Climate Change: Equitable Access to Cooling in New York City

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Our Mission:

Advance clean energy innovation and investments to combat climate change, improving the health, resiliency, and prosperity of New Yorkers and delivering benefits equitably to all.

Climate Change: Equitable Access to Cooling in New York City

Final Report

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Abstract

Climate change is expected to increase the average annual temperatures across New York State as well as the frequency, intensity, and duration of extreme weather events, such as heat waves. Subsequently, the demand for cooling and associated electricity usage is expected to increase under these scenarios. As demand for cooling increases, it is imperative to understand how cooling usage patterns and needs will change under future climate conditions. This is particularly and disproportionately true among impacted communities that have a (1) higher percentage of residents with underlying health, economic, and social challenges and (2) greater susceptibility to heat-related illness during extreme heat events. Heat vulnerability is generally defined by exposure (e.g., extreme weather, high surface temperatures), sensitivity (e.g., underlying conditions) and adaptive capacity (e.g., financial resources, poverty, social isolation) in the summer months, particularly during extreme heat events.

This report evaluates the impacts of climate change on indoor cooling needs in New York City to assess how these patterns will change under different climate scenarios. The analysis focuses on the economic and health impacts to heat-vulnerable populations in the City, as well as technology and policy options to meet future residential cooling needs while minimizing increases in energy use and demand. The report is intended to provide health, building, and policy stakeholders with research and insights to support their ongoing work in addressing New York City's challenges due to climate change.

Keywords

Space cooling, air conditioning, extreme heat, vulnerable populations, heat vulnerability index, climate change, urban heat island, cool roofs, green roofs

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The authors also appreciate the insights, research resources, and contacts provided by Project Advisory Committee (PAC) members throughout the study as well as the additional experts and stakeholders who participated in the structured dialogs with our team. Their organizations are provided below.

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- New York State Department of Health (DOH)
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- Arizona State University (ASU)
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- City of Phoenix
- City University of New York (CUNY)
- Columbia University, Earth Institute
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- Community Energy Engagement Program (CEEP), Center for NYC Neighborhoods
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- HOPE program, NYC
- Northern Manhattan Improvement Corporation (NMIC)
- Philadelphia Office of Sustainability
- The Point Community Development Center (The Point CDC) NYC
- WEACT for Environmental Justice

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Acronyms and Abbreviations

AC	Air Conditioning
AMI	Area Median Income
CDD	Cooling Degree Days
CLCPA	Climate Leadership and Community Protection Act
DCP	Department of City Planning
DOH	Department of Health
DOHMH	Department of Health and Mental Hygiene
EE	Energy Efficiency
EIA	Energy Information Administration (federal government)
GHG	Greenhouse Gases
HEAP	Home Energy Assistance Program
HVAC	Heating, Ventilation and Air Conditioning
HVI	Heat Vulnerability Index
ISEE	International Society of Environmental Epidemiology
LIHEAP	Low-Income Home Energy Assistance Program
NEEP	Northeast Energy Efficiency Partnerships
NRDC	National Resources Defense Council
NREL	National Renewable Energy Laboratory
NYCHA	New York City Housing Authority
NYISO	New York Independent System Operator
NYPA	New York Power Authority
O&M	Operations and Maintenance
PAC	Project Advisory Committee
PLUTO	Primary Land Use Tax Lot Output
PTAC	Packaged Terminal Air Conditioner
RCP	Representative Concentration Pathway defined by the Intergovernmental Panel on Climate Change
SEER	Seasonal Energy Efficiency Ratio
TRM	Technical Reference Manual/Technical Resource Manual
UHF	United Hospital Fund
UHI	Urban Heat Island
U.S.	United States of America
WAP	Weatherization Assistance Program

Summary

S.1 Background

The New York State Energy Research and Development Authority (NYSERDA) seeks to better assess the impacts of climate change on indoor cooling needs in New York City, with specific focus on vulnerable populations and communities. Heat vulnerability is generally defined by exposure (e.g., extreme weather, high surface temperatures), sensitivity (e.g., underlying health conditions) and adaptive capacity (e.g., financial resources, poverty, social isolation) in the summer months, particularly during extreme heat events. Guidehouse Inc. (Guidehouse) was engaged to perform an analysis of cooling usage patterns across New York City to understand how these patterns change under different climate scenarios. The analysis focuses on the economic and health impacts to vulnerable populations in the City, as well as technology and policy options to meet future residential cooling needs while minimizing increases in energy use and demand.

Guidehouse analyzed current residential cooling patterns across New York City and developed a spreadsheet-based model to project electricity consumption, demand, operating cost, capital cost, and other characteristics for residential space cooling systems under different climate scenarios. Guidehouse and researchers with the University at Buffalo conducted a literature review of public health research related to extreme heat as well as strategies to expand cooling access and mitigate heat risks. The study team then characterized current technology, policy, and market barriers related to the efficient use of, and equitable access to, cooling and prioritized a list of technology and policy options to meet the cooling needs of vulnerable populations, while minimizing increases in energy use and demand. The team then conducted structured dialogs and focus groups with key experts, community and environmental justice groups, utility administrators, and researchers in the areas of health, climate change, and vulnerable populations to refine the list of identified options. The team then prepared and analyzed three scenarios of prioritized technology and policy solutions to understand the overall impacts on cooling equity, electricity consumption, and cost for New York City residents. The report is intended to provide health, building, and policy stakeholders with research and insights to support their ongoing work to address NYC’s challenges due to climate change.

Guidehouse developed this report to summarize the major findings and insights from the Climate Change: Equitable Access to Cooling in New York City study over the course of the entire project: fall 2020 through spring 2021, accounting for a pandemic-related pause over summer/fall 2020. During several meetings and written comments, NYSERDA staff and PAC members[1] for this study provided insights, research resources, and contacts to support the research effort.

S.2 New York City Cooling Energy Demand Today

New York City's building stock consists of approximately one million buildings with total floorspace of over 5 billion square feet and 3.2 million residential housing units.[2] Residential and commercial buildings consume approximately 7,254 gigawatt-hours (GWh) per year for space cooling systems or approximately 17% of total electricity consumption. Within the residential sector, space cooling accounts for approximately 21% of annual home electricity consumption (3,338 GWh/year). Unlike many electrical appliances, space cooling demand is directly tied to weather and its impacts for residential utility bills are largely concentrated in the summer months.

Most New York City residential buildings today have one or more air conditioning (AC) systems providing space cooling during the summer, with a citywide AC adoption rate of 91%. Central split-AC systems are the most common AC type for single-family buildings, whereas multifamily buildings are predominantly served by self-contained window, room, or packaged terminal AC (PTAC) units. While the citywide AC adoption rate is high, the remaining 9% of homes represents almost 300,000 housing units across the City, or approximately 750,000 residents assuming an average household size of 2.6 residents per home. Even for residents with AC systems, some may operate their systems sparingly due to utility cost concerns or poor performance of older units. Due to the warming climate, more City residents will likely install and operate AC systems in the future, which will increase electricity consumption in the home as well as citywide.

Homes with better insulation, windows, roof, and minimal air leakage characteristics will require less cooling capacity and consumption per square foot relative to homes with inferior building characteristics. Building envelope technologies such as wall, floor, and ceiling insulation and windows are an often-overlooked component of residences, which decreases the potential for higher efficiency and reducing both space cooling and space heating consumption.

The choice of roofing materials has a number of effects relating to energy consumption in the individual home and surrounding neighborhood. Installing cool roof materials can reduce the heat gain in the individual building in the summertime and decrease space cooling demand. Furthermore, the technology can also reduce the localized air temperature in the surrounding neighborhood and decrease the urban heat island (UHI) effect that increases space cooling demand over a wider area. Nevertheless, many residential buildings will forgo upgrades until well past the useful life of building systems due to financial limitations.

Projecting residential cooling energy consumption and operating costs across New York City in future years involves an evaluation of several interacting factors that can either increase or decrease cooling demand per home or on a citywide basis. Table S-1 highlights several key factors analyzed in this study along with their impact on residential cooling demand, which are further discussed in this section. Factors such as climate change, housing and population growth, and greater AC system adoption will increase the energy consumption citywide for space cooling. Factors such as appliance standards, building codes, energy efficiency (EE) programs, and greenhouse gas (GHG) emissions policies will reduce the per unit cooling demand for NYC buildings.

There are many other contributing factors that will influence how NYC residents will use AC systems in the future, especially behavioral factors. Unforeseen events such as the COVID-19 public health crisis may dramatically shift how residents interact with residential and commercial buildings in future years.

Table S-1. Key Factors Affecting Cooling Electricity Consumption and Cost

Category	Factor	Description	Impact
Increase Cooling Consumption/ Cost	**Climate Change**	• Warmer climate will increase the daily and seasonal demand for space cooling in New York City.	Increased per-home cooling demand.
	Population Growth	• Expected population and housing growth will increase the number of homes with AC systems in future years.	Increased cooling demand citywide.
	AC Adoption	• Warmer climate will likely drive more homes to install AC systems.	Increased cooling demand citywide.
	Utility Rates	• Electricity rates increase over time, increasing cooling operating costs to consumers.	Increased per-home cooling cost
Decrease Cooling Consumption/ Cost	**EE/GHG Emissions Reduction Policies**	• Appliance standards and building codes improve the energy efficiency of New York City building stock over time. • Aggressive State and city GHG reduction targets encourage greater adoption of high-efficiency technologies.	Decreased per-home cooling demand.

S.3 Climate Change and Heat Risks for Vulnerable Populations

New York City residents today experience heat-related illness during summer heat waves each year. Over the 2016 summer season, there were 592 emergency department visits, 151 hospitalizations, and seven deaths related to heat-stress or hyperthermia.[3] These figures likely underestimate the number of heat-related illnesses and deaths.[4] Heat stress affects NYC residents while spending time indoors as well as while outdoors and while working or traveling across the city.

Global climate change will exacerbate heat-related challenges for residents concentrated in neighborhoods with poor housing conditions, less green space, lower incomes, and other exposure and sensitivity-related factors contributing to heat vulnerability. Public health experts at government agencies, universities, and other research institutions have conducted a wide range of statistical analyses to investigate historical and future health risks from extreme heat events. In future years, NYC is forecasted to experience hotter summers, warmer winters, heavier rainfall, greater coastal flooding, and more extreme weather events due to climate change.[5] The frequency and duration of extreme heat events are expected to significantly increase over the period 2020 to 2050, particularly over historical baselines.

Available public health research literature consistently identifies the connection between increased health risk during extreme heat events in the Northeast United States (U.S.) and find that climate change will significantly increase the magnitude of the health impacts due to heat stress over the 2020 to 2050 time period and beyond. The research findings also illustrate how several interconnected factors increase heat risk for vulnerable populations, and how underlying challenges will require a more comprehensive strategy to address cooling equity.

Experts at the New York City Department of Health and Mental Hygiene (DOHMH) and Columbia University developed a Heat Vulnerability Index (HVI) metric (1=low-risk, 5=high-risk) measuring how likely a person is to be injured or harmed during periods of hot weather to identify higher and lower risk neighborhoods in NYC based on neighborhood-level estimates for daytime surface temperatures, availability of green space, poverty level, and race.[6] The research literature also identified how cooling solutions, such as AC systems, heat alerts, and cooling shelters, can mitigate the adverse health impacts during extreme heat events.

While increasing AC system adoption may appear to be a straightforward solution to mitigate heat stress, the caveats provided above suggest deployment programs will need to address the wider concerns and situations of NYC residents to ensure the solutions provided meet the needs of all vulnerable populations and that those populations can access and make full use of the programs, policies, and technologies deployed.

S.4 Evaluating Changes in New York City Cooling Demand and Energy Use

Guidehouse developed a spreadsheet-based model to analyze how NYC residential space cooling demand, energy consumption, peak electricity demand, and building stock characteristics will change over the period between 2020 to 2050 as a result of climate change, population growth, and other factors. Guidehouse prepared three modeling scenarios to understand the impacts for key factors, isolate the contributions of existing energy efficiency and GHG emissions policies, and evaluate the potential value of new technology and policy solutions. Table S-2 below outlines key characteristics for these modeling scenarios. The Technology & Policy Solution Scenario in the model allows for customized inputs to evaluate different packages of equitable cooling solutions. In the preliminary analysis, Guidehouse modeled the impact of 50% adoption of high-efficiency AC systems. In the later analysis, Guidehouse models several packages of solutions identified through the structured dialogs with key experts and stakeholders. These include increasing adoption levels of high-efficiency AC systems, weatherization, and envelope upgrades, cool roof adoption, tree planting and urban greening, and cool pavements.

Table S-2. Summary of Cooling Demand Modeling Scenarios

Source: Guidehouse analysis.

Scenario	Description
Steady Progression Scenario	• Includes impacts of climate change, population growth, utility rates, normal appliance and building system turnover.
Current Policy Scenario	• Same as Steady Progression scenario with additional impact of EE programs.
Technology & Policy Solution Scenario	• Same as Current Policy scenario with customized adjustments for technology parameters: adoption rates, energy savings, upfront cost. • In the Preliminary Analysis, the Technology & Policy Solution scenario results show the impact for 50% adoption of high-efficiency AC systems. • Later in the analysis Guidehouse models several packages of solutions identified through the structured dialogs with key experts and stakeholders.

The following list summarizes Guidehouse's key conclusions regarding future NYC cooling demand in a changing climate and impacts that increased residential AC adoption would have on citywide electricity consumption, peak demand, and customer utility bills:

- **Residential Electricity Consumption**—Projected per-home cooling electricity consumption impacts from climate change are largely offset by New York State's energy efficiency targets, which are implemented by public agencies and through utility programs. A variety of federal, State, and local policies outline prescriptive requirements for NYC residential buildings related to energy efficiency, safety, and other characteristics—and over time improve the energy efficiency of the building stock. Furthermore, energy efficiency incentive programs offered by electric utilities and public organizations encourage the adoption of building technologies with performance above minimum codes and standards. Despite the above, NYC residential cooling electricity costs increase in future years due to projected utility rate increases. Overall citywide residential electricity cooling demand is relatively flat as population growth and climate change offsets energy efficiency gains.
- **Electricity Impacts from Increasing Residential AC Adoption—**Installing AC systems in the homes of vulnerable residents is one of the more promising strategies to address cooling access in NYC. The analysis suggests that increasing residential adoption of AC systems from 91% to 100% will have a modest impact on citywide energy consumption (1–2% of total NYC building consumption over 2020–2050). Similarly, extending access to AC systems for all homes would increase future citywide (Zone J) peak demand by 285 megawatt (MW) or approximately 2.2% over NYISO projections for 2035–2050. High-efficiency AC systems with grid-interactive features, as well as statewide energy shifts through State GHG emissions policies, could mitigate these electricity impacts.
- **Energy Insecurity for Vulnerable Populations**—Increasing access to AC systems for vulnerable populations can help mitigate health risks during extreme heat events, but the additional electric utility costs to operate the AC systems may create an additional economic burden if not managed correctly. The analysis suggests that an average residential cooling cost of $303 per year could be reasonable for most NYC residents. Nevertheless, vulnerable residents below the poverty line would likely face challenges affording cooling utility bills during the summer, even after available energy insecurity programs that limit energy spending to 6% of income.

S.5 Barriers to Equitable Cooling and Options to Expand Cooling Access

Although the majority of New York City homes have AC systems, many homes in vulnerable communities today either do not have working AC systems or choose not to use the systems due to behavioral preferences, economic challenges, and/or limited awareness concerning heat vulnerability. Changes in behavior, such as the stay-at-home order for the COVID-19 crisis, can also impact health risks as more residents are home during the day when they would normally be elsewhere. Due to the crisis, public cooling centers may close, limiting access to cooling through that channel. Future strategies must address the large number of technical, market, and policy barriers highlighted in Table S-3 that present challenges to providing equitable cooling.

Table S-3. Technical, Market, and Policy Barriers to Equitable and Efficient Cooling

Source: Guidehouse analysis based on literature review of resources described in section 5.1. Details for each barrier provided in section 5.1.

Technical	Market	Policy
• AC ownership by building landlords. • Challenges to building envelope upgrades. • Cost of any technology. • Cost of up-to-code technology. • High overnight temperatures. • Electrical upgrades for cooling technology. • Structural limitations of older buildings. • Operations and maintenance requirements. • Limitations of public programs.	• Lack of awareness about the danger of high temperatures. • Lack of awareness about cooling centers. • Preference for fans. • Stigma associated with cooling centers, concern for pets, lack of transportation. • Existing building stock with window units. • Cost-effectiveness of high-efficiency technology. • Requirements for technology success. • Lack of efficiency information for some solutions. • Lack of cooling technology information per Local Law 133[7] exemptions.	• Financial assistance gaps. • Building code compliance gaps. • Public housing AC requirements. • Landlord requirements for AC installation per Local Law 11.[8] [9] • Indoor temperature policy gaps. • Spatial gaps in cooling policy effectiveness.

Technology and policy solutions must be deployed to ensure that vulnerable populations have affordable access to cooling and are benefiting from energy efficiency and climate policies in the State as well as NYC. Guidehouse and the University at Buffalo conducted a literature review to identify available technology and policy solutions that could address cooling access. A broad list of over 60 identified solutions was narrowed to approximately 20 technology and policy options, summarized in Table S-4 below.

Table S-4. Narrow List of Technology and Policy Options

Source: Guidehouse analysis.

Technology Options	Policy Options
AC and Building Envelope Improvements • AC systems • Bundled building envelope sealing, insulation, and AC improvement. • Light-colored roofs such as Cool Roofs Program • Cool/Reflective Walls. **Public Cooling Spaces** • Cooling Centers • Cooling Oases **Public Space Improvements** • Coordinated tree planting with accompanying exaction. • Green infrastructure (e.g., green byways, bioswales, rain gardens). • Light-colored or porous pavement such as Cool Pavement Program.	**Legislation/Codes** • Update building code (e.g., ventilation, efficiency, individual metering). • Reduced fares on public transportation **Incentives/Rebates** • Provide incentives for AC, ventilation, building shell improvements, and fans. • Expand/target existing/new financing and incentive programs. • Advise changes to how NYC interacts with LIHEAP/WAP. • Tax abatement for installation or retrofit of cool roofs. **Programs/Plans** • Expand and enhance Cooling Center Program.

From the structured dialogs, it was evident that the largest priority is improving cooling inside residents' homes for both safety and comfort. Participants in the dialogs also made it clear that bill relief and increased funding and aid programs could greatly lessen the burden on residents and incentivize residents to both install and utilize cooling technologies. Using technology and policy solutions in tandem is the best way to improve accessibility and adoption of cooling in New York State as well as City. Other cooling options such as urban greening and cooling centers should be implemented as secondary measures to augment the focus of keeping residents safe and comfortable in their own homes. The following list summarizes Guidehouse's key conclusions regarding available equitable cooling solutions through the review of research literature and structured dialogs with key experts and stakeholders:

- **Technology and Policy Solutions**: Technology and policy solutions must be deployed to ensure that vulnerable populations have affordable access to cooling and are benefiting from energy efficiency and climate policies in New York State and New York City. At the household level, promising strategies center on providing financial access to AC through incentives or rebates. Promising building-level solutions include expanding access to both financial support for building shell improvements such as improved sealing and reflective walls/roofs, which can reduce indoor air temperatures. At the neighborhood level, cooling centers continue to be a encouraging option to provide access to cooling; through structured dialogs conducted by the team, improvements to cooling centers to make them more attractive and to promote their use include the implementation of affordable transit, development of amenities such as WiFi, and marketing and outreach to raise awareness of cooling centers. Other promising solutions include those that mitigate the urban heat island (UHI) effect, such as trees and green infrastructure, providing long-term cooling benefits at the street or neighborhood-level.

- **Importance of In-Home Solutions**: Cooling within the home is of high priority because residents feel most comfortable—and are therefore more likely to spend significant quantities of time—at home. In addition, it can be inconvenient and challenging to get transportation to cooling centers due to factors such as affordability, medical devices, children, and pets. Due to cooling center closures because of COVID-19, it is even more apparent that in-home solutions are the most pressing need. Safety within residents' own homes makes people safe and comfortable without solely resorting to less effective options such as urban greening and cool roofs.
- **Strategies for Cooling Success**: Solutions must combine cooling systems with electricity bill relief for eligible residents—providing an AC without the means to operate it will lead to poor operation and challenges. In addition, cooling equity programs should be deployed through existing operating programs such as Weatherization Assistance Program (WAP) and Home Energy Assistance Program (HEAP), without duplicating efforts, particularly on federal, State, city, and local levels.
- **Role for Heating Electrification**: Statewide goals for heating electrification and energy efficiency can support high-efficiency space heating and cooling but cannot sacrifice short-term health needs for long-term GHG emissions goals.
- **Improving Cooling Centers:** Cooling centers can be improved by dedicated funding and spaces for cooling centers in communities. The structured dialogs revealed that today's cooling centers are mostly an add-on function to existing spaces without funding for staff, signage, activities, refreshments, and other items. Furthermore, more should be done to provide accessible and affordable transportation to the cooling centers, along with improved communication strategies so that residents can identify and travel to the nearest cooling center. Where possible, the cooling centers should be located within the communities (e.g., common area of New York City Housing Authority [NYCHA] housing, local churches and schools, community centers). Installing community solar systems with storage or auxiliary generation systems at dedicated cooling centers can also improve the resiliency of the facilities to ensure operation during extreme heat events that may cause local grid interruptions.

S.6 Cooling Impacts and Costs for Equitable Cooling Solutions

Using the spreadsheet model described above, Guidehouse modelled three scenarios and two reference cases to evaluate the impact on cooling equity, electricity consumption, energy cost, and other factors over 2020–2050 timeframe. Guidehouse compiled data on costs, cooling, addressable market, and other characteristics to model the individual measures and scenario packages both on a per-unit and citywide basis. Table S-5 below outlines the key characteristics for the modeling scenarios to extend cooling access to vulnerable populations. Each scenario provides AC systems and other measures for the roughly 300,000 homes without cooling today. The initiatives were applied to all residents to estimate the overall citywide impacts and understand how activities for the majority of NYC's building stock will minimize the energy impacts of extending AC access to all residents.

Table S-5. Key Characteristics by Modeling Scenario

Source: Guidehouse analysis.

Key Characteristics by Modeling Scenario	Baseline/ Current Policy Scenario (Reference)	100% AC Saturation (Reference)	Targeted Cooling Relief Scenario	Expanded System-Wide Cooling Scenario	Accelerated System-Wide Cooling Scenario
Percentage of Homes with ACs*	91%	100%	100%	100%	100%
% of Above Code AC	10%	10%	10%	25%	35%
% of Above Code Envelope	5%	5%	5%	15%	25%
Cool Roof Deployment	Assumes current cool roof codes may eventually impact 50% of NYC roofs				Modified cool roof codes impact 100% of NYC roofs
Incremental Weatherization Projects	n/a	n/a	30,000 per year (target 300,000 by 2030)	30,000 per year (target 300,000 by 2030)	30,000 per year (target 300,000 by 2030)
Incremental Cool Pavement Installations	n/a	n/a	n/a	15 million SF per year	30 million SF per year
Incremental Tree Planting / Urban Greening	n/a	n/a	n/a	10,000 trees per year**	20,000 trees per year**
Cooling Centers***	n/a	n/a	Targeted improvements in the cooling center strategy for NYC by 2025		
Community Solar***				Piloting community solar initiatives and rates by 2025 with targeted rollout in key neighborhoods over 2020–2050	

Each scenario incorporates progressively more technology and policy measures.

* approximately 3.2 million housing units in NYC, of which 300,000 do not have cooling systems today.

** tree planting was found to have high cost and limited impact on building AC consumption, so Guidehouse also modeled the Expanded and Accelerated scenarios excluding tree programs.

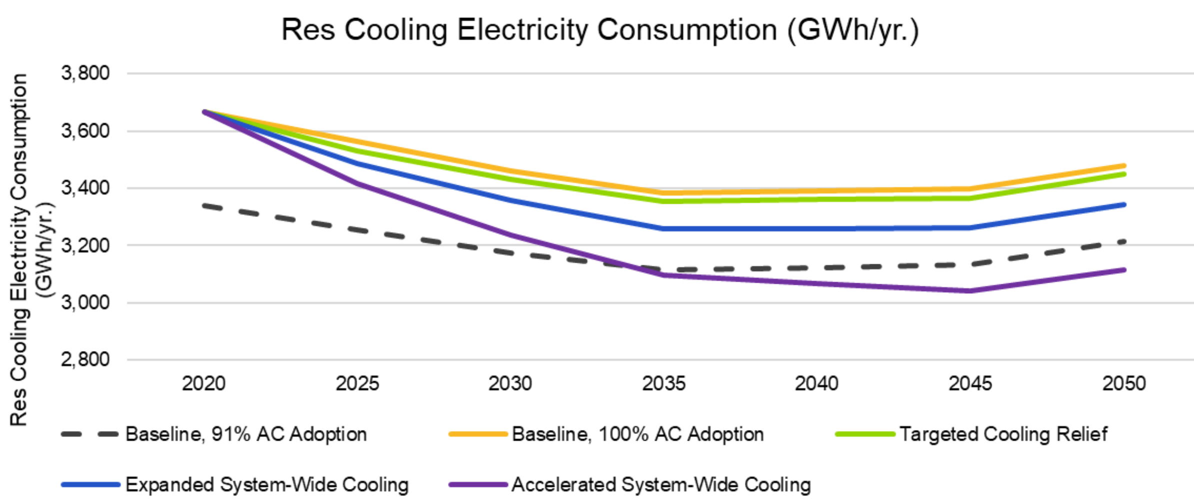
*** cooling centers and community solar are supporting measures that can theoretically offset cooling electricity consumption and cost at the home level, but it is highly uncertain what impact these solutions may have.

Before discussing the results of the scenarios, it is worth noting that NYC has already developed a variety of comprehensive programs and policies to address cooling equity. NYC has passed ambitious laws that will improve building energy efficiency, cool roof adoption, urban greening, and other initiatives in future years. Many of the ideas identified in the literature review and structured dialogs are already in place in NYC, so the analysis focused on what could be expanded or improved. The 2020 Cooling Assistance program in particular highlights NYC's leadership in addressing the equitable cooling issue in the face of the COVID-19 pandemic. The program provided approximately 70,000 AC units combined with bill relief to vulnerable residents, which would have reduced the number of homes without AC systems by 20% in a single year. This program provides an excellent example for how cooling can be delivered quickly and combined with bill relief, even if for a limited period of time.

Figure S-1 highlights the citywide increase in electricity consumption to install AC systems in every home. Extending access to AC systems to vulnerable populations will increase electricity consumption across the city, but energy efficiency measures explored in the scenarios can reduce this increase. The most-comprehensive solution would completely eliminate this increase. Measures such as cool pavements and tree planting can reduce UHI, but the indirect cooling impact on building AC consumption is minimal. Direct building related measures such as AC systems, envelopes, and roof improvements can have a more significant impact.

Figure S-1. Residential Cooling Electricity Consumption (Citywide)

Source: Guidehouse analysis using modeling process described in section 4.



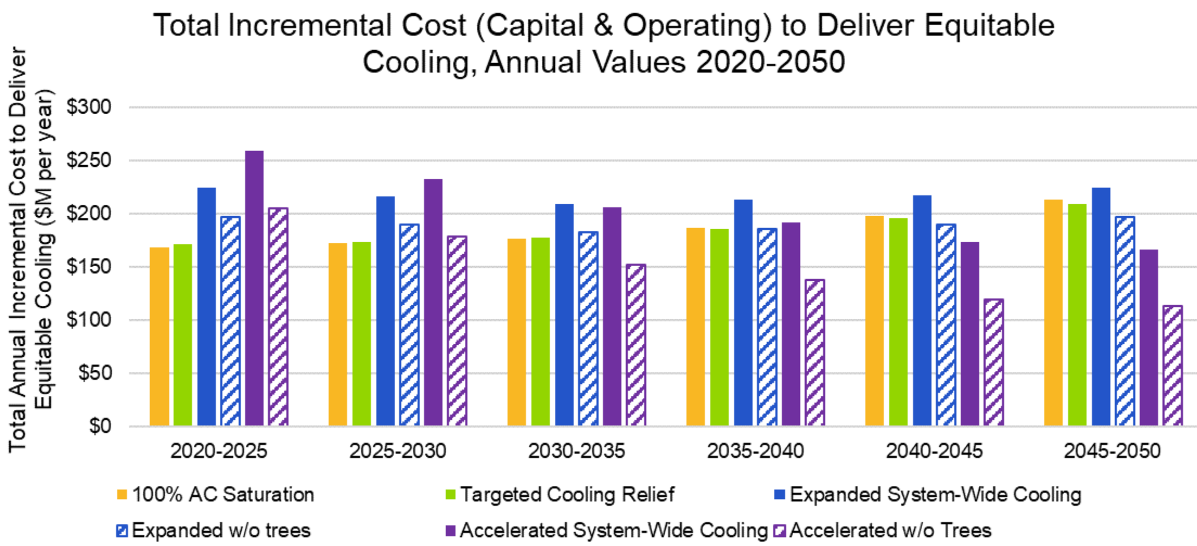
Space cooling can be delivered by air conditioners (AC only) or heat pump systems that can reverse the vapor-compression cooling cycle to provide high-efficiency space heating. Leaders in NYS and NYC are currently evaluating GHG reduction strategies and pathways to achieve climate targets, in particular, converting building space and water heating systems from fossil fuels to electric heat pumps. Because of the focus in this report for space cooling, similarities in cooling-mode operation, and uncertainties for NYC and NYS electrification strategies, the analysis does not distinguish between AC-only and heat pump products. Extending cooling to vulnerable communities with both AC-only and heat pump products is one potential solution to balance near-term health and safety goals while also supporting long-term GHG emission goals. Heat pump products should be considered for cooling equity programs in instances where installation does not pose significant incremental costs over an AC-only product. Alternatively, challenges in heat pump deployment for some existing buildings should not hold up equitable cooling with AC-only products to address immediate health risks. Given the variety of building types and configurations, stakeholders should recognize that a customized approach will be needed to address cooling equity and heating electrification across NYC.

