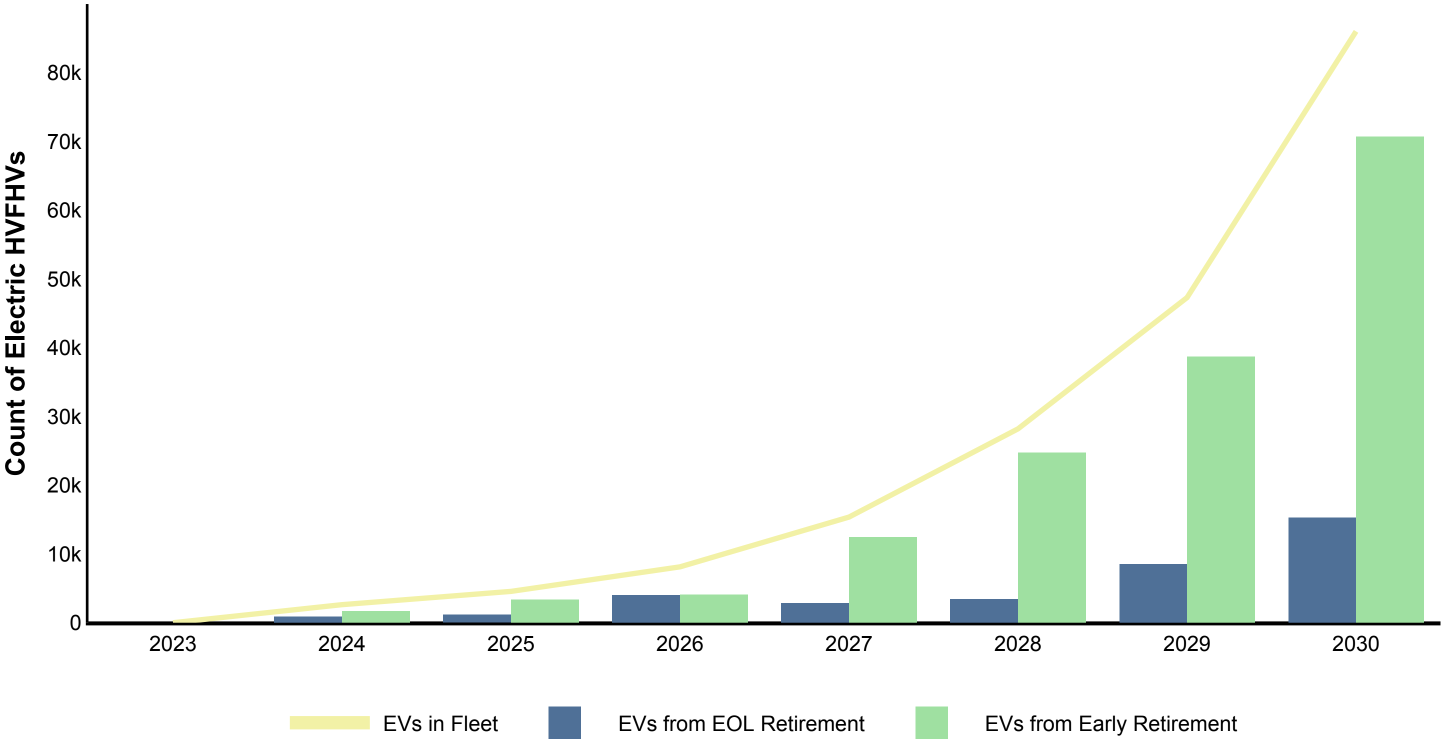


FIGURE 6.33 | SOURCE: NYC OMB, with TLC

PROJECTED FUEL ECONOMY OF ELECTRIC AND GASOLINE VEHICLES (2021-2027)

Vehicle Type	*(miles per gallon gas equivalent)*						
	2021	2022	2023	2024	2025	2026	2027
Gasoline Internal Combustion Engine Vehicles	43	43	43	44	44	45	45
100-Mile EV	93	94	96	97	98	100	100
200-Mile EV	102	102	103	103	104	105	105
300-Mile EV	113	114	115	116	117	118	118
Average EV	**103**	**104**	**104**	**105**	**106**	**107**	**107**

FIGURE 6.34 | SOURCE: U.S. EIA ANNUAL ENERGY OUTLOOK

6.d.ii.2. Electric Vehicle Vision

Criteria Screening

1. GHG Impact: 1,365,000 tCO_2e saved through 2050
2. Commitment: Mayoral commitment
3. Responsibility: Funded in the city's budget or capital plan

Context

The New York City Department of Transportation (DOT) released Electrifying New York: An Electric Vehicle Vision Plan for New York City in 2021 to support the city's vehicle electrification goals[89]. Included in this plan are a series of measures to boost EV-infrastructure build-out. Guided by the city's Pathways to Carbon-Neutral New York City report, DOT concluded that the city will need the electrification of nearly 400,000 vehicles to reach its climate goals. To serve this many vehicles, the city will need over 40,000 publicly accessible level-2 charger plugs and 6,000 fast charger plugs by 2030. As installation locations, DOT plans to target curbside spaces and municipal parking garages and lots that it operates as installation locations. DOT has committed to equip 20 percent of all spaces in municipal parking garages and lots with level 2 chargers by 2025, increasing to 40 percent by 2030.

Model Methodology

The Electric Vehicle Vision model generates a forecast through 2035 for GHG emissions reductions due to substitution of gasoline-burning vehicles with battery-electric or hybrid vehicles. The substitution rate for gasoline-burning vehicles is influenced by the increased availability of charging infrastructure. The model is performed in Microsoft Excel.

The model uses the following external inputs:

- New York State Department of Motor Vehicles registration data. These data are used to estimate the current number of EVs[90].
- 2022 EV sales (see limitations listed below) from EvaluateNY Original EV Registrations data. These data are used to estimate the number of new EV sales[91].
- The number of direct current fast chargers and level-2 charger ports installed in 2022, obtained from the Alternative Fuels Data Center from the U.S. Department of Energy and EvaluateNY. These data are used to estimate the current number of electric vehicle chargers in New York City[92].

The model takes the following assumptions:

- For every 10 percent increase in charger ports, an 8.44 percent increase in sales is assumed in the following year based on several studies that isolate the impact of charger infrastructure on EV uptake[93].
- A one-for-one vehicle substitution is assumed–new EV purchases are made by drivers who previously owned a gasoline-powered car.

Note the following exclusions and limitations:

- There is a cyclical effect between charger infrastructure and EV growth. As EVs increase in number, charger infrastructure will have to increase to support them. Thus, some of the increase in charger infrastructure is driven by the purchase of EVs, so the inducement effect of chargers may be smaller than estimated.
- Charger installations have inducement effects based on vehicle types and charger types. This analysis takes a general, conservative approach while other studies evaluated break out the effects of charger port installation. A study found that hybrid- and battery-electric vehicles have differing sensitivities to charging infrastructure[94]. While both can utilize charging infrastructure, battery-electric vehicles are more dependent on them for daily operation. An adequate level of public charger infrastructure is needed for battery-electric vehicle ownership if an at-home charger is not available. This results in a larger effect of charging infrastructure on battery-electric vehicle sales than hybrid-electric vehicle sales. A similar effect is seen with the charger type, the presence of direct-current fast chargers, which can charge vehicles in at least 30 minutes, seem to have a greater influence on EV sales than level-2 chargers that can take 4-8 hours. For the applied modeling methodology (see below), new sales are based on the installation of EV chargers regardless on the type, but other contemplated methods have specific inducement values based on the charger type.

Given the inputs and assumptions, the following steps are applied to generate the forecast:

1. Collect the number of publicly accessible chargers in New York City. Compile the number of all publicly accessible chargers in the five boroughs of New York City. Some data cleaning is necessary to ensure that all chargers included in this analysis are within the five boroughs.
2. Collect the number of EV sales per year. Estimate this value based on the number of new EV registrations in the five boroughs. Potential duplicates in the registration dataset are accounted for by isolating the vehicle identification number, which is unique to every vehicle.
3. Collect the quantity and type of current charger infrastructure. The quantity of new sales anticipated is dependent on the quantity of chargers installed in a given year. Using the U.S. Department of Energy database of electric charging infrastructure, a baseline for New York City is established for 2022 which is the sum of all publicly accessible chargers in the five boroughs.
4. Compute change in sales. The percent change in public chargers is calculated and the effect applied to the previous years' sales. This method is continued until the expected charger installations are exhausted. The graph below shows the increased growth of EVs in New York City given the increase in EV chargers. For every 10 percent increase in chargers:

$$Increase\_in\_EV\_Sales = \frac{\#\_of\_Chargers_t - \#\_of\_Chargers_{t-1}}{\#\_of\_Chargers_{t-1}} \times \frac{1}{10\%} \times 8.44\%$$

Discussion

Based on the graph below, the historical trend of EV sales shows rapid growth from 2011 to 2022. This growth could be explained by an increase of incentives for EVs, additional EV models, and increased charger infrastructure. The graph below applies a linear trend to forecast future growth of EVs to provide a conservative view of new sales if sales followed a constant increase. Based on the outputs of this analysis, the EV growth expected with charger installation is around 20 percent higher. If the historical trend continues, the potential increase in sales due to charger installation could be much higher than shown here.

FORECAST OF EV GROWTH DUE TO THE INSTALLATION OF EV CHARGERS

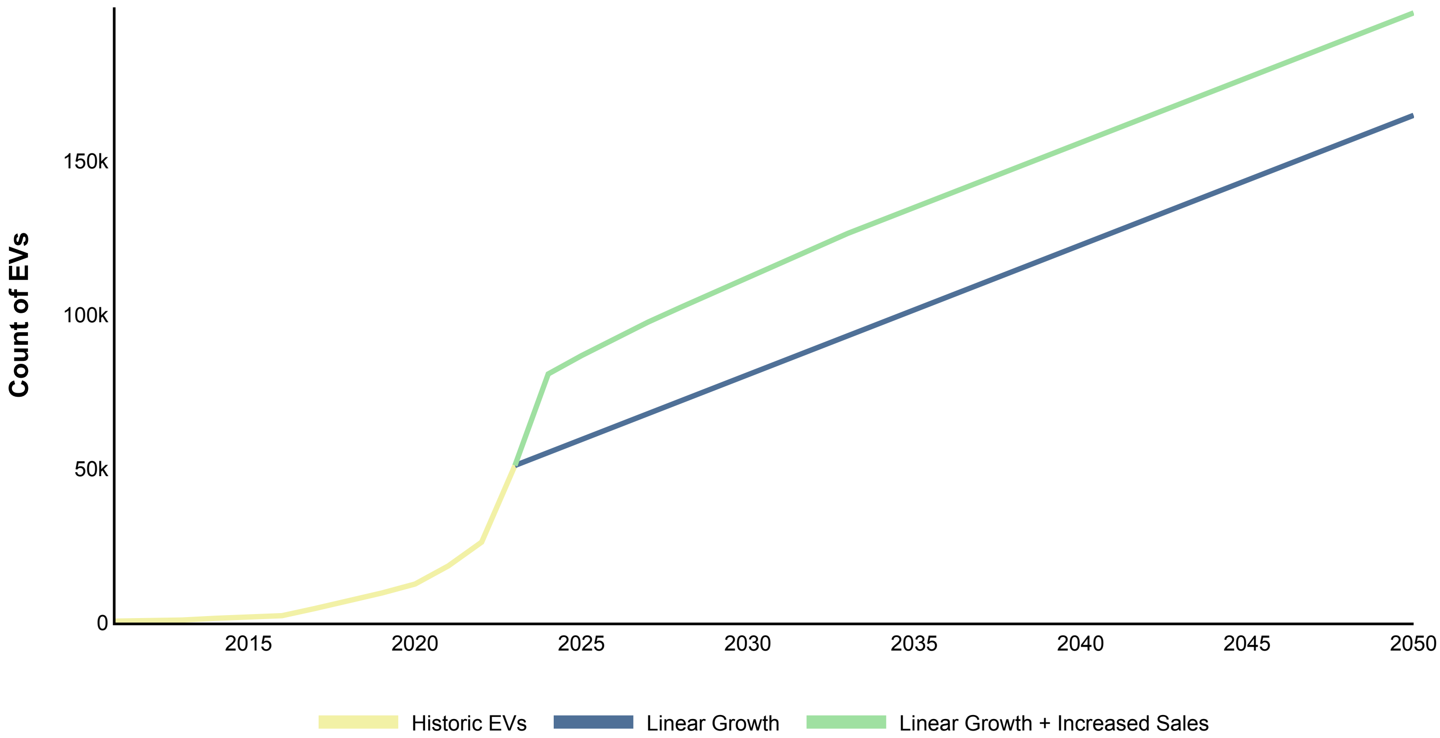


FIGURE 6.35 | SOURCE: NYC OMB

6.d.ii.3. School Bus Electrification (LL120-2021, EO53)

Criteria Screening

1. GHG Impact: 735,000 tCO_2e saved through 2050
2. Commitment: Required by local legislation, mayoral commitment
3. Responsibility: Funded in the city's budget or capital plan

Context

On April 22, 2021, Mayor Bill de Blasio committed to a 100 percent electric school bus fleet by 2035. Enacted November 7, 2021, Local Law 120 of 2021 (LL120) builds on Executive Order 53 to have an all-electric, carbon-neutral fleet by 2040[43,44]. LL120 requires that all school buses in use by September 1, 2035 be all-electric. The New York City Department of Education (DOE) is required to report to the mayor and the speaker of the city council on interim implementation targets as of July 1 of 2023, 2028, and 2033.

Model Methodology

The School Bus Electrification model generates a forecast through 2050 for GHG emissions reductions due to electrification of the school bus fleet. The model is performed in Microsoft Excel.

The model uses the following external inputs:

- School bus mileage and vehicle data from DOE and MOCEJ. These data are used to estimate the average yearly mileage of school buses.
- New York State Registration Data 2022 from the New York State Department of Motor Vehicles. These data are used to estimate the current fuel and vehicle type mix of New York City's school bus fleet[95].
- The School Bus Electrification Compliance Pathway, which is based on the anticipated school bus retirement from DOE and MOCEJ. These data are used to forecast the replacement of fossil fuel buses and purchasing of electric school buses.
- Electric school bus efficiency data from the Electric School Bus U.S. Market Study and Buyers Guide, developed by World Resources Institute (WRI). These data are used to estimate the forecasted electricity consumption of new electric school buses[96].
- WRI Electric School Bus tracking dataset. These data are used to confirm the current school bus fleet count.
- Data from the U.S. EPA's Clean School Bus Program Awards. These data are used to confirm new, anticipated electric school buses[97].

The model takes the following assumptions:

- School bus electrification will follow a phased pathway that targets older buses and delays rapid school bus electrification to later years. This adoption pathway follows the table below which assumes that from 2023 to 2026 electric bus replacement begins with transitioning 50 percent of buses that are reaching end of life (EOL), which scales up to 100 percent of buses reaching EOL in 2027. From 2028 through 2034, buses are transitioned linearly at a rate of 1,100 buses per year. This pathway will be aligned to meet state and city commitments.
- Based on vehicle information from the WRI and DOE, the assumed split of the fleet is 60 percent Type A and 40 percent Type C. This distinction is important because different bus types have different ranges and fuel efficiencies. The average efficiencies are applied to the respective bus types.

Note the following exclusions and limitations:

- The selected compliance pathway attempts to consider supply chain or operations constraints that may impact this commitment by delaying a steady transition to electric school buses to the later years of the commitment window. Other compliance pathways were analyzed in other versions of this model.
- A significant portion of the school bus fleet is operated by private operators that have differing barriers to EV adoption, including limited EV charging infrastructure and the capital cost of new electric buses.

ASSUMED ELECTRIC SCHOOL BUS PURCHASES (2023–2035)

Year	Cumulative Stock of Electric Buses	Number of Bus Purchases per Year
2023	50	50
2024	125	75
2025	250	125
2026	705	455
2027	1,441	736
2028	2,572	1,131
2029	3,702	1,131
2030	4,833	1,131
2031	5,963	1,131
2032	7,094	1,131
2033	8,224	1,131
2034	9,355	1,131
2035	10,485	1,131

FIGURE 6.36 | SOURCE: MOCEJ, with DOE

Given the inputs and assumptions, the following steps are applied to generate the forecast:

1. Collect school bus data. Working with DOE, characteristics of the school bus fleet were obtained. The key characteristics are bus type (Type A or C), bus age, fuel type, and mileage.
2. Determine the distribution of fuel type and bus type. Using the most recent registration data and information provided by DOE, an estimate of the quantity of gas, diesel, and electric buses is generated. This estimate is generated by finding the fuel mix of school buses in DOE and Department of Motor Vehicle's datasets. Based on these datasets, 90 percent of buses were able to be identified as gasoline, diesel, or electric. Following the equation below, a percentage for each fuel type was found. These data are supplemented with WRI data on school bus fleets to assume the split between Type A and Type C buses. The school bus fleet mainly utilizes Type A and Type C buses to provide its transportation services. Note that Type A buses, also known as “minibuses,” are typically 20 feet long, and are mainly used for Preschool and door-to-door routes. Alternatively, Type C buses are typically 35 feet long and are used to transport students on “general shuttle” routes.

$$Gasoline\_Percentage\_of\_Fleet = \frac{\#\_Gasoline\_School\_Buses}{Total\_School\_Bus\_Fleet}$$

3. Identify an electrification pathway. Given the parameters of the law, 100 percent of New York City’s school bus fleet must consist of zero-emissions vehicles by 2035. The selected pathway considers this deadline as well as operational barriers like cost and a limited supply chain in the near term. From 2023-2027, 50 percent of buses that reach EOL will be electrified. By 2027, this number scales up to 100 percent of EOL buses being transitioned to electric models. After 2028, there is a linear increase in electric school bus purchases to meet the goal of full electrification.
4. Determine School Bus Electrification model options. At the time of the analysis, DOE had 10 electric school buses in operation. It is assumed that models similar to those in operation or purchased through the Clean School Bus Program will replace compatible buses. For buses that do not have a similar model in operation, information from the Electric School Bus Buyer Guide is used as a supplement.
5. Compute the change in bus stock. Following the identified electrification pathway, the number of expected electric bus purchases in a year are separated into their respective bus types (A or C) and respective fuel type (gas or diesel). Then to calculate the change in emissions the formula is used for each bus and fuel type. The below example is for gasoline type A buses.

$$gal\_Gasoline_t = gal\_Gasoline_{t-1} - \left(\#\_Gasoline\_A\_Buses\_Replaced \times \frac{gal\_Gasoline}{Mile} \times Bus\_VMT_t\right)$$

Context

In Figure 6.37, the current projection shows a linear trend of electric school bus purchases. Funding and the availability of charging infrastructure has the potential to delay or modify the projected trajectory of electric school bus purchases. Further analysis will consider any new incentives available for electric school bus purchases and charging infrastructure needed to support them.

PROJECTION OF ELECTRIC SCHOOL BUSES

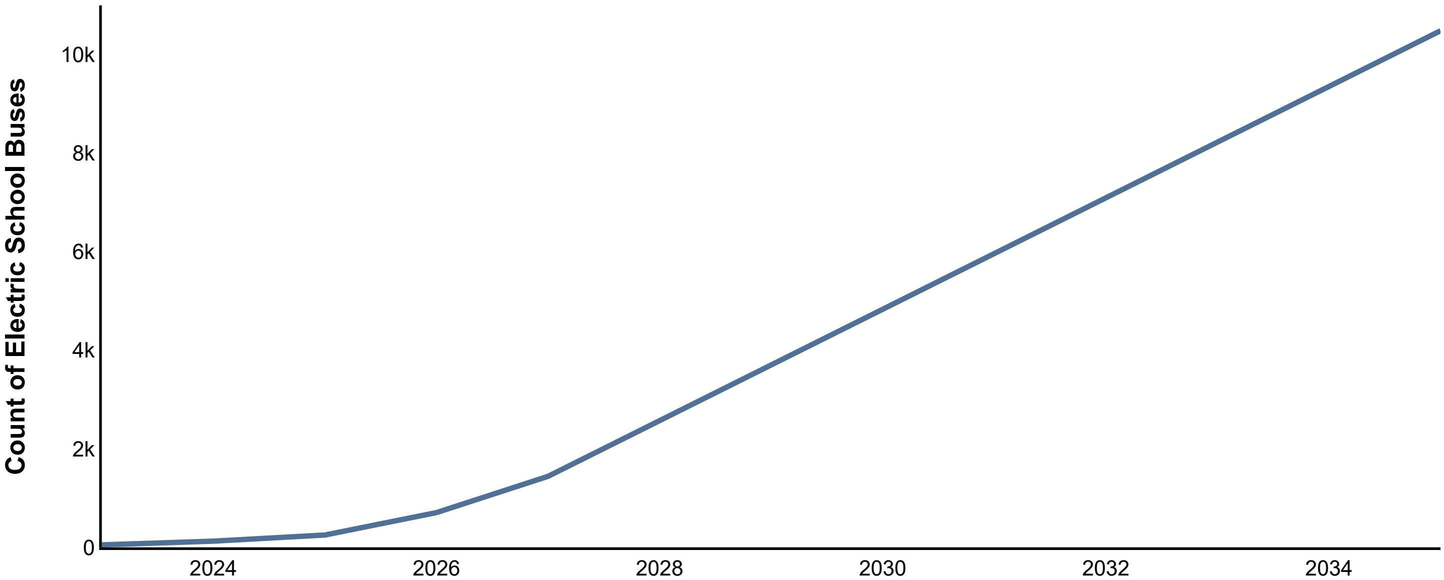


FIGURE 6.37 | SOURCE: MOCEJ, with DOE

6.d.ii.3. Bus Lanes (DOT Streets Plan, LL195-2019)

Criteria Screening

1. GHG Impact: 470,000 tCO_2e saved through 2050
2. Commitment: Required by local legislation, mayoral commitment
3. Responsibility: Funded in the city's budget or capital plan

Context

Local Law 195 of 2019 (LL195) directed DOT to issue and implement a transportation master plan every five years, beginning in 2021[45]. This plan must emphasize reducing vehicle emissions, improving access for individuals with disabilities, and increasing street safety and mass transit use. In addition, the law requires the development of 150 miles of physically protected or camera-protected bus lanes by 2026. At least 20 miles of bus lanes must be developed in the first plan year, and at least 30 miles in each successive year. Annually, DOT must publish an update on the plan, highlighting new initiatives and reporting progress.

Model Methodology

The Bus Lanes model generates a forecast through 2050 for GHG emissions reductions due to commuters switching from cars to buses. The substitution rate is influenced by the increased availability of bus lanes. The model is performed in Microsoft Excel.

The model uses the following external inputs:

- 2022 bus-lane location and length from New York City Open Data, provided by DOT. These data are used to construct the baseline of current bus lanes[98].
- The 2022 Citywide Mobility Survey (CMS) from New York City Open Data, provided by DOT. These data are used to estimate the travel patterns of New York City commuters[99].
- Statewide mode-share factor from the Federal Highway Administration's National Household Travel Survey. These data are used to estimate the average vehicle occupancy[100].
- Elasticity of transit ridership from the Bus Rapid Transit Practitioner's Guide, developed by the Transportation Research Board (TRB). These data are used to estimate increased ridership from bus-lane improvements[101].
- Formula for assessing the GHG reductions of transit-supportive roadway treatments from the California Air Pollution Control Officers Association's Handbook for Analyzing Greenhouse Gas Emission Reductions, Assessing Climate Vulnerabilities, and Advancing Health and Equity[102].

The model takes the following assumptions:

- Improvements to bus lanes will increase speed, and reliability will increase ridership.
  - The Bus Rapid Transit Practitioner's Guide details the potential ridership increases up to 15 percent due to implementation of exclusive lanes for buses.
  - Transit preferential treatments like transit signal priority, exclusive lanes, and queue jumping will have similar travel-time reductions.
  - According to the CMS, 38 percent of respondents who reduced their household's vehicle count started to use public transit, while 18 percent of respondents who increased their vehicles found that transit either inaccessible for a new job or unreliable, highlighting how public transit is incorporated in an individual's decision to buy a vehicle.
- Since the law allows for both new, protected bus lanes and protecting existing bus lanes, any new bus lane additions pursuant to the law will be treated as an upgrade of an existing lane. This analysis takes this conservative assumption due to the uncertainty of the placement of future bus lanes.
- Since the law allows for both new protected bus lanes and protecting existing bus lanes, any new bus lane additions pursuant to the law will be treated as an upgrade of an existing lane. This analysis takes this conservative assumption due to the uncertainty of the placement of future bus lanes. The original formula from the Handbook for Analyzing Greenhouse Gas Emission Reductions, Assessing Climate Vulnerabilities, and Advancing Health and Equity uses total transit mode share while this analysis only considers the mode share of buses to constrain the VMT reductions to bus commuters.

Note the following exclusions and limitations:

- VMT reduced from bus-lane improvements is highly location specific. Since this model assigns an average reduction for lane-mile protected, it will underestimate the impact of the improvement of a particular bus lane.

Given the inputs and assumptions, the following steps are applied to generate the forecast:

1. Determine citywide mode share. Transit mode share of buses in the city (E) and vehicle mode share in the city (F) are found in the CMS, which surveys preferred modes of travel to obtain a representation of the city's travel profile. In the 2022 CMS, it was estimated that bus trips represent 5 percent of the public transit trips taken in the city, while 31 percent of trips are taken by a private vehicle.
2. Compute bus-lane additions. The projected percent of transit routes that receive treatments (B), defined as installing protection to bus lanes, are assumed to conform to what is written in the law. Since the first compliance year is 2021, the assumed start of bus-lane installations is the year following the current year, in this case 2023. The subsequent bus-lane improvements or installations will follow the requirements of the law.

$$\%\_Lanes\_Treated = \frac{Cumulative\_\#\_Bus\_Lanes\_Upgraded}{Total\_\#\_Bus\_Lanes}$$

3. Determine the effect of bus lanes. The percent change in travel time due to treatments (C) and the elasticity of transit ridership with respect to travel time (D) are given by the TRB's Bus Rapid Transit Practitioner's Guide, sponsored by the Federal Transit Administration. Based on observations and research on the effects of operational improvements, reduced travel time due to replacing or complementing existing routes resulted in a median elasticity of -0.4. This elasticity is derived from several United Kingdom and United States studies that found estimated the elasticity of transit under the change of service[103,104]. The estimates are based on historical data of service level increase due to transit-supportive treatments and/or data from practical demonstrations of similar treatments. The TRB reports that travel time savings due to transit signal priority typically ranged from 8-12 percent; for this analysis a midpoint of 10 percent is used. The statewide mode shift factor ($\boldsymbol{G}$), a ratio used to estimate the amount of VMT displacement expected from a mode shift from a private vehicle to public transit based on average vehicle occupancy (1/average vehicle occupancy), is calculated using the Federal Highway Administration's travel survey. This factor is based on average vehicle occupancy, which estimates how much VMT is affected if a vehicle is taken off the road.
4. Compute the percent reduction in VMT. The output, a percent reduction in VMT, is applied to all passenger car fuel types.

$$\boldsymbol{\%\_VMT\_Reduction = -1 \times \frac{(B \times C \times D \times E \times G)}{F}}$$

Discussion

Figure 6.38 shows the number of protected bus lane-miles completed in a given compliance year. This model finds that protected bus-lane installations have not met their target for 2022 and 2023. Future analysis will consider changes in the rate of bus lane installation, as this will affect or even delay the trajectory of the projected emissions reductions.

CURRENT AND TARGET INSTALLATION OF BUS LANES FOR 2022 AND 2023 COMPLIANCE YEARS

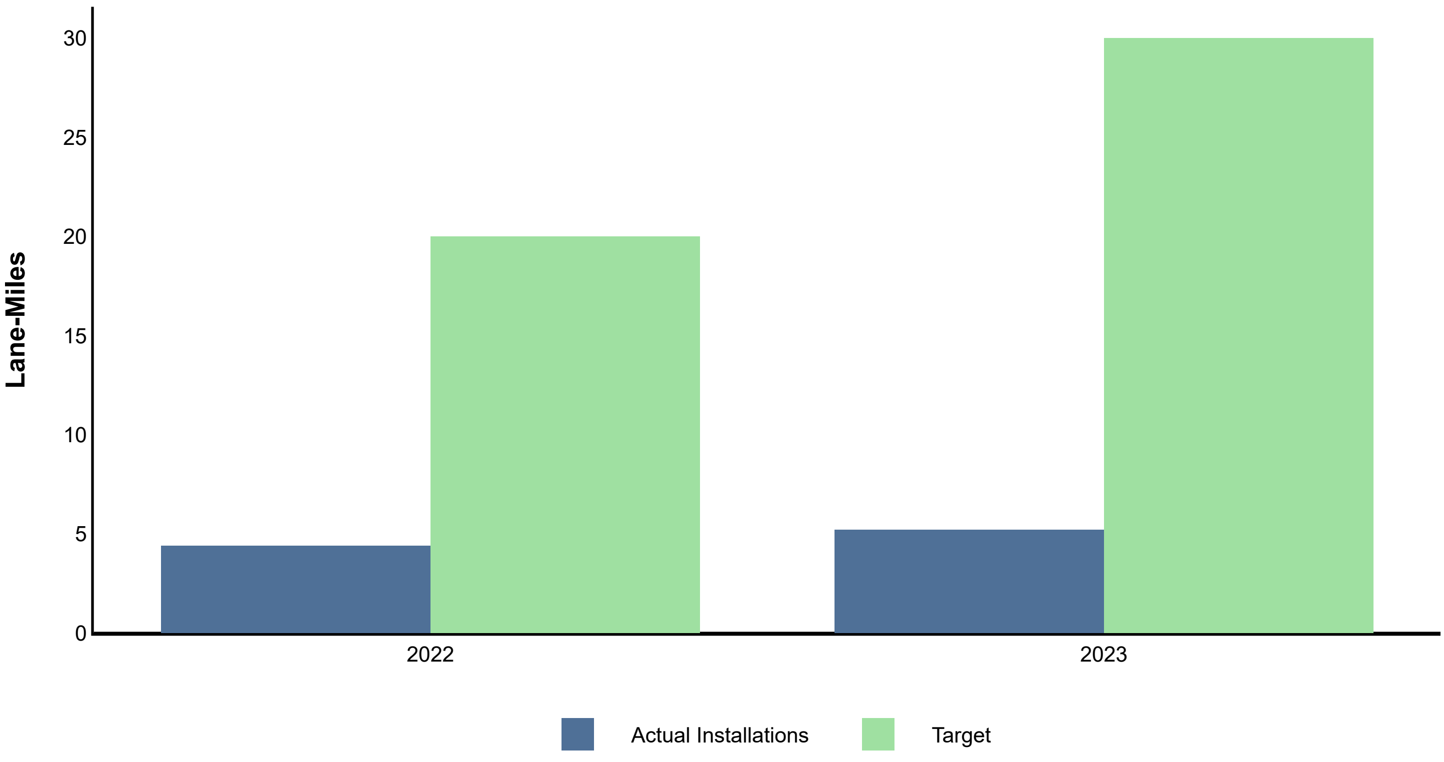


FIGURE 6.38 | SOURCE: NYC OMB

6.d.ii.4. Bike Lanes (DOT Streets Plan, LL195-2019)

Criteria Screening

1. GHG Impact: 230,000 tCO_2e saved through 2050
2. Commitment: Required by local legislation, mayoral commitment
3. Responsibility: Funded in the city's budget or capital plan

Context

LL195 directed DOT to issue and implement a transportation master plan every five years, beginning in 2021. This plan must emphasize reducing vehicle emissions, improving access for individuals with disabilities, and increasing street safety and mass transit use. In addition, the law requires development of at least 250 miles of protected bike lanes. Annually, DOT must publish an update on the plan, highlighting new initiatives and reporting progress.

Model Methodology

The Bike Lanes model generates a forecast through 2050 for GHG emissions reductions due to commuters switching from cars to bikes. The substitution rate is influenced by the increased availability of bike lanes. The model is performed in Microsoft Excel, QGIS, and R Studio.

The model uses the following external inputs:

- Mode preference for New York City commuters from DOT's 2022 CMS. These data are used to estimate the travel patterns of New York City commuters[99].
- New York City bike-lane expansion between 2005-2022, from DOT (These data are used to develop a trend of bike-lane installation[105].
- One-year bike commuter estimates from the American Community Survey (ACS) (B08006) 2005-2022. These data are used to develop a trend of commuter biking in New York City[106].
- Citi Bike fleet data 2013-2023. These data are used to develop a trend of Citi Bike installation in New York City[107,108].

The model takes the following assumptions:

- Increasing the connectivity of bike lanes will encourage commuters to utilize micromobility options instead of private vehicle use. This is determined by the bike lane's vicinity to points of interest and the roadway's level of utilization determined by average daily traffic.
- The increase in ridership will consider concerns of safety and accessibility. New bikers are making a conscious decision to bike given the current biking landscape. This aligns with the initial assumption that protected bike lanes are a significant driver of new bike trips.
- The existence of Citi Bike or bike-sharing services are an integral part of bike ridership growth. The 2022 CMS asked Citi Bike users what mode they would have used if Citi Bike had not been available. 12.6 percent of respondents said they would have used a private vehicle, taxi, or for-hire vehicle, highlighting the importance of Citi Bike in transportation mode choices. This analysis only considers bicycles as the mode-share option due to unreliability of the tracking of other modes and the robustness of bike-commute data going back to 2005.

Note the following exclusions and limitations:

- VMT reductions from bike-lane installment are highly location specific. For simplicity, this model assigns an average reduction per lane-mile added, likely underestimating the impact of the improvement of a particular bike lane.
- This analysis does not differentiate electric bikes from more-traditional mechanical bikes. Electric bikes have different use cases and the chance to displace longer-distance driving trips, which this model does not capture.
- This analysis does not output ridership increases on a borough-by-borough basis that would capture the differing sensitivities to the installation of biking infrastructure. For example, the CMS specifically for Manhattan shows that bike-lane installations in the borough may have a greater effect on public transit than private vehicle use. This is likely due to the unique travel patterns present in Manhattan. Based on the CMS (Figure 6.39), commuters that start and end in Manhattan tend to rely on walking or public transit over vehicle use for short distance trips (up to two miles) and even longer trips (two or more miles). These characteristics show that new bike trips may displace some walking or public transit trips. In the citywide view, vehicle use is more prevalent in trips greater than one mile (Figure 6.40).

SHARE OF NON-BIKE TRIPS AT EACH TRIP DISTANCE – STARTED OR ENDED IN MANHATTAN

Trip Distance *(miles)*	Walk	Bus	Commuter Rail	Subway	Private Vehicle	FHV	Micromobility	Ferry	Other
≤ 0.5	93.20%	1.30%	2.30%	0.00%	2.20%	0.40%	0.40%	0.10%	0.00%
0.5 – 1	67.30%	9.10%	13.90%	0.60%	8.10%	0.30%	0.10%	0.50%	0.00%
1 – 2	25.00%	11.30%	37.70%	0.30%	10.70%	7.90%	5.50%	0.70%	0.80%
2 – 5	6.90%	7.70%	61.00%	0.40%	15.00%	6.70%	0.50%	0.80%	1.00%
5 – 10	1.20%	4.30%	67.50%	1.60%	17.10%	4.50%	0.10%	1.00%	2.80%
≥ 10	0.40%	14.00%	34.00%	8.00%	34.00%	4.50%	0.20%	1.80%	3.10%

FIGURE 6.39 | SOURCE: NYC DOT

SHARE OF NON-BIKE TRIPS AT EACH TRIP DISTANCE – CITYWIDE

Trip Distance *(miles)*	Walk	Bus	Commuter Rail	Subway	Private Vehicle	FHV	Micromobility	Ferry	Other
≤ 0.5	86.20%	1.10%	0.00%	1.40%	10.20%	0.20%	0.20%	0.00%	0.50%
0.5 – 1	54.60%	6.70%	0.30%	7.60%	29.40%	1.00%	0.10%	0.00%	0.30%
1 – 2	18.70%	8.50%	0.10%	16.30%	50.90%	3.40%	1.50%	0.30%	0.40%
2 – 5	5.50%	10.20%	0.40%	30.80%	47.00%	4.60%	0.40%	0.50%	0.60%
5 – 10	1.20%	4.10%	1.50%	43.40%	42.90%	4.20%	0.00%	1.60%	1.10%
≥ 10	0.20%	7.60%	3.70%	19.20%	62.60%	3.80%	0.10%	1.50%	1.20%

FIGURE 6.40 | SOURCE: NYC DOT

- According to the 2022 CMS, about 8 percent of all bike trips are for recreational purposes so a portion of additional bike trips would not replace trips via other modes. Since this analysis does not make any assumptions about recreational trips, the output will be slightly overestimated.
- Bike ownership is not considered explicitly since the existence of Citi Bike is included, which is assumed to address some bike ownership concerns. Alternatively, since Citi Bike is a paid service, the cost of utilizing a bike in their fleet my impact a potential user's decision and would not address bike ownership for that subset of commuter. This analysis does not include Citi Bike cost, only the existence of Citi Bike infrastructure. Citi Bike is included by itself because it is the largest docked bike share system in New York City as shown by a recent mapping of bike-share and e-scooter systems in the U.S from the U.S. Department of Transportation's Bureau of Transportation Statistics[109].
- This analysis only considers a mode shift from vehicles to bikes. This will not capture any other micromobilty options that commuters consider more viable due to protected bike lanes. Given the robust data on biking trends, going back to 2005, this analysis assumes that leveraging biking data will yield a more accurate and conservative result.

Given the inputs and assumptions, the following steps are applied to generate the forecast:

1. Construct a baseline of ridership and bike lane growth. Using the American Community Survey 3-year bike commuters' dataset, DOT protected bike-lane installation data, and Citi Bike fleet data, a historical trend of biking in New York City is constructed.
2. Find the relationship between ridership and bike lane installations. Using a regression model, the number of bike commuters is examined by considering both lane mileage and the presence of Citi Bike fleet. The regression equation used is as follows:

$$\#\_Bike\_Commuters = 9,358 + (109 \times lane\_miles) + (8,543 \times Citi\_bike\_fleet)$$

HISTORICAL PROTECTED BIKE LANE-MILES, BIKE COMMUTERS, AND CITI BIKE FLEET

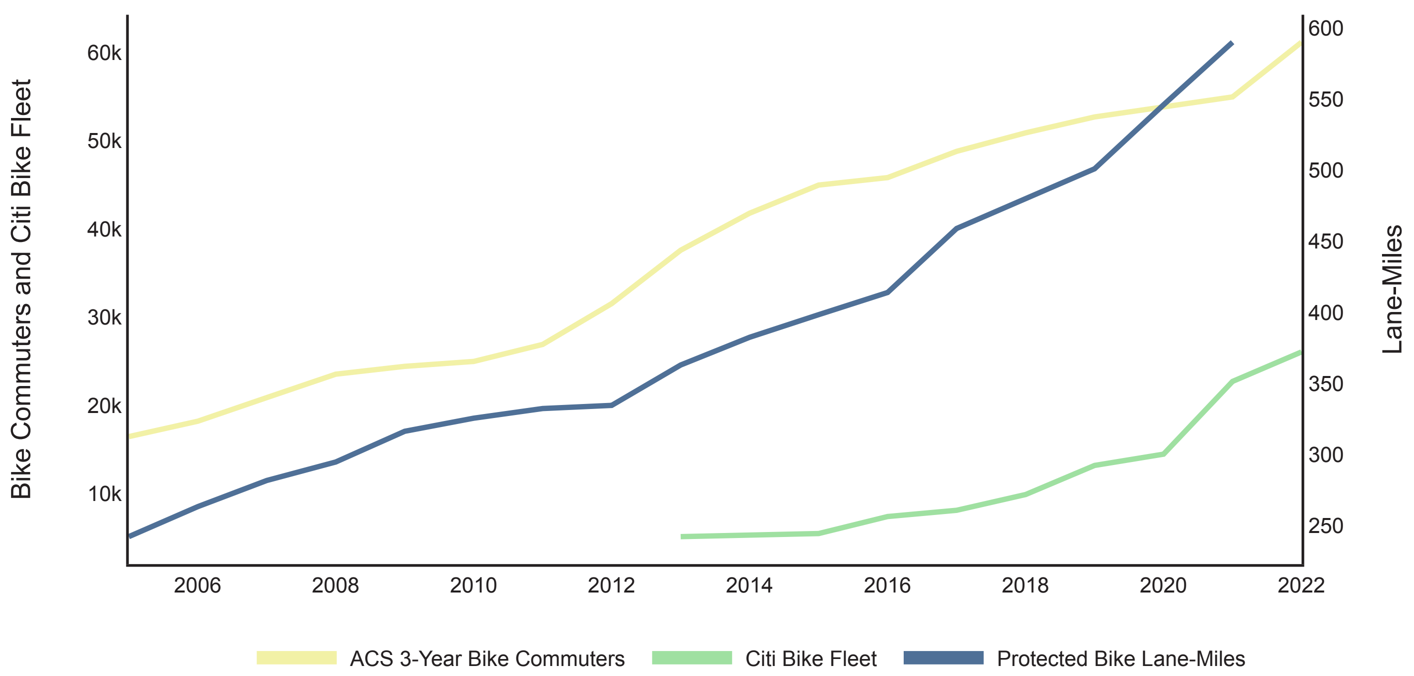


FIGURE 6.41 | SOURCE: NYC DOT

The results exhibit an R-squared value of 0.98, underscoring the robustness of this model. The regression model finds a strong correlation between bike lane mileage and daily bike commutes including the existence of Citi Bike. Both bike lane mileage and the existence of Citi Bike emerged as statistically significant factors, affirming their relevance in predicting and understanding patterns of bike commuting.

Based on the results of the regression model, this analysis estimates that each additional bike lane-mile will result in an additional 110 daily bike commutes. Assuming a commuter uses the same method to and from their destination, the initial estimate is doubled to approximate an additional 220 daily bike trips.