Expanding cooling access does require an investment in capital cost to install the AC systems, plant trees, upgrade building envelopes, install cool pavements, etc. In addition, the citywide cooling operating cost will increase based on the greater number of AC systems, as well as expected utility cost increases. Energy efficiency measures can reduce this operating cost and may require additional capital investment. The ultimate cost impact for NYC to extend cooling to vulnerable populations will consist of the combination of the capital and operating costs relative to today's baseline. Figure S-2 outlines the total incremental costs to deliver equitable cooling to all NYC residents including capital and operating cost impacts for a combination of AC systems, energy efficiency measures, and UHI initiatives. Across the range of scenarios, extending cooling access to homes without AC systems today would carry a cost of approximately $170 million to $260 million per year over the period 2020–2050. In particular, tree planting was found to have high cost (estimated $2,700 per tree) and limited impact on building AC consumption (9.3 kWh/yr per tree). Due to these factors, the Expanded and Accelerated scenarios exclude the tree programs. As described above, the baseline Current Policy scenario already includes previously committed energy efficiency measures and building codes and appliance standards, so that the incremental energy efficiency is relatively costly in early years. Scenarios that include significant energy efficiency measures have relatively lower combined costs in later years due to increasing electricity rates over time.

Figure S-2. Total Incremental Cost (Capital and Operating) to Deliver Equitable Cooling (Annual Values)

Tree planting was found to have high cost and limited impact on building AC consumption, so the Expanded and Accelerated scenarios exclude tree programs.

Source: Guidehouse analysis using modeling process described in section 4.



While the cost for each scenario varies by the set of opportunities, the total incremental cost to deliver equitable cooling to the approximately 300,000 homes in NYC without cooling today would average around $200 million per year. On a per-unit basis, this would amount to approximately $700 per unit, when including levelized per-unit capital cost of AC system, weatherization, tree planting, and other measures as well as annual operating cost. The value of extending cooling to all NYC residents would be substantial but monetizing the non-energy impacts and benefits to the vulnerable residents would provide a better comparison. Using available research into low-income weatherization programs in Massachusetts as an indicative value,[10] the per home annual impacts of weatherization (e.g., insulation, air sealing, replacing/repairing windows and doors) amount to $173 for heat stress and $1,382 for all benefit categories. This suggests that the health, comfort, and productivity impacts that equitable cooling would provide vulnerable NYC residents would partially or fully offset the capital and operating cost associated with the analyzed measures.

The following list summarizes Guidehouse's key conclusions regarding cooling impacts and costs for equitable cooling solutions identified through the modeling analysis:

- **Capital and Operating Costs**: The analysis identifies that extending cooling access to all NYC homes will carry significant incremental operating and capital costs. Beyond the modeled solutions, policy support mechanisms for free or low-cost AC systems, weatherization upgrades, and bill assistance will be needed to shift the burden of these costs away from vulnerable populations. The annual cost to deliver equitable cooling across NYC is estimated at $200 million per year, or approximately $700 per housing unit when including levelized capital cost and annual operating cost. How these costs should be allocated across residents, property owners, utility customers, and taxpayers will require more detailed discussions and evaluation of impacts for different stakeholder groups.
- **Value of Direct Cooling Measures**: Direct cooling measures such as high-efficiency AC, envelope upgrades/weatherization, and expanding cool roof laws for residential buildings have a more significant impact than indirect cooling measures on cooling energy consumption. UHI related measures such as tree planting, cool pavements, and cool roofs for nonresidential buildings will have more limited, indirect impact on residential cooling electricity consumption. An optimal solution would combine both direct measures to each home as well as indirect measures at the neighborhood level.
- **Value of Indirect Cooling Measures**: Increasing energy efficiency and UHI measures can reduce the operating cost but carry additional capital cost requirements. Energy efficiency measures are best deployed when the existing systems reach the end of their lifetime to minimize the incremental cost of installation (e.g., high-efficiency AC, cool roof codes during replacement), particularly through building codes and ordinances. Deploying incremental measures (urban greening/tree planting) or retrofits (weatherization upgrades before end-of-life) would carry higher costs. Indirect cooling measures, such as tree planting, as well as supporting initiatives like community solar can be valuable for the community and has a lot of interest in community action stakeholders due to co-benefits (e.g., beautification, jobs). Nevertheless, these solutions must have the buy-in of the community to prevent gentrification, resident displacement, and imposing maintenance requirements on residents.
- **Capturing Non-Energy Benefits**: Equitable cooling solutions will provide greater benefits to NYC residents than what is modeled for cooling energy consumption alone. The analysis does not consider the economic value of non-energy benefits related to avoided heat stress, heath impacts, carbon reductions, air quality, job development, livability, beautification, and other attributes. Including these would further increase the benefits and reduce the net program costs for extending cooling access. Assuming similar performance as low-income weatherization programs in Massachusetts,[11] these non-energy impacts would partially or fully offset the capital and operating cost associated with the analyzed measures.

In addition to evaluating citywide impacts, the analysis also modeled results by building type, borough, and neighborhood. Similar to the larger building stock, multifamily buildings consist of the majority of homes without AC systems today. Window/room or ductless mini-split AC systems are likely the most appropriate solution for these buildings unless ducts are available for forced-air heating or the building would soon require extensive upgrades to its heating system. Select Bronx, Brooklyn, and Manhattan neighborhoods with higher than average concentration of low-income residents, homes without AC, and HVI represent the highest priority areas with over 106,000 homes in need of ACs and other equitable cooling solutions:

- Bronx: 51,357 homes (Mott Haven/Hunts Point, Morrisania/East Tremont, Highbridge/South Concourse, University Heights/Fordham, Kingsbridge Heights/Mosholu, Soundview/Parkchester).
- Brooklyn: 36,532 homes (Bedford Stuyvesant, Bushwick, East New York/Starret City, N. Crown Heights/Prospect Heights, South Crown Heights, Brownsville/Ocean Hill).
- Manhattan: 18,377 homes (Central Harlem, East Harlem).

S.7 Recommendations

Based on the conclusions summarized above, Guidehouse recommends the following actions to NYSERDA, its partners, and other stakeholders when evaluating potential strategies to promote and advance equitable cooling in NYC. While Guidehouse provides recommendations on how to improve equitable cooling in NYC, it is important to recognize that NYC has already developed a variety of comprehensive programs and policies. Additionally, the recommendations build on the successes in energy efficiency, cool roof, urban greening, subsidized AC systems, and other initiatives.

1. The environmental justice and public health aspects of cooling equity should be communicated to key stakeholders while also recognizing the significant investment that will be necessary to deliver equitable cooling for vulnerable populations. The analysis revealed that both direct and indirect strategies to achieve cooling equity within the home require large, continued investments in capital and operating costs, electricity consumption and demand, and other resources. Similar policy and financial discussions on how to achieve equitable climate mitigation through building energy efficiency, heating and transportation electrification, and other strategies are taking place today on a State and local level. The opportunities, impacts, and costs for achieving cooling equity should be considered in these tough discussions.

2. A comprehensive analysis of the impacts of the 2020 Cooling Assistance program in NYC should be conducted to understand how the program may be continued and improved in future years, as well as extended to other parts of NYS. This analysis should include the types of AC systems installed, how residents used the systems, net impacts of the utility bill allowances, installer costs and challenges, and lessons learned from the program administration and deployment. The structured dialogs revealed some of the successes and challenges observed in the rollout of the 2020 program, but it is clear that there is more to learn about the program. Nevertheless, stakeholders suggested the program had a meaningful impact during COVID-19 restrictions to deliver cooling to vulnerable populations and should be expanded and improved in future years.
3. A comprehensive program should be developed to deliver AC systems to remaining NYC residents without AC by 2030 or earlier and establish permanent cooling bill credit programs for eligible customers. The 2020 NYC program exemplified how AC systems could be deployed across approximately 20% of the homes without AC systems today in a short period of time. Building on the Local Law 84 benchmarking requirements for larger buildings, this program can also offer comprehensive assessments for eligibility for heating electrification, envelope upgrades, cool roofs, etc. for eligible buildings. These assessments will identify the opportunities and challenges for individual buildings, and inform future energy efficiency and GHG reduction projects, such as heating electrification.
4. Additional research should be conducted to quantify the non-energy impacts and benefits of the equitable cooling program (described above) health, comfort, and productivity of vulnerable residents. The analysis focused on the capital and operating cost impacts to deliver cooling to vulnerable residents, but the value of extending cooling to all NYC residents would be substantial if monetizing on a similar basis. Guidehouse has not identified research that would monetize the impacts/benefits to vulnerable populations especially for Northeast U.S., but such research exists for several State energy efficiency programs related to low-income weatherization and other measures. Performing such an analysis would allow stakeholders to perform benefit-cost analyses on the same basis as more conventional utility programs, Climate Leadership and Community Protections Act (Climate Act) related programs, and State and local budget analyses.
5. Leaders across NYC government, electric utilities, community organizations, and other stakeholders should work together to discuss how to fund the equitable cooling program over the next 30 years. The analysis identified the capital and operating costs that will need to be invested annually to deliver equitable cooling for vulnerable populations. Nevertheless, further analysis and discussion is needed on how these costs should be allocated across residents, property owners, utility customers, and taxpayers, and the specific mechanisms to fund the programs. This research would need to evaluate whether vulnerable populations may experience unintended financial or other adverse impacts through the funding mechanism for the equitable cooling program.

6. The development of dedicated funding and spaces for climate-resilient cooling centers in communities should be encouraged. The structured dialogs revealed that today's cooling centers are mostly an add-on function to existing spaces without funding for staff, signage, activities, refreshments, and other items. Furthermore, more should be done to provide accessible and affordable transportation to the cooling centers, along with improved communication strategies so that residents can identify and travel to the nearest cooling center. Where possible, the cooling centers should be located within the communities (e.g., common area of NYCHA housing, local churches and schools, community centers) and have resilient features, such as community solar with storage or backup power systems to maintain operations during heat-related outages.
7. Existing programs for residential and commercial cool roofs, tree planting, and other UHI initiatives should be supported and expanded. Additional pilots concerning cool pavements and other emerging technologies should also be considered. As identified in this project, these programs can provide meaningful cooling benefits citywide even if they do not eliminate the need for AC systems in the home and can provide considerable non-energy benefits such as air quality, job development, livability, beautification, and other attributes. Many of these programs exist today in NYC and could be further expanded through additional funding and support.

1 Introduction

Guidehouse Inc. (Guidehouse) developed this report on behalf of the New York State Energy Research and Development Authority (NYSERDA) to summarize the analysis and the insights that have been developed in the Equitable Access to Cooling in New York City Under a Changing Climate study over the course of the entire project: fall 2020 through spring 2021, accounting for a pandemic-related pause over summer/fall 2020.

1.1 Background

According to New York State's climate change impact analysis, ClimAID,[12] climate change is projected to increase average annual temperatures across the State by 2.0–3.4˚F by the 2020s, 4.1–6.8˚F by the 2050s, and 5.3–10.1˚F by the 2080s. The frequency, intensity, and duration of extreme weather events such as heat waves is also expected to increase during this time. Subsequently, the demand for cooling and associated electricity usage is expected to increase under these scenarios.

As demand for cooling increases, it is imperative to understand how cooling usage patterns and needs will change under future climate conditions. This is particularly true among vulnerable communities that have a higher percentage of residents with underlying health, economic, and social challenges, and have greater susceptibility to heat-related illness during extreme heat events. Heat vulnerability is generally defined by exposure (e.g., extreme weather, high surface temperatures), sensitivity (e.g., underlying conditions) and adaptive capacity (e.g., financial resources, poverty, social isolation) in the summer months, particularly during extreme heat events. Potential heat mitigation solutions must ensure that vulnerable populations can achieve equitable access to cooling while also making sure that New York State can make progress toward its ambitious climate and clean energy goals.

1.2 Objectives

NYSERDA seeks to better understand the impacts of climate change on indoor cooling needs in New York City, with specific focus on vulnerable populations and communities. Guidehouse was engaged to perform an analysis of cooling usage patterns across the City to understand how these patterns will change under different climate scenarios. The analysis focused on the economic and health impacts to vulnerable populations, as well as ways to increase access to cooling and cooling penetration among vulnerable populations. The study also evaluated technology and policy options to meet the cooling needs of vulnerable populations while minimizing increases in energy use and demand.

1.3 Analysis Scope and Approach

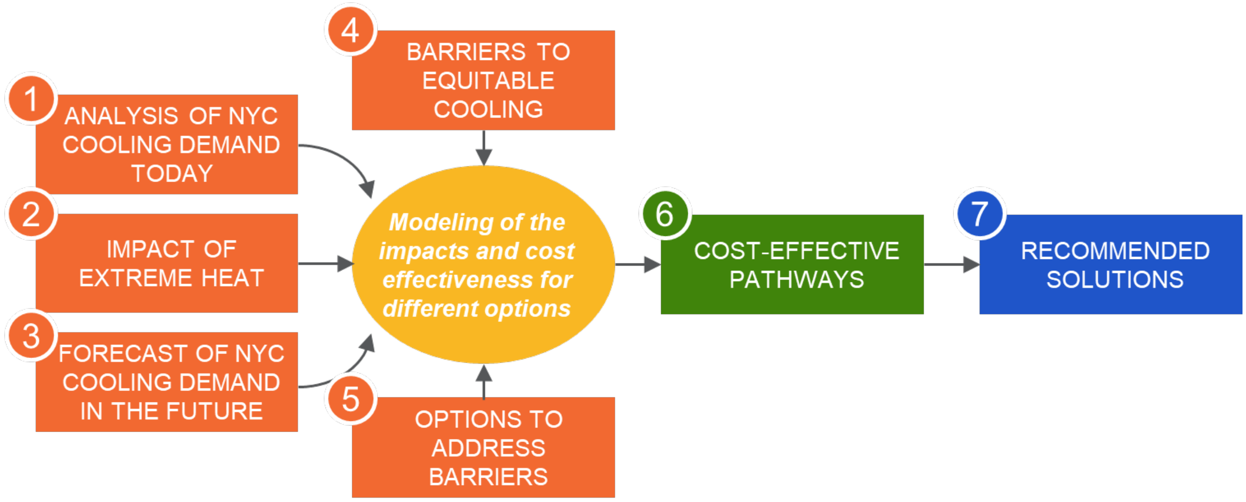
Guidehouse led the research and analysis, with contributions from Dr. Zoé Hamstead (University at Buffalo) and her research team. NYSERDA and the members of the Project Advisory Committee (PAC)[13] provided insights, research resources, and contacts to support the research efforts throughout the duration of the study.

The scope of the study includes seven key areas of analysis, as illustrated in Figure 1:

1. **Analyzing NYC's cooling energy demand today**. In section 2 Guidehouse analyzes the current building market and the key factors that will affect space cooling demand in future years, including climate change, consumer behavior, and State and local policies.
2. **Evaluating the impact of extreme heat events on vulnerable populations.** In section 3 Guidehouse summarizes the heat stress risks and health impacts for vulnerable populations in extreme heat events, including key findings from a review of public health literature.
3. **Evaluating changes in cooling demand and energy use in NYC**. Guidehouse developed a spreadsheet-based model of space cooling demand to evaluate the energy, economic, environmental, and health impacts for future climate scenarios, providing both quantitative and qualitative data that improves understanding of how increased temperatures and extreme weather events such as heatwaves will impact City residents and energy systems. The outputs of preliminary model analysis is summarized in section 4. The model is also used to evaluate various equitable cooling solutions in section 6.
4. **Identifying barriers to equitable cooling.** Section 5 outlines known barriers that prevent adoption of high-efficiency AC systems and other cooling solutions in vulnerable communities in NYC. The team also conducted structured dialogs and focus groups with key experts, community and environmental justice groups, utility administrators, and researchers in the areas of health, climate change, and vulnerable populations to refine the list of identified options.
5. **Evaluating technology and policy options.** In section 6, the team evaluated the cooling impacts, capital and operating costs, and non-energy benefits of the different equitable cooling options compare under current and future climate conditions, particularly in relation to vulnerable populations, using the model that was developed for the purposes of this study. Section 6 then summarizes the key findings related to the pros and cons, feasibility, applicability to the City, and strategies to overcome known barriers for the packages of cooling solutions.
6. **Recommendations.** Based on the key findings and conclusions throughout the analysis, Guidehouse prepared recommendations in section 7 for NYSERDA, its partners, and other stakeholders to consider when evaluating potential strategies to promote and advance equitable cooling in NYC.

Figure 1. High-Level Approach for the Study

Source: Guidehouse.



2 New York City Cooling Energy Demand Today

This section describes the current New York City building market and key factors that will affect building space cooling demand in future years, including climate change, consumer behavior, and State and local policies.

2.1 New York City Building Stock and Energy Consumption

NYC's total building stock of residential, commercial, and industrial buildings consists of approximately one million buildings with total floorspace of over 5 billion square feet and 3.2 million residential housing units.[14] Table 6 below highlights the number of housing units by New York City borough and building type, showing over 80% of NYC residents living in multifamily buildings. Each borough follows this trend with the exception of Staten Island, which has a greater percentage of single-family homes than multifamily homes. Assuming a population of 8.3 million residents in 3.2 million housing units, the average household size is approximately 2.6 residents per home.[15]

Table 1. Summary of Housing Units by Borough and Growth Rate

Source: NYC Housing and Vacancy Survey[16] (2012), adjusted upwards by 10% to align with 2018 American Community Survey[17] and NYC PLUTO database.[18]

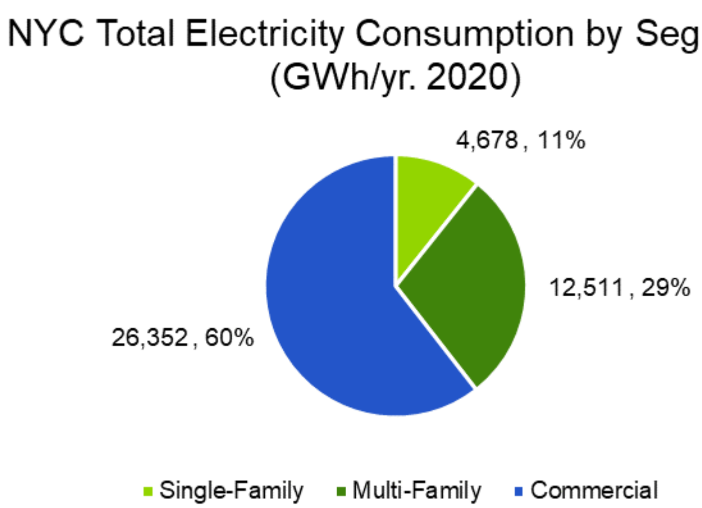
Borough	Single-Family Homes (2020)	Multifamily Homes (2020)	Total Homes (2020)	Percentage of NYC Total Homes by Borough (2020)
New York City	520,512	2,677,206	3,197,718	100%
Bronx	52,845	445,697	498,542	16%
Brooklyn	132,078	818,123	950,201	30%
Manhattan	14,920	770,345	785,265	25%
Queens	216,765	574,348	791,113	25%
Staten Island	103,904	68,694	172,597	5%
Percentage of NYC Total Homes by Housing Type	**16%**	**84%**	**100%**	**-**

Across the five boroughs, residential and commercial buildings consume approximately 43,211 GWh per year in electricity to power indoor lighting, heating, ventilation, and air conditioning (HVAC) systems, household appliances, and a variety of other end-use loads. HVAC systems are a significant portion of overall building energy consumption, with space cooling and ventilation systems using electricity, and most space heating systems using natural gas, fuel oil, or district steam today.[19]

As shown in Figure 2, commercial buildings account for the majority of building electricity demand in NYC (61%), with residential single-family and multifamily buildings accounting for 11% and 28% respectively. On average, homes in multifamily buildings (4,673 kWh/yr. per home) consume less than single-family homes (8,987 kWh/yr. per home) due to a combination of less floorspace, lower number of occupants, and shared building systems (e.g., central water heater serving multiple units).

Figure 2. New York City Total Electricity Consumption by Segment (2020)

Source: Guidehouse analysis based on energy consumption benchmarking data and building stock data by segment. See appendix B and appendix D for methodology description.

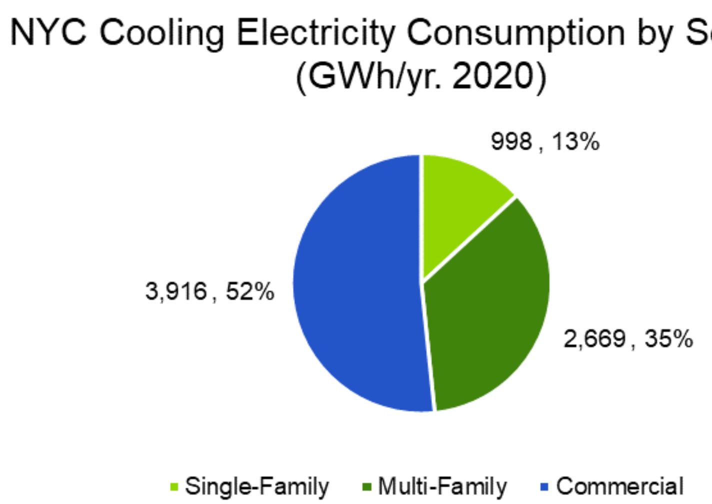


As shown in Figure 3, residential and commercial buildings consume approximately 7,254 GWh per year for space cooling systems or approximately 17% of total electricity consumption for buildings. Commercial buildings account for the majority of building electricity demand in the City (54%), with residential single-family and multifamily buildings accounting for 13% and 33% respectively.

Within the residential sector, space cooling accounts for approximately 21% of annual home electricity consumption. On average, multifamily homes (997 kWh/yr. per home) consume less than single-family homes (1,918 kWh/yr. per home) for space cooling. Unlike many electrical appliances, space cooling demand is directly tied to weather, and its impacts for residential utility bills are largely concentrated in the summer months. Unless the home uses electric heating, the largest monthly utility bill will coincide with the month with the hottest weather due to increased space cooling demand.

Figure 3. New York City Cooling Electricity Consumption by Segment (2020)

Source: Guidehouse analysis based on energy consumption benchmarking data and building stock data by segment. See appendix B and appendix D for methodology description.



2.2 New York City Building Characteristics

New York City homes use a variety of AC system designs to provide occupant comfort by reducing the indoor temperature and humidity in the home. AC systems should be sized for the home to provide a heat removal capacity based on the local climate, size of the home, and condition of building envelope and roof systems.[20] Homes with better insulation, windows, roof, and air leakage characteristics will require less cooling capacity and consumption per square foot than homes with inferior building characteristics.

Cooling electricity consumption is also determined by occupant behavior, which includes temperature preferences, occupancy patterns, and thermostat scheduling. Residents who set lower thermostat temperatures with occupancy throughout the day will have higher cooling demand and energy consumption than those who adjust the temperature setting when outside the home during the day. Changes in behavior, such as the NYC stay-at-home order for the COVID-19 crisis, can also have a significant impact on residential cooling demand as more residents are home during the day when they would normally be elsewhere.

Table 2 highlights key attributes for common residential AC systems in NYC. Central split-systems are the most common AC type for single-family buildings, whereas multifamily buildings are predominantly served by self-contained window, room, or packaged terminal AC (PTAC) units. Historically, residential and commercial buildings throughout the Northeast United States used steam heating systems, so many older buildings were not originally designed with the air ducts necessary for central AC systems. Although less efficient than central AC options, self-contained AC systems are a quick and inexpensive way to offer space cooling for older buildings. Central chiller systems are highly efficient and more common for high-rise, multifamily buildings, particularly more recent construction. In recent years, ductless split-system AC models have increased adoption in NYC and can offer high efficiency for older buildings. Heat pump systems are available in the same design and physical specifications for most AC systems and provide high-efficiency space heating by reversing the vapor-compression cooling cycle common for AC systems.

Table 2. Key Attributes of Common Residential AC Systems

Source: Guidehouse system lifetimes provided by New York State Technical Resource Manual, Version 7.[21]

AC System Type	Description	Typical Capacity (tons)	Relative Efficiency*	System Lifetime
Window AC/Room AC/PTAC	• Window or room ACs are self-contained units placed in a window or wall opening to cool individual rooms or smaller areas in residential buildings. • PTACs are higher capacity self-contained systems located in wall openings, commonly found in multifamily, hospitality, and healthcare buildings.	0.5–2 tons	Lower	13.5 years, average of room AC (12 years) and PTAC (15 years)
Split-System AC	• Single-family homes commonly use ducted split-system AC systems, also known as central air conditioners, that circulate refrigerant between an indoor unit, containing an evaporator coil and blower fan, and the outdoor unit, containing the compressor and condenser coil. • In recent years, ductless split-system models where the indoor unit resides on a wall with an integrated fan have seen increased adoption.	1–5 tons	Moderate	15 years
Chiller	• Large and high-rise multifamily and commercial buildings use hydronic chiller systems to generate chilled water which is pumped to air handlers, distributed fan coils, or radiant panels throughout the building.	Wide range from 10s to 1,000s of tons	Higher	20 years
Heat Pump	• Heat pumps are available with similar cooling performance, design, and physical specifications as various AC systems, with the added capability to provide space heating by operating the cooling cycle in reverse.	Similar attributes to AC-only products in the same category		

* Each of the AC system product categories use different energy efficiency metrics, making direct comparisons difficult.

Table 3 highlights key attributes for common building envelope systems in NYC and describes how each affects cooling demand within the home. Building envelope technologies such as wall, floor, and ceiling insulation and windows are a core component of residential buildings with long lifetimes. As such, most multifamily building residents, both owners and renters, cannot individually upgrade their major envelope systems, and often require action by the building owner or management to upgrade the entire building. Nevertheless, residents can usually reduce air leakage around their individual unit without requiring a whole building renovation.

Table 3. Key Attributes of Building Envelope Systems

Source: Guidehouse. System lifetimes provided by New York State Technical Resource Manual, Version 7.[22]

Envelope System Type	Description	System Lifetime
Insulation	• A variety of insulation products are available that reduce heat transfer between interior and exterior spaces such as walls, floors, and ceilings. • On summer days, increasing the amount or quality of insulation can better maintain comfortable temperatures indoors and reduce the runtime for AC systems.	Design life of 25 years, many buildings have delayed replacements or upgrades
Windows	• Windows typically have lower insulating properties than the surrounding walls and contribute to increased heat transfer and solar heat gain in the summer. • Higher efficiency windows can minimize this heat gain and reduce the runtime for AC systems.	
Air Leakage	• Building envelopes have imperfect seams around windows, doors, and walls, which allow air to enter and leave the conditioned space. • Performing air sealing around building envelope openings can reduce the amount of air entering or leaking from the conditioned space and reduce the runtime for AC systems.	