To extend this to citywide bike trips, this analysis uses DOT's Cycling with the City assumption that assumes that commute trips represent 20 percent of all trips. Given that commute trips are one-fifth of total trips it is expected the total additional cycling trips would be 1,100 trips.

REGRESSION EQUATION AND RESULTS

```
lm(formula = ACS ~ LaneMiles + CitiBikeExists, data = df[df$Year >= 2005 & df$Year <= 2019, ])
```

Min	1Q	Median	3Q	Max
-1,349.1	-1,065.1	-649.0	669.3	4259.7
Significance Codes:	0 '***'	0.001 '**'	0.01 '*'	0.05 '.'
Coefficients	Estimate	Std. Error	t-value	Pr(>|t|)
Intercept*	-9358.63	3321.16	-2.818	0.015521
LaneMiles***	109.50	10.92	10.023	3.49e-07
CitiBikeExistenceTrue***	8,543.84	1,667.90	5.123	0.000252

FIGURE 6.42 | SOURCE: NYC DOT

3. Mode shift estimations. To estimate which trips are affected, this model assumes that bike trips will replace modes in proportion to their current share of trips at each trip distance. For example, if 54 percent of one-to-two mile non-bike trips rely on automobiles, then 54 percent of new bike trips with one to two miles would have been auto trips (i.e., 54 percent multiplied by the share of bike trips with a distance of one to two miles). The data from Figure 6.40 and Figure 6.43 are used to calculate the number of new biking trips and the percentage of vehicle trips displaced. The output is Figure 6.44, which shows the percent of trips displaced by new biking trips. To generate Figure 6.44 the bike share at each bike trip distance in Figure 6.43 is multiplied by the share of non-bike trips (Figure 6.40), this is repeated for each mode and distance. A sample equation is shown below. The expected 36 percent shift from vehicles is the sum of all percentage shifts for all distances in the vehicle category shown in Figure 6.44. The same procedure described is used for Manhattan to generate a conservative estimate of the shift from vehicles, using Figure 6.39 and Figure 6.45. The expected shift from vehicles drops to 15 percent in Manhattan, as shown in Figure 6.46. A 15 percent shift is used in this analysis because it is in range with similar papers. A Citi Bike-focused paper, "Impact of bike sharing in New York City," shows that Citi Bike trips will likely replace 15-20 percent of private vehicle and taxi trips[110]. Additionally, a paper on mobility, "The Net Sustainability Impact of Shared Micromobility in Six Global Cities," showed that shared micromobility replaced 12-16 percent of private vehicle and ride-hailing trips[111].

$$Share\_Non\text{-}Bike\_Replaced\_by\_Bike\_Trips = Bike\_Share \times Non\text{-}Bike\_Share$$

4. Estimating reduction in VMT per bike-lane-mile added. Based on the CMS 2022, the average bike-trip distance from origin to destination is 1.7 miles; the comparable driving distance is an average of 2.4 miles. This analysis uses 2.4 miles to represent the driving distance displaced. Inputting the values into the formula shown below, there is an expected reduction of 143,000 VMT per bike lane installed.

$$Yearly\_VMT\_Reduction = Expected\_Mode\_Shift \times \frac{avoided\_driving\_miles}{trip} \times \frac{increase\_in\_trips}{day} \times \frac{365\ days}{year}$$

CHARACTERISTICS OF BIKE TRIPS IN CMS 2022

Bike Trip Distance *(miles)*	Trip Counts in Survey	7-day Weight	Share	Bike Distance *(Miles)*	
				Mean	Median
≤ 0.5	294	227,304	27%	0.3	0.3
0.5 – 1	296	188,749	23%	0.7	0.8
1 – 2	379	216,802	26%	1.4	1.4
2 – 5	418	144,587	17%	3.3	3.1
5 – 10	201	44,109	5%	6.6	6.3
≥ 10	40	9,183	1%	12.8	11.9
Total	**1,628**	**830,734**	**100%**	**1.6**	**1.5**

FIGURE 6.43 | SOURCE: NYC DOT

SHARE OF NON-BIKE TRIPS REPLACED BY BIKE TRIPS - CITYWIDE

Trip Distance *(miles)*	Walk	Bus	Commuter Rail	Subway	Private Vehicle	FHV	Micromobility	Ferry	Other
≤ 0.5	23.60%	0.30%	0.00%	0.40%	2.80%	0.10%	0.10%	0.00%	0.10%
0.5 – 1	12.40%	1.50%	0.10%	1.70%	6.70%	0.20%	0.00%	0.00%	0.10%
1 – 2	4.90%	2.20%	0.00%	4.20%	13.30%	0.90%	0.40%	0.10%	0.10%
2 – 5	1.00%	1.80%	0.10%	5.40%	8.20%	0.80%	0.10%	0.10%	0.10%
5 – 10	0.10%	0.20%	0.10%	2.30%	2.30%	0.20%	0.00%	0.10%	0.10%
≥ 10	0.00%	0.10%	0.00%	0.20%	0.70%	0.00%	0.00%	0.00%	0.00%
Total	**41.90%**	**6.10%**	**0.30%**	**14.30%**	**33.90%**	**2.20%**	**0.50%**	**0.30%**	**0.50%**
					Vehicle trips: 36.10%				

FIGURE 6.44 | SOURCE: NYC DOT

CHARACTERISTICS OF BIKE TRIPS IN CMS 2022 - STARTED OR ENDED IN MANHATTAN

Bike Trip Distance *(miles)*	Trip Counts in Survey	7-day Weight	Share	Bike Distance *(Miles)*	
				Mean	Median
≤ 0.5	86	23,746	9%	0.3	0.3
0.5 – 1	114	85,172	34%	0.7	0.7
1 – 2	157	63,829	26%	1.4	1.4
2 – 5	194	47,948	19%	3.4	3.4
5 – 10	127	24,626	10%	6.5	6.2
≥ 10	22	4,765	2%	12	11.6
Total	**700**	**250,087**	**100%**	**2.2**	**2**

FIGURE 6.45 | SOURCE: NYC DOT

SHARE OF NON-BIKE TRIPS REPLACING BIKE TRIPS - MANHATTAN

Trip Distance *(miles)*	Walk	Bus	Commuter Rail	Subway	Private Vehicle	FHV	Micromobility	Ferry	Other
≤ 0.5	8.90%	0.10%	0.20%	0.00%	0.20%	0.00%	0.00%	0.00%	0.00%
0.5 – 1	22.90%	3.10%	4.70%	0.20%	2.80%	0.10%	0.00%	0.20%	0.00%
1 – 2	6.40%	2.90%	9.60%	0.10%	2.70%	2.00%	1.40%	0.20%	0.20%
2 – 5	1.30%	1.50%	11.70%	0.10%	2.90%	1.30%	0.10%	0.10%	0.20%
5 – 10	0.10%	0.40%	6.60%	0.20%	1.70%	0.40%	0.00%	0.10%	0.30%
≥ 10	0.00%	0.30%	0.60%	0.20%	0.60%	0.10%	0.00%	0.00%	0.10%
Total	**40%**	**8%**	**34%**	**1%**	**11%**	**4%**	**2%**	**1%**	**1%**
					Vehicle Trips: 15%				

FIGURE 6.46 | SOURCE: NYC DOT

Discussion

Figure 6.47 shows the number of protected bike lane-miles completed in a given compliance year. This shows that bike-lane installations have not met their target for 2022 and 2023. Figure 6.48 shows that the expected reductions diverge in the years 2023 to 2027 and converge in 2028. Future versions of this analysis will consider changes in the rate of bike lane installation in the coming years, as this will affect the trajectory of emissions reductions projected.

CURRENT AND TARGET INSTALLATION OF PROTECTED BIKE LANES FOR 2022 AND 2023 COMPLIANCE YEARS

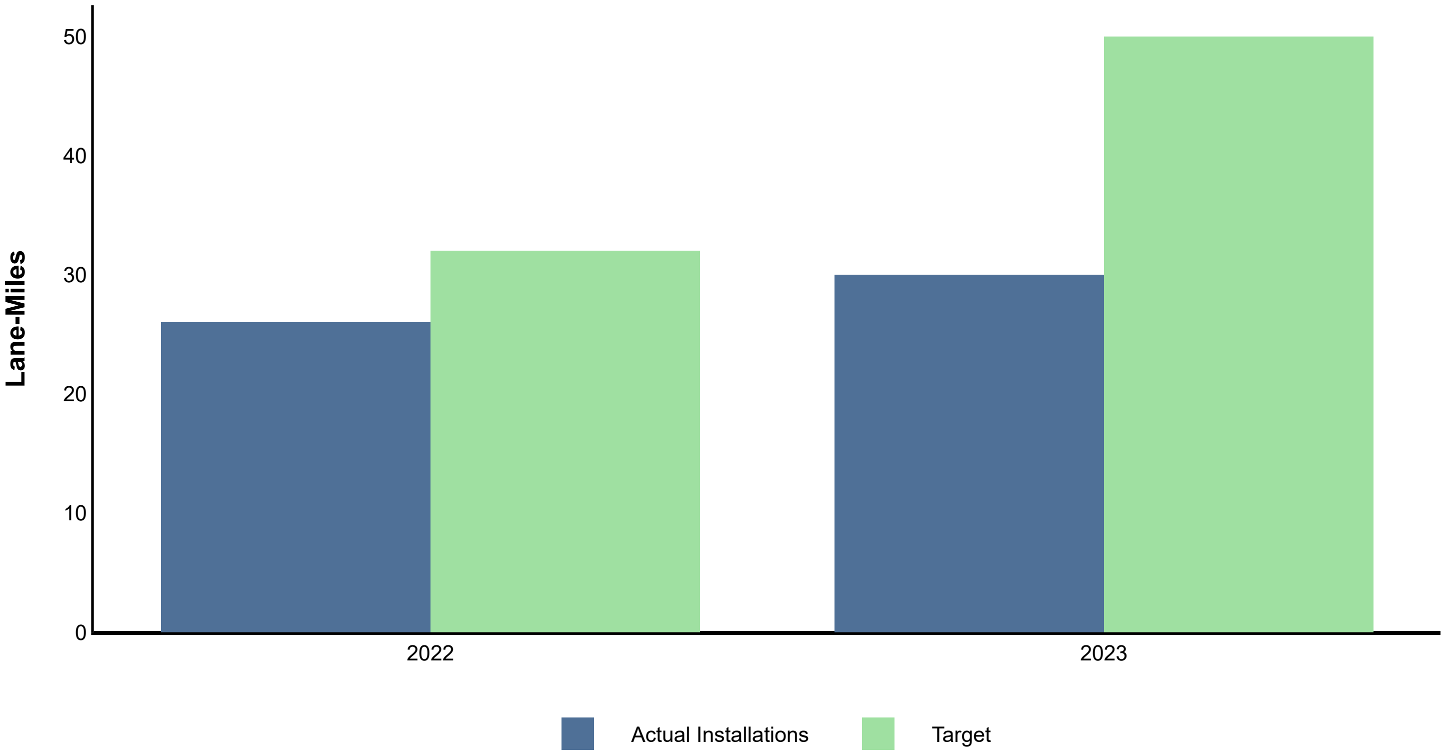


FIGURE 6.47 | SOURCE: NYC DOT

VMT REDUCTION BASED ON TARGET AND AVERAGE PROTECTED BIKE LANE INSTALLATION

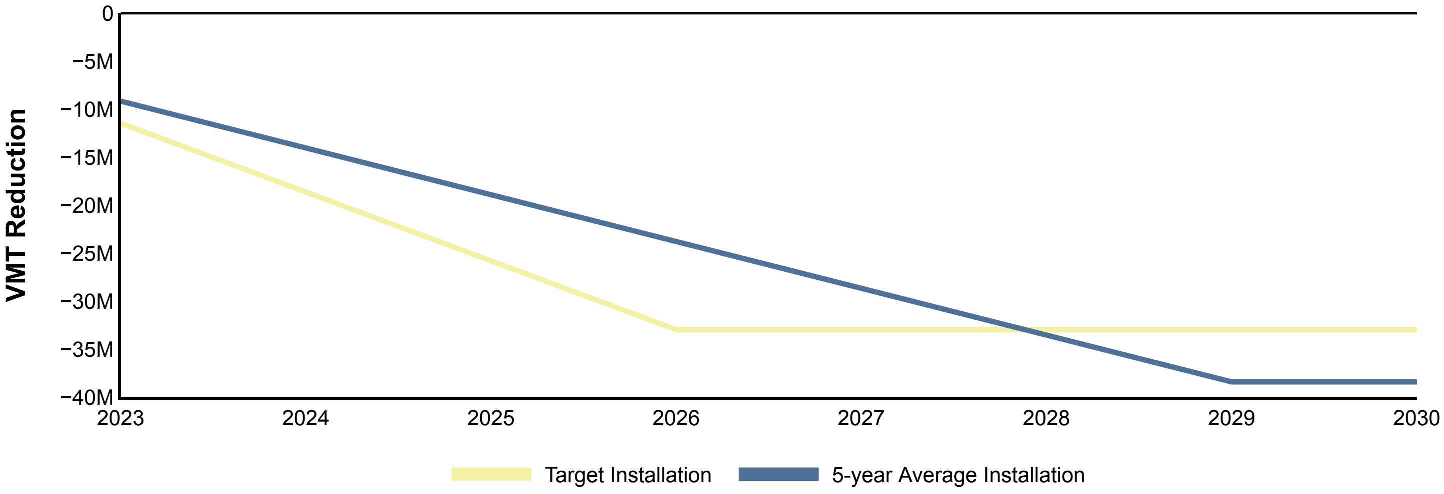


FIGURE 6.48 | SOURCE: NYC OMB

6.d.iii. WASTE SECTOR

6.d.iii.1. Mandatory Citywide Curbside Organics Collection (LL85-2023)

Criteria Screening

1. GHG Impact: 201,000 tCO_2e saved through 2050
2. Commitment: Required by local legislation, mayoral commitment
3. Responsibility: Funded in the city's budget or capital plan

Context

In 2023, Mayor Adams committed to making curbside organics collection available to all New Yorkers by the end of 2024. The city council then passed Local Law 85 in 2023 (LL85) to make residential curbside organics separation mandatory in all boroughs, beginning in October 2024, with penalties beginning in April 2025[46].

Model Methodology

The Mandatory Citywide Curbside Organics Collection model generates a forecast through 2050 for GHG emissions reductions due to the diversion of organics. The model is performed in Microsoft Excel.

The model uses the following external inputs:

- 2017 New York City Department of Sanitation (DSNY)'s Waste Characterization Study (WCS), which documents and analyzes the composition of the city's waste streams, including organic materials[112].
- 2023 DSNY organics implementation plan, which details the operations and timelines for curbside organic collected through LL85[113].
- 2022-2023 New York City waste facility data, provided by DSNY.
- Monthly waste tonnage data from the New York City Open Data portal, which provide information on the amount of waste streams collected by DSNY from residences and institutions[114].
- Recycling diversion and capture rates from the New York City Open Data portal, which provide information on how much targeted material is being recycled[115].
- Opt-in organics participation from the New York City Open Data portal, which provides information on households, residential buildings, and schools receiving curbside organics collection, including prior to LL85 when curbside collection was available by sign-up[116].
- U.S. EPA Waste Reduction Model (WARM) version 15, which estimates emissions, energy units and economic factors for materials management practices, such as composting and landfilling[117].
- The updated BEAM (Biosolids Emissions Assessment Model) tool customized to New York City's specifications (2023, Northern Tith, LLC). This is done to account for the most recent values for waste processing and deposition sites (landfills, incinerators, digesters, composting facilities, etc.) and practices[118].
- Monthly and annual precipitation at Central Park from the National Weather Service, used to determine wet-weather conditions for waste management techniques[119].

The model takes the following assumptions:

- Analysis was conducted prior to the completion of the year 2023 and values have been updated to reflect any changes after 2023. Note that baselines may differ from the New York City GHG Inventory.
- Baseline refuse is constant through 2050, even in the face of population growth. Between 2010 and 2020, the average annual change in refuse collection in each borough was less than 1 percent, indicating that with population growth, refuse has not greatly increased.
    - Curbside diversion rollout dates of March 27, 2023 for Queens; October 2, 2023 for Brooklyn; and October 7,2024 for Bronx, Staten Island, and Manhattan were used as stated by the DSNY as of November 30, 2023. For the years where curbside diversion is rolled out for a part of the year in a given borough, the diversion amounts for that borough reflect 2017's diversion values.
- NYCHA diversion in 2017 WCS was zero for organics. Currently, NYCHA is not broken out separately in the DSNY monthly waste tonnage data. Since the current datasets do not break out NYCHA waste, this analysis does to not separate NYCHA's waste stream. This waste is assumed to be in the residential organics diversion data for each borough, undifferentiated.
- A 30 percent organics capture rate is used by 2030, and 50 percent capture rate by 2050. This capture rate is based on the historical rollout of curbside recycling, assuming the organics program behaves similarly. Historical recycling capture trends show that after deployment of the program, capture rates slowly increased to 30 percent and reached a maximum of 50 percent diversion from the solid waste stream.
- The modeled target amount of yard waste getting composted (aerobically) is 80 percent (and 20 percent going to anaerobic digesters). The opposite is the case for non-yard (largely food) waste in that 80 percent is targeted to be sent to anaerobic digesters and 20 percent will go to aerobic composting facilities.
- DSNY provided 2022 data on the end sites and transfer facilities for non-commercial waste. Based on these data, this analysis assumes that 31 percent of refuse went to combustion sites, with the remaining 69 percent to landfill.
- Anything improperly recycled or put into the organics stream is incorporated into refuse. Only the organics that are accurately placed into the organics stream are considered for organics-stream emissions factors.
- No transfer of compost through community partners to curbside is accounted for, though in practice some residents who choose to bring organics to community drop-off sites could convert to curbside diversion. Organic materials composted outside of the DSNY stream are not included, and the baseline is set to zero, given that curbside opt-in composting was disrupted and removed during the COVID-19 pandemic.
- The 2017 WCS did not characterize the organics stream in Manhattan. To describe projected organics baselines for Manhattan, an average other-borough contamination rate of 5.8 percent is used, and it is assumed that all waste in the "organics" stream as labeled is food waste and all waste in the "leaves" stream as labeled is yard waste.
- Emissions factors from a mix of sources are used, based on New-York-City-specific needs. Emissions factors for WARM v15 include the emissions generated from transporting the materials by diesel truck.

Note the following exclusions and limitations:

- The monthly waste data from DSNY includes the waste picked up in several streams: refuse, paper recycling, metal-glass-plastic recycling (MGP), residential organics, school organics, leaves organics, and Christmas trees. As this analysis seeks to examine the impact of residential curbside composting only, school organics are excluded.
    - This analysis assumes that approximately 10 percent of waste may be from institutions rather than residences. All baseline tonnage values are discounted by 10 percent to account for residential values only.
- Christmas trees are also excluded, because they are collected by DSNY seasonally and are typically mulched for New York City Parks properties.
- Mulching of yard waste is not considered here—composting and anaerobic digestion are the only evaluated alternatives to landfilling and combusting refuse with organic material in this analysis.
- The materials in the paper and MGP waste streams that could have been composted properly is less than 5 percent of those streams in each borough according to the 2017 WCS. These sorting errors are assumed to be accidents, difficult to change, and not worth intervention at this time. Therefore, no shift in composting behavior for the paper and MGP streams is included in this analysis, but solely focus on a shift of organic materials from the refuse stream to dedicated organics stream.

Given the inputs and assumptions, the following steps are applied to generate the forecast:

1. Calculate growth rate for organics in the refuse stream. To calculate the annual growth rate (r) for the organics stream, the historical growth rate for 2013-2017 and 2005-2017 is calculated. The growth rate from 2013-2017, takes the 2.9 percent change and divides it by the four-year span which yields an annual growth rate of 0.7 percent. Also, this analysis considered the growth rate from 2005-2017. The 2005-2017 period shows a 6.3 percent change and yields an annual growth rate of 0.5 percent. This analysis uses the 0.5 percent growth rate since it provides a more conservative estimate given a slower rate of growth in the 2005-2013 period.

$$r = \frac{\%\_organics\_in\_waste_{2017} - \%\_organics\_in\_waste_{2005}}{2017 - 2005}$$

2. Calculate baseline waste values. Historical waste quantities (2010-2023), in short tons, are calculated from DSNY monthly tonnage data. Data are provided at the community-district level, so they are sorted and aggregated by borough and year. Waste is separated into the following streams: refuse, paper, MGP, organics, and leaves. The baseline is set to calendar year 2022, as it is the last year with comprehensive data at the time of analysis.
3. Calculate amount of compostable waste in the wrong streams. For each borough, the WCS provides the waste composition within each stream. The percent of waste that could have been composted (organics), but was instead in a different stream (indexed by j), is calculated as follows for both food and yard waste (indexed by i).

$$Share\_Organics_{ij} = \frac{Organics\_Suitable\_for\_Composting_{ij}}{All\_Waste_j}$$

$$Organics_i = All\_Waste_j \times share\_compostable\_waste_{ij}$$

4. Project annual organics waste stream size. Organics stream size, in tons, is projected as follows, where t_0 is the current year (2022), and t is the projection year.

$$organics_{it} = (historical\_organics\_stream_{t_0} \times share\_compostable\_waste_{ij|j=organics}) +$$
$$(historical\_leaves\_stream_{t_0} \times (1+r)^{t-t_0-1})$$
$$refuse_{it} = historical\_refuse\_stream_{t_0} \times share\_organics_{ij|j=refuse}) \times (1+r)^{t-t_0-1}$$

5. Project organics waste diversion tonnage. First, 2030 and 2050 maximum diversion projections are calculated based on diversion targets.

$$Organics\_Diversion_{it} = share\_diverted_t \times (organics_{it} + refuse_{it})$$

Then, intermediate-year projection values are modeled using a hybrid approach. From 2024-2030, an S-curve with rapid adoption in 2025 due to enforcement of the local law is reflected, slowing to reach a 30 percent capture rate in 2030. The trend then continues linearly until a 50 percent capture rate is reached in 2050. The sigmoidal formula used to derive organics diversion (y) values is as follows, where k is the slope of the S-curve (numbers from -1.5 to +3.5).

$$y_t = y_{max} \times \frac{e^{k\times(t-t_0)} - e^{-k\times(t-t_0)}}{e^{k\times(t-t_0)} + e^{-k\times(t-t_0)}}$$

The k values are not balanced (with an early inflection point of zero rather than a true zero midpoint) to heuristically consider the effects in 2025 where the curbside diversion program will be fully implemented across boroughs and monetary penalties will be allowed. In the most recent years of pre-COVID-19 data (FY 2016-2019), average recycling capture increased minimally each year (e.g., FY 2018-2019 was 0.2 percent), despite having an overall diversion rate in calendar year 2017 of close to 50 percent, indicating that early years are more crucial for growth than ongoing annual increases after time. This supports the early, quick adoption S-curve used followed by a slow, linear trajectory out to 2050.

EMISSIONS FACTORS FOR END-USE OF WASTE

Category	tCO_2e/short ton	Source
Food Waste Disposal (New York City Mix Of Landfill And Incineration)	0.21	New York City -specific BEAM
Food Waste Compost	(0.07)	
Food Waste Digestion And Land Applying Digestate	(0.08)	
Yard Waste Landfill	(0.17)	WARM v15
Yard Waste Combustion	(0.12)	
Yard Waste Compost	(0.05)	
Yard Waste Digestion And Land Applying Digestate	(0.09)	

FIGURE 6.49 | SOURCE: U.S. EPA and DSNY

Discussion

Figure 6.50 displays the historical average organics collection per community district in tons. The trends over time appear to coincide with the following events. In 2013, Local Law 77 initiated a voluntary curbside program pilot in Staten Island and later Brooklyn and Bronx. Organics diversion increased slowly and accelerated after 2015, when the pilot program was expanded to all boroughs. 2018 is the peak level of organics diversion as the program expansion was halted that year. Finally, the trend shows a steep decline in 2020 and 2021 as the curbside program halted for the COVID-19 pandemic from May 2020 to October 2021. Figure 6.51 displays the projected impact of the curbside organics program being expanded to all five boroughs. The amount of organics diversion rebounds to the 2018 peak by 2026. This rate of increase continues until 2031 when the trend becomes linear to reach a 50% capture rate of organics by 2050.

HISTORICAL AVERAGE ORGANICS COLLECTION PER COMMUNITY DISTRICT, TONS

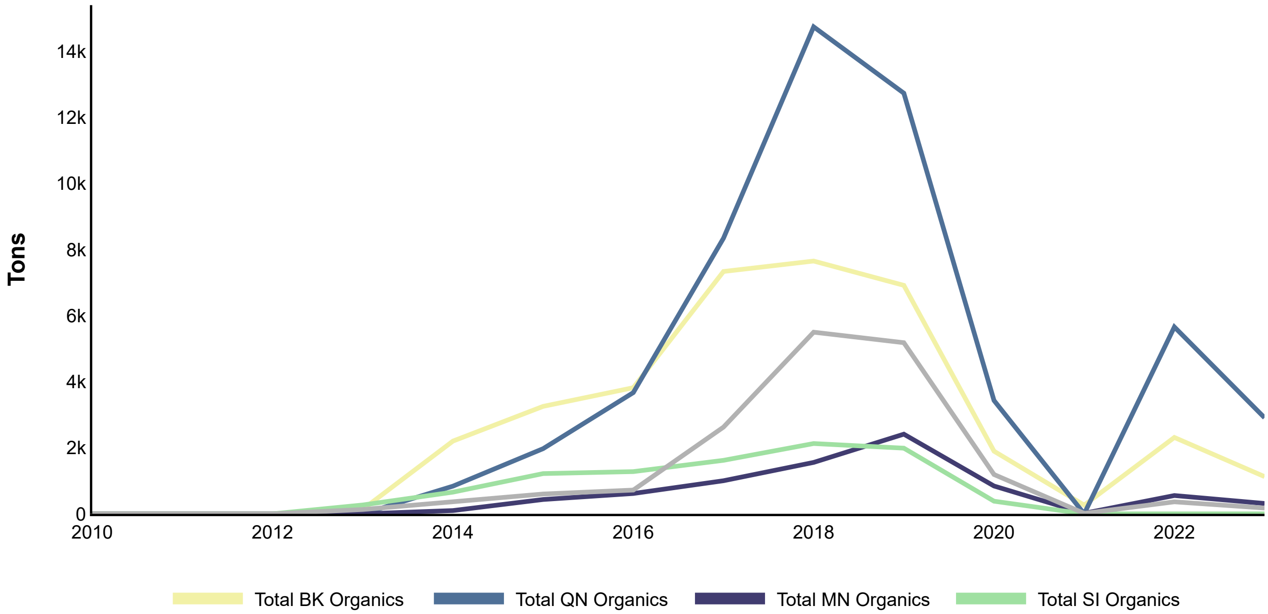


FIGURE 6.50 | SOURCE: DSNY

PROJECTED ORGANICS DIVERSION, TONS

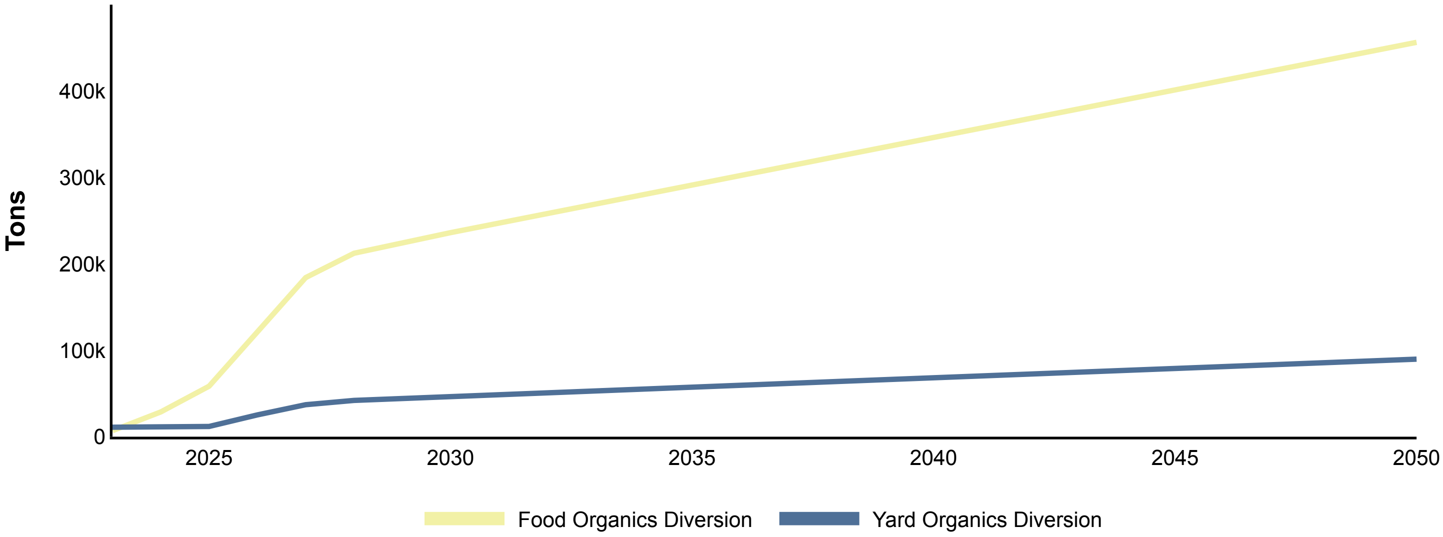


FIGURE 6.51 | SOURCE: NYC OMB

6.e. STATE ACTIONS

In addition to the city actions discussed before, OMB analysts considered a two state actions, Congestion Pricing and MTA Bus Electrification, that would directly impact GHG emissions in New York City. Similar to city actions, state actions are modeled to account for full achievement of their commitment.

6.e.i. Congestion Pricing

Context

The Manhattan Central Business District (CBD) Tolling Program, better known as congestion pricing, has two main goals. The first is to reduce traffic in the CBD, and the second is to generate $15 billion in revenue for the MTA[120]. The revenue will be allocated as follows: 80 percent to New York City subways and buses, 10 percent to Metro-North Railroad, and 10 percent to Long Island Railroad. The program will strive to achieve both goals by implementing tolls for drivers entering the CBD, affecting the activities of on-road vehicles, in particular the quantity of VMT citywide.

On April 1, 2019, the state authorized the MTA's Triborough Bridge and Tunnel Authority (TBTA) to establish the CBD tolling program as apart of its state budget making this a state action. The MTA will lead the implementation of congestion pricing. In 2007, with PlaNYC's release, Mayor Bloomberg proposed New York City's first congestion pricing plan[121]. Congestion pricing gained traction in 2019 after Governor Cuomo and Mayor de Blasio agreed to implement a congestion pricing plan officially approved in June 2023 by federal officials and scheduled to roll out in 2024.

Model Methodology

The Congestion Pricing model generates a forecast through 2045 for GHG emissions reductions due to commuter decisions to reduce VMT based on the toll. The model is performed in Microsoft Excel.

The model uses the following external inputs:

- MTA's Environmental Impact Assessment using the New York Best Practices Model (BPM), developed by the NYMTC. These data are used to estimate the VMT reduction of a selected tolling scenario[122].
- VMT by passenger cars, medium-duty trucks, and heavy-duty trucks from the New York City 2022 GHG Inventory, developed by MOCEJ. These data are used to demonstrate each tolling scenarios' impacts on total VMT in New York City.
- A toll structure recommendation from the Traffic Mobility Review Board. This reference is used to select the most comparable tolling scenario.

The model takes the following assumptions:

- VMT reductions will be consistent with the outputs from NYMTC's BPM. The BPM is an activity-based model that simulates the number and types of journeys each resident makes on an average weekday in the region. The BPM model can simulate the travel patterns of the tri-state (New York, New Jersey, and Connecticut) region as a whole and offers a more conservative estimate of the effects of congestion pricing.

- To capture the decisions of a commuter, the BPM utilizes socioeconomic data, such as, the social characteristics (e.g., population, social groups, facilities) of travelers to the CBD, and their economic characteristics (e.g., income and employment). These socioeconomic data are linked to a multitude of travel datasets like the National Household Travel Survey, which is a survey designed to capture how and why people travel, and the Hub Bound Travel Data Report 2019 for transit ridership and bridge crossings data. The model then uses these data to produce a model that simulates daily traffic flows and travel usage in the study area[123]. The BPM utilizes the value of time to incorporate the trade-offs commuters face when weighing their travel options. The value of time is a monetary value that a person uses to judge how much time they are willing to spend traveling. The value of time changes depending on a person's income, travel mode, and travel purpose. This way of monetizing travel time allows the BPM to represent the cost sensitivity of various travelers in response to tolling.
- Since the core model forecasts citywide emissions to 2050, this analysis assumes the reductions achieved in 2045 (forecast year in the BPM) will continue to 2050.
- The greatest reductions will be seen in the passenger car category. Passenger car trips have more alternative options to fulfill their trip purpose than that of a medium- or heavy-duty truck. This assumption is made for two reasons:
  - Private passenger cars make up 87 percent of the vehicles in the CBD and approximately 90 percent of the vehicles citywide.
  - Trips in private passenger vehicles can be fulfilled via alternative travel options like public transit and micromobility devices (bikes and e-bikes). In comparison, trips in medium-duty and heavy-duty vehicles tend not to have the same options as modeled in the BPM.
- The Environmental Impact Assessment details the potential impacts of seven tolling scenarios. For this analysis, Scenario B was chosen as a conservative estimate. All scenario options are outlined below with the E-ZPass peak toll amounts for passenger vehicles, and medium- and heavy-duty trucks.
  - **Scenario A:** Base Plan ($9). Passenger vehicles, commercial vans, and motorcycles receive no more than one toll per day. Taxis, FHVs, buses (transit and school buses), and medium- and heavy-duty trucks pay the toll each time they access the CBD.
  - **Scenario B:** Base Plan with Caps and Exemptions ($10). This scenario will function similarly to A but places a cap on the number of times medium- and heavy-duty trucks are tolled. In this scenario, medium- and heavy-duty trucks will receive no more than two tolls per day. Buses are exempt from the toll.
  - **Scenario C:** Low-Crossing Credits for Vehicles Using Tunnels to Access the CBD with Some Caps and Exemptions ($14). Vehicles with E-ZPass that access the CBD by using the four tunnel crossings (Hugh L. Carey Tunnel, Queens-Midtown Tunnel, Holland Tunnel and Lincoln Tunnel) receive a crossing credit, reducing the cost differential to manage "bridge shopping" (where drivers choose a route based on cost rather than time). Taxis are exempt from the toll. FHVs receive no more than three tolls per day. Buses and medium- and heavy-duty trucks pay the toll each time they access the CBD.
  - **Scenario D:** High-Crossing Credits for Vehicles Using Tunnels to Access the CBD ($19). E-ZPass holders are awarded a higher crossing credit, further reducing the cost differential for drivers who already pay tolls. Taxis, FHVs, buses, and medium- and heavy-duty trucks pay the toll each time they access the CBD.
  - **Scenario E:** High-Crossing Credits for Vehicles Using Tunnels to Access the CBD with Some Caps and Exemptions ($23). Maintains the same crossing credits as Scenario D. Taxis and FHVs receive no more than three tolls per day. Transit buses are exempt, while non-transit buses (privately operated and jitneys) and medium- and heavy-duty trucks pay the toll each time they access the CBD.

- **Scenario F:** High-Crossing Credits for Vehicles Using Manhattan Bridges and Tunnels to Access the Manhattan CBD, with Some Caps and Exemptions ($23). Crossing credit eligibility is extended to include all vehicles with E-ZPass that enter the CBD and have used a tolled crossing to access Manhattan (Robert F. Kennedy, Henry Hudson, and George Washington bridges). Taxis, FHVs, and medium- and heavy-duty trucks will only receive a toll once per day. Buses are exempt.
- **Scenario G:** Base Plan with Same Tolls for All Vehicle Classes ($12). This scenario will function similarly to scenario A with changes to the peak toll rates for vehicle classes. To reduce the number of trucks diverted, it applies the same toll rates to all vehicle classes instead of charging higher rates to medium- and heavy-duty trucks and buses. Passenger vehicles, commercial vans, and motorcycles receive no more than one toll per day.

COMPARISON OF TOLLING SCENARIOS

Vehicle Class	Scenario B	Scenario B (meets revenue target)	Proposed Scenario as of March 2024	Scenario C
Passenger Car / Commercial Vans Toll	Peak E-ZPass toll ($10), capped once per day	Peak E-ZPass toll ($13), capped once per day	Peak E-ZPass toll ($15), capped once per day	Peak E-ZPass toll ($14), capped once per day
Medium- And Heavy- Duty Trucks	Peak E-ZPass toll ($20-$30), capped twice per day	Peak E-ZPass toll ($26-$40), no cap	Peak E-ZPass toll ($24-$36) toll, no cap	Peak E-ZPass toll ($28-$42 toll), no cap
Transit And School Buses	Exempt	Only transit buses exempt	Transit Buses and commuter buses (e.g. Greyhound, Megabus) are exempt. School buses in contract with DOE are exempt	No cap
Taxis And For-Hire-Vehicles	Peak E-ZPass toll ($10), capped once per day	Exempt	Per-ride CBD toll passed to passenger	Taxis: Exempt FHVs: Peak E-ZPass toll ($14), capped at three times per day
Additional Exemptions	N/A	N/A	City owned vehicles are exempt; A 50 percent discount for low income drivers whose federal household adjusted gross income is no more than $50,000 or who receive public assistance.	N/A
Crossing Credits	N/A	N/A	Credits for drivers using tolled tunnels	Credits for drivers using tolled tunnels

FIGURE 6.52 | SOURCE: MTA

Note the following exclusions and limitations:

- The model is based on the April 2023 findings of the congestion pricing Environmental Impact Assessment. The Traffic Mobility Review Board voted on a version of congestion pricing that wasn't specifically modeled but fits within the range of the previously modeled scenarios. An updated analysis is pending.
- Interim years of the congestion pricing were linearly interpolated, which will not account for any dynamic changes.
- Scenario B features fewer exemptions and additional tolling opportunities than the current proposed scenario. A secondary version of scenario B with a 30-percent-higher toll to meet the revenue target was modeled and results in a 0.2 percent higher VMT reduction. Based on the table below, this scenario is closer in toll price but still doesn't align neatly with the proposed scenario. Since it appears that the proposed scenario fits somewhere in between B and C, this analysis opts to use the Scenario B to stay conservative.
- In the proposed scenario, as of November 30, 2023, the following tolls will be charged:
    - Passenger vehicles and commercial vans will receive a $15 toll no more than once per day.
    - Motorcycles will receive a $7.50 toll, half of the passenger vehicle toll.
    - Trucks will receive a $24 to $36 toll, depending on their size.
    - Transit buses will be exempt from the toll.
    - Taxis and FHVs will be exempt from the daily toll system. Instead, a per-ride CBD toll will be added to each trip and will be paid by the passenger.

Given the inputs and assumptions, the following steps are applied to generate the forecast:

1. Compile outputs from the Environmental Impact Assessment. Included in the environmental impact assessment is a comparison of tolling scenarios effect on forecasted VMT in New York. This comparison includes a breakdown by location. Some of the locations are identified as the CBD, New York City, and several other counties in the surrounding area in New Jersey and New York. For this analysis we selected the expected reductions in 2023 (assumed start date) and 2045 (forecasted year). To estimate the interim years, this analysis linearly interpolates between 2023 to 2045.
2. Allocate reductions to each vehicle type. The calculated reductions are to applied passenger medium- and heavy-duty vehicles. Vehicle types are indexed by v.

$$VMT\_Reduction_v = CY2022\_VMT_v \times \%\_VMT\_Reduction\_from\_Congestion\_Pricing_v$$

3. Output reduced yearly VMT for HVFHVs. This is calculated based on the share of HVFHV VMT to total VMT per year. Years are indexed by n.

$$HVFHV\_VMT\_Reduction_n = HVFHV\_VMT_n \times \%\_VMT\_Reduction\_from\_Congestion\_Pricing_n$$

Discussion

Figure 6.53 shows the percentage change of VMT in New York City under the different tolling scenarios. Scenarios D and E, which have some of the highest tolling frequencies, achieve the largest VMT reductions across the city. Even though scenario F's base toll is the same, crossing credits are expanded to the Robert F. Kennedy Bridge, Henry Hudson Bridge, and the George Washington Bridge. In addition, FHVs are charged once per day instead of three in scenario F. The difference in reductions further highlights a commuter's sensitivity to price when making a travel decision; as congestion pricing evolves, this analysis will want to consider any changes in the tolling structure.