Table 4 highlights key attributes for building roof systems in NYC and how each affects cooling demand within the home or building. The choice of roofing materials has a number of effects relating to energy consumption in the individual home and surrounding neighborhood. Installing cool roof materials can reduce summertime heat gain in buildings and decrease space cooling demand. Furthermore, the technologies can also reduce the neighborhood localized air temperature and decrease the urban heat island (UHI) effect that increases space cooling demand over a wider area (discussed further in section 2.3.6). The capital costs and impacts for upgrading roofing systems are typically applied across an entire building based on the amount of shared roof space, which poses challenges when assessing the impacts for individual housing units in larger multifamily buildings. Cool roofs also have a counteracting effect of reducing heat gain in the winter, which increases space heating energy consumption, although recent studies suggest the net impact is minor once accounting for increased insulating qualities.[23]

Table 4. Key Attributes of Building Roof Systems

Source: Guidehouse. System lifetimes provided by New York State Technical Resource Manual, Version 7.[24]

Envelope System	Description	System Lifetime
Roof Systems/ Cool Roofs	• Historically, flat or low-slope rooftops common for commercial and multifamily buildings had dark coloring, which trapped solar radiant heat. • This heat gain increased the runtime for the building's AC systems and contributed to localized air temperature increases in the surrounding neighborhood. • Cool roofs are specialized coatings and roofing materials with white or light colors that better reflect solar radiant energy and reduce heat gain. • Green roofs are a separate, independent cooling technology strategy and consist of vegetative systems located on building rooftops. Because of the greenery and evaporative cooling properties associated with them, green roofs can provide shade, mitigate urban heat island effect, and provide cooling to the internal structure of buildings. • Green roofs and cool roofs are separate from urban greening, which consists of tree planting and implementing increased green space in neighborhoods and cities.	25 years

2.3 Drivers for Future Growth in Cooling Demand

Projecting residential cooling energy consumption and operating costs across NYC in future years involves an evaluation of several interacting factors which can either increase or decrease cooling demand on a per home or citywide basis. Table 5 highlights several key factors analyzed in this study along with the impact on residential cooling demand, which are further discussed in this section. Factors such as climate change, housing and population growth, and greater AC system adoption will increase the energy consumption citywide for space cooling. Factors such as appliance standards, building codes, energy efficiency programs, and greenhouse gas (GHG) emissions policies will reduce the per unit cooling demand for NYC buildings.

The report recognizes that there are many other contributing factors that will influence how City residents will use AC systems in the future, especially behavioral factors. Personal preferences around comfort, time spent indoors, AC system usage, environmental sustainability, cooling cost, and other factors will influence future cooling electricity consumption for individual housing units. Unforeseen events such as the COVID-19 public health crisis may dramatically shift how NYC residents interact with residential and commercial buildings in future years.

Table 5. Key Factors Affecting Cooling Electricity Consumption and Cost

Source: Guidehouse analysis.

Category	Factor	Description	Impact
Increase Cooling Consumption/ Cost	**Climate Change**	• Warmer climate will increase the daily and seasonal demand for space cooling in NYC.	Increased per-home cooling demand
	Population Growth	• Expected population and housing growth will increase the number of homes with AC systems in future years.	Increased cooling demand citywide
	AC Adoption	• Warmer climate will likely drive more homes to install AC systems.	Increased cooling demand citywide
	Utility Rates	• Electricity rates increase over time, increasing cooling operating costs to consumers.	Increased per-home cooling cost
Decrease Cooling Consumption / Cost	**EE / GHG Emissions Reduction Policies**	• Appliance standards and building codes improve the energy efficiency of NYC building stock over time. • Aggressive State and City GHG reduction targets encourage greater adoption of high-efficiency technologies.	Decreased per-home cooling demand

2.3.1 Climate Change

Studies such as CLIMAID[25] and New York City Panel on Climate Change[26] have performed detailed modeling on the impacts that global climate change will have on the NYC region. Briefly, the City will experience hotter summers, warmer winters, heavier rainfall, greater coastal flooding, and more extreme weather events.[27] For this analysis on residential cooling demand and heat vulnerability, the report focuses on the number of extreme heat events and increase in summertime temperatures.

Table 10 summarizes the modeling results for extreme heat events from the 2019 New York City Panel on Climate Change.[28] The frequency and duration of extreme heat events are expected to significantly increase over the period 2020 to 2050, particularly over historical baselines. Under the 75th percentile scenarios for 2050, the yearly heat wave frequency will increase from one to five with an increase in average duration from four to nine days compared to historical averages. Across the entire cooling season, the number of days above 90°F increases from 10 to 45 by 2050 in the 75th percentile scenario. As shown in Table 11 and Figure 6, studies also show that climate change has already affected summertime weather patterns, with values for the 2010s and 2020s significantly warmer than historical averages.

Table 6. Summary of Extreme Heat Event Indicators

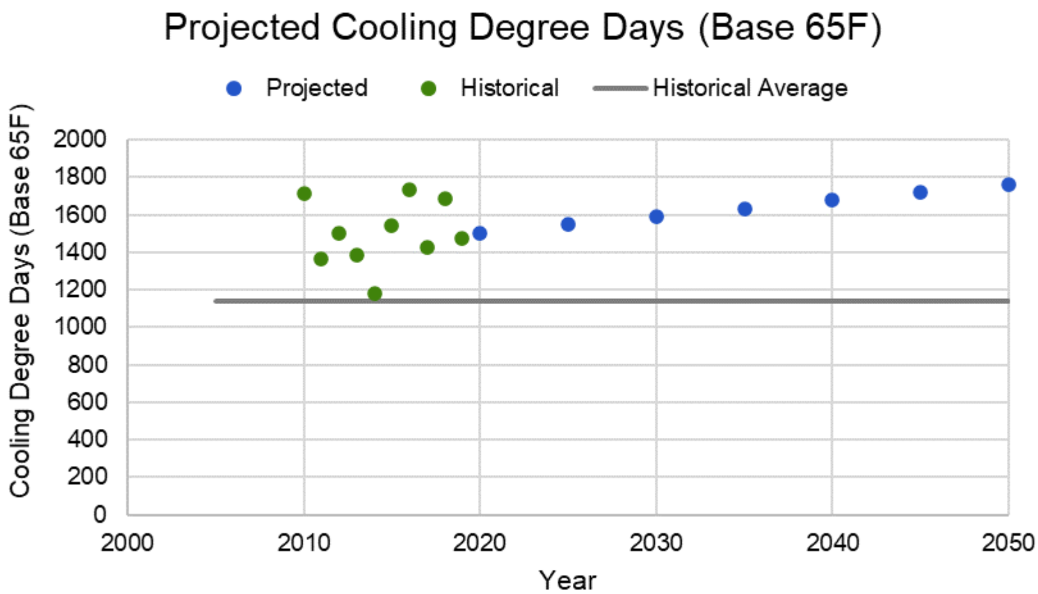
Source: New York City Panel on Climate Change 2019 Report.[29]

Indicator	Year	25th Percentile	75th Percentile	90th Percentile
Heat Waves per Year (no.)	Historic Baseline	1	1	1
	2020s	2	4	5
	2050s	3	5	6
Mean Heat Wave Duration (days)	Historic Baseline	4	4	4
	2020s	4	6	8
	2050s	5	9	13
Days Above 90°F	Historic Baseline	10	10	10
	2020s	11	25	34
	2050s	24	46	56

Figure 4 highlights historical and projected cooling degree days for NYC. Cooling degree days (CDD) represent the difference in daily average temperature and a 65°F base and are a useful indicator of cooling demand on a daily, monthly, or seasonal basis. For example, the New York Technical Resource Manual (TRM) uses CDD as a metric to evaluate energy savings of high-efficiency building systems for State and utility energy efficiency incentive programs. The number of CDD in New York City is expected to rise by 17% (261 CDD) in 2050 over the 2010–2019 average, or an average increase of 0.6% per year. As a benchmark for cooling demand, increased CDD in future years would subsequently increase per home cooling energy consumption by a similar amount. Historical averages and values for 2010–2019 are based on NYSERDA data, with future projections based on the 2016 New York City One City Built to Last Report,[30] incorporating IPCC Assessment Report 5 climate projections. The future CDD projections are consistent with the New York Independent System Operator (NYISO) analysis under development looking at the impact on the New York State electric utility system by climate change and Climate Leadership and Community Protection Act (Climate Act) policies.

Figure 4. Historical and Projected Cooling Degree Days (Base 65F)

Source: Guidehouse analysis, historical data from NYSERDA,[31] projections for CDD in future years based on 2016 New York City One City Built to Last Report.[32]



2.3.2 Population Growth

Citywide cooling electricity consumption is strongly correlated with future growth in NYC residents and housing units. Table 7 highlights the expected growth rate for the City and each borough over the coming decades from the New York City Population Projections by Age/Gender and Borough, 2010–2040 report.[33] Absent of other data, it is assumed housing growth matches population growth, and 2020–2040 annual growth rates are applied to 2050. In total, the number of NYC housing units would be expected to increase from 3.2 million in 2020 to 3.5 million in 2050 with an annual growth rate of 0.3%. Described in later sections, it is assumed all new homes meet current building codes and feature new code-compliant AC systems.

Table 7. Future New York City Housing Growth by Borough

Source: Expected population growth rates from the New York City Population Projections by Age/Gender and Borough, 2010-2040 report.[34]

Borough	Total Homes (2020)	Percentage of New York City Total by Borough (2020)	Total Homes (2050)	Annual Growth Rate (2020–2050)
Bronx	498,542	16%	574,363	0.47%
Brooklyn	950,201	30%	1,060,756	0.37%
Manhattan	785,265	25%	826,257	0.17%
Queens	791,113	25%	834,680	0.18%
Staten Island	172,597	5%	180,296	0.15%
New York City	3,197,718	100%	3,476,352	0.28%

2.3.3 AC Adoption

Table 8 highlights the current AC adoption rate in the City and each borough. Today most residential buildings have one or more AC systems providing space cooling during the summer, with a citywide adoption rate of 91%. As described in section 2.1, room, window, or PTAC systems are most common for multifamily buildings, with central AC systems most common for single-family homes. While the citywide adoption rate is high, the remaining 9% of homes represents almost 300,000 housing units across the City, which is similar to the total number of homes in a mid-sized U.S. city. This value would also represent approximately 750,000 residents assuming an average household size of 2.6 residents per home. Even for those with AC systems, some residents may operate their units sparingly due to utility cost concerns or poor performance of older units.

Table 8. Residential AC Adoption by Borough

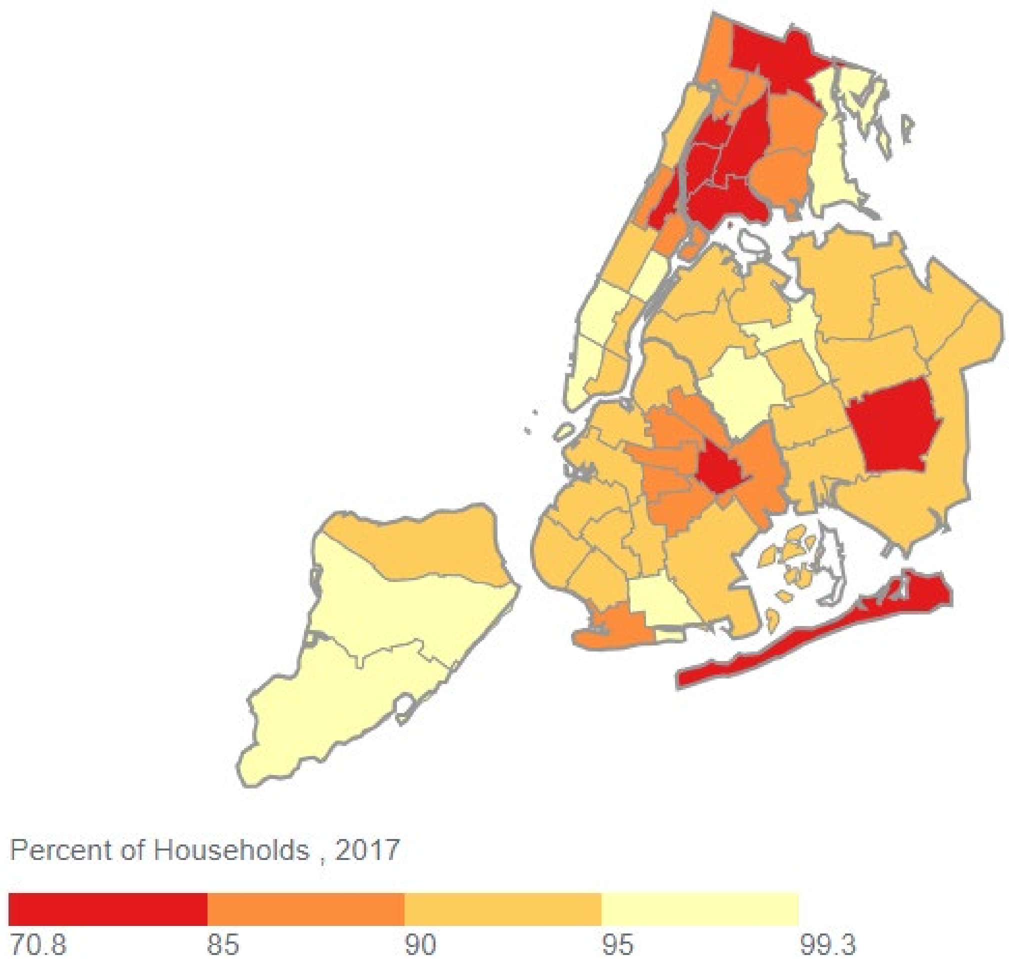
Source: New York City Housing and Vacancy Survey in Portal,[35] *2017*

Borough	Total Homes (2020)	Percentage of Homes with AC (2020)	Number of Homes without AC (2020)
Bronx	498,542	86%	71,742
Brooklyn	950,201	90%	91,101
Manhattan	785,265	93%	58,165
Queens	791,113	92%	60,713
Staten Island	172,597	95%	8,697
New York City	3,197,718	91%	290,418

Figure 5 highlights the AC adoption rate by NYC neighborhoods today, with lightly shaded areas indicating less AC adoption and darker areas, greater AC adoption. There is substantial variation in AC adoption on the neighborhood level from 75% in parts of Bronx and Brooklyn to 98% in parts of Staten Island and Manhattan. Due to warming climate, more City residents will likely install and operate their AC systems in the future, which will increase electricity consumption within the home and citywide. Section 4 describes the impacts of approaching 100% adoption for residential homes in future years. Section 6 evaluates several scenarios of equitable cooling solutions.

Figure 5. AC Adoption Rate by New York City Neighborhood (2017)

Source: New York City Environmental and Health Data Portal,[36] using data from the 2017 New York City Housing and Vacancy Survey.



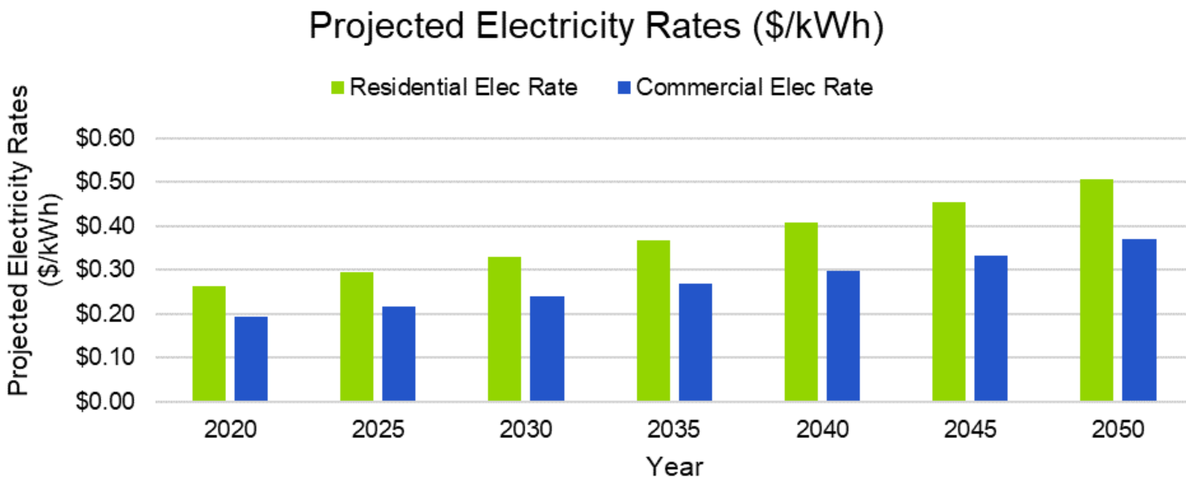
2.3.4 Utility Rates

AC system operation during the summer is a significant contributor to annual electricity consumption and utility cost. For residents that do not have electric space heating, electric utility bills generally spike in the summer due to the added consumption from AC systems, and often reach two or three times higher than an average monthly electricity bill. Figure 6 highlights electricity rates projected over the period 2020 to 2050. These estimates reflect reported Con Edison annual average rates for residential and commercial sectors based on Energy Information Administration (EIA) Form 861[37] and a 2.2% annual increase based on EIA Annual Energy Outlook national estimates through 2050.[38] Con Edison provides electricity service to most of New York City, although residents in New York City Housing Authority (NYCHA) buildings typically have lower electricity supply rates from New York Power Authority (NYPA). Although the utility rates assumed for this analysis reflect annual averages, the price of wholesale electricity and customer time-of-use rates can drastically rise during extreme heat events, in part due to increased electrical demand from building AC systems.

Today, residents may avoid purchasing or operating their AC systems to avoid the increased electricity bills. In future years, per unit and citywide electricity costs for space cooling would increase both from climate change and utility bill increases. Future electricity rates for the City are highly uncertain. New York State policies, such as the Climate Act, which aim to achieve 100% renewable electricity supply by 2040 and support electrification of transportation and building heating, will have a significant impact on how electric rates are determined. Utility industry experts are still evaluating the pathways to achieve these policy goals and their upward or downward impacts on electricity rates.

Figure 6. Projected Residential and Commercial Electricity Rates (2020–2050)

Source: Rates (2020) based on Con Edison annual average rates in EIA Form 861.[39] Future projections based on EIA Annual Energy Outlook estimates through 2050.[40] Future electricity rates for New York City are uncertain due to state policies and other factors.



2.3.5 Energy Efficiency and GHG Emissions Reduction Policies

New York State and New York City have developed a variety of policies, programs, and goals that will improve the energy efficiency for residential and commercial buildings, and ultimately reduce space cooling consumption on a per-home basis. Federal appliance standards and building codes by state and city agencies improve the energy efficiency over time through new building construction and replacement of existing systems when buildings reach their end of life. Aggressive State and City GHG reduction targets encourage greater adoption of more efficient building technologies, particularly heating electrification initiatives as high-efficiency heat pump technologies offer cooling energy savings over baseline systems.

Using future projections within the 2019 NYISO Gold Book[41] for topline energy consumption forecast and estimated impacts for energy efficiency and codes and standards for Zone J (NYC), the report estimates an average annual energy savings of 0.6% over 2019–2039. Because the analysis independently analyzed the impacts from normal appliance replacement and other energy efficiency initiatives, it is assumed that the incremental energy efficiency incentive programs account for half of this 0.6% annual reduction, or 0.3% per year. The model analyzes the energy savings from appliance replacement based on system lifetime and assumes the incremental incentive programs would continue through 2050.

This section provides an overview of key topics relating to energy efficiency and GHG emission reduction policies for NYC buildings:

- Appliance Standards and Building Codes
- Energy Efficiency Incentive Programs
- State and Local Policies for GHG Emission Reduction

2.3.5.1 Appliance Standards and Building Codes

A variety of federal, State, and local policies outline prescriptive requirements for NYC residential buildings related to energy efficiency, safety, and other characteristics, and overtime improve the energy efficiency of the building stock. In 2010, the City initiated its own energy conservation code, which expands beyond the the State energy conservation code. Individual appliances are covered by federal appliance standards or industry standards, and then adopted by the state and city codes. Some codes and standards retroactively apply to all buildings (e.g., smoke detectors, emergency lighting, and fire extinguishers) whereas others apply only during construction projects or appliance purchases. Most codes and standards relating to space cooling energy consumption apply to new construction, major renovation, or appliance purchase situations. New buildings must abide by the latest codes and standards, whereas older buildings will make upgrades on a delayed timeline. As building codes and appliance standards improve over time, residential buildings will generally adopt the new provisions or technologies at the end of the useful life for the existing systems. Figure 7 highlights federal standards for residential central AC systems over time. A NYC home built in 2000 installing a seasonal energy efficiency ratio (SEER) 10 air conditioner with a 15-year lifetime would likely need to replace the AC system in 2015 and purchase a SEER 13 model, which has higher energy efficiency than the previous model.

Figure 7. Residential Central AC System Efficiency Standards Over Time

Source: EIA Today in Energy (July 30, 2019)[42] citing U.S. Department of Energy appliance standards.

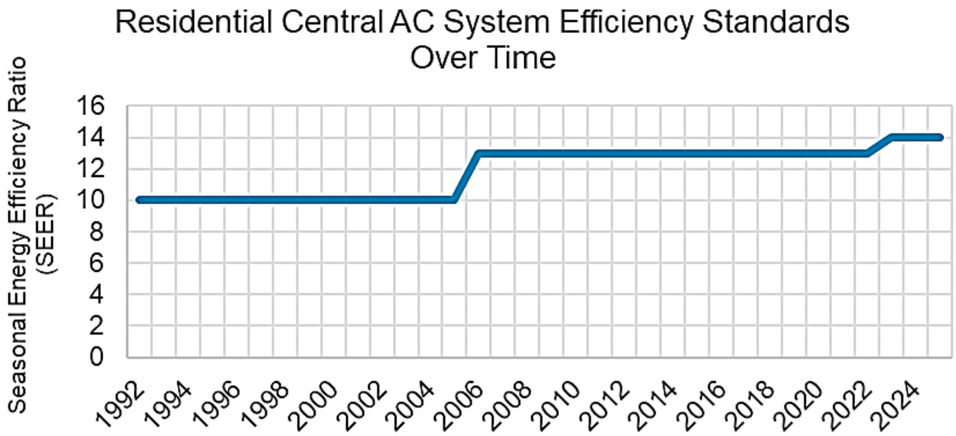


Table 9 highlights the characteristics of below code and code efficiency building systems for NYC residences based on NYS TRM. The estimated saturation of below code building systems in NYC homes is approximately 70% for AC, building envelopes, and roof systems. The estimated saturation of systems meeting current building codes in City homes is approximately 20% for AC systems, 25% for building envelopes, and 32% for roofs. Today's building codes and appliance standards provide an estimated 10% cooling energy savings over the older installed base of AC systems, envelope systems, and roofs. AC systems have an estimated annual replacement rate of 7% based on a 14-year lifetime. Envelope and roof systems have a lower replacement rate (4%) based on their longer 25-year lifetime. These represent average values from the NYS TRM, and many residential buildings will forego upgrades until well past the useful life of building systems. Certain retrofit technologies, such as air sealing, have lower cost and installation complexity, and can be performed cost-effectively before normal replacement cycles. Appendix E provides additional details on building system characterization.

Table 9. Characteristics for Below Code and Code Building Systems

Source: Below code/installed base estimates based on NYSERDA Residential Baseline Study,[43] code efficiency, energy savings, and lifetime based on New York State Technical Resource Manual, Version 7.[44]

Building System	Below Code/ Installed Base	Code Efficiency for New Systems	Estimated Cooling Savings over Installed Base	Lifetime (Years)	Annual Replacement Rate (%)	Notes
AC Systems	12 SEER	14 SEER	10%	14	7%	Assumes balance of room AC, split system, and chiller.
Envelope Systems	R-11 wall, R-19 ceiling, no air sealing	R-21 wall, R-49 ceiling, no air sealing	11%	25	4%	Envelope improvements would also reduce heating energy consumption.
Roof Systems	No Cool Roof	Cool Roof	10%	25	4%	Cool roofs reduce heat gain in the winter, which increases space heating energy consumption, although increased insulating qualities mitigates this risk.

2.3.5.2 Energy Efficiency Incentive Programs

Table 10 highlights the characteristics of above efficiency building systems for NYC residences based on NYS TRM. The estimated saturation of above code building systems in City homes is approximately 10% for AC systems and 5% for building envelopes. Energy efficiency incentive programs offered by Con Edison, NYSERDA, and other organizations encourage the adoption of building technologies with performance above minimum codes and standards. These programs provide moderate energy savings over code compliance technologies, with greater energy savings over below code technologies. Most utility programs provide prescriptive incentives for measures (e.g., several hundred dollars per ton for a high-efficiency AC system) and performance incentives for more custom measures (e.g., $ per calculated kWh savings for a large multifamily retrofit). Many programs have separate initiatives to target single-family, multifamily, rental, low-income, and other customer segments. Appendix E provides additional details on building system characterization.

Table 10. Characteristics for Above Code Building Systems

Source: Above code efficiency, energy savings, and lifetime based on New York State Technical Resource Manual, Version 7.[45]

Building Systems	Below Code/ Installed Base	Above Code Efficiency for New Systems	Estimated Cooling Savings over Installed Base	Notes
AC Systems	12 SEER	17 SEER	30%	Assumes balance of room AC, split system, and chiller.
Envelope Systems	R-11 wall, R-19 ceiling, no air sealing	R-27 wall, R-60 ceiling, with air sealing	18%	Envelope improvements would also reduce heating energy consumption.
Roof Systems	No Cool Roof	Cool Roof	10%	Current code covers large flat roofs only and could be expanded in the future to cover all types of roofs (See section 6).

Building energy efficiency is a key component of City and State goals to reduce GHG emissions, and energy efficiency programs have seen significant funding increases recently. The New Efficiency: New York State report outlines a set of strategies to achieve approximately 30,000 GWh reduction in forecasted sales by 2025, including approximately 3% of investor-owned utility sales. [46] In January 2020, Former Governor Cuomo announced[47] an additional $2 billion to be contributed to utility energy efficiency and building electrification initiatives through 2025, that is, $893 million for electric energy efficiency; $553 million for gas energy efficiency; and $454 million for heat pumps. In total, NYS has allocated $6.8 billion for energy efficiency through 2025, with particular focus on high-efficiency heat pump systems. Energy efficiency funding commitments from NYSERDA ($1.2 billion), NYPA ($1.5 billion), LIPA ($500 million), and other State utilities ($1.3 billion) such as Con Edison will substantially reduce building energy consumption throughout the State. As described in section 2.3.3, programs that encourage heating electrification with high-efficiency heat pumps will also reduce cooling electricity consumption.

2.3.5.3 State and Local Policies for GHG Emission Reduction

In addition to building codes and incentive programs, City, and State policies will encourage building owners to improve the energy efficiency and performance for their buildings to achieve the State's GHG emissions and climate resiliency goals. The list below highlights several key policies:

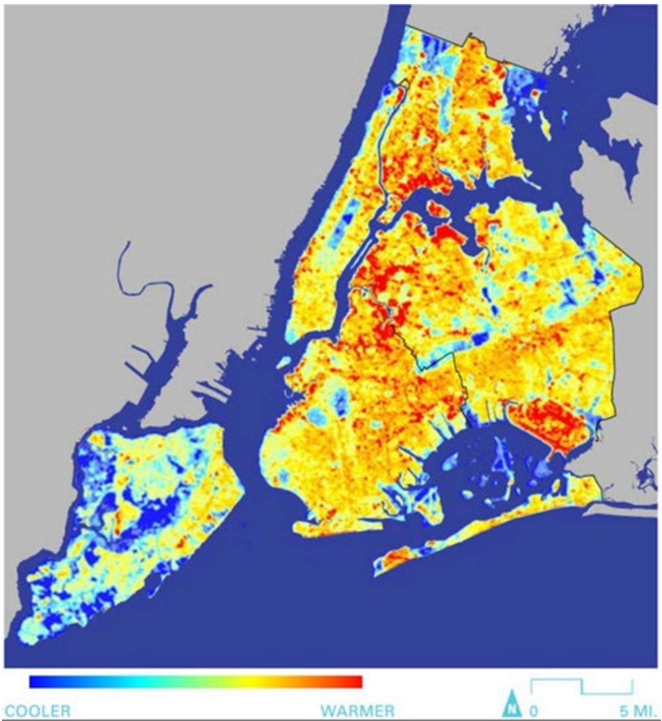
- **Climate Leadership and Community Protection Act**[48] Climate Act is an ambitious climate target for NYS that includes 100% carbon-free electricity by 2040 and economy-wide, net-zero carbon emissions by 2050. Many of the goals put forth by the Climate Act also seek to increase the penetration of distributed energy resources such as battery storage, offshore wind, and solar. The Climate Act has also put forward an energy efficiency goal of becoming 23% more energy efficient by 2030 from a 2012 baseline and includes a requirement to direct at least 35–40% of the program's benefits to historically disadvantaged communities.[49]
- **State of the City 2020**[50] is a proposal made by New York City Mayor Bill de Blasio to invest in renewable energy, achieve carbon neutrality, and reduce energy consumption. The proposal outlines the goal to stop using natural gas and other fossil fuels in large building systems in NYC by 2040. This will primarily be done through electrifying building stock in the City, which offers the opportunity to improve energy efficiency for cooling. This proposal builds on previous reports such as One City Built to Last[51]in 2014, which outlined necessary steps to improve the resiliency of the City's infrastructure to address future climate change and natural disasters.
- **NYC Local Law 97 of 2019**[52] amends the NYC charter and the administrative code of the City to achieve specific GHG reduction targets in buildings by 2050. With an overall goal of 40% reductions in citywide buildings by 2030 and 80% reduction by 2050, Local Law 97 provides a prescriptive carbon limit per square foot for common building types. Starting in 2024, owners of covered buildings (25,000 square feet and greater) need to annually submit an emission intensity report and show compliance with carbon intensity limits. They can comply with the carbon intensity targets by performing energy conservation measures (e.g., weatherization, insulation, and air sealing), purchasing renewable electricity, replacing fossil fuel heating systems, and other measures. The law outlines two compliance periods today (2024–2029 and 2030–2034) with future targets to be set later.