COMPARISON OF SCENARIO REDUCTIONS IN 2045

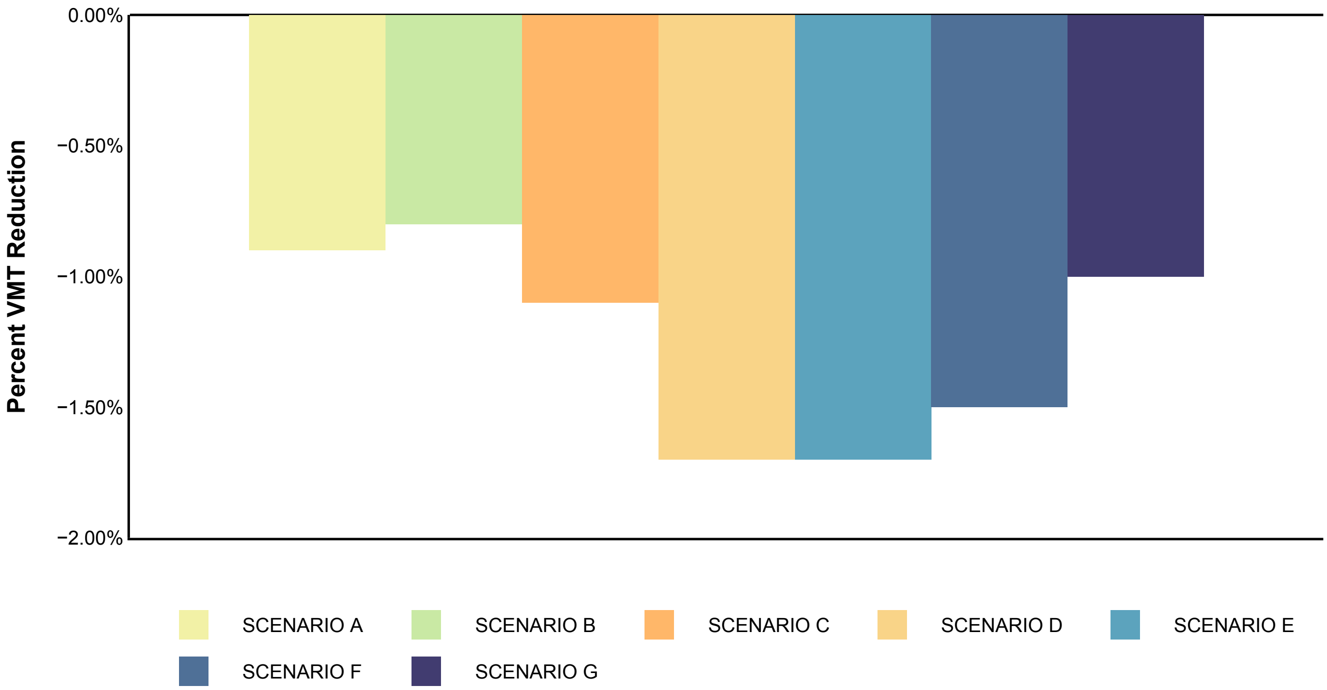


FIGURE 6.53 | SOURCE: NYC OMB

6.e.ii. Metropolitan Transportation Authority (MTA) Bus Electrification

Context

After the 2019 passage of the CLCPA, the state has committed to reduce its GHG emissions by 40 percent by 2030 and 85 percent by 2050[124]. To support the state's goals, the MTA has committed to decarbonize their bus fleet by transitioning to EVs by 2040 and bolstering its EV charging capacities to support a fully electric fleet[125].

Model Methodology

The MTA Bus Electrification model generates a forecast through 2040 for GHG emissions reductions due to electrification of compressed natural gas, diesel, and hybrid buses. The model is performed in Microsoft Excel.

The model uses the following external inputs:

- Fleet data, provided by the MTA, which include a retirement schedule and prospective capital plan purchase for electric buses. These data are used to forecast the replacement of fossil-fuel buses and purchasing of electric buses.

The model takes the following assumptions:

- The model assumes a phase out based on the retirement of certain bus models during the forecast period. The retired bus models will be replaced by a zero-emission bus model, which will be electric.
- Battery-electric bus mileage is assumed to be equivalent to the models they are replacing.

Note the following exclusions and limitations:

- The MTA fleet transition plan mentions exploring other alternative fuel types, for instance hydrogen fuel cells. This model does not consider hydrogen fuels cells in the forecast.
- From 2030 to 2040, the rate of electric bus adoption is uncertain. To support the projected electric bus fleet, additional charging infrastructure or improvements to battery capacity will be required to optimally operate a fully electric fleet.
- Any new changes to congestion pricing will affect the MTA's transit system. This could manifest in an increased fleet size or additional bus mileage.

Given the inputs and assumptions, the following steps are applied to generate the forecast:

1. Identify electrification pathway. Data from the MTA capital plan is used to determine a trajectory of bus replacement. Given the MTA's capital plan schedule, this analysis relies on the estimated quantity of gas, diesel, or electric buses per year. This includes the phaseout of certain fuels as well as the introduction of newer buses that are used as transition vehicles until electric models and charger infrastructure become available. Projections for the MTA fleet makeup are conducted according to the data from the capital plan. The transition pathway is broken into stages, each of which have a four-year window. With this window, there is some variability as to when a new bus will officially come online. The output is an annual percentage change in bus activity, split by energy source (indexed by f).

$$\Delta bus\_count_{ft} = bus\_count_{ft} - bus\_count_{ft-1}$$

2. Calculate the fuel consumption of buses. The annual miles are calculated for each bus fuel type as shown by the annual-miles formula below. Once calculated, this analysis estimates the forecasted fuel consumption needed to achieve the same level of service using the "required kWh" formula. This is done based on the yearly change from the prior step. For electric buses that are not replacing an existing bus in the fleet, the average mileage of all bus types is used to estimate the forecasted fuel consumption.

$$Annual\_Fuel\_Requirement = Average\_Annual\_Miles \times \frac{therm}{mile}$$
$$Annual\_kWh\_Requirement = Average\_Annual\_Miles \times \frac{kWh}{mile}$$

FUEL ECONOMY AND EMISSIONS FROM MTA BUSES

Bus Type (Current Fuels)	Fuel	miles per gallon / miles per therm 2019	Annual tCO_2e	Annual Miles
Standard: Fulfill Local, Limited, And Select Bus Service	Diesel	3.7	70	25,721
	Hybrid	4.5	58	25,574
	CNG	1.8	75	25,438
Articulated: Same As Standard; Larger Vehicle	Diesel	3	84	24,367
	CNG	1.5	88	24,558
Express: Fulfill Express Bus Service; Coach Style Vehicle	Diesel	4.3	70	29,678

FIGURE 6.54 | SOURCE: MTA

Discussion

Based on Figure 6.55, the current electric MTA bus transition plan shows a slow ramp up in the 2020-2024 and 2025-2029 periods. After 2029, all new bus purchases will be electric, coinciding with the increased share of electric buses shown in 2030-2034. As the MTA fleet transitions away from fossil-fuel buses, future analysis will consider any adjustments to the transition plan, especially as alternative fuel technology improves.

MTA FLEET SHARE

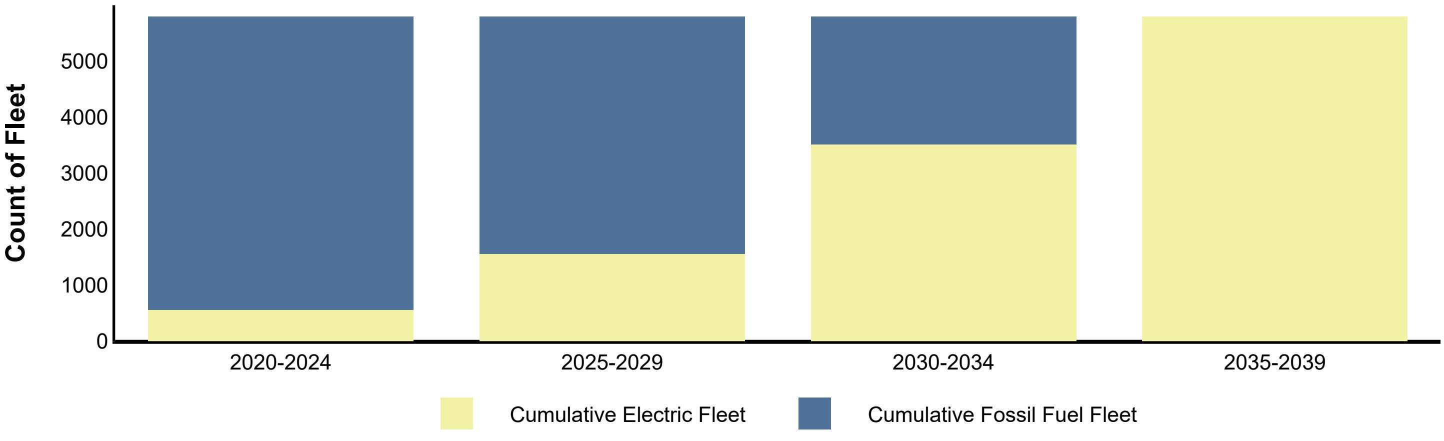


FIGURE 6.55 | SOURCE: MTA

6.f. CITY GOVERNMENT OPERATIONS

Context

To meet New York City's emissions goals set by LL97, GHG emissions from city government operations must be reduced by 40 percent by FY 2025 and 50 percent by FY 2030, compared to FY 2006 emissions levels. This analysis forecasts emissions reductions from city government operations, including capital projects, expense projects, fleet conversions, solid waste emissions, biofuel conversions, and the Tier IV REC purchases.

City government operations emissions forecasting is guided by several pieces of legislation and commitments that establish the framework and targets for emissions reductions across various sectors of municipal operations:

- LL97 sets emissions limits for city-owned buildings, mandating significant improvements in energy efficiency and a transition to cleaner energy sources.
- Local Law 101 of 2021 (LL101) mandates new city-owned buildings and major renovations to be net-zero energy, to significantly cut GHG emissions from municipal construction and operations[126].
- Executive Order 89 of 2021 (EO89) increases accountability and transparency in city operations to support climate change mitigation efforts. EO89 aims to ensure that city agencies adhere to and transparently report their progress towards meeting the city's climate mitigation goals[4].

Model Methodology

The City Government Operations Emissions Forecast model generates a forecast through 2050 for GHG emissions reductions due to installation of solar photovoltaics (PV), electrification/deep energy retrofits, equipment improvements, high-efficiency lighting upgrades, and HVAC upgrades. The modeling is performed in Microsoft Excel.

The model uses the following external inputs:

- Historical emissions and activity data from the City Government FY 2022 GHG Inventory[18].
- Agency emissions data. These data are a result of EO89, which requires the city to report each agencies' emissions annually.
- Existing and planned agency projects from DCAS DEM. These projects include the installation of solar PV, electrification/deep energy retrofits, equipment improvements, high-efficiency lighting upgrades, and HVAC upgrades.
- Existing and planned agency projects that fall under EO89 and LL101 referred to as the CCB. More information about the process to collect data on these projects can be found in Appendix 3. LL101 requires reporting on capital projects that intend to reduce GHG emissions. These projects include improvements to the building envelope, equipment improvements, installation of solar PVs, lighting upgrades, and HVAC upgrades.
- DCAS Fleet projections. These data are used to forecast the emissions reductions from decreased diesel and gasoline consumption as the fleet transitions to EVs.
- Emissions factors from MOCEJ and DCAS DEM.
- Median-percentile global emissions-reduction targets to limit warming to 1.5°C with no or limited overshoot based on the IPCC Sixth Assessment Report Synthesis Report. These data are used to calculate science-based target emissions[127].

The model takes the following assumptions:

- Projects will be completed according to their anticipated timelines.
- Solid waste reductions are assumed to be generated from a -3 percent landfill-methane growth rate which is due to methane gas capture from capped landfills. The rate is based on the LL97 Implementation Action Plan's expected reductions from solid waste.[128] In 2006 solid waste emissions were 286,168 tCO_2e and the 2030 emissions target is 49,800 tCO_2e.

$$\%\_Waste\_Reduction = \frac{2006\_Solid\_Waste\_Emissions - 2030\_Solid\_Waste\_Emissions}{(2030 - 2006) \times 2006\_Solid\_Waste\_Emissions}$$

- The effects of the city's purchase of Tier IV RECs to offset its entire electricity consumption will be realized in 2027.
- The IPCC-aligned target takes the following reductions from FY 2006 GHG emission levels: 69 percent reduction by 2035, 76 percent reduction by 2040, and 100 percent reduction by 2050. This target is determined by the IPCC's median-percentile global reductions required to stay within 1.5°C. These reductions are applied to city government operation's FY 2006 emissions levels to produce the IPCC-aligned target line.

Note the following exclusions and limitations:

- Projects that have significant emissions reductions, but are not verifiable, are omitted.
- Projects tend to include multiple types of work; the current analysis is not able to stratify projects by category to analyze the most impactful project types.
- Projects that do not have anticipated completion dates or require further justification of completion dates are omitted.
- This analysis is in the context of the emissions targets in 2025 and 2030 required by LL97 but have been projected to 2050 to match citywide emissions projections. Future projects beyond 2033, except for fleet projections, are not included in this analysis given the uncertainty of timeline, impact, and current funding.

Given the inputs and assumptions, the following steps are applied to generate the forecast:

1. <u>Calculate science-based GHG emissions targets.</u> Using the historical City Government GHG Inventory and the IPCC targets, apply the science-based emissions reductions targets. Targets are based on a FY 2006 baseline, so the FY 2006 historic emissions value is used as a starting point. They are set for the years 2035, 2040, and 2050. Targets for in-between years are linearly interpolated.

$$tCO_2e_{2035\_target} = tCO_2e_{2005} \times (1 - 69\%) = 1.2\ million\ tCO_2e$$
$$tCO_2e_{2040\_target} = tCO_2e_{2005} \times (1 - 76\%) = 0.9\ million\ tCO_2e$$
$$tCO_2e_{2050\_target} = tCO_2e_{2005} \times (1 - 100\%) = 0\ million\ tCO_2e$$

2. <u>Collect existing and planned projects.</u> Through consultation with DCAS DEM and data collection under the CCB, a dataset of GHG emissions-reducing agency projects is constructed. To construct a dataset of projects, the two data inputs are merged. Some projects are reported twice across datasets, but using a projects' funding record, duplicated projects are identified and omitted from the final analysis.

3. Apply expected reductions. Using projects' anticipated completion dates, the expected electricity or fuel reductions are applied in that year. Most of the project reductions are reported as the change in fuel consumption before the project's start and after the project's completion. Biofuel conversions follow a different process as shown by the biofuel equation below. To apply the expected reductions, the previous biofuel consumption is used to estimate the forecasted consumption of the new biofuel blend. To ensure the forecasted fuel is able to meet the required heating needs, this analysis uses the relative Btus per gal of each blend. Since biofuel blends produce different levels of GHG emissions, the difference between emissions generated from the new biofuel blend and the existing biofuel blend is used to estimate the expected GHG emissions reductions. Projects with forecasted fuel consumption are subtracted by their previous year's fuel consumption to produce fuel changes. The fuel changes are then multiplied by emissions factors supplied by MOCEJ and DCAS DEM, to produce the GHG reductions. In the emissions reduction formula below the year is denoted by n.

   a. Biofuel conversions:

$$Forecasted\_Fuel\_Consumption_{forecasted\_fuel} = Baseline\_Fuel\_Consumption_{baseline\_fuel} \times \frac{MMBtu/gal_{forecasted\_fuel}}{MMBtu/gal_{baseline\_fuel}}$$

   b. Emissions reductions:

$$Emissions\_Reductions_n = \sum_{forecasted\_fuel} (Forecasted\_Fuel\_Consumption_{forecasted\_fuel;n} - Baseline\_Fuel\_Consumption_{baseline\_fuel;n}) \times Emissions\_Factor_{forecasted\_fuel}$$

Discussion

DCAS DEM's capital planning extends to FY 2033, while fleet projections continue through FY 2050. Therefore the current analysis only forecasts city government emissions to FY 2033. One goal for future iterations of this forecast is to produce a more robust projection for all sectors, especially in the years following FY 2033. Future project data will assist in assessing the remaining sources of GHG emissions, as well as potential strategies to reduce these emissions. Based on the graph below, emissions reductions are highest in FY 2026 and FY 2027. The pace of reductions drops significantly following FY 2027, further highlighting the need to update this analysis as planned projects receive higher certainty and new projects are planned.

EMISSIONS REDUCTIONS FROM CITY GOVERNMENT OPERATIONS BY TYPE OF REPORTED PROJECT

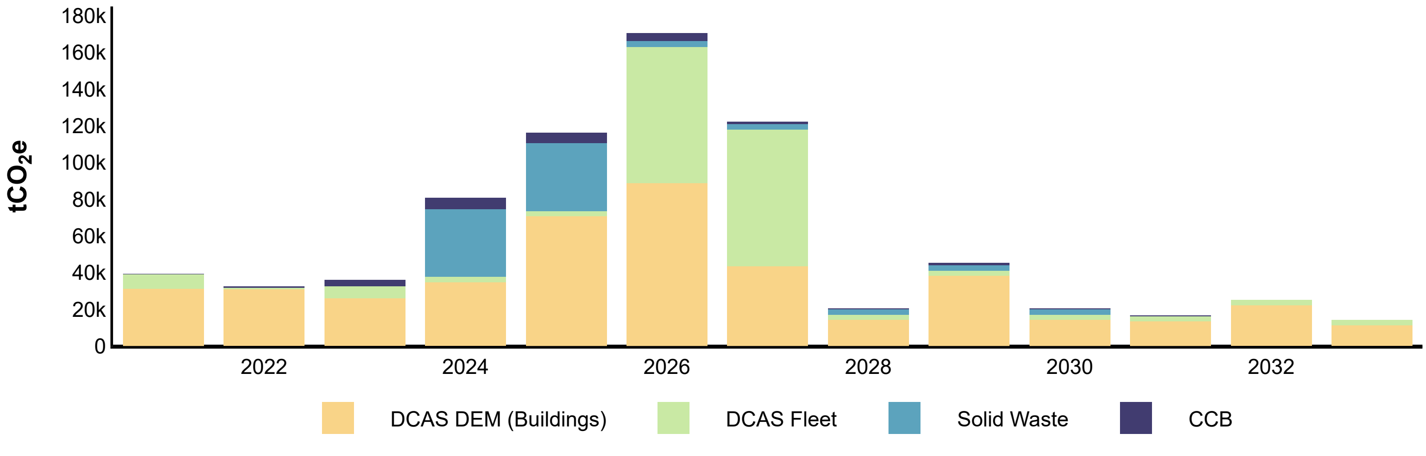


FIGURE 6.56 | SOURCE: NYC OMB, with DCAS

6.g. CITY-BASED OPTIMIZATION MODEL FOR ENERGY

DISCLAIMER: This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation of use.

COMET-NYC is a tool built by U.S. EPA's Office of Research and Development (EPA/ORD) to find the lowest-cost mix of technologies and fuels that meet projected energy demand. This tool is used to assess the impacts of market trends, federal policies, and state actions on New York City's GHG emissions and air pollution. The model requires inputs of current energy-system characteristics, energy-use projections, projected costs and efficiencies of energy technologies, and relative costs of extraction for energy resources.

New York City–specific data sources are used for most inputs within COMET-NYC, although some state-level or national sources are used where city-level data are not available[16]. VMT projections from NYMTC are used for transportation demand. Population projections from NYMTC, combined with statistics of residential and commercial real estate from PLUTO, are used to find the projected demand for energy in residential and commercial buildings. Projections from NYSERDA are used to adjust these energy demand forecasts to account for increased cooling load and decreased heating load due to climate change. The New York Independent System Operator (NYISO) Gold Book is used to find projected electricity demand in the rest of New York State and to find the locations of current electric generators in New York State[129]. National projections from the AEO are used to find the projected cost and efficiency of new energy technologies, as well as cost curves for generating energy from fossil or renewable sources[130]. The model was also calibrated to match historical New York City GHG emissions from the GHG Inventory[18].

The remainder of this section provides some technical details of the COMET-NYC model, including a background of the motivation of COMET-NYC, details of the optimization framework, descriptions of energy-use sectors, and a discussion of the model output.

BACKGROUND

To reach GHG reduction targets, decision-makers need to understand the climate, air quality, and health implications of energy supply and use in their regions. Climate mitigation goals often stretch to 2050 or even 2100, and developing mitigation strategies to reach these goals requires long-term planning of many difficult-to-predict factors in the energy system. These include technology development and adoption, climate change, the availability of water and energy resources, and energy, climate, and environmental policy. Further complicating this challenge, climate and environmental metrics are not the only lenses through which mitigation strategies are judged. Strategies must also provide affordable and reliable energy.

In this complex landscape, planners need tools and information that will allow them to understand the synergies and tradeoffs among air, climate, and energy objectives and to develop robust and cost-effective management strategies. Given a limited number of resources, planners can benefit from systematically evaluating multiple potential strategies for achieving economic and environmental goals related to energy-transition issues.

COMET-NYC is a new tool from EPA/ORD to provide this systematic evaluation. EPA/ORD develops and applies energy system tools to evaluate the long-term economic and environmental benefits of technology and infrastructure. COMET-NYC aims to aid understanding of the environmental (climate and air quality) and health implications of energy supply and use, as well as the energy resources and technologies that may help achieve environmental goals[16].

COMET-NYC is a representation of the New York City energy system, including electric generating units (EGUs) throughout the NYISO that supply New York City's electricity. The model includes a database of the extraction or import of energy resources, the conversion of these resources into useful energy, and the use of the energy to meet end-use demands within the five boroughs of New York City and the rest of New York State. Outputs of the model include the technological mix, total system cost, criteria air pollutant emissions, GHG emissions, and estimates of energy commodity prices.

U.S. EPA's COMET is built on The Integrated MARKAL-EFOM System (TIMES) energy systems modeling framework. TIMES uses the MARKet ALlocation (MARKAL) energy-environmental-economic optimization framework to determine the technology investment choice and related fuel consumption for end-use energy demand sectors such as buildings and transportation[131]. Energy conversion technologies (e.g., power plants, combined heat and power (CHP)) are deployed based on their capital costs, operation and maintenance costs, and parameters such as efficiency, availability, and capacity factors. MARKAL uses linear programming to determine the technology investments and fuel consumption that result in the least system-wide discounted cost while satisfying energy demand and user-defined constraints (e.g., sector- or system-wide emission limits, renewable or electrification standards).

Using scenario analyses, the model can also explore how the least-cost pathway changes in response to various input changes, such as the introduction of new energy-efficient technologies or a new policy to stimulate emission reductions. COMET-NYC uses scenario analyses to model the impact of state energy commitments. Other scenario analyses could include the introduction of new energy-efficient technologies or other policies to stimulate emission reductions.

TIMES FRAMEWORK

TIMES is an economic model generator for local, national, multi-regional, or global energy systems, which provides a technology-rich basis for representing energy dynamics over time. TIMES is maintained through the Energy Technology and Systems Analysis Program of the International Energy Agency. TIMES can assist in the design of least-cost pathways for sustainable energy systems and is ideally suited for the preparation of Low-Emissions Development Strategies, Intended Nationally Determined Contributions, and Nationally Determined Contributions roadmaps. It is usually applied to the entire energy sector but may also be applied to study single sectors such as the electricity and district heat sector.

Description

TIMES consists of generic variables and equations depicting an energy system for each distinct region in a model. To construct a TIMES model, a preprocessor first translates all data defined by the modeler into special internal data structures. This step is called matrix generation. Once the model is solved (optimized), a report writer assembles the results of the run for analysis by the modeler. The matrix generation, report writer, and control files are written in the General Algebraic Modeling System (GAMS). GAMS is a powerful, high-level language specifically designed to facilitate the process of building large-scale optimization models. To build, run, and analyze a TIMES model, several software tools have been developed or are currently under development, so that the modeler does not need to provide the input information directly in GAMS. COMET-NYC used the user-interface tool VEDA 2.0.

In TIMES, a complete scenario consists of four types of inputs: energy service demand curves, primary resource supply curves, a policy setting, and the descriptions of a complete set of technologies. The basis of a TIMES model is a network diagram called a Reference Energy System (RES), which depicts an energy system from resource supply to end-use demand (Figure 6.57). The RES constructs an energy system from a list of technology types, energy carriers, and user demands. The four technology types represented are resource, process, conversion, and demand technologies as defined in detail below:[132-135]

1. Resource technologies represent the extraction cost and availability of resources such as coal, oil, and natural gas.
2. Conversion technologies represent the conversion of fuel inputs into electricity.
3. Process technologies represent other means of converting resources into end-use fuels including refineries and coal-to-liquid processes.
4. Demand technologies represent the technologies that meet specific user demands, such as vehicles, air conditioners, and water heaters.

ILLUSTRATIVE REFERENCE ENERGY SYSTEM

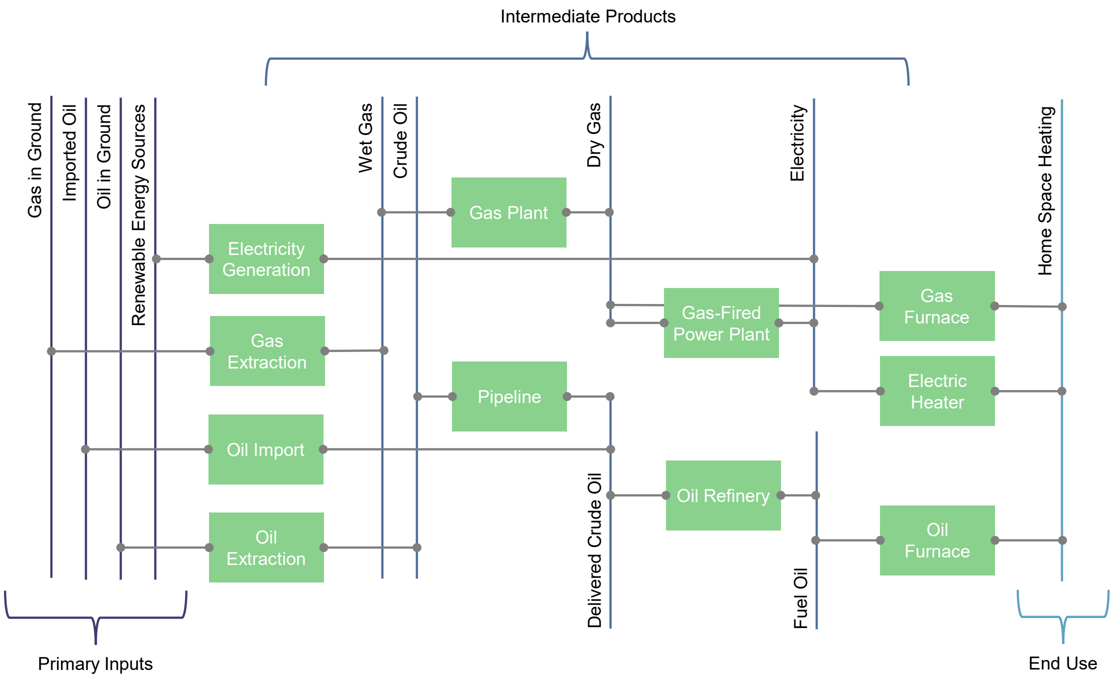


FIGURE 6.57 | SOURCE: U.S. EPA

These technologies feed into a final stage consisting of end-use demands for useful energy services. End-use demands include items such as residential lighting, commercial air conditioning, and automobile VMT. Estimates of end-use energy service demands (e.g., VMT, residential lighting, steam heat requirements in the paper industry) are provided by the user for each region to drive the reference scenario. In addition, the user provides estimates of the existing stocks of energy-related equipment in all sectors, and the characteristics of available future technologies, as well as present and future sources of primary energy supply and their potentials.

Using these as inputs, the TIMES model aims to supply energy services at minimum global cost (at minimum loss of total surplus) by simultaneously making decisions on equipment investment and operation, primary energy supply, and energy trade for each region. For example, if there is an increase in residential lighting energy service relative to the reference scenario (perhaps due to a decline in the cost of residential lighting or due to a different assumption on GDP growth), either existing generation equipment must be used more intensively or new—possibly more efficient—equipment must be installed. The choice by the model of the generation equipment (type and fuel) is based on the analysis of the characteristics of alternative generation technologies, on the economics of the energy supply, and on environmental criteria.

TIMES is thus a vertically integrated model of the entire extended energy system. The scope of the model extends beyond purely energy-oriented issues, to the representation of environmental emissions, and potentially other materials, related to the energy system. In addition, the model is suited to the analysis of energy-environmental policies, which may be represented with accuracy thanks to the explicitness of the representation of technologies and fuels in all sectors.

In TIMES, the quantities and prices of the various commodities are in equilibrium (i.e., their prices and quantities in each time period are such that the suppliers produce exactly the quantities demanded by the consumers). This equilibrium has the property that the total economic surplus is maximized.

It is useful to distinguish between a model's structure and a particular instance of its implementation. A model's structure exemplifies its fundamental approach for representing a problem—it does not change from one implementation to the next. All TIMES models exploit an identical underlying structure.

The structure of a TIMES model is ultimately defined by variables and equations created from the union of the underlying TIMES equations and the data input provided by the user. This information collectively defines each TIMES regional model database, and therefore the resulting mathematical representation of the RES for each region.

Data Requirements

The user-input sets contain the fundamental information regarding the structure and the characteristics of the underlying energy-system model. The user-input sets can be grouped according to the type of information related to them:

- Components of the energy system: regions, commodities, processes
- RES within each region
- Interconnections (trade) between regions
- Time structure of the model: periods, time slices, time slice hierarchy
- Properties of processes or commodities

The following is a list of the classifications of data needed to build instances of TIMES models, and the most common data parameters for each classification. TIMES documentation files include all the necessary information regarding input data needs to build a basic TIMES model. Figure 6.58 summarizes the parameters needed to build a typical energy system model using TIMES.

TIMES is "demand driven" in that feasible solutions are obtained only if all the specified end-use demands for energy services are satisfied for every time period in the modeling horizon. TIMES also distinguishes between two types of units for characterizing energy system technologies, activity, and capacity. Activity represents the use of a technology. Most technology activity is measured in petajoules (PJ). Capacity represents the size (installed capacity) of the technology stock and is measured according to the ability to provide for some amount of activity per unit time. Accordingly, capacities for most technologies are measured in PJ per year (PJ/yr). Electricity generation technology capacities are measured in gigawatts (GW), and transportation technology activities are measured in billions of miles per year.

Scenario Data Needs

Scenario analyses help assess long-term technological development in the energy system by considering potential research and policy developments. Over a period of decades, it is not possible to know which technologies will achieve fundamental breakthroughs and which will not. Changes in economic structures, consumer preferences, resource supplies, and other variables similarly lead to inherent unpredictability. Scenario analysis allows the researcher to consider the consequences of these changes and assess the value of policy or technology developments.

VARIABLE TYPES IN THE MODEL AND CORRESPONDING DATA REQUIREMENTS

Variable Type	Input Requirements
End-Use Energy Service Demands	Projections for energy service demands for: • TRANSPORTATION: Light-duty vehicle demand (bn-vmt-yr), bus transportation demand (bn-vmt-yr), heavy-duty short-haul truck transportation demand (bn-vmt-yr), passenger rail transportation demand (pn-passs-miles), medium-duty truck transportation demand (bn-vmt-yr), • RESIDENTIAL BUILDINGS: space cooling (PJ/yr), space heating (PJ/yr), water heating (PJ/yr), lighting (billion lumens/yr), other electricity demand (PJ/yr), other natural gas demand (PJ/yr), • COMMERCIAL BUILDINGS: space cooling (PJ/yr), space heating (PJ/yr), water heating (PJ/yr), lighting (billion lumens/yr), other electricity demand (PJ/yr), other natural gas demand (PJ/yr), • The load shape for electricity demand profile
Energy Carriers *Any kind of entity that is a form of energy that is produced or consumed in the energy system (e.g., coal, refined oil, natural gas, gasoline, electricity)*	• Transmission efficiency • Transmission capacity • Investment cost • Operation and maintenance cost • Electricity transmission and distribution cost • Reserve margin for electricity
Resource Technologies *Technologies that characterize raw fuels exported or imported into the energy system*	• Resource supply cost for each supply step • Cumulative resource limits for an energy carrier for each period • Cumulative resource limits for an energy carrier over the entire modeling horizon (e.g., an aggregate proven capacity for a coal reserve) • Cost and capacity limits of resource transportation • Cost of extraction and production of resource
Process, Conversion, and Demand Technologies *Any kind of technology that can change the location, form, and/or structure of the energy carriers*	• New capacity investment cost • Fixed operation and maintenance cost • Variable operation and maintenance cost as a function of activity • Fuel delivery charges • Technical efficiency as a ratio between input and output • Technology investment availability year • Availability factor • Capacity utilization factors • Base year installed capacity • Upper bound on new capacity investment (if exists) • Upper bound on incremental new investment (growth rate) • Upper bound on total capacity installed over the modeling horizon • "Hurdle" rate for a technology
Emissions	• Emissions factor per unit of fuel consumed • Emissions factor for per unit of activity • Emissions factor for per unit of installed capacity • Upper bound for emission for each period • Emission constraints over the entire modeling horizon • Emission constraints for any given sector

FIGURE 6.58 | SOURCE: U.S. EPA

The scenario approach to assessing technology futures requires that driving forces and technologies are chosen so that the model produces informative, internally consistent scenarios. Any scenario approach must identify the key driving forces that are expected to have an impact on the issues under consideration. Scenarios are then built from combinations of values or realizations of these driving forces. Major driving forces for the energy system technology futures include:

- Economic growth
- Population growth
- Changes in the structure of the economy, work, and recreation
- Land use, transportation, air pollution, and climate change policy
- Oil and natural gas supply
- Consumer attitudes
- Rates and patterns of technological change

COMET-NYC STRUCTURE

COMET-NYC uses New York City's annual GHG Inventory reports to calibrate energy consumption in residential, commercial, and industrial buildings. The modeling period runs from 2010 until 2050 with five-year intervals for reporting.

Furthermore, COMET-NYC includes data specific to New York City such as that for DEP, NYSERDA, and a variety of other sources. Where local data are unavailable, COMET-NYC relies on a database created for U.S. energy system.

COMET-NYC consists of six regions, which includes Brooklyn, Bronx, Manhattan, Staten Island, Queens and New York State (to cover EGUs and electricity demand in the rest of the state). The six regions are interconnected through technology links (i.e. fuel trades). The naming conventions for each fuel type don't change from one region to another. For instance, in the model, the New York State region represents all the EGUs in New York State except the ones in the New York City. This region is the source of electricity and transfers electricity to other regions via trade technologies. Transmissions constraints between the rest of state and New York City are incorporated, although the model has the capacity to invest and expand transmission capacity.

In addition to the six regions, there is an outer region for modelling fuel supply. This is the supply region of the model that characterizes the fossil energy sources located outside of the city and state. The fuel trade allows the commodity flows between regions. For each import (or trade) option, transportation cost, capacity limits, and capacity extension cost (investment cost) are defined.

System-Wide Model Assumptions

- COMET-NYC applies a 5 percent discount rate to the system-wide economy (that covers all six regions). This discount rate can be adjusted for a specific technology if this technology requires a different rate.
- Each year in the planning horizon is divided into 12 different time slices. The fraction that each time slice represents within a year is presented in Figure 6.59.
- Grid transmission losses are characterized as "transmission efficiency." This value is selected as 93.5 percent based on the EIA state profile[63].
- The reserve margin/capacity for electricity is 20 percent.

TIME-SLICE FRACTIONS USED TO CHARACTERIZE LOAD-DURATION CURVES

Description	Time Fraction
Intermediate Day – AM	8.22%
Intermediate Night – PM	9.57%
Intermediate Night	15.32%
Summer Peak	0.32%
Summer Day – AM	9.75%
Summer Day – PM	10.87%
Summer Night	12.53%
Summer Peak	0.27%
Winter Day – AM	8.15%
Winter Day – PM	10.87%
Winter Night	13.81%
Winter Peak	0.32%

FIGURE 6.59 | SOURCE: U.S. EPA

Pollutant Coverage

COMET-NYC includes emissions factors for: CO_2e, nitrogen oxides (NOx), particulate matter less than 10 µm (PM_{10}), $PM_{2.5}$, sulfur dioxide (SO_2), volatile organic compounds (VOC), CH_4, carbon monoxide (CO), organic carbon (OC), and black carbon (BC) for each region and sector across the whole energy system related to fuel consumption.

BUILDINGS MODULE

The building end-use energy demands are split into residential, commercial, and industrial buildings. The level of end-use demand in each of the three sub-sectors is estimated using a bottom-up approach based on the AEO, EIA's Commercial Building Energy Consumption Survey, PLUTO, and other related official data.

COMET-NYC characterizes existing building stock through its end-use energy service demand and includes a suite of future technologies to meet these demands using PLUTO and the LL84. PLUTO contains data on all buildings in New York City—where each building has a unique Borough-Block-Lot (BBL) number. LL84 provides annual measurements of energy and water consumption. Both data are matched (by BBL as well as reporting year) to allocate existing building stock to the associated energy use for each building. Building sector energy consumption is then allocated into end-use energy service demands (i.e., space heating, water heating, space cooling, lighting, conveyance, process loads, and miscellaneous). The energy consumption values must be paired with existing technology stock. Since there is no specific data for New York City, EIA's Commercial and Residential Energy Consumption Surveys are used[77,78]. The technology capacity, costs, and efficiency data for Middle Atlantic Census Division are gathered for our calculations. Similarly, future technology representations are gathered from AEO.

In scenario analyses to study the impact of state and federal action, COMET-NYC includes several actions that impact demand for clean technologies in commercial and residential buildings. Federal actions include the IRA's investment tax credit for energy property and the residential clean energy credit. The investment tax credit for energy property includes a 6 percent tax credit for CHP and solar photovoltaic (PV), and the residential clean energy credit includes additional subsidies for the cost of solar PV as described in Figure 6.60. State action includes the NY-Sun Initiative Megawatt Block Program, which provides subsidies for solar PV in residential buildings[136]. Figure 6.61 shows the level of the NY-Sun subsidy.

RESIDENTIAL CLEAN ENERGY CREDIT

Year	% Reduction of Solar PV Cost
2023	30%
2032	30%
2033	26%
2034	24%

FIGURE 6.60 | SOURCE: U.S. IRS

NY-SUN INITIATIVE MEGAWATT BLOCK PROGRAM

Year	Capacity Subsidy for Residential Solar PV
2010	1,000.0
2015	634.4
2020	167.8
2022	950.1
2023	586.5

FIGURE 6.61 | SOURCE: NYSERDA

Residential Sector

The residential sector workbook characterizes end-use energy demands for space heating, space cooling, water heating, lighting, and other appliances to meet end-use demands. Several technology options are defined.

Figure 6.62 illustrates a sample RES diagram for residential space heating demand. Total energy demand for the residential sector is classified under four main sections (space heating, space cooling, water heating, lighting) and two aggregated fuel consumptions (other-electricity and other-natural gas).

ILLUSTRATIVE REFERENCE ENERGY SYSTEM FOR SPACE HEATING CHARACTERIZATION

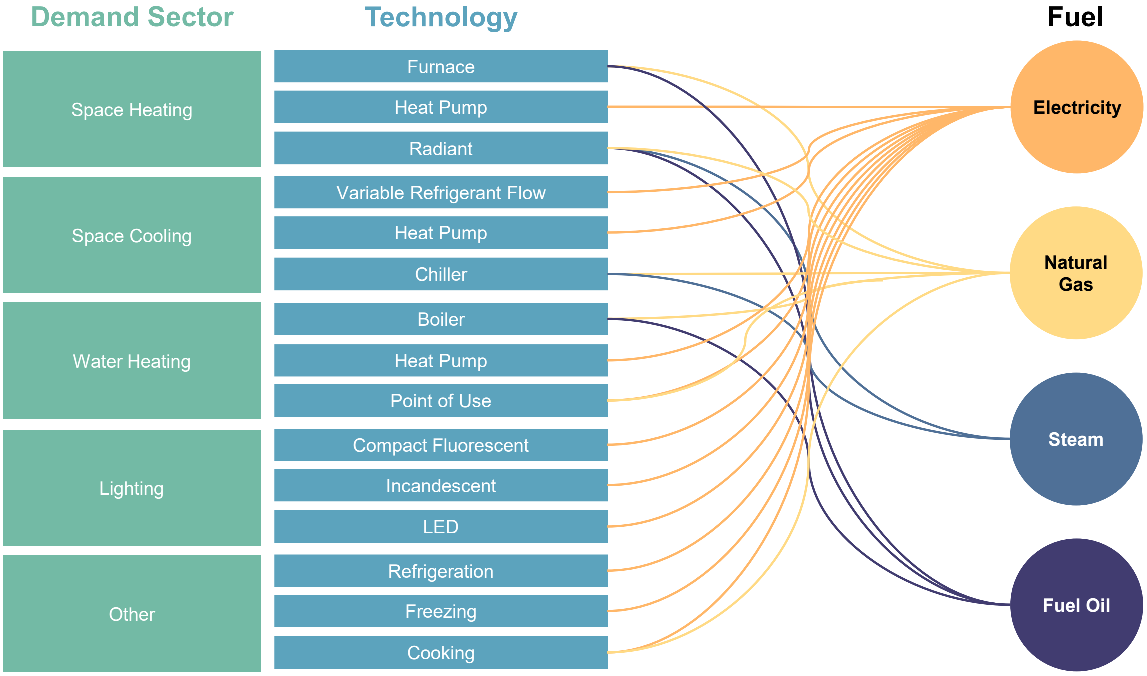


FIGURE 6.62 | SOURCE: U.S. EPA

Residential Energy Demand Services

The residential sector energy demand structure consists of six different end-use energy demands. These end-use demands are: space cooling, space heating, water heating, lighting, other electricity use, and other natural gas use. The final energy consumption for end-use services is driven by the model under a set of predefined end-use service demands, energy balance requirements, and environmental and energy policies defined through constraints. These demands are summarized in Figure 6.63.

For the residential sector, energy service demand for one-to-four-unit multi-family buildings are merged to calculate the demand for the calibration year. Building sector end-use demand is determined based on the change in the projected number of single-family and multi-family housing units. These projections are calculated using population projections from NYMTC and nationwide trends in the number of individuals per household from the AEO[137]. These values are provided in Figure 6.64.

The end-use energy service demand is calculated using square footage of heated or cooled space and average HDD and cooling degree days (CDD). The HDD and CDD values are from NYSERDA's projections based on the impacts of climate change on New York State[138]. These values are provided in Figure 6.65.

To characterize technology trends and their impacts on energy consumption, emissions and cost, a suite of technology options with available fuel combinations and energy efficiency attributes are included into COMET-NYC along with model constraints and energy demands.