2.3.6 Urban Heat Island Effect

New York City cooling demand is influenced not only by climate change and building stock characteristics, but also by the trend for urban areas to have higher localized temperatures, known as the urban heat island (UHI) effect. Compared with rural and suburban regions, major cities such as NYC have a higher density of tall masonry buildings, dark colored roofs, asphalt roadways, and concrete sidewalks that absorb daytime solar heat. These features significantly increase the average surface temperature more than local weather would otherwise suggest. As shown in Figure 8, denser parts of the city such as Bronx or Queens have higher surface temperature than lower density areas with trees, grasses, marshes, and waterways, such as Central Park or Staten Island. Residents living in areas of the City with a greater UHI effect will experience greater ambient temperatures throughout the day, especially during nighttime when buildings and roads release heat more slowly than vegetative surfaces. As such, these neighborhoods will experience greater demand for cooling and will be more susceptible to heat stress events. Because most building AC systems reject waste heat to the exterior air, greater adoption of AC systems in the future may increase local ambient temperatures, contributing to local UHI effect.

Figure 8. Thermal Imagery Showing UHI Effect in New York City

Source: Cool Neighborhoods New York City Report.[53]



2.4 Impact of Extreme Heat Events on Vulnerable Populations

This section summarizes heat stress risks and health impacts for heat-vulnerable populations in extreme heat events, including key findings from a review of public health literature.

2.5 Heat Stress Risks and Heat Vulnerability Index

New York City residents today experience heat-related illness during summer heat waves each year. Table 11 highlights the number of heat stress related emergency department visits, hospitalizations, and deaths across NYC in 2016. Over the 2016 summer season, residents experienced 592 emergency department visits, 151 hospitalizations, and four deaths related to heat-stress or hyperthermia.[54] Heat stress can affect residents when indoors as well as outdoors when working or traveling across the city. The rates of heat stress (i.e., events per 100,000 residents) vary across City boroughs, with residents in the Bronx and Brooklyn reporting greater rates than other boroughs.

Table 11. Summary of Heat-Related Health Statistics for New York City in 2016

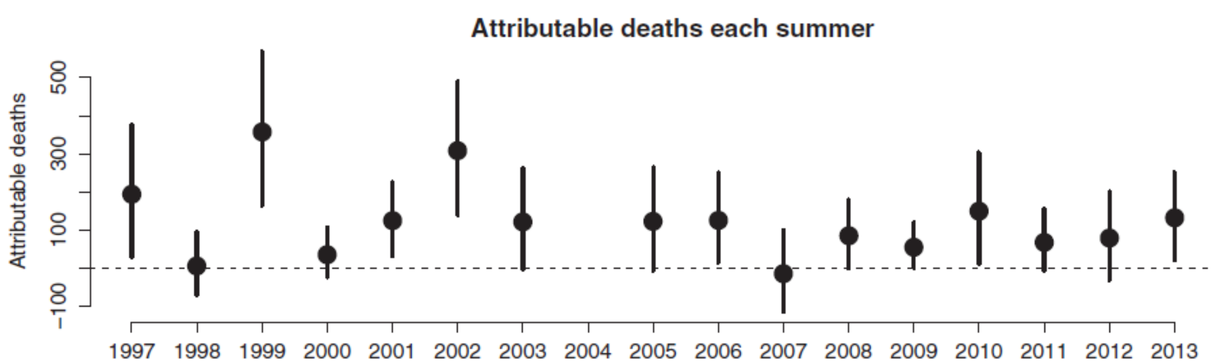
Source: New York City Bureau of Vital Statistics and New York State Statewide Planning and Research Cooperative System (SPARCS) Deidentified Hospital Discharge Data.[55]

Borough	Emergency Department Visits		Hospitalizations		Deaths
	Number	Rate per 100,000 Residents	Number	Rate per 100,000 Residents	Number
New York City	592	7.0	151	1.8	4
Bronx	108	7.5	33	2.3	n/a
Brooklyn	208	8.0	59	2.3	n/a
Manhattan	79	4.8	18	1.1	n/a
Queens	163	7.1	n/a	1.4	n/a
Staten Island	34	7.2	n/a	1.9	n/a

These values represent officially reported heat-related illnesses and deaths through State hospital records, but the actual impact of heat stress on NYC public health is much greater. Matte et al. (2016)[56] estimated the annual number of deaths from exacerbation of chronic conditions (e.g., respiratory or cardiovascular conditions, or non-external-cause deaths) attributable to extreme heat events in NYC from 1997–2013. As shown in Figure 9, the attributable deaths to extreme heat increases substantially when considering heat-stress impacts on chronic illnesses. The study estimates that the annual number of nonexternal-caused deaths attributable to extreme heat events ranged from negative14 to 358, with a median of 121 and an average of 115. This is a significant increase over the average of 10 reported hyperthermia deaths analyzed in the study over 1998–2013.

Figure 9. Estimated Nonexternal-Caused Deaths for May through September, 1997–2013

Vertical lines are 95% confidence intervals. Source: Matte Et al. (2016).[57]



New York City residents experience both hot summers and cold winters, and direct health impacts from winter cold-stress events today are similar in magnitude to heat-stress events. Over the 2016 winter season, NYC residents experienced 439 emergency department visits, 232 hospitalizations, and nine deaths related to cold stress. Climate change will increase average annual temperatures in NYC, leading to both warmer summers and winters. Schwartz et al. (2015)[58] modeled the change in expected cold deaths and heat deaths in different U.S. regions due to climate change. The study found a net increase in annual weather-related deaths in the Northeast U.S. compared to a 1990 baseline, as heat-stress deaths increased more than the decrease in cold-stress deaths over 2030–2100.

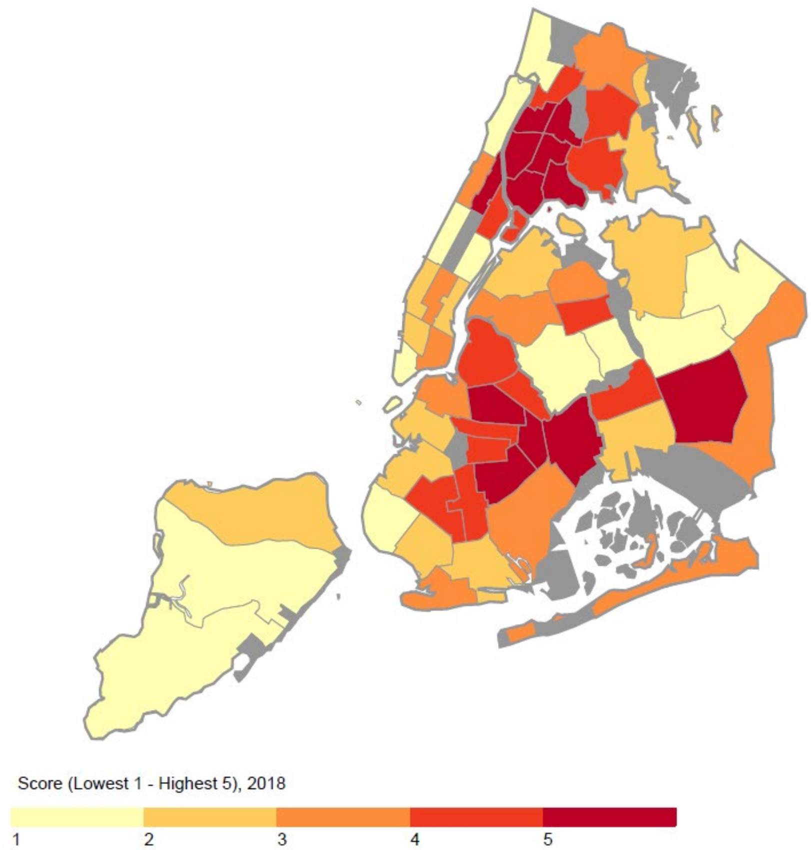
Public health researchers have identified links between a range of environmental and social factors and risk of heat stress. Experts at the New York City Department of Health and Mental Hygiene (DOHMH) and Columbia University developed a Heat Vulnerability Index (HVI) metric to identify higher and lower risk neighborhoods in New York City based on neighborhood-level estimates for:[59]

- Environmental factors, relating to UHI effects (section 2.3.6)
    - Daytime surface temperatures
    - Availability of green space
- Social factors, relating to available public health research literature (section 3)
    - Poverty level, measured as the percentage of residents living below the federal poverty level
    - Race, measured as the percentage of non-Hispanic Black residents
    - Air conditioning prevalence

Figure 10 highlights neighborhood-level HVI values for 2018 in the City. Through statistical analysis, each neighborhood receives a score from 1 (lowest risk) to 5 (highest risk). The NYC DOHMH states that "differences in these risk factors across neighborhoods are rooted in past and present racism."[60] Vulnerable residents such as the elderly or those with chronic illnesses are present in every NYC neighborhood, so even lower risk areas have residents who are susceptible to heat stress.[61] The spreadsheet model is designed to readily segment results by neighborhood and HVI score and use these results in section 6 and when preparing the recommendations.

Figure 10. Heat Vulnerability Index (HVI) by New York City Neighborhood, 2018

Source: New York City DOH Environmental and Health Data Portal.[62]



2.6 Public Health Literature on Heat Risk and Mitigation

Public health experts at government agencies, universities, and other research institutions have conducted a wide range of statistical analyses to investigate historical and future health risks from extreme heat events. Dr. Zoé Hamstead with the University at Buffalo and her research team reviewed available public health literature relating to heat risk for vulnerable populations, future impacts from climate change, and cooling mitigation strategies with particular focus on NYC and the Northeast U.S. This section summarizes key findings on the following topics from a subset of the approximately 50 public health research papers:

- Heat impacts on health
- Heat impacts on vulnerable populations
- Cooling solutions for extreme heat events

Appendix C provides full references for public health research resources collected during this literature review. Readers are encouraged to review these and other materials for a more complete view of the latest research findings.

Table 12 summarizes key research literature findings related to heat impacts on health. The research literature consistently identifies the connection between increased illnesses and death during extreme heat events in the Northeast U.S. Furthermore, the studies suggest that climate change will significantly increase the magnitude of the health impacts due to heat stress over 2020–2100.

Table 12. Key Research Literature Findings Related to Heat Impacts on Health

Source: Research studies cited directly in table.

Research Study	Key Findings
Knowlton et al. (2007)[63]	• Projected [NYC] regional increases in heat-related premature mortality by the 2050s ranged from 47% to 95%, with a mean 70% increase compared with the 1990s.
Anderson, Bell (2011)[64]	• Mortality risk during a heat wave was on average 2.50% higher for every extra day a heat wave lasted. • A 1°F increase in average mean temperature during a heat wave was associated with a 4.39% increase in the relative risk of mortality during that heat wave. • The first heat wave of the season has higher mortality effects than later heat waves in season.
Hondula et al. (2015)[65]	• A statistically significant positive association between high temperatures and all-cause mortality was evident in six of the seven study cities [including Boston and Philadelphia in Northeast U.S.]. • Threshold temperatures for statistically significant increases in heat-related mortality varied from 1.6 °C (Philadelphia) to 3.8 °C (St. Louis) above the summer mean temperature. • Threshold temperatures were exceeded on 13.0–27.9% of summer days during each city's study period.
EPA 2017[66]	• Recent heat and population projections for 49 U.S. cities show that without additional adaptation or acclimatization, a no action scenario (RCP 8.5) would result in an additional 9,300 heat-related deaths annually in the modeled cities by 2090.
Madrigano et al. (2015)[67]	• In the Northeast U.S., an increase in temperature from 70°F to 90°F was associated with an 8.88% increase in mortality in urban counties.
Petkova et al. (2013)[68]	• During the 2020s, median heat-related mortality rates calculated across all models and the Representative Concentration Pathway (RCP) 4.5 and RCP8.5, were 9.1 and 10 per 100,000 for NYC, [baseline of 3.7 per 100,000]. • In the 2050s, NYC was projected to experience median mortality rates of 14.3 and 18.9 per 100,000. • By the 2080s, projected median heat-related mortality rates across all models and the RCP4.5 and RCP8.5 were 17.1 and 34.3 per 100,000 for the City.

Table 13 summarizes key research literature findings related to heat impacts on vulnerable populations. The studies evaluated the statistical connections between environmental and social factors of resident communities and heat stress during extreme heat events. The research findings illustrate how several interconnected factors increase heat risk for vulnerable populations, and how underlying challenges will require more a comprehensive strategy to address cooling equity. Increasing AC system adoption may appear to be a straightforward solution, but deployment programs will need to address the wider concerns and situations of NYC residents. Section 5.1 describes these barriers in greater detail.

Table 13. Key Research Literature Findings Related to Heat Impacts on Vulnerable Populations

Source: Research studies cited directly in table.

Research Study	Key Findings
Hondula et al. (2015)[69]	• Places with greater risk of heat-related mortality had more developed land, young, elderly, and minority residents, and lower income and educational attainment, but the key explanatory variables varied from one city to another.
Madrigano et al. (2015)[70]	• Deaths during heat waves were more likely to occur at home than in institutions and hospital settings and were more likely among those living in census tracts that received greater public assistance and among Non-Latinx Black residents. • Deaths during heat waves were more likely among residents in areas of the city with higher relative daytime summer surface temperature and less likely among residents living in areas with more green space.
Klein Rosenthal et al. (2014)[71]	• Citywide there were over 4% more deaths on days with a Heat Index equal to or above 100°F compared to all other warm season days from 1997 to 2006. All-cause mortality of seniors aged 65 and over increased significantly in NYC during extremely hot days from 1997 to 2006. • Excess mortality during heat event days was unevenly distributed in NYC's Community Districts and United Hospital Fund (UHF) areas. • Significant positive associations were found between heat-mortality rates and neighborhood-level measures of poor housing conditions, poverty, impervious land cover, seniors' hypertension and surface temperatures. • Disparities in the prevalence of AC ownership and use in UHF areas among seniors aged 65 years and older were found. Percent Black/African American and percent poverty by UHF area were strong negative predictors of seniors' AC access in multivariate regression. There was a trend for an increasing mortality rate ratio for areas with the least proportion of White population.
Madrigano et al. (2018)[72]	• Twenty-eight percent of New Yorkers did not have access to a functioning AC or used it less than half the time or not at all during very hot weather. • Among those who did not own AC, the most common explanation was inability to afford it (40% of participants), followed by a response of "don't need it" (33%), "don't like AC" (20%), and "building wiring not equipped" (8%). • Although the majority of the population owned AC (87% of participants), 15% stated that they used it "less than half the time" in the preceding summer during very hot weather. The top two reasons that AC owners curbed their use were their electricity bill (24%) and a desire to conserve electricity (21%). [Other responses include "don't like AC (12%) and prefer fan (13%)]. • Race/ethnicity and household income were strongly associated with AC access. Non-Hispanic Black New Yorkers were twice as likely to not have AC, compared with the rest of the population [after adjustment]. Similarly, the odds of not having AC were three times greater for those with a household income less than $30,000 per year compared to those with greater household incomes after adjustment.

The research literature also identified how cooling solutions can mitigate the adverse health impacts during extreme heat events. Knowlton et al. (2007)[73] developed several future climate scenarios and projected the number of heat-related premature deaths in 2050 for the NYC metropolitan region. The study also assessed how "acclimatization" effects and adaptive strategies such as AC systems, heat alerts, cooling shelters, and gradual physiological adaptation could reduce mortality. As shown in Table 14, the scenarios that include acclimatization reduced regional increases in summer heat-related premature mortality by approximately 25% in 2050.

Table 14. Heat-Related Premature Mortality Projections from Knowlton et al., 2007

Source: Excerpt from Knowlton et al. (2007)[74] See study for full details.

Year, Scenario Assumptions	Mean Summer Daily Temperature	Total Regional Heat-Related Premature Deaths	Increase in Deaths over 1990s	Reduction in Deaths from Acclimatization
1990s	72.9	1,418	-	-
2050s A2 Scenario[1]	76.7	2,764	1,346	-
2050s A2 Scenario with Acclimatization[1]	76.7	2,376	958	388
2050s B2 Scenario[1]	75.8	2,421	1,003	-
2050s B2 Scenario with Acclimatization[1]	75.8	2,087	669	334

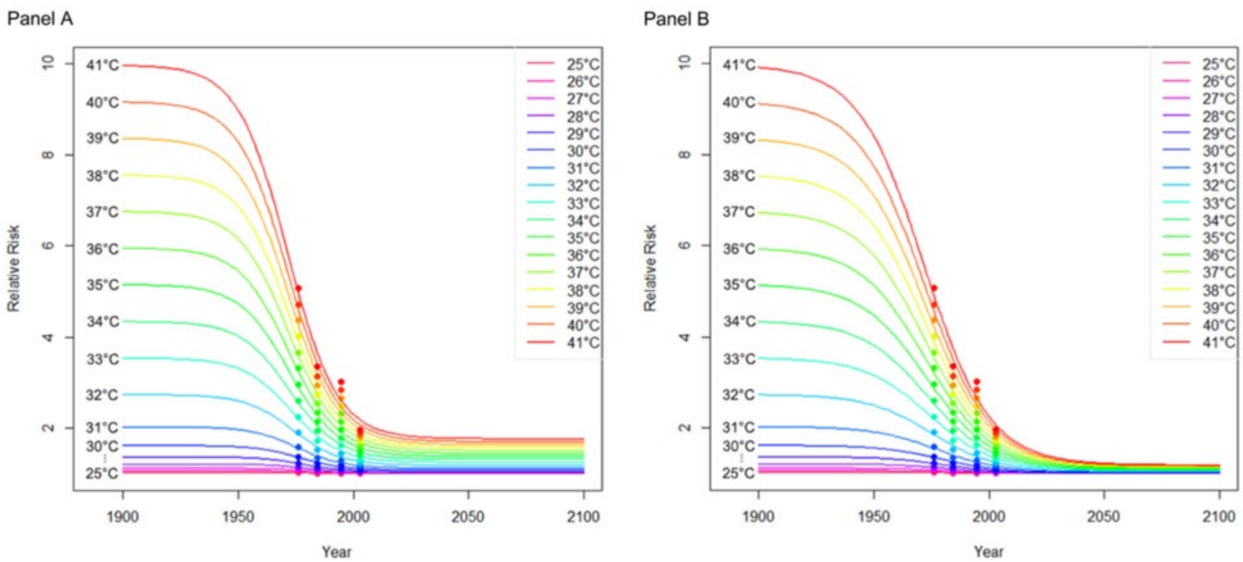
[1] A2 scenario assumed rapid human population growth, relatively weak environmental concerns, and a lack of aggressive GHG regulations. B2 scenario assumed more-moderate population growth and increased concerns around environmental sustainability, with more aggressive GHG regulations, compared with A2.

Petkova et al. (2017)[75] modeled the relative risk for heat-related mortality in NYC, both historically starting in 1990 and projected to 2100. As shown in Figure 11, the study found relative risks were fairly constant during the first part of 20th century (1900–1950), suggesting little adaptation to heat during this period. In the latter half of the 20th century, relative risks decreased from the 1970s to the 2000s, consistent with substantial adaptation to heat. The study concluded that increased access to AC in recent years was the primary cause of the apparent increase in adaptation, and further adaptation to heat can reduce heat-related mortality.

Figure 11. Temperature-Specific Mortality Curves for NYC from Petkova et al., 2017

Temperature-specific mortality curves for New York City, 1900–2100. *(A)* Adaptation model assumes that temperature-specific relative risks will decrease by an additional 20% ("low adaptation") between 2010 and 2100 compared with the 2000s. *(B)* Adaptation model assumes that temperature-specific relative risks will decrease by an additional 80% ("high adaptation") between 2010 and 2100 compared with the 2000s. Points represent the relative risks (RRs) calculated using the distributed lag non-linear model (DLNM) for each temperature for the 1970s (1973–1979), 1980s (1980–1989), 1990s (1990–1999), and 2000s (2000–2006). RRs were calculated for June–September using a model with a quadratic spline with 4 degrees of freedom and 22ºC as a reference temperature.

Source: Petkova et al. (2017)[76] See study for full details.



3 Evaluating Changes in New York City Cooling Demand and Energy Use

This section highlights the results from the cooling demand and energy use analysis under different scenarios and summarizes key indicators for vulnerable communities including how cooling utility cost impacts energy insecurity challenges. Section 6 summarizes the detailed evaluation of equitable cooling solutions, building on the analysis in this section.

Guidehouse developed a spreadsheet model to analyze how NYC residential space cooling demand, energy consumption, peak electricity demand, and building stock characteristics will change over 2020–2050 due to climate change, population growth, and other factors. Appendix D provides a detailed description for the analysis approach and assumptions. Guidehouse prepared three modeling scenarios to understand the impacts for key factors, isolate the contributions of existing energy efficiency and GHG emissions policies, and evaluate the potential value of new technology and policy solutions.

Table 15 outlines key characteristics for the modeling scenarios described in this section. The Technology and Policy Solution Scenario in the model allows for customized inputs to evaluate different packages of equitable cooling solutions. The preliminary analysis modeled the impact of 50% adoption of high-efficiency AC systems. The later analysis modeled several packages of solutions identified through the structured dialogs with key experts and stakeholders. These include increasing adoption levels of high-efficiency AC systems, weatherization, and envelope upgrades, cool roof adoption, tree planting and urban greening, and cool pavements.

Table 15. Summary of Cooling Demand Modeling Scenarios

Source: See section 2 for more details.

Scenario	Description
Steady Progression Scenario	• Includes impacts of climate change, population growth, utility rates, normal appliance and building system turnover.
Current Policy Scenario	• Same as Steady Progression scenario with additional impact of energy efficiency programs.
Technology & Policy Solution Scenario	• Same as Current Policy scenario with customized adjustments for technology parameters: adoption rates, energy savings, upfront cost. • In the Preliminary Analysis, the Technology and Policy Solution scenario results show the impact for 50% adoption of high-efficiency AC systems. • Later analysis models several packages of solutions identified through the structured dialogs with key experts and stakeholders.

This section summarizes preliminary findings relating to the following topics, with section 6 describing the modeling results into the equitable cooling scenarios:

- Residential electricity consumption
- Residential electricity costs
- NYC electricity consumption from increasing residential AC adoption
- NYC electricity peak demand from increasing residential AC adoption
- Operating and capital costs

Appendix D provides key modeling results.

3.1 Residential Electricity Consumption and Costs

Figure 12 provides the average cooling electricity consumption for NYC homes projected for 2020–2050 under different scenarios. These values represent the weighted per-home average of single-family and multifamily homes and highlight the impacts of climate change, existing policies, and normal replacement cycles for building technologies. The analysis suggests that the per-home impact of climate change on cooling demand can largely be offset by normal appliance replacement and committed energy efficiency goals. As described in section 2.3.1, climate change will increase the annual cooling demand by 17% in 2050 over 2010–2020 historical values as measured by cooling degree days (CDD). Federal appliance standards along with State and local building codes will gradually improve the energy efficiency of NYC buildings. The steep decline in 2020–2035 highlights the contribution from today's appliance standards as more efficient AC systems replace older inefficient units at the end-of-life point (average AC system lifetime of 14 years). Envelope and roof measures have 25-year lifetimes, so their impact on per-home cooling consumption continues through 2045 until the entire NYC housing stock meets today's appliance and building efficiency codes. The impact of climate change counteracts these efficiency gains throughout 2020-2050 but is most clearly seen in 2045–2050, after all building systems have been updated. Climate change would further increase cooling electricity consumption post-2050 without additional mitigation measures that could reduce per-home cooling demand.

Figure 12. Projected Cooling Electricity Consumption per Home

Source: Guidehouse analysis.

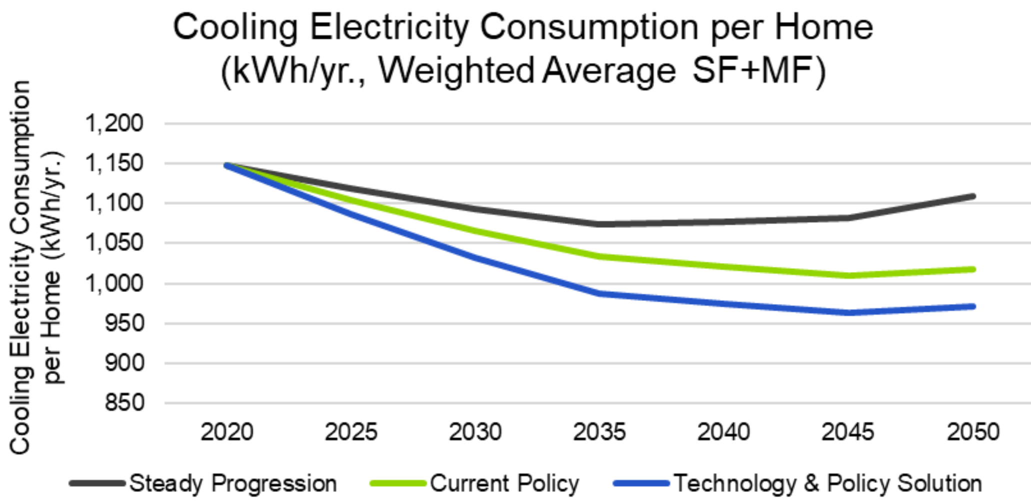
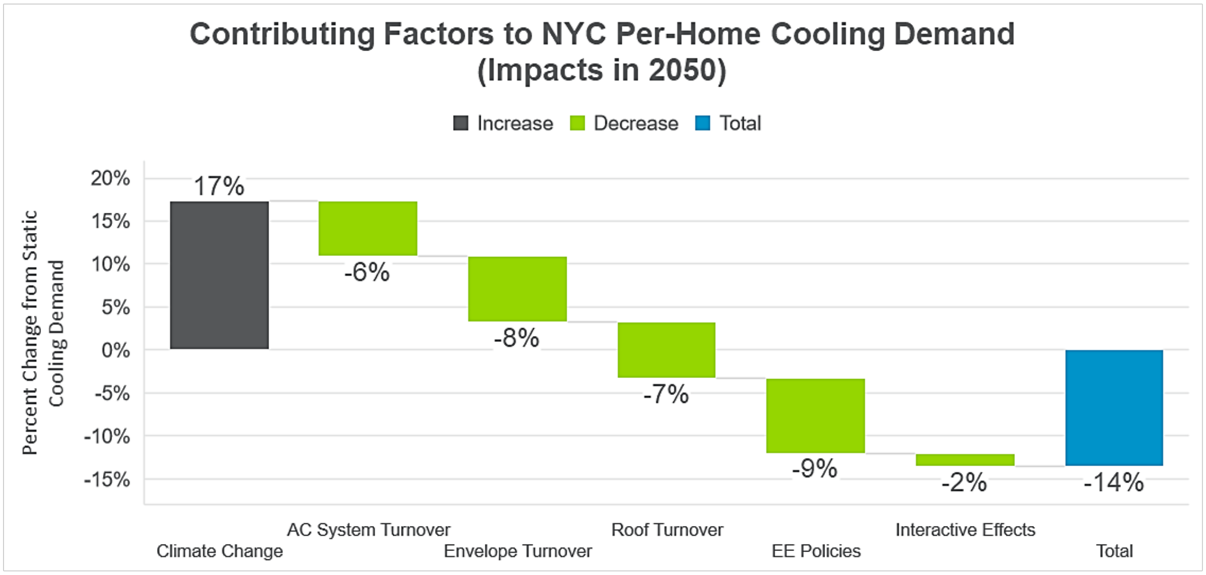


Figure 13 highlights how different factors contribute to the modeled NYS per-home cooling demand in 2050. Climate change will increase cooling demand whereas assumed energy efficiency gains from appliance turnover and replacement of building systems at the end-of-life point, as well as incremental energy efficiency policies in the State, will decrease cooling demand. The Steady Progression scenario includes appliance turnover and the Current Policy scenario includes the additional impacts of energy efficiency policies. Figure 13 highlights the individual impacts for each energy savings strategy, whereas the scenario analysis includes the interactive effects of the combined set. This analysis examined the impacts of one set of appliance standards and building codes. Should additional codes and standards take effect, cooling energy consumption would be reduced further in future years.