RESIDENTIAL SECTOR DEMAND PROJECTIONS

Borough	2015	2020	2025	2030	2035	2040	2045	2050
Residential Cooling Demand (PJ)								
Bronx	4.47	4.91	5.14	5.28	5.42	5.96	6.04	6.48
Brooklyn	8.15	8.94	9.36	9.61	9.86	10.80	10.94	11.73
Manhattan	6.66	7.29	7.46	7.65	7.83	8.54	8.62	9.20
Queens	6.50	7.15	7.39	7.56	7.71	8.41	8.48	9.04
Staten Island	1.39	1.51	1.54	1.56	1.59	1.73	1.74	1.86
Residential Heating Demand (PJ)								
Bronx	23.25	21.66	22.67	23.40	23.70	22.80	22.85	21.93
Brooklyn	39.29	36.54	38.28	39.53	39.94	38.34	38.36	36.81
Manhattan	42.72	39.70	40.58	41.92	42.22	40.37	40.23	38.43
Queens	19.80	18.47	19.10	19.66	19.75	18.86	18.78	17.93
Staten Island	7.27	6.73	6.85	6.97	7.00	6.69	6.65	6.35
Residential Lighting Demand (Billion Lumens/Year)								
Bronx	1.64	1.59	1.67	1.73	1.77	1.79	1.82	1.84
Brooklyn	2.81	2.72	2.87	2.96	3.02	3.06	3.10	3.13
Manhattan	2.69	2.60	2.68	2.77	2.82	2.84	2.86	2.88
Queens	1.42	1.38	1.43	1.48	1.50	1.51	1.52	1.53
Staten Island	0.54	0.52	0.53	0.54	0.55	0.56	0.56	0.56
Residential Miscellaneous Electric Demand (PJ)								
Bronx	4.87	4.74	4.69	4.51	4.45	4.38	4.32	4.25
Brooklyn	9.56	9.29	9.21	8.86	8.71	8.57	8.43	8.30
Manhattan	6.79	6.59	6.37	6.13	6.01	5.89	5.78	5.66
Queens	4.91	4.79	4.68	4.49	4.39	4.30	4.21	4.12
Staten Island	2.45	2.37	2.28	2.16	2.11	2.07	2.02	1.98
Residential Miscellaneous Gas Demand (PJ)								
Bronx	0.49	0.69	0.69	0.69	0.67	0.66	0.65	0.65
Brooklyn	0.91	0.90	0.90	0.89	0.87	0.85	0.85	0.85
Manhattan	1.41	1.40	1.36	1.34	1.31	1.27	1.27	1.27
Queens	0.18	0.18	0.18	0.17	0.17	0.16	0.16	0.16
Staten Island	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08
Residential Water Heating Demand (PJ)								
Bronx	7.67	7.94	8.29	8.43	8.36	8.26	8.12	7.98
Brooklyn	12.48	12.90	13.48	13.71	13.58	13.38	13.14	12.90
Manhattan	13.28	13.72	13.99	14.23	14.05	13.79	13.48	13.18
Queens	6.25	6.49	6.69	6.78	6.68	6.55	6.40	6.25
Staten Island	2.07	2.13	2.16	2.17	2.13	2.09	2.04	1.99

FIGURE 6.63 | SOURCE: U.S. EPA, with EIA's Commercial and Residential Energy Consumption Surveys

NEW YORK CITY POPULATION PROJECTIONS

Region	2010	2015	2020	2025	2030	2035	2040	2045	2050
Brooklyn	2,552,911	2,593,655	2,647,112	2,760,391	2,820,822	2,860,506	2,894,388	2,928,160	2,956,932
Bronx	1,385,108	1,423,160	1,454,816	1,515,667	1,548,245	1,573,786	1,595,881	1,616,845	1,633,550
Manhattan	1,585,873	1,636,537	1,668,548	1,698,050	1,735,482	1,754,534	1,768,412	1,781,885	1,791,292
Staten Island	468,730	477,525	484,897	491,202	495,047	498769	502,327	505,464	507,920
Queens	2,250,002	2,294,943	2,349,324	2,418,636	2,463,405	2,483716	2,500,457	2,517,076	2,528,763

FIGURE 6.64 | SOURCE: NYMTC[137]

HEATING AND COOLING DEGREE DAYS

Region	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
COOLING DEGREE DAYS, CDD											
Brooklyn	1112	1142	1503	1544	1635	1636	1637	1653	1801	1815	1938
Bronx	1112	1142	1503	1544	1635	1636	1637	1653	1801	1815	1938
Manhattan	1112	1142	1503	1544	1635	1636	1637	1653	1801	1815	1938
Staten Island	1112	1142	1503	1544	1635	1636	1637	1653	1801	1815	1938
Queens	1112	1142	1503	1544	1635	1636	1637	1653	1801	1815	1938
NYC	1112	1142	1503	1544	1635	1636	1637	1653	1801	1815	1938
HEATING DEGREE DAYS, HDD											
Brooklyn	4376	4376	4376	4376	3930	3933	3958	3938	3759	3741	3576
Bronx	4376	4376	4376	4376	3930	3933	3958	3938	3759	3741	3576
Manhattan	4376	4376	4376	4376	3930	3933	3958	3938	3759	3741	3576
Staten Island	4376	4376	4376	4376	3930	3933	3958	3938	3759	3741	3576
Queens	4376	4376	4376	4376	3930	3933	3958	3938	3759	3741	3576
NYC	4376	4376	4376	4376	3930	3933	3958	3938	3759	3741	3576

FIGURE 6.65 | SOURCE: NYSERDA[142]

RESIDENTIAL TECHNOLOGY AND FUEL COMBINATIONS

End-use Demand	Technology Type	Fuel
Space Heating	Radiant – Boiler System	Electric, Natural Gas, Distillate
	Furnace	Natural Gas, Distillate, Kerosene
Space Cooling	Room AC	Electric
	Central AC	Electric
Space Heating and Cooling (Simultaneous)	Air-Source Heat Pump	Electric
	Ground-Source Heat Pump	Electric
Water Heating		Electric, Natural Gas, Distillate, Solar
Lighting	Incandescent	Electric
	CFL	Electric
	LED	Electric
	Halogen	Electric
	Linear Fluorescent	Electric
	Reflector	Electric

FIGURE 6.66 | SOURCE: U.S. EPA

Figure 6.66 shows main technology categories with available fuel options. All cost and efficiency values for residential space heating, space cooling, water heating, and lighting are taken from the AEO Residential Technology Equipment Type Description File. All parameters related to residential sector technologies are provided exogenously into the model.

Residential Emissions Accounting

COMET-NYC tracks fuel-combustion-related emissions as well as some process and leakage emissions occurring along the energy system. For instance, CO_2 emissions are tracked through quantity of fuel combusted and verified for 2010 and 2015 using the GHG Inventory. Methane emissions are tracked throughout the system, with the main contribution coming from oil and gas operations, which are beyond the geographical scope of this analysis. Criteria air emissions factors are derived from U.S. EPA's National Emissions Inventory platform and AP-42 datasets[22,139].

RESIDENTIAL FUEL USE AND TECHNOLOGY MIX CONSTRAINTS

	Fuel/Tech	At Least	At Most	Year
Residential Space Heating	Diesel	17.4%	20.2%	2015
	Diesel		12.3%	2020-2030
	Diesel			2055
	Electric	0.9%	1.8%	2015
	Electric		2.2%	2020
	Electric	3.0%		2055
	Natural Gas	73.4%		2015
	Natural Gas	85.0%		2020
	Natural Gas	54.0%		2055
	Furnace	46.6%		2015
	Furnace	34.0%		2055
	Furnace- Diesel		15.0%	2015
	Furnace- Diesel		9.2%	2020-2030
	Furnace-Electric	4.4%		2020-2030
	Furnace-Electric	6.6%		2055
	Radiant	42.7%		2015
	Radiant	31.2%		2055
Residential Water Heating	Diesel	13.4%	29.9%	2015
	Diesel		18.3%	2020
	Diesel			2055
	Diesel	4.1%		2020
	Electric	2.8%	3.5%	2015
	Electric		3.5%	2020
Residential Space Cooling	Central Heat Pump	2.3%		2015
	Central Heat Pump	1.7%		2055
	Central AC	38.1%		2015
	Central AC	27.8%		2055
	Central AC	59.4%		2015
	Central AC	43.0%		2055

FIGURE 6.67 | SOURCE: U.S. EPA , with LL84 Dataset and EIA's Commercial and Residential Energy Consumption Surveys

Residential Sector Constraints

COMET-NYC utilizes constraints to mimic more realistic outputs in accordance with the existing city policy implications. Figure 6.67 shows these constraints—for each technology, a lower and upper bound can be specified. If left unspecified, the model does not place a constraint on the level of this technology. For instance, to model the city's plan to phase out petroleum-based space heating options, an upper bound on diesel consumption is set for the 2015-2050 period. However, a lower bound on electricity consumption on the space heating is also included to assure that the share of electricity-based space heating will not drop unrealistically over the modeling period. In addition to fuel-share constraints, technology splits are included to mimic AEO 2016 Residential Unit Consumption of Energy with respect to the equipment classes[140].

Commercial Sector

The commercial sector representation in COMET-NYC covers energy-service demands for space heating, space cooling, lighting, water heating, and other commercial uses.

Commercial Energy Demand Services

The commercial sector is an aggregation of commercial, institutional, and industrial buildings. The methodology and technology structure are similar to the residential sector, so some sections of the commercial sector are abbreviated. The commercial sector module includes details of commercial-sector energy demands and their corresponding end-use technologies. These end-use energy demands are space heating, space cooling, water heating, lighting, other electricity use, and other natural gas use. Figure 6.68 shows these demand projections, by borough.

Demands are calculated by determining the energy intensity (PJ per square foot) for each end-use demand from the average stock equipment efficiency in the AEO reference case and multiplying those intensities by the regional square footage.

End-use energy service demands are calculated by determining the energy intensity per square foot for each demand type. For calibration year, total fuel consumption values are used to calculate base year end-use demand values. Average stock efficiency rates that are presented in the AEO reference case are multiplied by fuel consumption values to get the aggregate end-use demand for New York City. Building stock square footage is used to get the energy intensity value for each end-use demand type. Space heating and space cooling demand for the rest of the modeling period is calculated from AEO equipment stock data (including average HDD and CDD days). Other end-use energy demands are calculated similarly to the residential sector.

Commercial Technology Structure

Several demand technology and fuel combinations are included in the model (Figure 6.69). Each of these technology and fuel combinations have distinct technology attributes such as investment cost, operation and maintenance cost, starting year, and fuel efficiency. The AEO's Commercial Technology Equipment Type Description File and Commercial Building Energy Consumption Surveys were used to determine demand in each end-use sector such as space heating or cooling[141]. Specifically, these surveys are used to allocate technology shares among end-use service demands.

Final energy consumption in 2010 and 2015 are calibrated against reported actual final energy consumption data provided by the NYC Health Department.

COMMERCIAL SECTOR DEMAND PROJECTIONS

Borough	2015	2020	2025	2030	2035	2040	2045	2050
Commercial Cooling Demand (PJ)								
Brooklyn	26.29	26.88	28.45	29.05	29.05	29.10	31.35	31.21
Bronx	12.43	12.86	13.63	13.90	13.90	13.95	15.06	15.02
Manhattan	50.76	52.71	55.73	55.54	55.55	55.47	59.52	59.03
Staten Island	21.62	22.19	23.55	23.75	23.67	23.57	25.27	25.03
Queens	4.04	4.14	4.36	4.32	4.26	4.24	4.55	4.50
Commercial Heating Demand (PJ)								
Brooklyn	24.70	22.17	22.64	22.78	22.47	21.21	20.86	19.65
Bronx	11.81	10.61	10.83	10.89	10.77	10.19	10.03	9.46
Manhattan	47.33	42.43	42.29	42.56	41.86	39.35	38.54	36.16
Staten Island	3.75	3.35	3.32	3.29	3.23	3.03	2.97	2.78
Queens	20.06	18.06	18.21	18.26	17.91	16.82	16.46	15.43
Commercial Lighting Demand (Billion Lumens/Year)								
Brooklyn	14.71	15.67	17.01	17.78	18.69	19.58	19.81	20.00
Bronx	7.04	7.51	8.14	8.51	8.96	9.41	9.53	9.63
Manhattan	28.85	30.69	32.52	34.00	35.62	37.18	37.46	37.66
Staten Island	2.26	2.40	2.53	2.61	2.72	2.84	2.86	2.87
Queens	12.15	12.97	13.91	14.49	15.14	15.78	15.89	15.96
Commercial Miscellaneous Electric Demand (PJ)								
Brooklyn	14.58	16.25	18.31	20.11	22.06	24.20	26.56	29.16
Bronx	6.97	7.78	8.76	9.62	10.58	11.63	12.78	14.04
Manhattan	28.59	31.83	35.01	38.46	42.05	45.96	50.23	54.89
Staten Island	2.24	2.49	2.72	2.95	3.22	3.51	3.83	4.19
Queens	12.03	13.45	14.97	16.39	17.87	19.51	21.30	23.26
Commercial Miscellaneous Gas Demand (PJ)								
Brooklyn	1.20	1.27	1.39	1.55	1.82	2.18	2.18	2.19
Bronx	0.58	0.61	0.67	0.74	0.87	1.05	1.05	1.05
Manhattan	2.36	2.49	2.66	2.97	3.48	4.13	4.13	4.12
Staten Island	0.19	0.19	0.21	0.23	0.27	0.32	0.31	0.31
Queens	0.99	1.05	1.14	1.27	1.48	1.75	1.75	1.75
Commercial Water Heating Demand (PJ)								
Brooklyn	4.04	4.12	4.30	4.39	4.46	4.51	4.56	4.61
Bronx	1.93	1.98	2.06	2.10	2.14	2.17	2.20	2.22
Manhattan	7.92	8.08	8.22	8.40	8.49	8.56	8.63	8.67
Staten Island	0.62	0.63	0.64	0.64	0.65	0.65	0.66	0.66
Queens	3.34	3.41	3.52	3.58	3.61	3.63	3.66	3.68

FIGURE 6.68 | SOURCE: U.S. EPA , with EIA's Commercial and Residential Energy Consumption Surveys

COMMERCIAL TECHNOLOGY AND FUEL COMBINATIONS

End-Use Demand	Technology Type	Fuel
Space Heating	Boiler	Electric, Natural Gas, Diesel
	Furnace	Natural Gas, Diesel
Space Cooling	Centrifugal Chiller	Electric, Natural Gas
	Reciprocating Chiller	Electric
	Scroll Chiller	Electric
	Screw Chiller	Electric
	Rooftop AC	Electric, Natural Gas
	Window/Wall AC	Electric
	Central AC	Electric
Space Heating and Cooling (Simultaneous)	Air-Source Heat Pump	Electric
	Ground-Source Heat Pump	Electric
Water Heating		Electric, Natural Gas, Diesel, Solar
Lighting	Incandescent	Electric
	CFL	Electric
	LED	Electric
	Halogen	Electric
	Linear Fluorescent	Electric
	Metal Halide	Electric

FIGURE 6.69 | SOURCE: U.S. EPA

Commercial Emissions Accounting

Emissions accounting procedures mirror those for the residential sector.

Commercial Sector Constraints

Similarly to in the residential sector, COMET-NYC uses constraints to achieve realistic adoption of certain commercial technologies. Figure 6.70 shows these constraints.

COMMERCIAL FUEL USE AND TECHNOLOGY MIX CONSTRAINTS

	Fuel/Tech	At Least	At Most	Year
Commercial Space Heating	Electric	9.20%		2015
	Electric	6.70%		2055
	Electric		10.80%	2020
	Natural Gas	49.10%		2015
	Natural Gas	49.10%		2020
	Natural Gas	35.80%		2055
	Diesel		8.10%	2015
	Diesel		8.10%	2055
	Boiler	31.00%		2015
	Boiler	22.60%		2055
	Furnace	47.80%		2015
	Furnace	34.90%		2055
Commercial Space Cooling	Electric	77.90%		2010
	Electric	56.90%		2055
	Natural Gas	17.10%		2010
	Natural Gas	12.50%		2055
	Rooftop	49.30%		2015
	Rooftop	36.00%		2055
	Central	14.50%		2015
	Central	10.60%		2055
	Window/Wall	10.80%		2015
	Window/Wall	7.90%		2055
	Ground-Source Heat Pump	3.20%		2015
	Ground-Source Heat Pump	2.30%		2055
	Air-Source Heat Pump	5.20%		2015
	Air-Source Heat Pump	3.80%		2055
Commercial Water Heating	Electric	0.60%	3.50%	2015
	Electric	-0.40%		2055
	Natural Gas	76.30%	83.90%	2015
	Natural Gas	38.20%	61.30%	2055
	Diesel	20.80%		2015
	Diesel	10.40%		2055
	Solar		1.00%	2055

FIGURE 6.70 | SOURCE: U.S. EPA, with LL84 Dataset and EIA's Commercial and Residential Energy Consumption Surveys

TRANSPORTATION MODULE

The transportation sector covers the vehicle technologies that are used to meet the transportation demand for numerous transportation modes. Technologies are classified under two main technology sets: light-duty vehicles and heavy-duty vehicles.

Light-duty-vehicle technologies include gasoline, diesel, CNG, hydrogen (H_2), and electric-powered cars including plug-in hybrids, EVs, and hybrids, which meet demand measured in billion vehicle miles traveled per year (bn-vmt-yr). Heavy-duty-vehicle technologies include heavy-duty short-haul trucks, buses, and electric passenger rail to account for New York City's extensive public transit system.

Light-Duty Vehicles

Light-duty-vehicle demand accounts for personal VMT, and is represented not only by various demand technologies (including different fuel type and efficiency levels) but also fuel distribution networks for gasoline, diesel, electricity, and others. Mini-compact, compact, full-size, minivan, pick-up truck, small sport utility vehicle (SUV), and large SUV are the main vehicle class sizes.

Light-Duty-Vehicle Energy Demand

Light-duty-vehicle demand for the base year is calculated with respect to the total fuel consumption provided in the GHG Inventory report. Aggregate VMT is calculated using base year average vehicle efficiency. Demand trajectories are taken from the AEO forecasts and adjusted for each borough according to population forecasts. Light-duty-vehicle transportation demands are exogenous to the model, and are gathered from NYMTC's Transportation Conformity Determination's regional transportation forecast[143]. 2010 light-duty vehicle fleet distribution for the New York City is set as a constraint.

Light-Duty-Vehicle Technology Structure

The light-duty demand is met by 12 different engine types for seven car classes. Available fuel-technology pairs for seven car classes are presented in Figure 6.72.

LIGHT-DUTY-VEHICLE DEMAND PROJECTION

Region	*(billion VMT)*								
	2010	2015	2020	2025	2030	2035	2040	2045	2050
Brooklyn	4.35	4.53	4.71	7.98	8.18	8.37	8.55	8.72	8.48
Bronx	3.01	3.09	3.23	3.14	3.20	3.27	3.32	3.36	3.45
Manhattan	3.11	3.08	3.14	3.56	3.63	3.70	3.76	3.82	3.87
Staten Island	2.03	2.08	2.14	2.18	2.24	2.29	2.33	2.37	2.41
Queens	7.16	6.88	6.92	4.71	4.84	4.96	5.07	5.17	5.16
TOTAL	**19.66**	**19.66**	**20.14**	**21.58**	**22.08**	**22.59**	**23.02**	**23.45**	**23.37**

FIGURE 6.71 | SOURCE: U.S. EPA, with NYMTC and AEO

LIGHT-DUTY-VEHICLE FUEL AND TECHNOLOGY COMBINATIONS

		Mini-Compact	Compact	Full-Size	Minivan	Pickup	Small SUV	Large SUV
Gasoline	Conventional	X	X	X	X	X	X	X
	Advanced	X	X	X	X	X	X	X
	Hybrid		X	X	X	X	X	X
	Plug-in hybrid (20 miles per charge)		X	X	X	X	X	X
	Plug-in hybrid (40 miles per charge)		X	X	X	X	X	X
Diesel	Conventional		X	X	X	X	X	X
	Hybrid		X	X	X		X	X
CNG	Conventional		X	X	X	X		
	Flex fuel		X	X	X	X		
H2	Fuel cell		X	X	X	X	X	X
Electric	100-mile range	X	X	X	X	X	X	X
	200-mile range	X	X	X	X	X	X	X

FIGURE 6.72 | SOURCE: U.S. EPA

Light-Duty-Vehicle Emissions Accounting

COMET-NYC assigns CO_2e emissions factors to each transportation fuel based on carbon content of the fuel. The emissions are then calculated by means of the total consumption of the fuel within the transportation technologies. For criteria air pollutants, emissions factors are defined on the technology itself to represent transportation-related air regulations. Transportation-sector criteria pollutant emissions factors for each vehicle type and fuel are gathered from the MOVES model[144]. COMET-NYC includes county-level emissions factors simulated via MOVES using vehicle in-place data per county obtained from New York State Department of Environmental Conservation.

Light-Duty-Vehicle Constraints

The light-duty-vehicle sector includes seven car classes including mini-compact, compact, full-size, minivan, pick-up, small SUV, and large SUV. Car shares are based on regional car and truck sales (sales data by class) for the Middle Atlantic region presented in AEO.

Heavy-Duty Vehicles

The heavy-duty-vehicle sector includes buses, short haul heavy-duty trucks, medium-duty trucks, passenger rail transport, and subway in COMET-NYC.

Heavy-Duty-Vehicle Energy Demand

Input data that are concerning heavy-duty technologies are collected from New York City 2010 fuel consumption data, AEO 2014 demand projections, and EPAUS9r fleet constraints[145][146].

Heavy-duty-vehicle energy demands are calculated with the assumption that calibration-year existing-technology combinations in EPAUS9r are also valid for New York City. The New York City energy consumption value for the transportation sector is combined with the average efficiency of the existing fleet to calculate the demand, then the demand is extended according to the AEO demand projections. These demand projections are summarized in Figure 6.73.

All heavy-duty-vehicle transportation demands are exogenous to the model. The demands are projected using population and economic activity data. The inventory years are calibrated in the model.

Heavy-Duty-Vehicle Technology Structure

Figure 6.74 represents the available engine and fuel type pairs in COMET-NYC and distinguishes them with respect to the efficiency improvements and different vintage years with available fuel options. User-defined constraints are set for the calibration year to mimic the real fuel investment data.

Heavy-Duty-Vehicle Emissions Accounting

Emissions accounting procedures mirror those for light-duty vehicles.

Heavy-Duty-Vehicle Constraints

In the heavy-duty-vehicle sector, the model has two constraints. CNG-powered buses are given a fixed amount of investment for 2010 to represent existing stock of the CNG bus fleet. The model has both commuter rail and subway to meet passenger rail demand. The percent of total demand that can be met by commuter rail is constrained by lower bounds that belong to the actual New York City transportation data for 2010.

HEAVY-DUTY-VEHICLE DEMAND PROJECTION

Borough	2015	2020	2025	2030	2035	2040	2045	2050
Bus Transportation ***(bn-vmt)***								
Bronx	0.06	0.06	0.06	0.07	0.07	0.07	0.08	0.08
Brooklyn	0.11	0.11	0.12	0.12	0.13	0.13	0.14	0.14
Manhattan	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.09
Queens	0.09	0.1	0.1	0.1	0.11	0.11	0.12	0.12
Staten Island	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03
Medium-Duty Trucks ***(bn-vmt)***								
Bronx	0.09	0.09	0.09	0.09	0.09	0.09	0.1	0.1
Brooklyn	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.18
Manhattan	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Queens	0.14	0.14	0.14	0.14	0.14	0.14	0.15	0.15
Staten Island	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Passenger Rail ***(bn-pass-miles)***								
Bronx	1.66	1.73	1.85	1.96	2.07	2.21	2.34	2.48
Brooklyn	3	3.17	3.37	3.56	3.73	3.97	4.18	4.43
Manhattan	1.87	1.96	2.07	2.17	2.25	2.37	2.49	2.62
Queens	2.66	2.79	2.94	3.07	3.19	3.38	3.59	3.79
Staten Island	0.53	0.58	0.61	0.64	0.67	0.7	0.76	0.81
Short-Haul Heavy-Duty ***(bn-vmt)***								
Bronx	0.11	0.12	0.12	0.13	0.14	0.15	0.16	0.16
Brooklyn	0.2	0.21	0.22	0.23	0.25	0.26	0.28	0.29
Manhattan	0.13	0.13	0.14	0.14	0.15	0.16	0.17	0.17
Queens	0.18	0.19	0.2	0.2	0.21	0.22	0.24	0.25
Staten Island	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05
TRN.SHIP ***(bn-t-m)***								
Brooklyn	1.87	1.76	1.65	1.57	1.56	1.58	1.58	1.58

FIGURE 6.73 | SOURCE: U.S. EPA, with NYMTC and AEO

HEAVY-DUTY-VEHICLE DEMAND TYPES, FUEL, AND TECHNOLOGY COMBINATIONS

End-Use Demand	Fuel	Efficiency Improvements
Bus Demand	Diesel	Improved Eff, Adv. Tech, Adv. Hybrid
	Electric	Improved Eff, Adv. Tech, Adv. Hybrid
	CNG	Improved Eff, Adv. Tech, Adv. Hybrid
	Hydrogen fuel cell	Hybrid
Medium- and Heavy-Duty Vehicles - Short-Haul Demand	Diesel	Improved Eff, Adv. Tech, Adv. Hybrid
	CNG	Improved Eff, Adv. Tech, Adv. Hybrid
	Hydrogen fuel cell	Hybrid
Rail Passenger Demand - Commuter	Diesel	
	Electric	
Rail Passenger Demand - Passenger Rail Subways & Streetcars	Electric	

FIGURE 6.74 | SOURCE: U.S. EPA

ELECTRIC SECTOR MODULE

The power sector module of the model contains technology characterization for all EGUs located in New York State. In addition, imports from Canada and neighboring states are represented. The EGUs in New York City are dual-fuel generators using natural gas or oil. The module also includes CHP capacity, and CHP for district heating. CHP details are taken from the U.S. Department of Energy CHP database. The transmission and distribution network capacity for electric trade linkages are included.

Total generation for each of the three different regions are then calculated based upon generation reported from input data sources (EIA 923, EIA 860, EPA Carbon Emissions Monitoring System, and NYISO Gold Book) and membership of generating facilities to each region[147-149]. COMET-NYC determines the electricity demand for the New York City's boroughs through detailed technology representation in buildings and transportation. The electricity demand for the rest of the state is taken exogenously from NYISO Gold Book's high-demand scenario. Based on the total electric demand, COMET-NYC acts as a capacity expansion model, and calculates future EGU capacity based on capital, operations and maintenance, and fuel costs. In addition, COMET-NYC incorporates constraints to mimic the city's access to upstate renewable sources in zones G, H, and I.

All the electricity generated in the city is used in the city. Total emissions from each generating facility in New York and New Jersey are calculated based upon total generation, fuel emission coefficient and heat rate. COMET is not a dispatch model; therefore, some assumptions were made on how generation is allocated to the city. These assumptions are then used to calculate the emissions-intensity of electricity. Following list includes main assumptions:

1. 100 percent of generation in zone J is used to serve zone J's load. For example, if New York City's load is 50,000 GWh and zone J's annual generation is 25,000 GWh, zone J's regional distribution factor is 50 percent.
2. The model includes imports from Canada and PJM grid, specific to Public Service Enterprise Group (PSEG). The total aggregate electricity generation from PSEG plants are represented as import flows, and we calculated an emissions intensity for that flow based on the generator heat rate and fuel consumption data.
3. New York City's remaining load (i.e. after subtracting zone J generation and PSEG imports) is served by generation in A-F and GHI. The model optimizes on the least-cost pathway for the capacity expansion. For calculating New York City-specific electricity intensity. We assume a 50/50 split between zones A-F and zones GHI.

We added an installed reserve margin of 20 percent based on information from NYISO[150].

To model the impact of federal actions, COMET also includes the clean electricity production tax credit and the investment tax credit from the IRA. The level of the clean electricity tax credit is provided in Figure 6.75. The investment tax credit provides a 6 percent investment tax credit for PV and wind

CLEAN ELECTRICITY PRODUCTION TAX CREDIT

Year	Million $/PJ	Applied To
2021	1.02	Hydro, Solar, and Wind
2024	1.02	Hydro, Solar, and Wind
2024	0.61	Nuclear
2025	0.61	Hydro, Solar, and Wind
2025	0.61	Nuclear
2034	0.61	Hydro, Solar, and Wind
2034	0.61	Nuclear

FIGURE 6.75 | SOURCE: U.S. IRS[151]

DISCUSSION

The reference case as a baseline case that contains all implemented federal and state policies relevant to energy and the environment starting in 2010. The methodology and data sources described in the previous sections are utilized to generate a reference case for New York City such that sector-by-sector energy consumption reported in the GHG Inventory matches COMET-NYC's modeled energy consumption. Figure 6.76 shows the result of this comparison for the 2015 GHG Inventory and the COMET model. The values are relatively well-calibrated, except some smaller demand sectors (i.e., marine diesel use and school buses).

In 2015, gasoline was the main fuel meeting the light-duty demand, whereas diesel was mainly consumed by buses and heavy-duty short-haul vehicles. Although an increase in GHG emissions is expected with population growth, urbanization, and economic development, the implementation of national light-duty fuel efficiency standards and vehicle turnover to more efficient technologies lead to reduced fuel consumption and therefore reductions in citywide emissions, and transportation GHG emissions. In addition, increasing penetration of EVs contributes to reduction in CO_2e emissions. In the heavy-duty sector, the diesel consumption is still prominent and grows steadily. However, compared to the light-duty sector, its contribution to is to overall CO_2e emissions is low.

The projected end-use service demands in buildings depend on various drivers such as population, economic growth, number of people per household, building envelope efficiency, and additional need for cooling and heating. With increase in population, one would expect the energy demand in buildings to increase as well. There has been a shift in number of HDD and CDD over the years, and with climate change, the number of CDD is projected to increase and the number of HDD is projected to decrease.Because of these trends in HDD, space heating demand for residential and commercial buildings is projected to decrease 8 and 22 percent in 2050 compared to 2015, respectively. The space cooling demand for residential and commercial buildings is projected to increase 41 and 17 percent in 2050 compared to 2015, respectively. These shifts in demand yield a decrease in total energy demand, resulting in less need for fuel in the buildings sector. On top of this, the technology turnover rate, efficiency improvements in technologies, and switching to electric appliances yield further decreases in fuel and electricity consumption for the buildings sector. As a result, significant reductions in CO_2e emissions are observed.

COMPARISON OF COMET AND NEW YORK CITY GHG INVENTORY

Sector	Energy Source	Unit	2015 – Inventory	2015 – COMET	Percent Difference
Buildings	Fuel oil	gallon	401,012,088	387,541,977	-3%
Buildings	Electricity	kWh	49,040,294,907	46,385,403,130	-5%
Buildings	Natural gas	SCF	306,491,262,644	289,721,363,531	-5%
Buildings	Steam	kg	9,585,774,413	9,207,070,687	-4%
Transport	Electricity – subway and commuter rail	kWh	2,163,557,443	2,146,698,448	-1%
Transport	Diesel – commuter rail	gallon	1,440,319	1,404,325	-2%
Transport	Diesel – marine navigation	gallon	5,377,481	6,512,467	21%
Transport	Jet fuel – aviation	gallon	268,598	262,189	-2%
Transport	Passenger cars	VMT	20,031,919,734	19,662,888,322	-2%
Transport	Medium-duty trucks	VMT	505,647,835	509,091,642	1%
Transport	Heavy-duty trucks + solid waste collection vehicles	VMT	655,658,982	655,658,982	0%
Transport	Transit bus + school bus	VMT	290,884,069	345,771,777	19%

FIGURE 6.76 | SOURCE: NYC OMB, with U.S. EPA

NEW YORK CITY GRID MIX

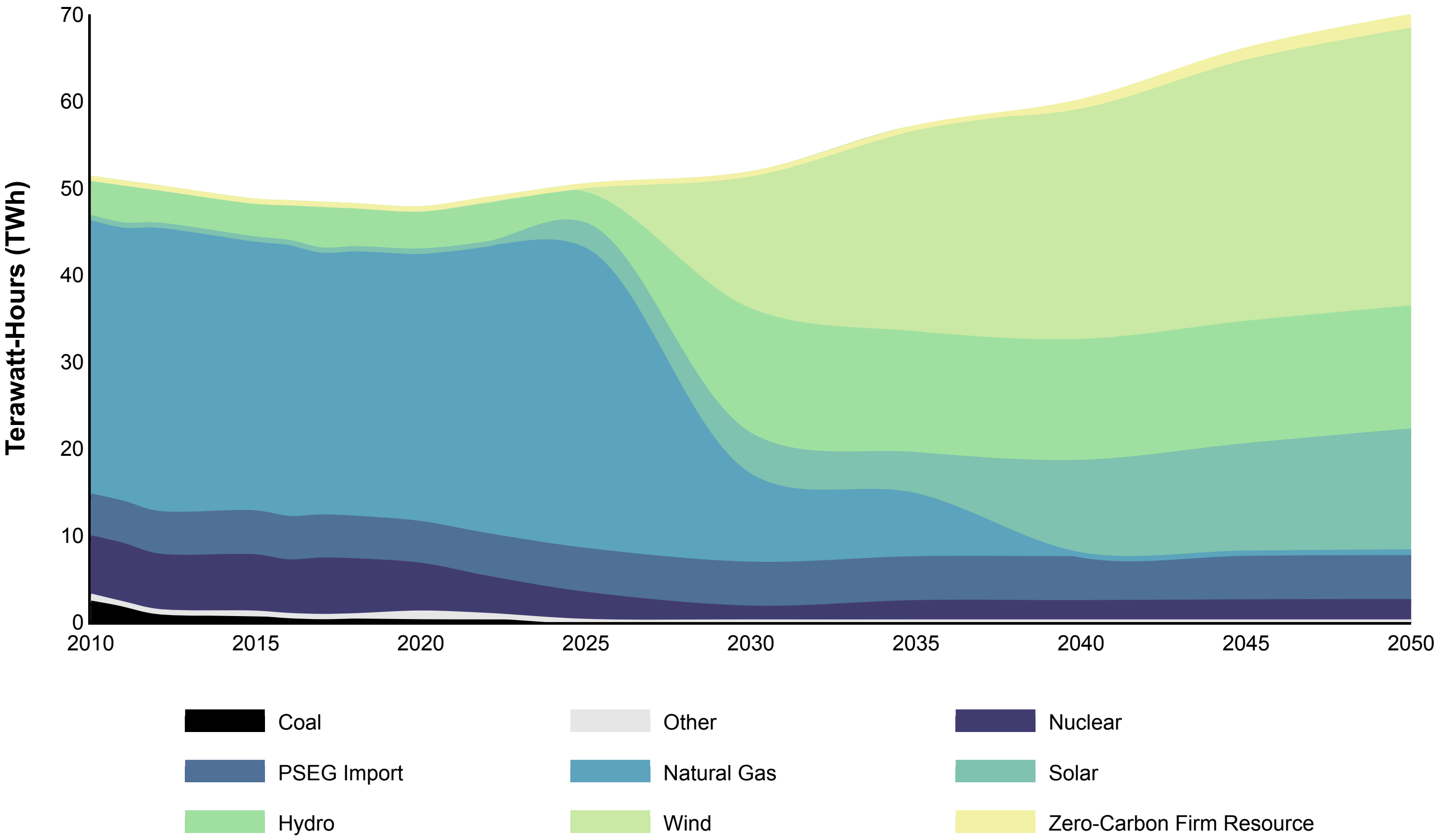


FIGURE 6.77 | SOURCE: NYC OMB, with U.S. EPA

The New York City grid-mix graph reflects the expected transformation of New York City's energy supply from 2010 to 2050, based on the successful implementation of New York State's LSR initiative and other state actions. The gradual reduction of natural gas in the city's energy portfolio is aligned with state policies promoting clean energy. Growth in renewable sources, such as wind and solar, is projected to increase significantly, in line with the state's renewable energy targets.

The category labeled "Zero-Carbon Firm Resource" represents future technologies that are anticipated to supply reliable, non-intermittent power without greenhouse gas emissions. These technologies are essential to meet the demand for energy while achieving a fully decarbonized grid and are factored into projections, although they are not yet in existence.

GLOSSARY

AC	Air Conditioning
AEO	United States Energy Information Administration's Annual Energy Outlook
AQ	Air Quality
B	Billion
BBL	Borough-Block-Lot
BC	Black Carbon
BEAM	Biosolids Emissions Assessment Model
BIL	Bipartisan Infrastructure Law (Infrastructure Investment and Jobs Act of 2021)
BK	Brooklyn
bn-vmt-yr	Billion Vehicle Miles Traveled per Year
BPL	Brooklyn Public Library
BPM	New York Best Practices Model
Btu	British thermal unit
BX	Bronx
CBD	Manhattan Central Business District
CCB	Carbon Capital Budget
CDD	Cooling Degree Day
CF	Capacity Factor
CFL	Compact Fluorescent Light
CH4	Methane
CHP	Combined Heat and Power
CIG	New York City Cultural Institutions Group (in Department of Cultural Affairs)
CLCPA	New York Climate Leadership and Community Protection Act
CMAQ	U.S. EPA's Community Multiscale Air Quality
CMS	New York City Department of Transportation's Citywide Mobility Survey
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COMET	United States Environmental Protection Agency’s City-based Optimization Model for Energy Technologies
COP	Coefficient of Performance
CRDG	Climate Resiliency Design Guidelines
CUNY	City University of New York
DCAS	New York City Department of Citywide Administrative Services
DCP	New York City Department of City Planning
DEM	New York City Department of Citywide Administrative Services, Division of Energy Management (DCAS-DEM)
DEP	New York City Department of Environmental Protection
DHS	New York City Department of Homeless Services
DHW	Domestic Hot Water
DOB	New York City Department of Buildings
DOC	New York City Department of Correction
DOE	New York City Department of Education
DOHMH	New York City Department of Health and Mental Hygiene (NYC Health Department)
DOT	New York City Department of Transportation
DSNY	New York City Department of Sanitation
DU	Dwelling Unit
ECC	Energy Conservation Code
ECM	Energy Conservation Measure
EGU	Electric Generating Unit
EIA	United States Energy Information Administration
EO	Executive Order
EOL	End of Life
EPA/ORD	United States Environmental Protection Agency's Office of Research and Development
ESR	Environmental Sustainability and Resiliency Task Force (in New York City Mayor's Office of Management and Budget)
EUI	Energy Use Intensity
EV	Electric Vehicle
ExCEL	Expenses for Conservation and Efficiency Leadership
FDNY	New York City Fire Department
FHV	For-Hire-Vehicle
FMS	New York City Financial Management System
GAMS	General Algebraic Modeling System
GHG	Greenhouse Gas
GPC	Greenhouse Gas Protocol for Cities
GW	Gigawatt
H+H	New York City Health and Hospitals Corporation
HCR	New York State Homes and Community Renewal

HRA	New York City Human Resources Administration
HVAC	Heating, Ventilation, and Air Conditioning
HVFHV	High-Volume For-Hire-Vehicles
IAP	Local Law 97 of 2019 Implementation Action Plan
IPCC	Intergovernmental Panel on Climate Change
IRA	Inflation Reduction Act of 2022
IRS	United States Internal Revenue Service
kg	kilogram
klbs	Thousand pounds (weight)
kW	kilowatt
kWh	kilowatt-hour of electricity
LED	Light-Emitting Diode
LL	Local Law
LSR	Large-Scale Renewables
M	Million
MARKAL	MARKet ALlocation
MGP	Metal-Glass-Plastic Recycling
MN	Manhattan
MOCEJ	NYC Mayor's Office of Climate and Environmental Justice
MOVES	United States Environmental Protection Agency's Motor Vehicle Emission Simulator
MTA	Metropolitan Transportation Authority
MW	Megawatt
MWh	Megawatt-hour of electricity
N_2O	Nitrous Oxide
NG	Natural Gas
NO_x	Nitrogen Oxides
NPCC	New York City Panel on Climate Change
NTA	Neighborhood Tabulation Area
NYCEDC	New York City Economic Development Corporation
NYCHA	New York City Housing Authority
NYISO	New York Independent System Operator
NYMTC	New York Metropolitan Transportation Council
NYPL	New York Public Library
NYSERDA	New York State Energy Research and Development Authority
OC	Organic Carbon
OMB	New York City Mayor's Office of Management and Budget
PACT	New York City Housing Authority's Permanent Affordability Commitment Together
Parks	New York City Department of Parks and Recreation
PECM	Prescriptive Energy Conservation Measure
PJ	Petajoule
PlaNYC	PlaNYC: Getting Sustainability Done report
PLUTO	Primary Land Use Tax Lot Output dataset
PM_{10}	Particulate Matter up to 10 Micrometers in Diameter
$PM_{2.5}$	Particulate Matter up to 2.5 Micrometers in Diameter
PSEG	Public Service Enterprise Group
PV	Photovoltaic
QN	Queens
QPL	Queens Public Library
REC	Renewable Energy Certificate
RES	Reference Energy System
RTEM	Real-Time Energy Management
SCA	New York City School Construction Authority
SCF	Standard Cubic Foot
SED	New York Metropolitan Transportation Council Socioeconomic and Demographic 2055 Forecast
SI	Staten Island
SO2	Sulfur Dioxide
SUV	Sport Utility Vehicle
TAG	Technical Advisory Group
tCO_2e	Metric tons of carbon dioxide equivalent greenhouse gas emissions
TIMES	The Integrated MARKAL-EFOM System
TLC	New York City Taxi & Limousine Commission
$tPM_{2.5}$	Metric tons of particulate matter with diameter up to 2.5 micrometers
TRB	Transportation Research Board
TWh	Terawatt-hour
U.S. EPA	United States Environmental Protection Agency
VMT	Vehicle Miles Traveled
VOC	Volatile Organic Compounds
WARM	United States Environmental Protection Agency's Waste Reduction Model
WCS	Waste Characterization Study
WRI	World Resources Institute

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