Figure 13. Contributing Factors to New York City Per-Home Cooling Demand

Source: Guidehouse analysis.

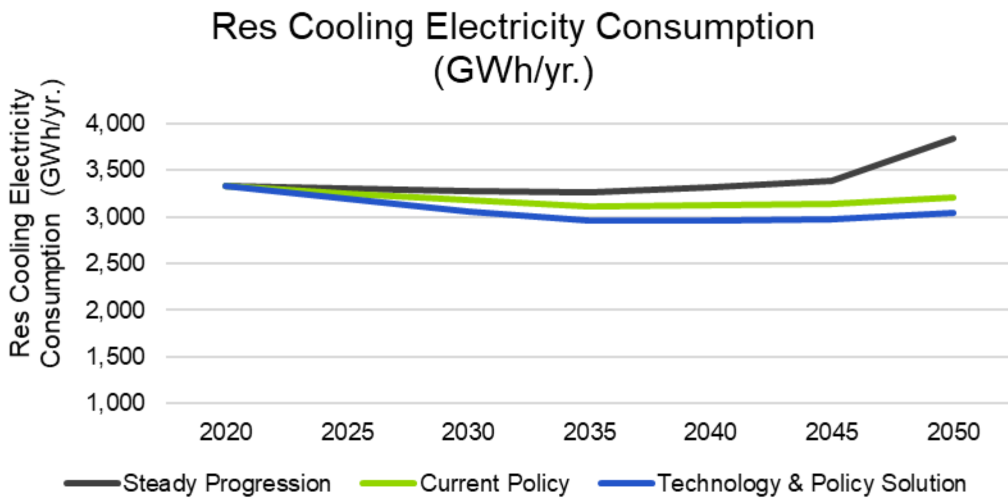


The Current Policy scenario outlines the impacts of normal appliance replacement cycles and committed EE policies by NYC and NYS. As such, this represents the most realistic baseline by which to compare technology and policy solutions, including increased installations of high-efficiency systems and greater adoption of AC systems by those who do not have cooling access today. The Technology and Policy Solution scenario results show results for 50% adoption of high-efficiency AC systems, up from approximately 10% today. This process highlights both the significant impacts that existing policies will have on electricity demand in NYC and how additional opportunities could provide incremental improvements.

Figure 14 provides the citywide cooling electricity consumption for NYC homes projected for 2020–2050 under different scenarios. These values represent the per-home results shown in Figure 12 multiplied by the number of single-family and multifamily homes in each year. The findings suggest that citywide residential cooling electricity consumption will remain relatively stable. While the per-home averages decrease significantly in Figure 12, the citywide results show less decline due to the overall increase in City housing stock in future years.

Figure 14. Projected Residential Cooling Electricity Consumption

Source: Guidehouse analysis.



3.2 Residential Electricity Costs

Figure 15 provides the average cooling electricity cost for NYC homes projected for 2020–2050 under different scenarios. These values represent the weighted per-home average of single-family and multifamily homes and incorporate projected utility rate increases of 2.2% per year as described in section 2.3.4. Even with the decreased cooling energy consumption, increases in utility rates raise the per-home cooling operating cost over 2020–2050. Existing policies have reduced the expected annual utility cost for cooling, and various technology and policy solutions could reduce the AC system operating cost further. These per-home cooling utility cost estimates reflect nominal utility rate growth rates and have not been adjusted for inflation. Historical wage growth in NYC averages around 1.5–2.0% based on historical hourly and weekly earning data from the New York State Department of Labor.[77] Based on these historical averages, annual utility rate increases of 2.2% may raise the share of household income for cooling. In this case, utility costs would have a larger share of household income and increase the amount of residents classified as energy insecure. This topic is further discussed in section 4.2.

Figure 15. Projected Cooling Electricity Cost per Home

Source: Guidehouse analysis.

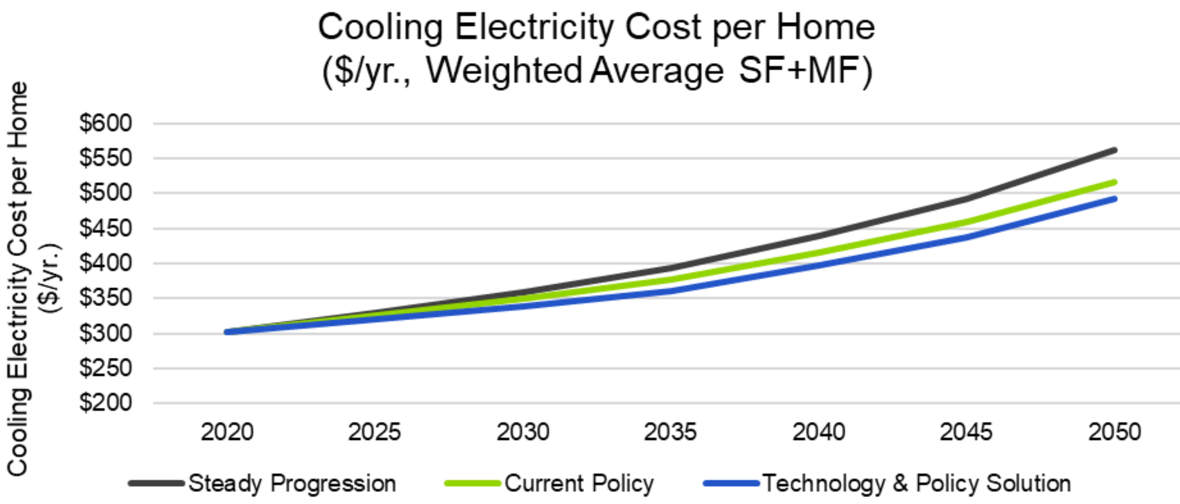
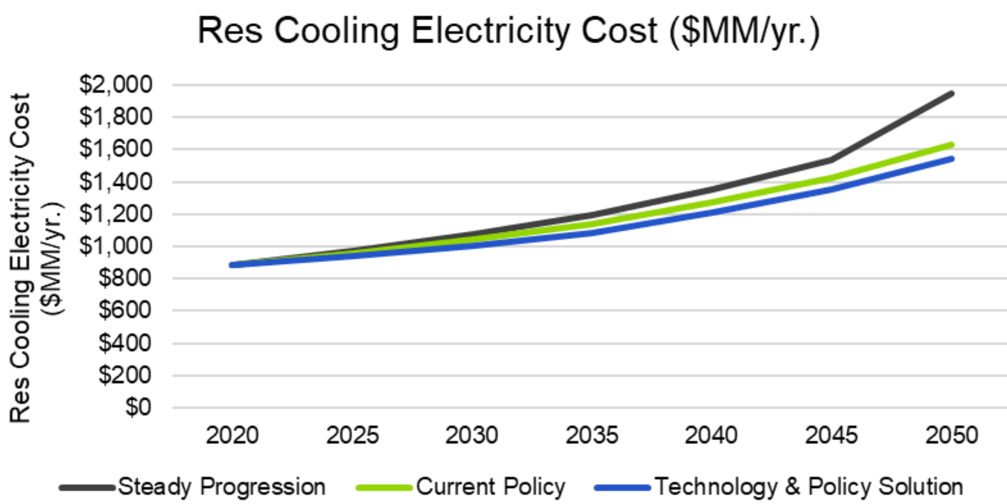


Figure 16 provides the citywide cooling electricity cost for New York City homes projected for 2020–2050 under different scenarios. These values represent the per-home results shown in Figure 17 multiplied by the number of single-family and multifamily homes in each year. In all scenarios, NYC residential cooling electricity cost increases in future years due to projected utility rate increases. As described in section 4.1.4, future electricity rates for NYC are highly uncertain and New York State policies such as the Climate Act will have a significant impact on how future electric rates are determined. Rates may increase to accommodate additional infrastructure needs but could also decrease due to increased transportation and building heating consumption. Although out of scope for this study, additional research is necessary to determine future rate impacts and their potential effects for cooling access for vulnerable populations.

Figure 16. Projected Residential Cooling Electricity Cost, Citywide

Source: Guidehouse analysis.



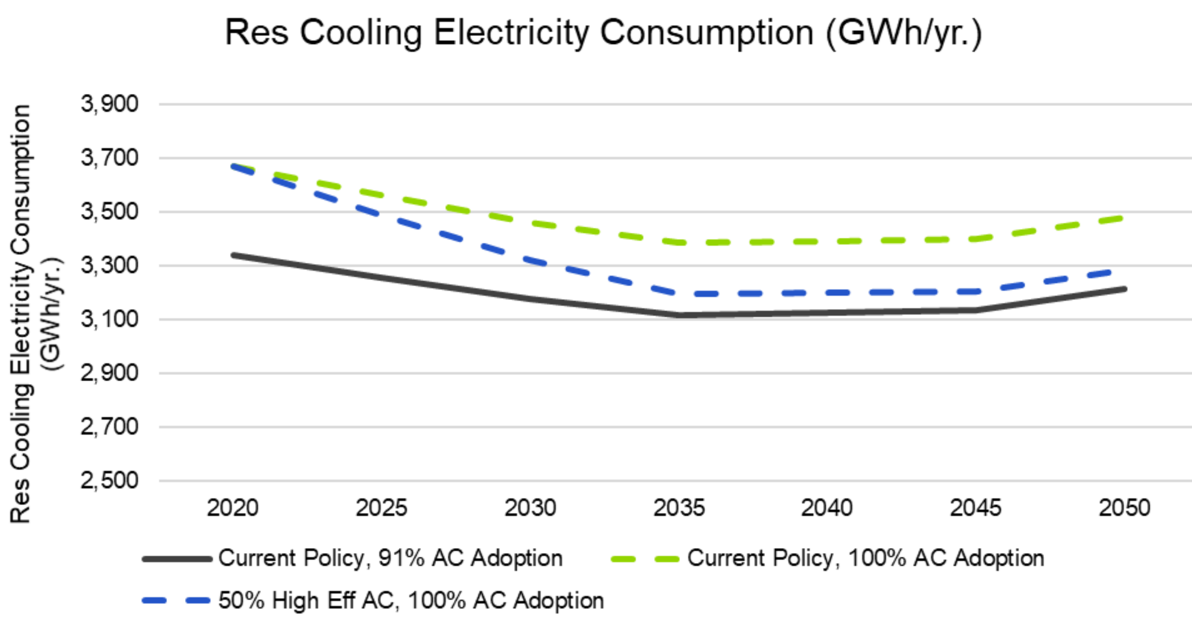
3.3 New York City Electricity Consumption from Increasing Residential AC Adoption

Installing AC systems in the homes of vulnerable residents is one of the more promising strategies to address cooling access across NYC. Although expanding AC system access appears relatively straightforward, section 5.1 describes several challenges relating to capital and operating cost for the systems, constraints within a building's electrical or physical infrastructure, personal preferences and behavior, and other known barriers. Beyond the individual homes, introducing a significant number of new AC systems to the City electrical grid may have a detrimental impact on daily electricity consumption and hourly demand during the peak summer season. To understand these impacts for the electricity grid, Guidehouse conducted a sensitivity analysis concerning residential AC adoption rate.

Figure 17 provides the annual cooling electricity consumption for NYC homes projected for 2020–2050 under different scenarios for AC adoption. The solid grey line represents a steady residential AC adoption rate of approximately 91% as found in the Current Policy scenario described above. The green dotted line represents the annual cooling electricity consumption if 100% of homes adopted AC systems in 2020. Increasing cooling system adoption in NYC from 91% to 100% would increase citywide residential cooling electricity consumption by 8–10% per year over 2020–2050. New AC systems would meet current appliance standards and have lower consumption than average installed base in early years. The blue dotted line represents the 100% AC adoption scenario, where 50% of all AC units installed in each year are high efficiency.

Figure 17. Projected Residential Cooling Electricity Consumption Impact under Different AC Adoption Scenarios

Source: Guidehouse analysis.



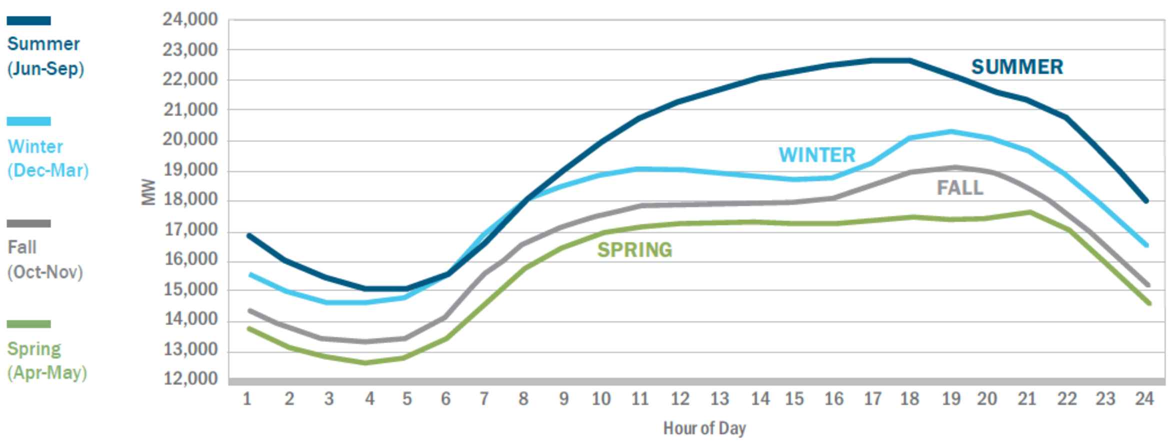
This analysis suggests that increasing adoption of residential AC systems to address cooling access for vulnerable populations will have a modest increase in citywide residential cooling electricity consumption due to the already high installed base of 91% today. The total residential cooling impact is relatively minor (1–2% increase) when considering total electricity consumption for both residential and commercial segments across the City. Furthermore, the analysis suggests that increasing energy efficiency for AC systems, particularly those installed for vulnerable residents, can reduce the electricity consumption growth. Nevertheless, it is recognized that installing an AC system is not a universal solution and therefore an evaluation of other technology and policy solutions that can mitigate heat risk and cooling equity is included.

3.4 New York City Electricity Peak Demand from Increasing Residential AC Adoption

Beyond increasing electricity consumption, residential and commercial space cooling is the most significant driver for peak demand in the NYS electricity grid today. Figure 18 highlights hourly electricity demand across the State in different seasons in 2017. Summer electrical demand follows daily temperature patterns by increasing throughout the day, with a peak occurring at 6:00 pm (18:00) when many New York residents arrive home, reduce thermostat settings, and increase AC system usage. Electrical system operators such as NYISO and the City's electrical utilities must design the electrical generation, transmission, and distribution infrastructure around the annual and seasonal peak periods. If greater AC adoption for vulnerable residents increases peak demand above planned levels, grid operators would need to build additional infrastructure or curtail load through demand response programs to maintain system reliability and minimize service disruptions.

Figure 18. NYISO Seasonal Hourly Demand Patterns across New York State, 2017

Source: NYISO 2018 Power Trends report. [78]



To understand the impacts that increased AC adoption could have on peak demand, Guidehouse modeled the incremental load addition when increasing AC system adoption to 100% for NYC homes. The NYS TRM estimates incremental AC systems contribute approximately 1 kilowatt (kW) to peak demand, with a range of 0.7 to 2.2 kW for room AC, PTAC, and central AC systems. Table 16 outlines the incremental peak demand impacts for increasing the residential AC adoption rate to 100% under the Current Policy scenario. The baseline summer peak demand is based on adjusted NYISO Gold Book values for NYC (Zone J),[79] including projected climate adjustment based on the Itron NYISO 2019 report.[80] Extending access to AC systems for all NYC homes would increase future (Zone J) peak demand by approximately 2.2% or 285 MW. High-efficiency AC systems would help mitigate this peak demand increase, as would future building technologies with grid-interactive features, including:

- **Connectivity:** ability to communicate with grid networks and program a setpoint schedule for time-of-use rates.
- **Load Shedding:** ability to temporarily decrease consumption based on grid-signals.
- **Load Shifting:** ability to adjust the normal operating schedule to avoid peak periods.
- **Thermal Energy Storage:** ability to store space cooling during low periods for use during peak periods.
- **Variable Capacity:** ability to adjust performance while meeting occupant needs.

Table 16. Projected Peak Demand Change from 100% Residential AC Adoption

The analysis focuses on 2035–2050 to isolate the impact of AC adoption by minimizing the peak demand savings impacts of normal appliance replacement.

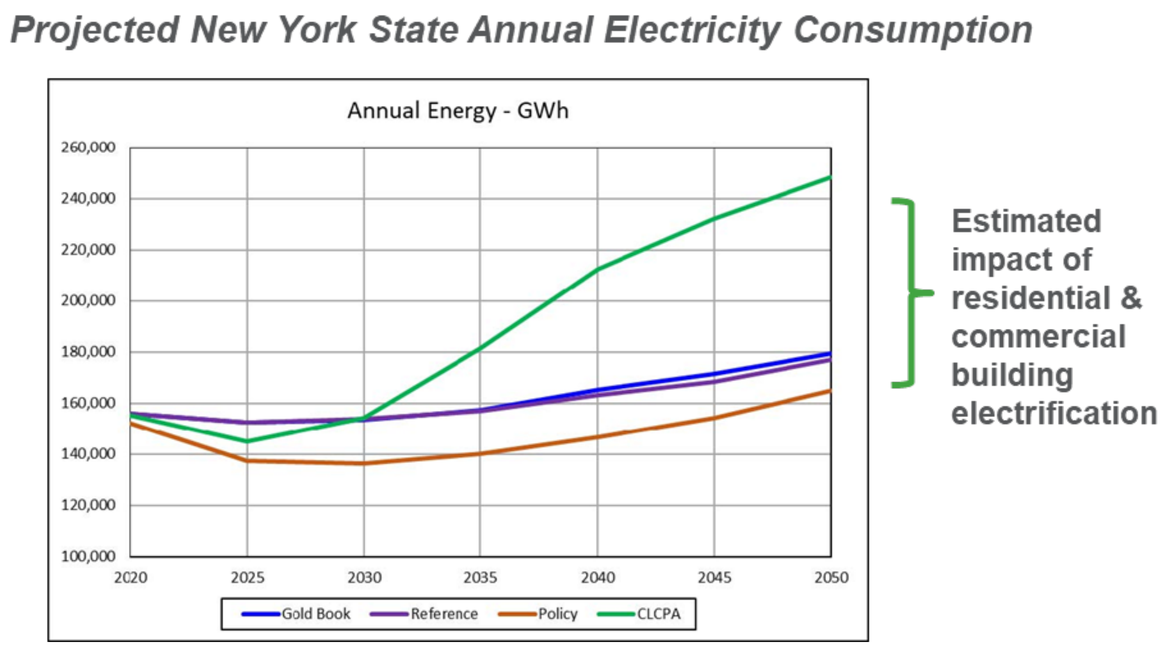
Source: The baseline New York City summer peak demand is based on adjusted NYISO Gold Book values for NYC (Zone J),[81] *including projected climate adjustment based on the Itron NYISO 2019 report.*[82] *Peak demand impacts of AC systems based on NYS TRM values.*[83]

Key Values	Units	2035	2040	2045	2050
Baseline New York City Summer Peak Demand (MW)	MW	12,158	12,857	13,195	13,532
Peak Demand Change (MW) from 100% Residential AC Adoption	MW	285	285	285	285
Percentage Change for 100% Residential AC Adoption	%	2.3%	2.2%	2.2%	2.1%

As previously discussed, electricity production and consumption patterns throughout NYS will change in future years based on Climate Act policy goals concerning renewable electricity, energy storage, building and transportation electrification, and GHG emission reduction. Figure 19 highlights projected NYS annual electricity consumption in future years due to current forecasts and potential Climate Act impacts. Although Figure 19 highlights statewide impacts, the NYC grid will see similar trends. Electric load growth from Climate Act policies for building and transportation electrification will require grid operators to explore new strategies to meet electricity demands. The expected increase from increasing residential AC adoption would be relatively small in comparison and may not be as significant due to changes in the seasonal demand patterns. Both the NYISO study and the National Renewable Energy Laboratory (NREL) Electrification Futures study[84] suggest that NYS grid demand would switch from a summer peak to a winter peak due to electrification policies. In this case, the grid infrastructure needed to accommodate the new winter peak demand would likely cover the summer demand increase from greater residential AC adoption. The implications of Climate Act on future electricity consumption, demand, and rates are highly uncertain at this time. NYISO, utilities, and grid experts across the State are analyzing potential pathways to minimize impacts on customers while meeting State energy and GHG policy goals.

Figure 19. Projected Impacts from Climate Act Policies on New York State Annual Electricity Consumption

Source: Itron, New York ISO Climate Change and Resilience Study–Phase 1. [85]



3.5 Operating and Capital Costs

The analysis methodology developed will also consider the cost effectiveness of different technology and policy solutions to increase cooling access for vulnerable populations. The total economic impact for AC system use includes both upfront purchase and capital costs as well as annual operating costs. The combined lifecycle cooling costs include both the capital cost and operating cost over the expected lifetime of the AC system (i.e., combined cooling cost includes upfront cost plus 14 years' operating cost). High-efficiency AC systems and other technologies typically have a higher capital cost but have lower annual operating cost relative to conventional options. Some cooling solutions such as increasing greenspace or light-colored surfaces have virtually no operating costs after installation. In addition, high-efficiency technologies with limited market adoption today may achieve lower costs in future years as higher sales volumes and installation familiarity decreases per-unit capital costs.

Section 6 evaluates the per-unit and citywide impact of various technology and policy solutions and assess their cost effectiveness in achieving equitable cooling access.

3.6 Energy Insecurity and Cooling Utility Cost for Vulnerable Populations

Increasing access to AC systems for vulnerable populations can help mitigate health risks during extreme heat events, but the additional electric utility costs to operate the AC systems may create an additional economic burden if not managed correctly. In some cases, vulnerable residents may hesitate to turn on their new AC systems due to economic concerns and, therefore, still experience heat-related illness in the home. Energy insecurity is often defined as the level where utility bills account for more than 10% of income on a monthly or annual basis. In recent years, various programs are available to minimize energy insecurity, including discounted rates for low-income customers offered by New York City utilities,[86] and statewide programs to minimize energy bills to no more than 6% of income.[87] Nevertheless, vulnerable communities may face situations where these programs are unavailable or bureaucratic hurdles make access difficult, and it is important to understand the economic impacts that AC use may have on different New York City populations.

The analysis of per-home cooling energy consumption and cost considers the characteristics of an average home from an energy standpoint, but the economic situation of neighboring residents can be considerably different even with the same home size and floorplan. To understand cooling energy cost impacts across different income levels, Guidehouse analyzed how monthly electricity costs for cooling and other appliances compared to energy insecurity thresholds of 10% and 6%. In 2019, the New York City Mayor’s Office estimated that approximately 20% of residents are living at or below the poverty line of approximately $32,000 for a family of four.[88] Energy insecurity thresholds at 10% and 6% of monthly income would be $267 and $160 per month, respectively.

Table 17 summarizes the monthly income, energy insecurity thresholds, and monthly cooling costs for homes above and below the New York City poverty line in 2020. Seasonal utility bills for AC systems average $303 per year, or $75 per month over a four-month cooling season ($506 for single-family homes and $263 for multifamily homes). The analysis suggests that average residential cooling cost of $303 per year could be reasonable for most New York City residents. For residents at the New York City poverty line (30% AMI), a $118 average monthly electricity bill and up to $170 per month in the four-month cooling season is close or below the energy insecurity thresholds. For residents 50% below the New York City poverty line (15% AMI), average monthly electricity costs will exceed the 6% threshold and exceed the 10% threshold during summer months with high-space cooling loads.

Table 17. Projected Cooling Costs and Energy Insecurity Thresholds for Vulnerable Residents

Area median income (AMI) values and income segments vary based on the number of adults and children in a home; most indicators use a baseline of two adults and two children; area median income of approximately $107,000 for New York City.

Source: The New York City Department of Housing Preservation and Development (HPD). [89]

Vulnerable Residents	Annual Income (Family of Four)	Monthly Income	Energy Insecurity Threshold (10% of Income)	Energy Insecurity Threshold (6% of Income)	2020 Monthly Cooling Cost (Four Cooling Months)	2020 Monthly Electricity Cost (12-Month Average)
50% of New York City Poverty Line (15% AMI)	$16,005	$1,334	$133	$80	$75 per mo. ($303 annual cost)	$118 per mo. average, including cooling ($170 per mo. during cooling season)
100% of New York City Poverty Line (30% AMI)	$32,010	$2,668	$267	$160		
Very Low Income (50% AMI)	$53,350	$4,446	$445	$267		

The findings suggest that vulnerable residents below the New York City poverty line would face challenges affording cooling systems during the summer, even after available programs that limit energy spend to 6% of income. These findings suggest that providing utility bill credits during summer months would be necessary to enable vulnerable populations to operate the AC systems without undue financial burden. This topic is further discussed in sections 5 and 6. The analysis does not include space or water heating costs, which may be included in monthly rent for some residents, or the purchase cost for AC systems. In addition, vulnerable residents often reside in buildings that may have older, less efficient, and poorly performing building systems, which would increase operating costs above these averages.

4 Technology and Policy Options to Expand Cooling Access

This section discusses various technology and policy options for consideration in helping mitigate or offset the additional load induced by increasing AC unit ownership and usage to achieve equitable access to cooling throughout NYC, especially for vulnerable populations. An initial broad list of options developed through a comprehensive literature review was narrowed to a final list of prioritized scenarios based on applicability to NYC, feasibility, cooling or load-offsetting potential and barriers to adoption or equitable access. The list of option was informed through structured dialogs with experts, researchers and policymakers inside and outside of NYC and the State. In-depth interviews with residents as well as community and environmental action groups within NYC contribute critically to the team's understanding of the needs and considerations of the City's vulnerable populations with respect to extreme heat and cooling access, the prioritization of technology and policy options, and framing of associated barriers and benefits.

4.1 Research Methodology

A two-pronged approach was deployed to identify, study, and prioritize technology and policy options to provide cooling access to vulnerable populations in NYC, while mitigating or offsetting increased energy use associated with cooling. This approach used a broad review of literature and secondary research, paired with a series of in-depth dialogs. Guidehouse began with a thorough review of existing literature and secondary sources to delineate the universe of available technology and policy options, and compiled an initial "broad list" of options. Guidehouse then gathered sufficient information characterizing each option to prioritize options in terms of feasibility, appropriateness, and applicability to NYC, potential for cooling or offsetting energy use, and associated barriers and benefits. The team then carried out in-depth dialogs and interviews with researchers, program implementers, policymakers, and community and environmental group leaders to refine option characterization, gather additional quantitative information, and explore barriers and equity issues, non-energy impacts, efficacy, and other key attributes of options to narrow to a prioritized list of options for modeling.

The in-depth review of existing literature and documentation included all technology and policy options for provision of cooling, urban heat islands, heat, and health which appeared viable at the outset of Task 2. Guidehouse researchers paired with University of Buffalo colleagues to compile reports, articles, papers, presentations, plans, and other publicly available sources of information, then extract qualitative and quantitative information to characterize each option in terms of cooling or energy use offsetting potential, effect on urban heat islands, feasibility, applicability to NYC, examples of successful deployment and case studies, barriers to equitable access or adoption, and co-benefits and non-energy impacts associated with each option. Figure 20 summarizes a wide range of resources consulted within the literature review, while section 8 provides a detailed bibliography for these reference resources.

Figure 20. Literature Review Summary

Source: Guidehouse.

Sources	Document Types	Subjects
• Internet search	• Research papers	• Heat and health
• Recommendations from PAC and interviews	• Journal articles	• Urban heat islands (UHI)
• Bibliographies in research papers	• Reports by utilities and state/local agencies	• Cooling technologies
• Citations in reports	• State/local plans	• Cooling-related policies and programs
• Conference proceedings	• Presentations	• Equitable access barriers
• Internal subject matter expert suggestions	• News articles	• Non-energy impacts
	• Websites	• Environmental justice
	• Online media articles	

Based on the detailed literature review, the research team created a broad list of potential technology and policy options to deliver equitable cooling to residents throughout NYC, while mitigating associated increases in energy use. This "broad list" is described in detail in section 5.4.

Guidehouse then undertook a series of targeted in-depth structured dialogs, to gather quantitative information to further characterize measures, and to better inform feasibility and applicability of technology and policy options for NYC, as well as to understand associated barriers, equity issues and non-energy impacts. More detail on interview participants can be found in Table 23. Interviews were particularly valuable in providing the perspective and lived experience of NYC residents and researchers, allowing the team to better assess suitability of measures to NYC and anticipate challenges and barriers specific to the City that might not be apparent when considering successes in other regions. During the literature review Guidehouse compiled a list of researchers, subject matter experts, and policymakers serving as authors on, or mentioned in, key documents on heat and health, urban

heat islands, technology and policy options, and associated considerations. Based on literature review findings, Guidehouse identified topics needing further investigation and/or quantification and paired these to individuals in the list of potential interviews. Interviews often yielded additional contact suggestions and the team conducted interviews with these resources where feasible.
Table 18 lists the organizations interviewed as part of the structured dialogs informing Task 2.

Table 18. Structured Dialogue Interview Summary

Source: Guidehouse. PAC denotes those who also participated in the Project Advisory Committee.

Institution	Topic Areas
Arizona State University (ASU); PAC	Heat and health; urban heat islands; low-income energy needs
Barcelona Laboratory for Urban Environmental Justice and Sustainability	Urban heat islands; urban greening and tree planting; gentrification and displacement; policy, heat and health
City of Phoenix	Cool pavement; urban heat islands
City University of New York (CUNY)	Urban heat islands; cool roofs; cool pavement
Columbia University, Earth Institute	Heat and health
Columbia University, Mailman School of Public Health	Social and environmental determinants of health; policy, heat and health; HEAP/WAP
Community Energy Engagement Program (CEEP), Center for NYC Neighborhoods	NYC low-income energy needs
Global Cool Cities Alliance (GCCA); PAC	Urban heat islands; cool roofs; cool pavement
GuardTop	Cool pavement; urban heat islands
HOPE program, NYC	Cool roofs; job creation
Natural Resources Defense Council (NRDC)	Heat and health; cool roofs; urban heat islands
Northern Manhattan Improvement Corporation (NMIC)	HEAP/WAP implementation and policy; weatherization; policy, heat and health
New York State Department of Health (NYS DOH); PAC	Policy, heat and health; urban heat islands
NYSERDA Clean Energy Siting	Solar siting and considerations in New York: City and State
NYSERDA; PAC	Heat pumps and electrification; policy, energy, buildings and modeling
Philadelphia Office of Sustainability	Urban heat islands; urban greening and tree planting; gentrification and displacement; policy, heat and health
The Point Community Development Center (The Point CDC) NYC	NYC community policy and advocacy; environmental justice; low-income energy needs
Union of Concerned Scientists (UCS); PAC	Heat and health; urban heat islands; low-income energy needs
WEACT for Environmental Justice	NYC community policy and advocacy; environmental justice; cooling shelters; low-income energy needs

The research team used themes and findings drawn from the structured dialogs to refine the "broad list" to create a narrow "prioritized list" including only the most impactful and appropriate technology and policy options available for NYC. This prioritized list, detailed in section 5.5, includes technology and policy options which have the potential to contribute the most to equitable cooling access in NYC, with the fewest implementation, cost, and accessibility challenges, while being appropriate to and feasible for operation in NYC. The final step in this process was to develop three prioritized packages of technology and policy options referred to as "scenarios" for modeling. These modeling scenarios are described in detail in section 6.

4.2 Understanding Equitable Access to Cooling

Understanding what makes cooling access equitable is essential if NYSERDA is to address environmental justice issues in tandem with the public health threat posed by a changing climate for NYC residents. Guidehouse explored topics surrounding equity and equitable access through a series of structured dialogs with community members, environmental and social justice organizations within NYC, and experts in the fields of low-income communities, weatherization and energy insecurity, heat and health, urban heat islands, cooling technologies, electrification, urban displacement and energy policy. From those interviews, the team distilled many key insights into equitable cooling access, which will help frame the discussion about technology and policy options to accomplish the goal of equitable cooling.

Voices from across the spectrum of those interviewed homed in on the primacy of safety in people's own homes as foundational to any plan for equitable cooling access. Primary strategies should help people stay safely in homes rather than transporting them elsewhere or encourage them to leave their homes to escape the heat. Secondary strategies that make the community as a whole more livable or pleasant (e.g., parks, tree cover) or get people out of hot homes (e.g., cooling centers, transportation) are important, but will not replace in-home cooling on the hottest days or during outbreaks of transmissible disease, as highlighted by the COVID-19 pandemic. Furthermore, these strategies are inherently less equitable and may place additional stress and burden on vulnerable populations. Dignity and self-determination are important components of equity conferred by safety in one's own home. The NYC AC assistance program in summer 2020 provides a good example for combining equipment installation and bill relief, but also revealed challenges with expanding this type of strategy, which will be addressed in greater detail in section 6.4.

Structured dialogs also reinforced the understanding that how programs or policies are implemented can be just as important as the options themselves. Interviews suggested that NYSERDA work with communities and individuals to ensure technology and policy options for equitable cooling access are not undertaken *on behalf of* vulnerable populations, but *in concert with* them. To mitigate unintended consequences and negative impacts from well-intentioned programs, it is essential that State and local agencies work with vulnerable populations to co-create programs and solutions that will be culturally sensitive, appropriate, and embraced by the communities they are intended to serve. As an example, tree planting and greening programs confer a wide array of benefits to communities through beautification, improvements in livability, and increases in property values, in addition to cooling benefits. However, if not consulted, vulnerable communities may be harmed through gentrification and displacement, or unforeseen financial burdens associated with tree care and maintenance. By contrast, a tree planting and greening program co-created and implemented within the community can proactively tackle gentrification and displacement, create jobs, avoid maintenance costs borne by individuals, and ensure community members are invested in tree survival leading to increased shading and heat abatement over time.

Interviews also provided a practical lens through which to view barriers and challenges to equity from the standpoint of vulnerable communities. Dialogue participants articulated that providing an efficient AC unit to every New Yorker without home cooling would only solve part of the challenge of equitable cooling access—if people cannot afford to use the units, that outcome is not equitable. Because energy insecurity is a salient issue for many of NYC's most vulnerable citizens, pairing provision of cooling with adequate bill relief is the only way to ensure equitable cooling access. Similarly, cooling centers are not an equitable cooling solution if they are lacking in resources, not able to provide comfortable spaces, food and water, interesting activities, or if they are not accessible to people with very young children, pets, or those with constraints on mobility. Cooling centers should be centrally located in communities and be attractive places where people want to spend time in order to advance equity and provide cooling access. Furthermore, COVID-19 causes significant shifts in resident occupancy and transportation patterns, and the availability of cooling from commercial and public buildings was significantly restricted.[90]

Structured dialogs also suggested in order to be equitable, cooling access solutions would have to harness multiple technology and policy tools and plan across multiple relevant time horizons. Because the needs and barriers facing different vulnerable populations without cooling access are so diverse, a diverse set of technology and policy options will need to be deployed in concert to reach everyone and balance near-term crisis abatement with longer term sustainability. While NYCHA residents may benefit from dedicated on-premise cooling centers, weatherization benefits those in single-family homes. Similarly, longer term structural changes and investments need to be made to achieve long-term sustainability and equity targets, but not at the expense of people's lives and wellbeing in the present. While electric heat pumps are more efficient in the long-run, efficient traditional AC units may be needed in the near-term from a cost and equity perspective.

4.3 Barriers to High-Efficiency Cooling

While most New York City homes have AC systems today, the vast majority of systems have efficiency ratings at or below current codes. Installing higher efficiency AC systems would reduce cooling operating cost, but many residents often face challenges affording the incremental capital cost for the premium systems. Similarly, the majority of NYC homes could reduce cooling and heating operating costs by improving the performance of their building envelope, including insulation, air tightness, windows, doors, roofs, and other measures. Nevertheless, upgrading building infrastructure in multifamily buildings, particularly as a rental resident, is very challenging and often impossible without buy-in from outside parties. Improving the energy efficiency and performance of AC and other building systems are especially challenging for vulnerable residents, who experience additional financial, health, and socioeconomic barriers.

Table 19 below summarizes the technical, market, and policy barriers related to the efficient use of, and equitable access to, cooling for vulnerable populations in NYC. The list of barriers was compiled using a variety of external and internal data sources,[91] as well as the structured dialogs with key stakeholders. These technical, market, and policy barriers limit the access, adoption, or utilization of cooling technologies today. The subsections below describe each of these barriers in greater detail. This list of barriers was used to develop recommendations in section 7 for how the identified barriers can be overcome so that the qualified solutions can be deployed effectively.

Table 19. Technical, Market, and Policy Barriers to Equitable and Efficient Cooling

Source: Guidehouse analysis based on literature review of resources described below.

Technical	Market	Policy
• AC ownership by building landlords • Challenges to building envelope upgrades • Cost of any technology • Cost of up-to-code technology • High overnight temperatures • Electrical upgrades for cooling technology • Structural limitations of older buildings • Operations and maintenance requirements • Limits of public programs	• Lack of awareness of danger of high temperatures • Lack of awareness of cooling centers • Preference for fans • Stigma around cooling centers, concern for pets, lack of transportation • Existing stock with window units • Cost-effectiveness of high-efficiency technology • Requirements for technology success • Lack of efficiency information for different solutions • Lack of cooling technology information per Local Law 133 exemptions[92]	• Financial assistance gaps • Building code compliance gaps • Public housing AC requirements • Landlord requirements for AC installation per Local Law 119[93] • Indoor temperature policy gaps • Spatial gaps in cooling policy effectiveness

Certain barriers were repeated throughout the research literature and interviews as limiting factors and could be considered across multiple categories. For simplicity, each barrier is only shown once in the category considered as the most appropriate. Lastly, the barriers are ordered based on the expected impact on residents' ability to access cooling, with those having the most impact at the top within their respective categories. The ranking was done based on our team's qualitative assessment.

4.3.1 Technical Barriers

Technical barriers are defined as the factor that could limit the adoption of cooling technology, or the utilization of the full capabilities of cooling technology.

- **Ownership of cooling systems by building owners, not tenants**: In rental apartments, tenants likely do not own core building appliances, which limits opportunities for individuals to upgrade AC systems such as central systems, PTACs, through-the-wall, and sometimes window AC units. Individuals cannot opt for more efficient cooling technologies if they do not make purchasing decisions.
- **Residents or building tenants cannot easily influence upgrades to the building envelope**: Unless the resident owns their building or collective action is taken to appeal for building upgrades, initiating building envelope upgrades—such as air sealing, window replacements, and improved insulation—is challenging. Furthermore, these projects may pose short-term occupancy issues during construction, which could be problematic for elderly residents.

- **Cost of purchasing cooling technology**: Low- or moderate-income individuals, who also tend to live in areas that experience more severe heat impacts, may not be able to purchase cooling technology due to the prohibitive cost of the technology itself. Although window AC systems are available for several hundred dollars (with older units at lower cost), the upfront cost can be a barrier for residents with limited disposable income, even if they have experienced summer heat stress in previous years.
- **Higher cost of efficient cooling technology**: The higher upfront cost for more efficient systems would encourage vulnerable residents to use their current underperforming systems past their working life, repair older inefficient systems rather than purchase new systems, and purchase older used systems that are less efficient than newer models. Central cooling systems or ductless mini-split AC systems are more efficient than distributed systems, such as window and wall AC units, but are significantly more expensive than lower efficiency window AC or PTAC systems. For roof or envelope upgrades, oftentimes an engineer or architect must be hired to assess the viability of the cool roof and establish a detailed maintenance plan, which increases upfront cost.
- **The persistence of high overnight temperatures:** Indoor temperatures in non-air-conditioned residences remain high for days after a heat wave, even at night, due to the buildings' thermal inertia. This creates risk for residents who take advantage of the daytime cooling centers and are without AC technology in their homes. Vulnerable populations often live in areas that experience more severe heat impacts during extreme heat events.
- **Older buildings may require electrical upgrades for cooling**: Older NYC buildings that do not have cooling systems today may require upgrades to the electric panel or outlets to accommodate new window AC systems. If installed without upgrades, the start-up of a window AC system may cause electric breakers to trip, turning off power to electric devices connected to that wiring branch, including potentially sensitive equipment, such as medical devices.
- **Structural limitations in buildings:** A building's mechanical structure or architectural layout could limit the ability to install technologies such as cool roofs, green walls, and exterior shading devices. In certain situations, energy efficiency projects, such as air sealing, are not feasible if there are more critical structural issues.
- **High-efficiency technologies may incur additional operations and maintenance requirements:** Many cooling technologies carry at least some operational and maintenance (O&M) cost, such as the added electric bill surcharge for operating an AC system, and the need for seasonal maintenance for cool and green roofs.
- **Cost of publicly funded upgrade programs:** Many programs exist in NYC to improve the affordability or adoption of cooling technologies. Nevertheless, many cost-effective building technologies have a high cost when applied across an entire building (range of tens to hundreds of thousands of dollars). This high cost per project limits how many buildings public programs can impact per year based on limited funding sources. This limitation creates the need for cost-effective solutions that building owners or vulnerable residents can employ on their own with minimal public assistance.

4.3.2 Market Barriers

Market barriers are defined as consumer characteristics or behaviors that impact the market penetration of cooling technologies and alternative cooling options (i.e., cooling centers).

- **Lack of awareness around danger of high-indoor temperatures:** Residents may not desire cooling technology due to personal preferences and may be unaware of the danger of high-indoor temperatures, leading to health impacts and in some cases mortality.
- **Lack of awareness around the existence and location of cooling centers:** Residents who lack cooling technology at home may be unaware of the existence of cooling centers, or know where to find them, and therefore are unable to access these facilities to protect themselves.
- **Certain segments of the population prefer fans**: A survey[94] of preferred cooling technologies showed that some people prefer fans to AC systems or other cooling technologies. Fans are less effective during extreme heat events and do not reduce indoor humidity.
- **Stigma around cooling centers, concern for pets, and lack of transportation and mobility issues**: Residents may feel (1) unable to leave their pet in a safe environment, (2) unable to access transportation to cooling centers, and/or (3) that cooling centers are uncomfortable places and are associated with a negative stigma. Transportation may be cost-prohibitive or not allow pets to accompany residents. These situations create transportation and social barriers to cooling access, regardless of need.
- **Existing multifamily building stock utilizes window units**: Many multifamily buildings in NYC use window ACs as their primary cooling technology, which are among the least efficient cooling technology options. For example, many pre-1960 buildings do not have central cooling systems, and typically use window and wall AC units instead.[95] These buildings therefore cannot take advantage of energy efficiencies provided by central AC systems or ductless mini-split AC systems without significant installation costs.
- **Cost-effectiveness of high-efficiency technologies:** As building and appliance codes improve, the overall energy efficiency of the building stock increases, but can have a counteracting effect on high-efficiency cooling technologies that are above code. With the overall building baseline improved, high-efficiency technologies provide less incremental energy savings, and therefore have longer paybacks for their initial cost investment.
- **Additional requirements for technology success:** Technologies, such as cool roofs or green walls, will only succeed when paired with maintenance plans and proper regulatory enforcement (i.e., zoning, building codes, etc.). Therefore, if consumers do not properly maintain the technology, and if there is no enforcement, the potential efficiency benefits of the cooling technology diminish.
- **Lack of information around efficiency tiers for different cooling technologies:** Limited information exists for consumers to compare the upfront, operating, and lifecycle cost for different AC systems and technologies. Without this information, customers who might be inclined to invest in energy-efficient cooling technologies will likely choose less efficient options or repair their older less efficient systems for convenience and lower cost.
- **Effects of Local Law 133:** The local law states that buildings in which the ownership and responsibility of HVAC systems are held by each individual resident are not required to benchmark for energy and water efficiency.[96] Therefore, the benchmarking data could provide an incomplete picture of cooling-technology efficiency and penetration.

4.3.3 Policy Barriers

Policy barriers can be defined as federal, State, or local policies (or, lack thereof) that adversely affect adoption of cooling technology or access to cooling technologies in NYC.

- **Financial assistance gaps:** Federal, State, and local public assistance to counteract energy insecurity through need-based benefits (e.g., Home Energy Assistance Program [HEAP] in the U.S.) are primarily designed to provide utility bill support during the heating season. These programs require updates, such as allowing utility assistance for cooling during summer months, to address health risks during heat events and reflect how the changing climate causes shifts from heating costs in the winter to cooling costs in the summer. This leads to insufficient financial aid for cooling technologies for summer heat. In addition, residents must physically present themselves at the HEAP office in NYC to receive benefits which creates barriers due to scheduling during working hours and lack of access to transportation.
- **Building code compliance gaps:** City and State building codes have increased in recent years, leading to improvements to the energy efficiency of the building stock. Nevertheless, the lack of enforcement for building codes and design practices included within the new codes often limits the use of efficient cooling technologies.
- **Public housing AC requirements:** Residents in public housing, which are some of the City's most vulnerable to rising temperatures and extreme heat events,[97] must apply for approval and pay a monthly fee for each AC system they put in their homes.[98] These fees disincentivize installations of AC systems for the lowest income residents and increase their annual operating cost.
- **Effects of Local Law 11:** Due to Local Law 11 of 1998[99] (regulating window units) requirements and liability, landlords may establish rules that window AC systems can be installed only by someone deemed qualified (i.e., the building superintendent, a maintenance professional, or an HVAC technician). This may increase the cost and complexity for installing AC systems.
- **Indoor temperature policy gaps:** Lack of policy and regulation[100] requiring buildings to have a maximum indoor temperature[101] may create dangerous conditions for vulnerable individuals and communities. Similar to minimum temperature heating laws in NYC today, establishing regulations for maximum temperature thresholds in summer is another potential policy strategy. However, many interviewees familiar with policy impacts did not feel that a blanket policy covering all housing was the best approach because (1) the costs of compliance could likely largely be passed through to tenants in the form of higher rents, thus further burdening the vulnerable and (2) landlords could be liable in situations where residents do not operate the window/room AC systems due to economic or personal reasons depending on how the policy is formulated. On balance, most experts felt that providing AC systems combined with the bill relief needed for people to operate the systems would be a better solution than maximum temperature regulations, which may have unintended negative consequences. However, others felt there could be a place for temperature threshold regulations in certain types of housing for at-risk people if these concerns regarding pass-through in rents and liability were adequately addressed through policy

mechanisms (e.g., coupling regulation with adequate financial support to prevent unintended reductions in available housing for populations in need). Shelters, jails, and supportive housing facilities are good examples of the specific types of housing serving at-risk populations for which this policy option might be appropriate.

- **Spatial gaps in policy:** Policy that is enacted citywide or statewide may encompass areas where cooling benefits are realized to a lesser extent. These solutions will work best in neighborhoods with the highest impacts from extreme heat events, including those most impacted by urban heat island (UHI) effects. Heat mitigation policies could be enacted on a neighborhood-by-neighborhood basis to provide cooling access or relief during heat events to local areas where these solutions will have greatest impact, without significantly increasing cost for local areas where the impacts will be less. These policies aimed at improvements in under-served neighborhoods would need to be done in concert with policies that allow long-time residents to benefit from the policies (i.e., protect them from getting priced out of the neighborhoods once they receive investment).

4.4 Identifying and Prioritizing Technology and Policy Options

The study team identified technology and policy solutions that could meet the cooling needs of NYC residents, particularly those of vulnerable populations, while minimizing the associated increases in energy use. These options were identified by reviewing relevant literature and policies from the New York City and New York State government and by conducting structured dialogs and focus groups with State and municipal agencies, community and environmental justice groups, utility administrators, and researchers in the areas of health, climate change, and vulnerable populations to refine the list of identified options.

The team prioritized the technology and policy options based on relevance to vulnerable populations and their feasibility and applicability in NYC. Structured dialogs with stakeholders were integral to the prioritization process and were used to help to determine which targeted measures would assist at-risk residents most effectively, their applicability to NYC and associated considerations, barriers, and benefits.

4.4.1 Key Characteristics

Guidehouse has compiled data on costs, cooling, addressable market, and other characteristics to model the individual measures and scenario packages both on a per-unit and citywide basis. Table 20 delineates the modeling characteristics used to evaluate and categorize each technology and policy option.

Table 20. Technology and Policy Option Characteristics

Source: Guidehouse analysis.

Characteristic	Description
Target Population	Population that the option aims to benefit.
Potential Service Delivery	Portion of New York City that could potentially receive the option.
Unit of Intervention	Level at which the option provides cooling, such as apartment-, building-, parcel-, street-, or neighborhood-scale.
Market Introduction Rate	Whether the option can be introduced as a retrofit or addition to an existing building or can only be adopted through new construction.
Applicable Building Type	Applicability of the option to single-family homes and/or multifamily homes.
Per Unit Cooling Benefits	Anticipated cooling provided by the option.
Net Unit Energy Consumption	Net direct energy consumption of the option.
Net Impact on Heat Urban Island Effect	Characterization of positive or negative impact of the option on neighborhood temperatures.
Upfront and Annual Operating Costs	Estimated upfront and any ongoing costs for the option.
Non-Energy Benefits / Positive Impacts	Positive externalities and side-benefits of the option in addition to cooling or energy consumption (e.g., community engagement or improved property value).
Non-Energy Negative Impacts	Negative externalities and impacts of the option other than energy consumption.
Limitations	Known and notable limitations of the option.
Barriers to Implementation, Access, or Equity	Identified barriers to implementing the option, providing widespread access to the solution, or providing equitable cooling benefits from the solution.
Proven Success Example(s)	Best practice examples of successful execution of this equitable cooling option.

4.4.2 Broad List

Through detailed online research of keywords and input from the PAC and internal sources, Guidehouse pulled together an initial summary of existing cooling efforts. Based on this initial literature review of technology solutions, previous policy efforts, and initiatives on equitable access to cooling, Guidehouse identified roughly 60 technology and policy solutions that had the potential to address cooling access in New York City. These solutions were characterized by their feasibility, applicability to NYC, and effectiveness at reaching target populations. This "broad list" was then prioritized based on a more in-depth literature review in addition to structured dialogs with community members, community organizations, and heat and health experts, this broad list of initially identified solutions was narrowed to about 20 technology and policy options (i.e., the "narrow list").

Table 21 and Table 22 summarize the broad lists of technology and policy options, respectively. Technology options include solutions that provide cooling at the at the home, the building, and neighborhood level. The list of technologies includes options that can be further leveraged in conjunction with policy to increase access to cooling for New York City's vulnerable residents through increased efficiency.

Table 21. Broad List of Technology Options

Source: Guidehouse analysis.

Home/Building-Level Technology Options	Neighborhood-Level Technology Options
AC Options • AC systems • Multistage evaporative coolers **Building Shell Improvements** • Improved window thermal insulation • Improved building sealing/airtightness • Passive House design **Building Structural Shading** • External window shading **Building Reflective Cooling** • Light-colored roofs such as Cool Roofs Program • Cool/reflective Walls **Building Greening** • Extensive green roofs • Intensive green roofs • Green blue roofs • Green walls/facades/living walls	**Public Cooling Spaces** • Cooling Centers • Coaling Oases **Public Reflective Cooling** • Light-colored or porous pavement such as Cool Pavement Program • Light-colored/reflective streets **Public Greening** • Urban green spaces within a 20-minute walk from any residence • Coordinated tree planting • Exaction for tree planting • Green infrastructure/Green Streets Program **Water Features** • Pavement-watering • Water installations (fountains, pools, misters, ponds).

Policy options include legislative/code options, incentive or rebate options, and programmatic options. There are several policy-type solutions currently in place that improve access to cooling, such as the Low-Income Home Energy Assistance Program (LIHEAP) and the Weatherization Assistance Program (WAP). By leveraging existing HEAP/WAP systems for example, cooling units can be distributed cost-effectively and efficiently, and by working with community groups already undertaking greening and beautification efforts, NYC can ensure participation by communities that will benefit from these improvements. This list of policy options identifies new options to leverage or existing policies to enhance to provide access to New York City's vulnerable through expansion or reform.

Table 22. Broad List of Policy Options

Source: Guidehouse analysis.

Legislation/Codes	Incentives/Rebates	Programs/Plans
• Passive House Design Standards. • Require individual metering in mid-sized buildings. • Expand use of Building Enclosure Commissioning. • Alley Landscape Ordinances/Building Code. • Evaluate efficiency standards for cooling technologies. • Anti-Idling Campaign. • Reduced fares on public transportation. • Reduce number of vehicles in urban areas.	• Provide incentives for AC, ventilation, and fans. • Streamline existing programs that provide ACs to low-income households. • Commercial—Property Assessed Clean Energy Financing (C-PACE). • Low to no-interest loans for EE retrofits/rehabilitation. • Green Mortgage. • Commercial/Multifamily Energy Service Agreements. • Coordinate with State to Streamline Financing & Incentive Programs. • Reforms to LIHEAP/WAP to include cooling-related building improvements. • Rebates on Specific Cool Roof Materials. • Green/Cool Roof Tax Abatement.	• Expand education to small business and building owners on weatherization/EE resources. • Program for large building owners to get expert assistance on EE upgrades and resources. • Planning tool identifying high performance energy retrofit strategies. • Increase reliance on renewable-based electric supply. • Install solar power and storage as back-up power source for emergency shelters. • Signage and Programming for Cooling Centers. • Increase Number of Cooling Centers. • Increase Number of Cooling Rest Areas for Outdoor Workers.

4.4.3 Narrow List

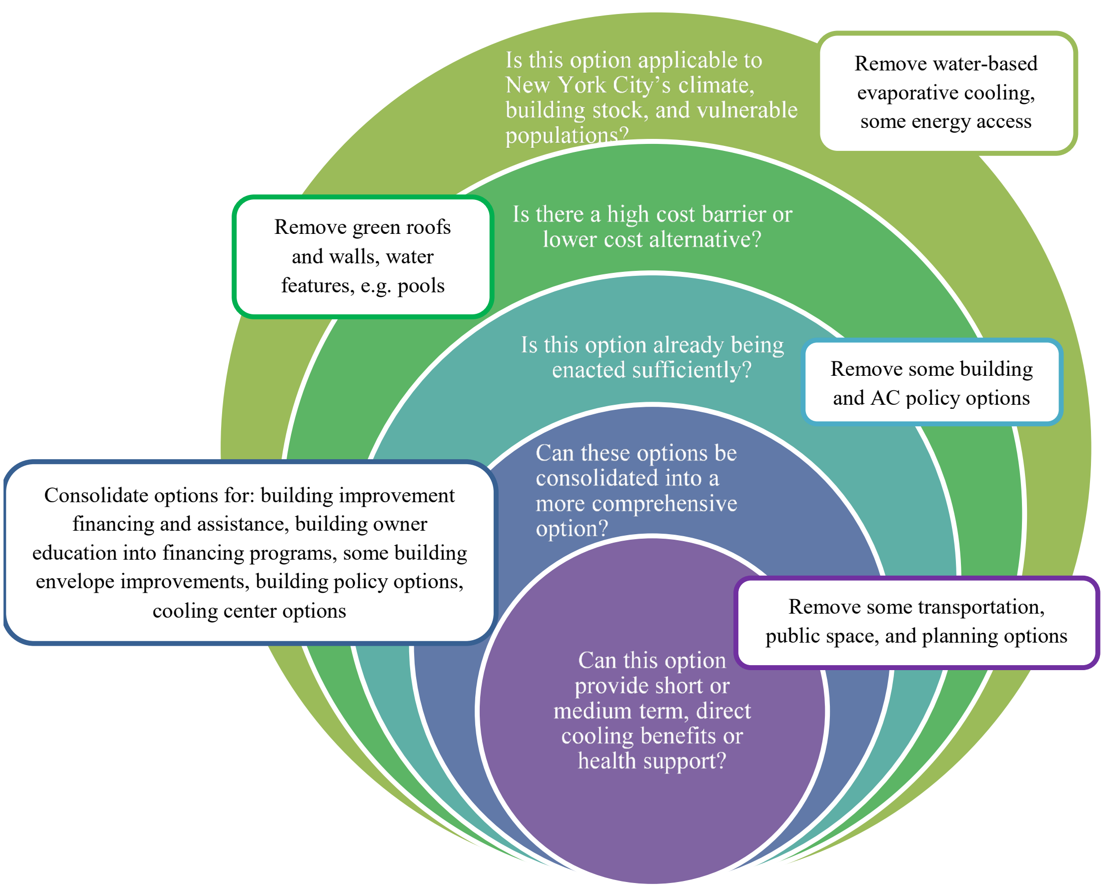
To narrow the broad list, Guidehouse undertook a secondary, in-depth literature review in order to prioritize those measures that were either proven feasible in cities similar to New York or had scientific corroboration and backing from various journal articles. A further prioritization was undertaken based on the findings from structured dialogs with community members, community organizations, and heat and health experts both from New York State as well as from academic and government institutions across the country.

Through prioritization, the broad list of technology and policy options was narrowed to approximately 20 options (i.e., the "narrow list"). Prioritization included consideration of costs, cost-effectiveness, feasibility, relative cooling and non-cooling benefits, and current adoption in New York City. Figure 21 shows examples of how the list was narrowed based on these questions.

Figure 21. Technology and Policy Option Prioritization Approach

The figure below should be interpreted as a narrowing from the largest circle (i.e., all the options) to the smallest circle (i.e., the "narrow list")

Source: Guidehouse.



This led to the narrow list of technology and policy options presented in Table 23. Structured dialogs with communities that represent and include vulnerable populations will provide direct input on the barriers that they face in accessing these solutions, informing the findings to be included in the report. These dialogs, as well as dialogs with experts in relevant heat, health, and cooling fields will also provide input into any further technology or policy options to include in analysis and modeling.

Table 23. Narrow List of Technology and Policy Options

Source: Guidehouse prioritization after process described in section 5.4 from broad list detailed in Table 21 and Table 22.

Technology Options	Policy Options
AC and Building Envelope Improvements • AC systems • Bundled building envelope sealing, insulation, and AC improvement. • Light-colored roofs such as Cool Roofs Program. • Cool Walls **Public Cooling Spaces** • Cooling Centers • Cooling Oases **Public Space Improvements** • Coordinated tree planting with accompanying exaction. • Green Infrastructure (e.g., green byways, bioswales, rain gardens). • Light-colored or porous pavement such as Cool Pavement Program.	**Legislation/Codes** • Update building code (e.g., ventilation, efficiency, individual metering). • Reduced fares on public transportation. **Incentives/Rebates** • Provide incentives for AC, ventilation, building shell improvements, and fans. • Expand/target existing/new financing and incentive programs. • Advise changes to how New York interacts with LIHEAP/WAP. • Tax abatement for installation or retrofit of cool roofs. **Programs/Plans** • Expand and enhance Cooling Center Program.

4.5 Prioritized Options and Solution Packages

Synthesizing extensive secondary literature research and findings from in-depth interviews with experts and community members, Guidehouse developed a final set of “prioritized” technology and policy options, organized into packages referred to as “solutions” to mitigate heat risk and increase cooling access equitability. Each prioritized technology and policy option is characterized in section 5.5.4.

Given the financial and temporal constraints that may help shape the choice of solution eventually adopted and implemented, Guidehouse outlined three different solutions (i.e., combinations of technology and policy options) that NYSERDA might pursue, each with a slightly different focus, scope, and associated cost. The three solutions described in this section originated from the narrow list of technology and policy options, which was in turn filtered from the initial broad list and refined through the findings from structured dialogs. Guidehouse assessed the opportunities and costs of increasing adoption for each measure specific to New York City with special attention to applicability, feasibility, impact (i.e., reduction in cooling load increase and provision of equitable cooling), and the potential for multiple benefits. The following options have not been recommended nor have they been modelled in isolation; rather, each of the subsequent sections lays out a set of technology and policy options recommended as a layered, multi-pronged approach or “solution.”

4.5.1 Prioritized Technology and Policy Options

- **Efficient AC**: Installing AC systems in the homes of vulnerable residents is an impactful strategy to improve cooling access across New York City, providing immediate cooling in the resident's home. Although expanding AC system access appears relatively straightforward, there are several challenges relating to capital and operating cost for the systems, constraints within a building's electrical or physical infrastructure, personal preferences and behavior, and other known barriers. Beyond the individual homes, introducing a significant number of new AC systems to the New York City electrical grid may have a detrimental impact on daily electricity consumption and hourly demand during the peak summer season. Another barrier to the effectiveness of this measure is the reluctance of residents to utilize cooling technology because of high energy bills. To overcome both barriers, improved building codes and standards as well as bill relief can be implemented in tandem with this measure. These are expanded on below.
- **Weatherization/Building Shell Improvements:** Improved weatherization and building shells can reduce the wasted energy when cool air escapes a building, thereby reducing net cost for customers and providing better cooling for people in their own homes. Current programs such as the Weatherization Assistance Program (WAP), RetrofitNY, and NYCHA weatherization assistance programs exist to provide cooling-related building improvements to income-eligible persons, especially to homes occupied by the elderly, persons with disabilities, and children. However, some residential lower-income properties lack basic structural integrity and make typical building shell improvements irrelevant. Another potential problem is a split incentive situation with the landlord of multifamily residential buildings. This measure is highly feasible in New York City, and a strategy to implementation would be improved buildings codes and standards, which is expanded on below.
- **Cool Roofs:** Cool roofs consist of retrofitting existing building with white or reflective roof coating to reduce internal building temperatures in the summer and thereby reduce AC use and the load on the grid. Because of the reduced internal cooling usage, there is less heat expelled to the area surrounding the building and can help reduce localized air temperatures. However, cool roofs can reduce heat gained in the winter and increase space heating consumption. Currently, New York City runs a CoolRoofs program that retrofits nonprofit and low-income housing at no cost, and retrofits other buildings if the building owner pays for the paint coating. Due to the surface area available and the existence of this measure, further implementing cool roofs is highly feasible in NYC. A strategy to implementation would be through improved buildings codes and standards, which is expanded on below.
- **Cool Pavements:** Through retrofitting existing pavement with reflective or light concrete, heat is dispersed instead of absorbed by asphalt roads and emanated up to pedestrians. In New York City, though much of the sidewalk (>90%) is already light colored, asphalt street surfaces present another opportunity to deploy cool pavement technologies. After engaging in structured dialogs with cool pavement experts, Guidehouse found that cool pavements for roads and other asphalt surfaces have lifetimes five to seven years longer than traditional pavement, can be deployed during normal resurfacing projects, have minimal material costs and no labor impacts,

and are resistant to typical pavement wear and tear including winter weathering. Though this measure has been implemented with success in cities like Phoenix and Los Angeles, it has yet to be tested at large scale in-situ in cold climates. It is unlikely that cool pavements are feasible as a primary measure in New York City, but it could work in conjunction with other suggested measures.

- **Tree Planting/Urban Greening:** Tree planting and urban greening can decrease the amount of heat absorbed by buildings and lower ambient temperature. Currently, New York City has about a quarter of its land covered by trees, and there have been projects and ordinances to increase urban greening in the City. Relevant projects include the MillionTrees NYC program, which started in 2007 and fulfilled its goal in 2016, and ordinances from the Department of Buildings requiring more street trees in front of buildings. Tree planting and urban greening are very applicable measures in NYC. To avoid uneven distribution of urban greening benefits, implementation should focus on planting more trees in neighborhoods with high Heat Vulnerability Indices.
- **Cooling Centers:** Cooling centers provide free cooling for residents who may not have access to cooling in their homes, or are worried about the financial cost of running their AC. In NYC, cooling centers consist of public spaces that have cooling such as libraries, community centers, etc., making augmentation of this measure very applicable to the city. Some strategies to better implement cooling centers would be to provide accessible and affordable transportation to the cooling centers, as transportation is a barrier for vulnerable populations. Furthermore, cooling centers require dedicated spaces and funding sources to improve on current practices of using existing spaces without additional funding support. It is also worth noting that this is a supplementary solution to providing cooling access, as residents would generally prefer cooling available in their own homes.
- **Community Solar:** Community solar programs can be used to offset the potential load from AC and other cooling technologies as there is increased adoption and access, especially when sited on NYCHA or municipal developments. Although solar energy in general is a good strategy to avoid blackouts and provide local renewable electricity to residents, the cost of installing a solar photovoltaic system to specifically address increased AC cooling demand would require considerable funding and further evaluation. Installing community solar systems with storage or auxiliary generation systems at dedicated cooling centers can also improve the resiliency of the facilities to ensure operation during extreme heat events that may cause local grid interruptions.
- **Building Codes and Standards:** Appliance standards and building codes can improve the energy efficiency of NYC building stock over time. Changes to building codes can require the reduction of building energy consumption, shift building design standards toward energy efficiency, require street tree plantings, require the use of cool or green roofs, put standards in place or increase standards for window operability, ventilation, etc. Aggressive State and City GHG reduction targets in turn encourage greater adoption of high-efficiency technologies. However, there is little room for using the policy as a lever in NYC to accomplish goals of equitable cooling access because NYC has some of the most progressive codes and standards (C&S) and Local Laws in place in the country. The aim should be to use other tools to facilitate compliance with the existing ambitious C&S and laws.

- **Bill Relief:** Bill relief provides financial aid for customers' energy bills, making it more likely that a resident will take advantage of cooling technologies. This measure can be implemented to encourage use of existing ACs and should also be implemented in tandem with the installation of higher efficiency technology to offer financial relief to residents. Current programs in NYC offering bill relief include the Home Energy Assistance Program (HEAP) and the Weatherization Assistance Program (WAP), but these can be improved by increasing financial aid sums and improving access to customers.
- **HEAP/WAP Reform:** The Home Energy Assistance Program (HEAP) and Weatherization Assistance Program (WAP) provides financial relief to vulnerable populations for energy bills. Through structured dialogs, it is apparent that financial energy aid can increase the effectiveness of many technological cooling measures such as efficient AC technology. In order to increase accessibility to HEAP/WAP for residents, the program criteria should be expanded so that a broader population have access and become more inclusive for cooling needs in addition to the current heating focus. With increased funding and reach, the expanded programs would have a lasting impact on New York City residents.
- **Displacement Mitigation Policies:** Displacement mitigation policies help low-income populations retain residence in areas as they are gentrified by attributes such as urban greening. These policies can increase and ensure equitable access to cooler areas. Displacement mitigation policies should be implemented in tandem with cooling policies such as urban greening and weatherization improvements, which can drive up property prices and rent and push out vulnerable residents who need the renovations the most. Displacement mitigation policies are already underway in NYC, making this policy option very applicable.
- **Accessible Transit**: Reduced or free fares on public transportation can help residents reach cooling centers, parks, and other cooling locations. Some services such as HEAP/WAP require the resident to travel to a physical location for administrative purposes, which is also constrained by transportation costs. Accessible transit policies are very applicable in Manhattan, where the majority of residents are dependent on public transportation to travel around the City.

4.5.2 Recommended Solution Packages

- Guidehouse developed three solution packages termed to be modeled, each consisting of sets of policy and technology options to be undertaken in concert to achieve equitable access to cooling for NYC's vulnerable residents while mitigating increased energy usage. These scenarios address the near-term cooling needs of vulnerable populations while encouraging longer-term infrastructural and policy changes to address and mitigate the root causes and experience of extreme heat across NYC and offsetting or mitigating increased energy usage.
- Table 24 and Table 25 outline the three solutions Guidehouse modeled to compare the impact and associated costs of implementation. Each has a different focus, in recognition that NYSERDA and NYC will face competing temporal and financial constraints and goals in ultimately selecting an approach. The scenarios are progressively more far-reaching and comprehensive, with each successive solution building on the technology and policy options in the previous solution. Section 6 provides potential implementation timeline and details for each scenario.

The Accelerated System-Wide Cooling scenario includes near- and long-term approaches and initiatives to address immediate needs of residents that will face extreme heat crises each summer in NYC as well as longer term structural and code changes to drive a more efficient building stock and reduce UHIs over time throughout the City. Some of these structural changes that address root causes leading to large changes across time include large-scale tree planting, widespread adoption of cool roofs, adoption of aggressive new construction codes and standards around passive buildings and green walls, and overall urban greening. Moreover, the Accelerated System-Wide Cooling scenario accelerates the rate of replacement for road surfaces with cool pavement sealing to target vulnerable communities sooner and accomplish full resurfacing throughout NYC with cool pavements rapidly. This scenario also provides for the immediate cooling needs of people in their homes through AC units, bill relief, home weatherization and cooling center expansion.

Cooling equity is one of many issues that NYSERDA and NYC government leaders must address over the next several decades and a moderate scope may be more achievable relative to a comprehensive package. To this end, the second scenario, the Expanded System-Wide Cooling scenario, approaches equitable cooling also with both near and longer-term goals and interventions in mind, but without accelerating some of the structural and infrastructure changes beyond the rate at which they would naturally occur. As an example, due to life span of roads and the natural cycling of road surface replacements, it could take many decades to completely update all road surfaces throughout NYC with cool pavement. Under this scenario, NYC could switch road resurfacing to cool pavement products but only following the natural cycle of replacements. Nevertheless, cool pavement products are an emerging technology and would require pilot projects to assess the feasibility for NYC and other cold-weather regions.

The Targeted Cooling Relief scenario addresses the reality that NYC and other organizations face funding choices across a broad range of initiatives and goals which may constrain the financial resources available to tackle equitable access to cooling. This scenario proposes a concise set of interventions and measures aimed at providing emergency relief and immediate support to vulnerable populations across NYC in the face of extreme heat, without undertaking costly and long-term planning horizon investments in structural change through infrastructure upgrades, codes and standards, and other mechanisms. Section 6 provides potential implementation timeline and details for each scenario.

Table 24. Scenario Measure Summary

Source: Guidehouse solutions packages detailed in section 5.5.5, a detailed view can be found in Table 30.

Solution	Targeted Cooling Relief Scenario	Expanded System-Wide Cooling Scenario	Accelerated System-Wide Cooling Scenario
Efficient AC	✓*	✓*	✓*
Efficient Heat Pumps**			✓*
Weatherization/Building Shell Improvements	✓*	✓*	✓*
Cool Roofs	✓	✓	✓/✓*
Cool Pavements		✓	✓/✓*
Tree Planting/Greening		✓	✓/✓*
Cooling Centers	✓	✓	✓
Community Solar		✓	✓
Bill Relief	✓*	✓*	✓*

✓ Represents normal implementation rates, ✓* represents accelerated implementation, and ✓/✓* represents a combination of normal and accelerated implementation rates.

** Heat pumps are not considered in the Targeted Cooling Relief and Expanded System-Wide Cooling scenarios, as they support the longer-term structural change to electrification; these are included for consideration in the Accelerated System-Wide Cooling scenario. See section 6.2.2.

Table 25. Detailed Package View for Each Scenario

Source: Guidehouse solutions packages detailed in section 5.5.5, a broad view can be found in Table 29.

Scenario	Summary	Measure List
Targeted Cooling Relief Scenario	Focused effort to provide safe cooling in the home in the shortest timeframe possible at lower cost and without longer term investments and structural changes.	Efficient AC
		Bill relief
		Weatherization and audit
		Cooling centers
		Cool roof program continuation
Expanded System-Wide Cooling Scenario	Focused on both near and long-term interventions but allowing some structural interventions to occur on a naturally occurring cycle rather than an accelerated one to reduce near-term costs; addresses the primacy of safe home cooling through bill relief, AC unit provision, weatherization, and cooling center expansion; moderate acceleration of community solar to offset AC-induced grid load increases.	Efficient AC
		Bill relief
		Weatherization and audit
		Cool pavement sealing on all road surfaces
		Cool roof program continuation
		Tree planting/greening
		Cooling centers
		Community solar
Accelerated System-Wide Cooling Scenario	Focused on both near and long-term interventions with an aggressive acceleration of cool pavement, tree planting, and other structural changes; addresses the primacy of safe home cooling through bill relief, AC unit provision, weatherization and cooling center expansion; rapid expansion of distributed solar generation to offset AC-induced grid load increases.	Efficient AC/Heat Pumps
		Bill relief for vulnerable residents
		Weatherization and audit
		Cool pavement sealing on all road surfaces
		Cool roof program expansion
		Tree planting/greening
		Cooling centers
		Community solar

5 Estimated Impacts of Technology and Policy Scenarios

5.1 Introduction to Scenario Modeling Results

Guidehouse has compiled data on costs, cooling, addressable market, and other characteristics to model the individual measures and scenario packages both on a per-unit and citywide basis. Using the model described in section 4, Guidehouse modelled three scenarios and two reference cases to evaluate the impact on cooling equity, electricity consumption, energy cost, and other factors over 2020–2050 timeframe. The key assumptions, data inputs, and results are described in this section.

The table below outlines the key characteristics for the modeling scenarios to extend cooling access to vulnerable populations. Each scenario provides AC systems and other measures for the roughly 300,000 homes without cooling as estimated via 2017 New York City Housing and Vacancy Survey data. Initiatives were applied to all residents to estimate the overall citywide impacts and understand how activities for the majority of NYC's building stock will minimize the energy impacts of extending AC access to all residents. Section 6.4 describes the potential impacts of the 2020 Cooling Assistance program.

Table 26. Key Characteristics by Modeling Scenario

Source: Guidehouse analysis.

Key Characteristics by Modeling Scenario	Baseline/ Current Policy Scenario (Reference)	100% AC Saturation (Reference)	Targeted Cooling Relief Scenario	Expanded System-Wide Cooling Scenario	Accelerated System-Wide Cooling Scenario
Percentage of Homes with ACs*	91%	100%	100%	100%	100%
Percentage of Above Code AC	10%	10%	10%	25%	35%
Percentage of Above Code Envelope	5%	5%	5%	15%	25%
Cool Roof Deployment	Assumes current cool roof codes may eventually impact 50% of NYC roofs.				Modified cool roof codes impact 100% of NYC roofs.
Incremental Weatherization Projects	n/a	n/a	30,000 per year (target 300,000 by 2030)	30,000 per year (target 300,000 by 2030)	30,000 per year (target 300,000 by 2030)
Incremental Cool Pavement Installations	n/a	n/a	n/a	15 million SF per year	30 million SF per year
Incremental Tree Planting/Urban Greening	n/a	n/a	n/a	10,000 trees per year**	20,000 trees per year**
Cooling Centers***	n/a	n/a	Targeted improvements in the cooling center strategy for NYC by 2025.		
Community Solar***				Piloting community solar initiatives and rates by 2025 with targeted rollout in key neighborhoods over 2020-2050.	

Each scenario incorporates progressively more technology and policy measures.

* Approximately 3.2 million housing units in NYC, of which approximately 300,000 do not have cooling systems as of most recent data.

** Tree planting was found to have high cost and limited impact on building AC consumption, so Guidehouse also modeled the Expanded and Accelerated scenarios excluding tree programs.

*** Cooling centers and community solar are supporting measures that can theoretically offset cooling electricity consumption and cost at the home level, but it is highly uncertain what impact these solutions may have.

Table 27 summarizes the key cooling impact and cost assumptions for each solution that were modeled in the analysis. This analysis relies on numerous assumptions for the average NYC home, and the actual installation costs for individual homes will vary greatly. Guidehouse modeled the AC system costs of $3,650 to represent a 3-ton split-system AC, without furnace or furnace fan. Window, room, and PTAC

AC systems would likely have lower capital costs for replacements of existing units and potentially new installations. In support of statewide heating electrification efforts, heat pump products could be installed in place of AC-only systems. Heat pumps typically carry a modest installed cost premium over AC-only systems, and changes in system architecture (e.g., window AC to ductless mini-split) would require additional installation costs. These topics are further discussed in the next section.

Table 27. Key Characteristics for Each Equitable Cooling Solution

Source: Guidehouse analysis based on values from literature review and structured dialogs.

Equitable Cooling Solution	Measure Cost	Incremental Cost over Code/ Baseline	Measure Savings over Existing Stock (Percentage of Home Cooling, kWh per unit)	Notes
Code AC System	$3,650	n/a	n/a. Assumes targeted homes do not have cooling today.	Per home, see section 2.3.5 and discussion in previous paragraph
Above Code AC	$4,650	$1,000	30% of cooling energy (20% over code AC system).	Per home, see section 2.3.5
Above Code Envelope	$1,745	$395	18% of cooling energy	Per home see section 2.3.5
Cool Roof Deployment	n/a	n/a	10% of cooling energy	See section 2.3.5
Incremental Weatherization Projects	$1,745	$395	18% of cooling energy	Per home, see section 2.3.5
Incremental Cool Pavement Installations	n/a	$0.025 per sq.ft.	0.185 kWh/yr per sq.ft.	Per sq.ft. of pavement; cooling impacts from LBNL report,[102] Costs from CoolSeal interview.[103]
Incremental Tree Planting/Urban Greening	$2,700 per tree	$2,700 per tree	9.3 kWh/yr per tree	Per tree. Cooling impacts from 2018 U.S. Forest Service report,[104] costs from NYC Parks estimates.[105]
Cooling Centers***	n/a. Cooling centers and community solar are supporting measures that can theoretically offset cooling electricity consumption and cost at the home level, but it is highly uncertain what impact these solutions may have.			
Community Solar***				

* Approximately 3.2 million housing units in NYC, of which 300,000 do not have cooling systems today.

** Tree planting was found to have high cost and limited impact on building AC consumption, so Guidehouse also modeled the Expanded and Accelerated scenarios excluding tree programs.

Before discussing the results of the scenarios, recognize that NYC has already developed a variety of comprehensive programs and policies to address cooling equity. NYC has passed ambitious laws that will improve building energy efficiency, cool roof adoption, urban greening, and other initiatives in future years. Many of the ideas identified in the literature review and structured dialogs are already in place in NYC, so the analysis focused on what could be expanded or improved. The 2020 Cooling Assistance program (Get Cool) in particular highlights NYC's leadership in addressing the equitable cooling issue in the face of the COVID-19 pandemic. Cities and regions without the track record of NYC in addressing the UHI effect and extreme heat could consider additional opportunities that have not already been implemented in NYC.

5.2 Electricity Consumption, Operating Cost, and Upfront Cost Results for Each Scenario

5.2.1 Cooling Electricity Consumption for Each Scenario

The following figures compare the weighted average per-home cooling consumption as well as citywide residential cooling consumption under each scenario. In Figure 24, each scenario of energy efficiency and urban heat island measures reduces the average per-home cooling electricity consumption over time compared with the Current Policy baseline. This baseline incorporates the impacts of climate change, previously committed energy efficiency measures, and gradual improvements in building stock over time due to building codes and appliance standards.

Figure 22. Cooling Electricity Consumption per Home (Weighted Average SF+MF)

Source: Guidehouse analysis.

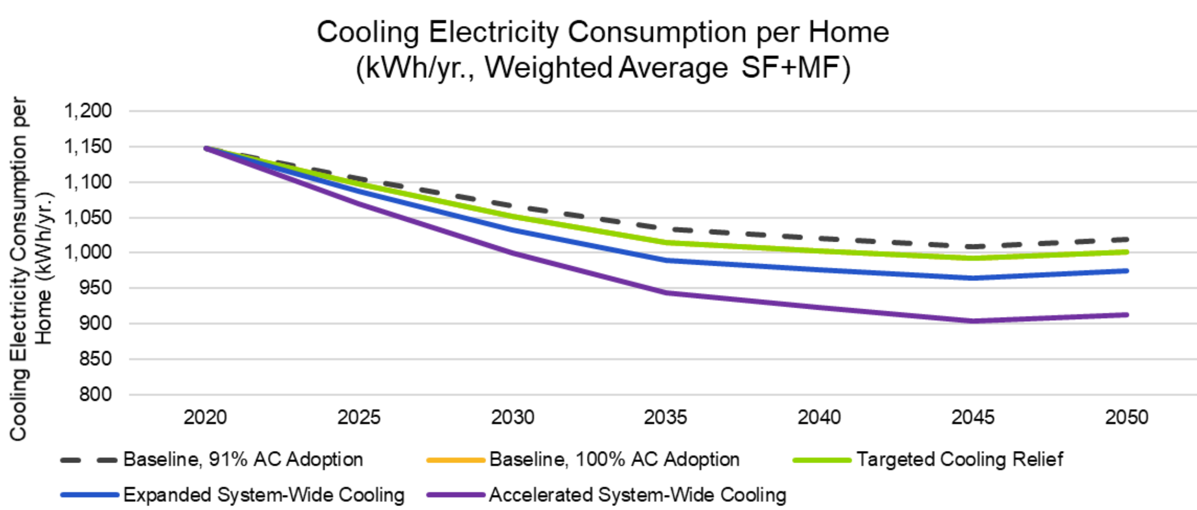


Figure 23 highlights the citywide increase in electricity consumption to install AC systems within every home. As described in section 4, extending access to AC systems to vulnerable populations will increase electricity consumption across the City, but energy efficiency measures explored in the scenarios can reduce this increase. The most-comprehensive solution would completely eliminate the increase. Measures such as cool pavements and tree planting can reduce UHI, but the indirect cooling impact on building AC consumption is minimal. Direct building related measures such as AC system, envelope, and roof improvements can have a more significant impact.

Figure 23. Residential Cooling Electricity Consumption (Citywide)

Source: Guidehouse analysis

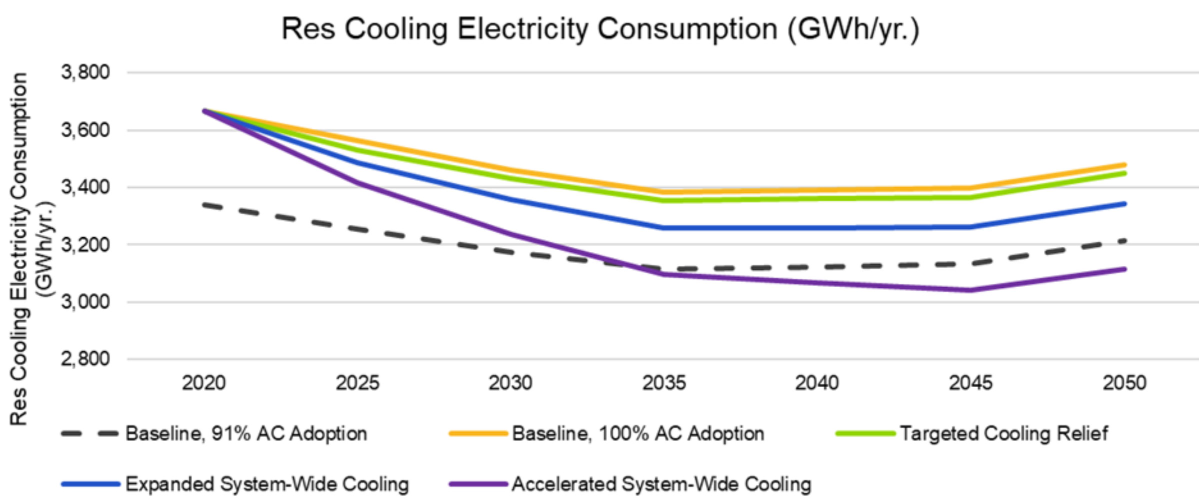


Table 28 describes the energy savings impact of each equitable cooling solution in the three scenarios. As described above, solutions that directly address cooling energy consumption within the building such as higher efficiency AC systems, envelope weatherization/upgrades, and cool roofs have the most significant impacts. Of these, high-efficiency AC systems and cool roofs have the greatest impact on cooling demand, assuming that adoption significantly increases through expanded building codes and incentive programs. Weatherization provides heating energy savings in addition to cooling benefits, and it may be valuable in support of heating electrification efforts by decreasing the size/capacity of the new systems. More diffuse solutions such as tree planting, urban greening, and cool pavements reduce UHI effects citywide, but have an indirect impact on building cooling consumption. These solutions support the goals of cooler daytime and nighttime temperatures, as well as improved livability, comfort, and beautification, but do not provide the same impact as expanding AC access. An optimal solution would combine both direct measures to each home as well as indirect measures at the neighborhood level.

Table 28. Energy Savings Impact of Equitable Cooling Solutions in Each Scenario

Source: Guidehouse analysis based on modeling process described in section 4.

Cooling Scenario	Measure List	Cooling Electricity Savings Relative to 100% AC Reference Case (GWh/yr, %)	Savings % Relative to 100% AC Reference Case
-Targeted Cooling Relief Scenario	Providing ACs to Vulnerable Populations (10% ACs High Efficiency)	n/a, including in reference case	n/a
	Weatherization (30,000 per year)	31	0.9%
	Cool roof code/program continuation	n/a, including in baseline	n/a
Expanded System-Wide Cooling Scenario	High-Efficiency ACs Achieve 25% Market Share	75	2.1%
	High-Efficiency Envelope Upgrades Achieve 15% Market Share	18	0.5%
	Weatherization (30,000 per year)	31	0.9%
	Cool pavement (15 MSF per year)	14	0.4%
	Cool roof code / program continuation	n/a, including in baseline	n/a
	Tree planting (10,000 per year)	0.5	0.0%
Accelerated System-Wide Cooling Scenario	High-Efficiency ACs and Heat Pumps Achieve 35% Market Share	124	3.6%
	High-Efficiency Envelope Upgrades Achieve 25% Market Share	37	1.1%
	Weatherization (30,000 per year)	31	4.2%
	Cool pavement (15 MSF per year)	28	0.9%
	Cool roof code expanded to 100% of roofs	145	0.8%
	Tree planting (10,000 per year)	1	0.0%

5.2.2 Value of Heat Pumps to Support Equitable Cooling and Heating Electrification

As discussed in section 2.2, space cooling can be delivered by air conditioners (AC only) or heat pump systems that can reverse the vapor-compression cooling cycle to provide high-efficiency space heating. Leaders in NYC and throughout the State are currently evaluating GHG reduction strategies and pathways to achieve climate targets (see section 2.3.5), in particular, converting building space and water heating systems from fossil fuels to electric heat pumps. Recent proposals target heat pump sales of 50–70% by 2030 and 100% by 2050,[106] as well as restrictions on the sale of fossil fuel systems over 2025–2035 for different building segments.[107]

Assuming the same system design, physical specifications, and efficiency level, heat pump systems would have roughly the same performance and operating cost in space cooling mode as AC-only products. High-efficiency models are available from major manufacturers for both AC-only and heat pump products and eligible for energy efficiency incentive programs today. On an upfront cost basis, most heat pump products would be expected to have a modest cost premium over AC-only products (e.g., conversion from window AC to window HP) and may have lower upfront cost than a combined heating and cooling system (e.g., conversion from central split-system AC and gas furnace to central split-system heat pump). Major changes in system architecture (e.g., window AC to ductless mini-split) would require additional installation costs, which can be significant for multifamily buildings if moving from a distributed to centralized system design (e.g., window ACs in each unit to a centralized VRF or water-source HP configuration). Furthermore, cold-climate performance specifications[108] and products exist today for central and ductless heat pumps, but models are under development[109] for window heat pumps and PTHPs which are common in NYC.

Because of the focus in this report for space cooling, similarities in cooling-mode operation and uncertainties for NYC and NYS electrification strategies, there is no distinction between AC-only and heat pump products in the analysis. Nevertheless, it is important to recognize the long-term role for electric heat pump products to reduce GHG emissions in NYC, and therefore, heat pumps are highlighted in the Accelerated System-Wide Cooling scenario. Extending cooling to vulnerable communities with both AC-only and heat pump products is one potential solution to balance near-term health and safety goals while also supporting long-term GHG emissions goals.

- Heat pump products should be considered for cooling equity programs in instances where their installation does not pose significant incremental costs over an AC-only product.
    - For example, a building without space cooling today that may need to replace a central boiler and could install a central VRF heat pump system or ductless mini-splits in each home and potentially minimize the incremental cost over the boiler replacement.
- Alternatively, challenges in heat pump deployment for some existing buildings should not hold up equitable cooling with AC-only products to address immediate health risks.
    - For example, if the building requires extensive building or grid infrastructure upgrades to electrify space heating, water heating, cooking, and other appliances, window AC systems can provide a quality short-term solution while more comprehensive upgrades are considered.

Given the variety of building types and configurations, stakeholders should recognize that a customized approach will be needed to address cooling equity and heating electrification across NYC. A citywide program to install space cooling systems in existing buildings could provide AC-only systems today, while also conducting inspections to understand what upgrades may be necessary to electrify the entire building in the medium-term future.

5.2.3 Value of Cooling Centers and Community Solar for Equitable Cooling

As described above, Guidehouse did not directly model the impacts of improved cooling centers and community solar because these are supporting initiatives to the central goal of expanding cooling equity within the home.

Section 5.5.4 provides details on how cooling centers are operated today and potential improvements that would improve their attractiveness and usability for NYC residents to escape the heat. The list below summarizes these observations:

- Improve and implement accessible and affordable transportation to cooling centers. In addition to accessibility and affordability, pet-friendly transportation is also an improvement opportunity to incentivize residents to use cooling centers.
- Create dedicated cooling centers as opposed to pre-existing public locations. These cooling centers should also have other features to be engaging, stimulating, and attractive to residents, i.e., WiFi, food options, games, or art.
- Improve marketing and outreach to raise awareness about the existence of cooling centers in communities.

In most cases, cooling centers are located within public spaces that would normally have space cooling present (e.g., libraries, museums, shopping malls, etc.), so there would be very minor increases in energy consumption due to their greater usage by residents. Establishing new cooling centers, such as recreation rooms in large apartment buildings, would increase electricity consumption over today's baseline. Nevertheless, in a future where every home has a cooling system, a centralized cooling center could allow residents to leave their homes and setback the thermostat temperature, which would partially offset the cooling center consumption. More research is necessary to understand the energy and health impacts of a combined strategy.

Community solar offers the opportunity to install solar PV systems on rooftops, parking lots, and other locations in the neighborhoods themselves. Depending on the design, the solar PV systems would offset the amount of grid-supplied electricity to operate the buildings, while others may direct the generated electricity to the local grid and earn credits on the building's utility bill. Furthermore, community solar tariffs through local utilities and energy providers would allow residents to indirectly source their electricity from the neighborhood systems and encourage greater local development. While it is difficult to project how community solar would address space cooling demand for individual buildings, recent non-wires-alternatives projects in NYC (e.g., Brooklyn Queens Demand Management [BQDM] Project by Con Edison[110]) demonstrate the ability for targeted energy efficiency, distributed generation batteries, and other emerging technologies to address localized grid constraints. In the structured dialogs, many community stakeholders were excited for the economic, environmental, and job creation benefits that community solar systems could bring to NYC neighborhoods. Evaluating the neighborhood-level resource potential, economics, and feasibility is outside the scope of this analysis. Installing community solar systems with storage or auxiliary generation systems at dedicated cooling centers can also improve the resiliency of the facilities to ensure operation during extreme heat events that may cause local grid interruptions.

5.2.4 Operating Cost and Capital Cost for Equitable Cooling

The following figures compare the operating cost, capital cost, and combined cost for each scenario relative to the baseline of Current Policies with 91% AC adoption. Expanding cooling access does require an investment in capital cost to install the AC systems, plant trees, upgrade building envelopes, install cool pavements, etc. In addition, the citywide cooling operating cost will increase based on the greater number of AC systems, as well as expected utility cost increases. Energy efficiency measures can reduce this operating cost and may require additional capital investment. The ultimate cost impact for NYC to extend cooling to vulnerable populations will consist of the combination of the capital and operating costs relative to today's baseline.

Figure 24 outlines the incremental operating cost impacts to deliver equitable cooling to all NYC residents through a combination of AC systems, energy efficiency measures, and UHI initiatives. As expected, increasing AC adoption increases annual operating costs. Nevertheless, packages of energy efficiency measures can reduce the incremental operating cost (e.g., Targeted Cooling and Expanded System-Wide Cooling scenarios). The Accelerated System-Wide Cooling scenario achieves citywide energy savings post-2030 that the cooling operating cost for 100% of homes would be less than the expected cost for the current saturation of 91% of homes.

Figure 24. Incremental Operating Cost to Deliver Equitable Cooling (Annual Values)

Tree planting was found to have high cost and limited impact on building AC consumption, so Guidehouse also modeled the Expanded and Accelerated scenarios excluding tree programs.

Source: Guidehouse analysis.

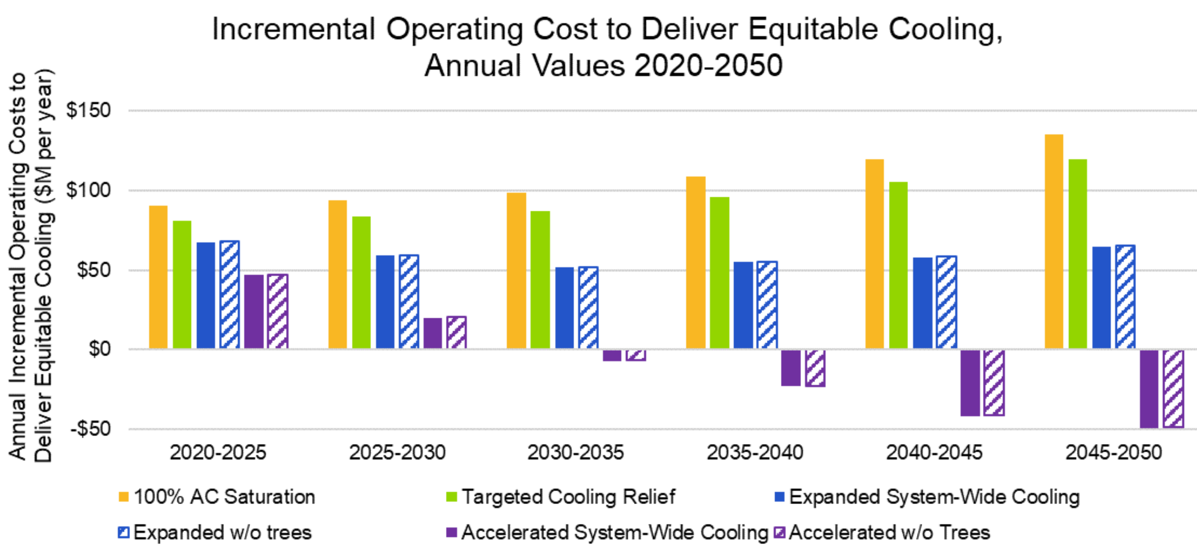
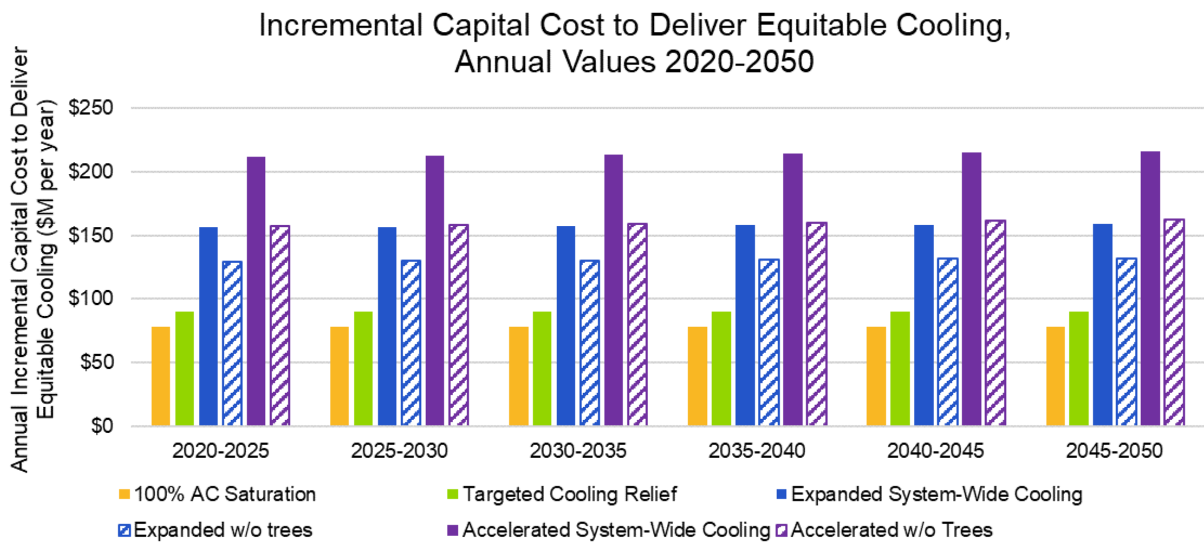


Figure 25 outlines the incremental capital cost impacts to deliver equitable cooling to all NYC residents through a combination of AC systems, energy efficiency measures, and UHI initiatives. By itself, providing AC systems to the approximately 300,000 homes without those today would carry an average annual cost of approximately $80 million (assumed $3,650 total installed cost split over a 15-year lifetime). Implementing additional energy efficiency measures would lower operating cost (Figure 25), but raise annual capital costs. Due to the relatively small cooling utility costs for the average NYC home (roughly $300/yr) and the stringent building energy codes in NYC, energy efficiency measures carry a lengthy payback period over code-level replacements. In particular, tree planting was found to have high cost (estimated $2,700 per tree) and limited impact on building AC consumption (9.3 kWh/yr per tree), so Guidehouse also modeled the Expanded and Accelerated scenarios excluding tree programs. Please note that the installed costs for 2020 are assumed across the analysis period 2020–2050.

Figure 25. Incremental Capital Cost to Deliver Equitable Cooling (Annual Values)

Tree planting was found to have high cost and limited impact on building AC consumption, so Guidehouse also modeled the Expanded and Accelerated scenarios excluding tree programs.

Source: Guidehouse analysis.



Please note that installed costs for 2020 are assumed across the analysis period 2020-2050.

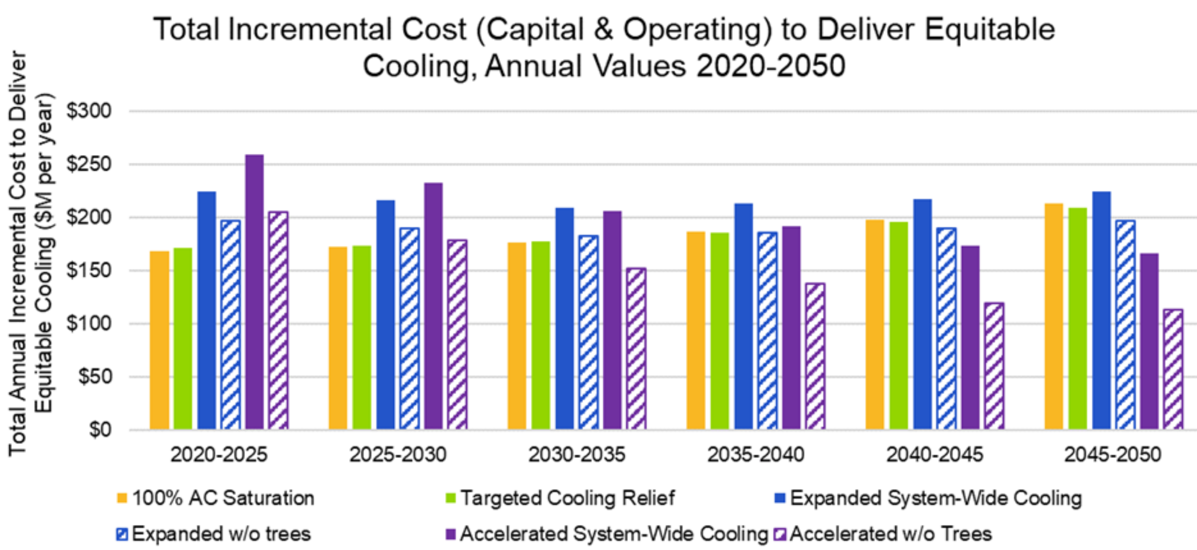
The economic analysis assumes cooling operating costs to increase based on forecasted electricity rates using national estimates, whereas no changes are assumed in capital costs. These assumptions may artificially improve the payback periods for most measures in future years (i.e., greater annual cost savings for the same incremental cost). This trend is reflected in the 2040, 2045, and 2050 years in Figure 26 below. Guidehouse recognizes that projecting future capital costs in NYC is highly uncertain. Largescale cooling equity programs may lower the per-project cost of AC installations, weatherization upgrades, tree planting programs, and other strategies. Furthermore, it is expected that solutions such as cool roofs and cool pavements to be primarily deployed through building codes and normal infrastructure repair schedules and assume very low or no incremental cost over conventional practices. It is also recognized that electricity rates may differ from the EIA national forecasts once accounting for City and State goals of building and transportation electrification.

Figure 26 outlines the total incremental costs to deliver equitable cooling to all NYC residents including capital and operating cost impacts for a combination of AC systems, energy efficiency measures, and UHI initiatives. Across the range of scenarios, extending cooling access to homes without AC systems today would carry a cost of approximately $170 million to $260 million per year over the period 2020–2050. As described above, the baseline Current Policy scenario already includes previously committed energy efficiency measures and building codes and appliance standards, so that the incremental energy efficiency is relatively costly in early years. Scenarios that include significant energy efficiency measures have relatively lower combined costs in later years due to increasing electricity rates over time.

Figure 26. Total Incremental Cost (Capital and Operating) to Deliver Equitable Cooling (Annual Values)

Tree planting was found to have high cost and limited impact on building AC consumption, so Guidehouse also modeled the Expanded and Accelerated scenarios excluding tree programs.

Source: Guidehouse analysis.



5.3 Levelized Per-Unit Costs and Monetizing Non-Energy Impacts/ Benefits

Table 29 describes the estimated per unit costs to deliver equitable cooling in NYC on an annual basis. While the cost for each scenario varies by the set of opportunities, the total cost to deliver equitable cooling to the approximately 300,000 homes in NYC without cooling today would average around $200 million per year.[111] On a per-unit basis, this would amount to approximately $700 per unit, when including levelized per-unit capital cost of AC system, weatherization, tree planting, and other measures as well as annual operating cost. The share of operating versus capital cost will vary by the scenario's measures (i.e., greater EE measures result in lower operating but higher capital costs). These costs represent the total cost and do not consider any cost-sharing by resident, building owner, donations, or city budgets. How these costs should be allocated across residents, property owners, utility customers, and taxpayers is outside the scope of the analysis.

The value of extending cooling to all NYC residents would be substantial but monetizing the non-energy impacts and benefits to the vulnerable residents would provide a better comparison. Guidehouse has not identified research that would monetize the impacts/benefits to vulnerable populations especially for Northeast U.S., but available research into low-income weatherization programs in Massachusetts would provide a reasonable estimate. Furthermore, incremental weatherization is included in each of the mitigation scenarios.[112] Table 29 summaries the monetized annual impacts from low-income weatherization programs, including heat stress and total benefits. The per home annual impacts of weatherization (e.g., insulation, air sealing, replacing/repairing windows, and doors) amount to $173 for heat stress and $1,382 for all benefit categories. This suggests that the health, comfort, and productivity impacts that equitable cooling would provide vulnerable NYC residents would partially or fully offset the capital and operating cost associated with the analyzed measures. Capturing these benefits would also support the environmental justice goals within the Climate Act and may be of interest to the Just Transition Working Group. Guidehouse understands that non-energy impacts for energy efficiency programs in NYS are captured through a 10% adder, rather than primary research or adapted estimates from other jurisdictions.

Table 29. Per-Unit Annual Costs and Potential Weatherization Non-Energy Impacts

Source: Guidehouse analysis based on modeling process described in section 4 and results in section 6. Low-income weatherization non-energy impacts/benefits based on 2016 Massachusetts Non-Energy Impacts Study.[113]

<table>
<tr><th>Metric</th><th>Value</th><th>Notes</th></tr>
<tr><td>Annual Cooling Related Cost to Deliver Equitable Cooling (Total NYC).</td><td>$200 million per year</td><td>Includes capital and operating cost, average across all scenarios 2020–2050.</td></tr>
<tr><td>Per Unit Cooling Related Cost (per home).</td><td>$700 per unit</td><td>Includes capital and operating cost, average across all scenarios 2020–2050. Approximately 300,000 NYC homes do not have AC today; the share of operating versus capital will vary by scenario/measures.</td></tr>
<tr><td>Estimated Impacts/Benefits from Low-Income Weatherization—Heat Related Stress Benefits</td><td>• $146 household benefit
• $27 societal benefit
• $173 total benefit</td><td rowspan="2">Annual benefits, Table E.1 of 2016 Massachusetts Non-Energy Impacts Study (2016)</td></tr>
<tr><td>Estimated Impacts/Benefits from Low-Income Weatherization All Benefits</td><td>• $942 household benefit
• $440 societal benefit
• $1,382 total benefit</td></tr>
</table>

Beyond societal benefits, deploying high-efficiency and grid-interactive ACs across NYC in the Accelerated System-Wide Cooling scenario could reduce summer peak demand requirements compared with the Targeted Cooling Relief scenario that expands AC adoption with baseline efficiency products. Section 4.1.4 describes peak demand impacts from extending cooling access to vulnerable residents, resulting in a net increase in peak demand of approximately 285 MW. Achieving sales share of 35% high-efficiency AC models under the Accelerated System-Wide Cooling scenario would increase NYC peak demand by approximately 225 MW, resulting in a savings of approximately 60 MW compared to 100% AC Saturation scenario without additional energy efficiency measures (285 MW). Hypothetically, this 60 MW reduction could result in $3–6 million in annual benefits assuming $50–100 per kW based on projected marginal cost of service estimates in Con Edison's Benefit Cost Analysis Handbook.[114] It is difficult to project the monetary value for these peak demand savings in future years, particularly as the annual peaks and hourly load shapes will change due to heating and transportation electrification.

Table 30. Projected Peak Demand Change from 100% Residential AC Adoption

The analysis focuses on 2035–2050 to isolate the impact of AC adoption by minimizing the peak demand savings impacts of normal appliance replacement.

Source: The baseline New York City summer peak demand is based on adjusted NYISO Gold Book values for New York City (Zone J),[115] *including projected climate adjustment based on the Itron NYISO 2019 report.*[116] *Peak demand impacts of AC systems based on New York State TRM values.*[117]

Key Values	Units	2035	2040	2045	2050
Baseline New York City Summer Peak Demand (MW)	MW	12,158	12,857	13,195	13,532
Peak Demand Change (MW) from 100% Residential AC Adoption	MW	285	285	285	285
Percentage Change for 100% Residential AC Adoption over Baseline	%	2.3%	2.2%	2.2%	2.1%
Peak Demand Change (MW) from Accelerated System-Wide Cooling Scenario (100% AC, 35% above Code AC Adoption)	MW	226	225	224	223
Percentage Change for Accelerated System-Wide Cooling Scenario over Baseline	%	1.9%	1.7%	1.7%	1.6%
Peak Demand Savings for Accelerated System-Wide Cooling Scenario over 100% AC Adoption	MW	-59	-61	-62	-63

5.4 Impacts of 2020 Cooling Assistance Program

During the course of this project, government, utility, and industry leaders across the State launched a pilot for the most impactful cooling strategy identified in Guidehouse's research and structured dialogs. The 2020 NYC AC assistance program provided approximately 70,000 AC units combined with bill relief to vulnerable residents in NYC during the COVID-19 pandemic. Assuming approximately 300,000 NYC homes do not have AC systems today, 2020 program would have reduced this number by over 20% in a single year. This program provides an excellent example for how cooling can be delivered quickly and combined with bill relief, even for a limited period of time. The research shows that this strategy will be effective to deliver cooling solutions to vulnerable residents but will be incomplete without ongoing bill relief. Past research suggests a certain percentage of residents with AC systems will not operate them due to the fear of high electricity bills and other concerns.[118] The health, comfort, and productivity benefits of delivering AC systems to NYC residents can only be achieved if the residents feel financially comfortable to operate the systems during heat events.

In terms of cost, the 2020 NYC AC assistance program appears to have attractive deployment costs. Guidehouse compared the calculated per-unit cost estimates for delivering AC system with bill relief to the estimated costs for the 2020 Cooling Assistance program[119]:

- Sixty-five million dollars for over 74,000 AC installations averages to $875 per unit installed. Assuming a 12-year lifetime for a window/room AC, this would be a levelized cost of $73 per year.
- In addition, Con Edison provided up to $40 per month bill credits for June through September (four months) for a total of $160 per year.
- Combined capital and operating costs for this program were $233 per year.
- The AC costs assume whole-home solutions consisting of a mix of window/room ACs, PTACs, split-system, and central chiller designs when projecting across the whole city, which is why a higher cost is used in the modeling analysis.

In section 7.2, Guidehouse recommends that City and State leaders conduct an evaluation to develop a comprehensive understanding for the impacts of the 2020 Cooling Assistance program in NYC, lessons learned, and how it may be improved in future years, including permanent bill relief.

5.5 Solution Needs by Neighborhood

This chapter describes the results of the analysis into three scenarios of technology and policy solutions to address equitable cooling challenges in NYC today. This section describes, where available, the modeling results on the borough and neighborhood levels.

Table 31 summarizes the number of homes that require AC systems by building type, percentage of low- income residents, and HVI by borough. Bronx and Brooklyn have higher than average concentration of low-income residents, homes without AC, and HVI, and they should be prioritized for equitable cooling solutions. Similar to the larger building stock, multifamily buildings consist of the majority of homes without AC systems today, and the boroughs of Bronx, Brooklyn, Manhattan, and Queens have the highest multifamily need. Staten Island differs from the other boroughs, with most homes classified as single-family. Window/room or ductless mini-split AC systems are likely the most appropriate solution for these buildings unless ducts are available for forced-air heating or the building would soon require extensive upgrades to its heating system (see section 2.2).

Table 31. Summary of Homes without Space Cooling by Borough

Source: Guidehouse analysis based on values from literature review.

Borough	Number of Homes	% Low Income	Heat Vulnerability Index (HVI)	% Homes Without Cooling	SF Homes w/o Cooling	MF Homes w/o Cooling	Total Homes w/o Cooling
Bronx	498,542	29%	3.8	14%	7,605	64,138	71,742
Brooklyn	950,201	21%	3.5	10%	12,663	78,438	91,101
Manhattan	785,265	15%	2.2	7%	1,105	57,060	58,165
Queens	791,113	14%	2.5	8%	16,635	44,078	60,713
Staten Island	172,597	13%	1.0	5%	5,236	3,461	8,697
Total or Weighted Average	**3,197,718**	**19%**	**2.9**	**9%**	**43,244**	**247,174**	**290,418**

Table 32 summarizes the number of homes that require AC systems by building type, percentage of low-income residents, and HVI by neighborhood. Neighborhoods with higher-than-average concentrations of these factors should be prioritized for equitable cooling solutions, and are highlighted in red cells in Table 37. Select Bronx, Brooklyn, Manhattan neighborhoods with higher-than-average characteristics for all three factors (italicized) represent the highest priority areas with over 106,000 homes in need of ACs and other equitable cooling solutions:

- **Bronx** (Mott Haven/Hunts Point, Morrisania/East Tremont, Highbridge/South Concourse, University Heights/Fordham, Kingsbridge Heights/Mosholu, Soundview/Parkchester): 51,357 homes.
- **Brooklyn** (Bedford Stuyvesant, Bushwick, East New York/Starret City, N. Crown Heights/Prospect Heights, South Crown Heights, Brownsville/Ocean Hill): 36,532 homes.
- **Manhattan** (Central Harlem, East Harlem): 18,377 homes.

Table 32. Summary of Homes without Space Cooling by Neighborhood

Source: Guidehouse analysis. Section 2 provides details for information sources.

	Neighborhood Name	Borough	Number of Homes	% Low Income	Heat Vulnerability Index (HVI)	% Homes Without Cooling	SF Homes w/o Cooling	MF Homes w/o Cooling	Total Homes w/o Cooling
1	Mott Haven/Hunts Point	Bronx	52,195	42%	5	16%	869	7,326	8,195
2	Morrisania/East Tremont	Bronx	53,694	41%	5	24%	1,377	11,617	12,994
3	Highbridge/South Concourse	Bronx	45,508	37%	5	15%	743	6,265	7,008
4	University Heights/Fordham	Bronx	45,546	40%	5	20%	980	8,266	9,246
5	Kingsbridge Heights/Mosholu	Bronx	51,661	33%	4	13%	695	5,865	6,561
6	Riverdale/Kingsbridge	Bronx	44,595	18%	1	11%	529	4,465	4,995
7	Soundview/Parkchester	Bronx	65,653	28%	4	11%	779	6,574	7,353
8	Throgs Neck/Co-op City	Bronx	49,374	11%	2	4%	220	1,854	2,074
9	Pelham Parkway	Bronx	45,257	20%	3	13%	600	5,057	5,657
10	Williamsbridge/Baychester	Bronx	45,060	19%	4	17%	812	6,848	7,660
11	Williamsburg/Greenpoint	Brooklyn	61,242	24%	4	7%	562	3,480	4,042
12	Brooklyn Heights/Fort Greene	Brooklyn	57,317	17%	3	10%	781	4,836	5,617
13	Bedford Stuyvesant	Brooklyn	50,674	31%	5	11%	775	4,799	5,574
14	Bushwick	Brooklyn	42,452	27%	5	12%	702	4,350	5,052
15	East New York/Starret City	Brooklyn	58,221	28%	4	11%	906	5,614	6,521
16	Park Slope/Carroll Gardens	Brooklyn	48,862	9%	2	8%	523	3,239	3,762

Table 32 continued

	Neighborhood Name	Borough	Number of Homes	% Low Income	Heat Vulnerability Index (HVI)	% Homes Without Cooling	SF Homes w/o Cooling	MF Homes w/o Cooling	Total Homes w/o Cooling
17	Sunset Park	Brooklyn	41,398	27%	4	7%	403	2,495	2,898
18	N. Crown Heights/Prospect Heights	Brooklyn	47,052	24%	5	14%	883	5,469	6,352
19	South Crown Heights	Brooklyn	42,548	20%	5	12%	716	4,433	5,148
20	Bay Ridge	Brooklyn	50,373	16%	1	6%	427	2,646	3,073
21	Bensonhurst	Brooklyn	75,655	17%	3	8%	883	5,472	6,355
22	Borough Park	Brooklyn	44,481	32%	3	9%	526	3,255	3,781
23	Coney Island	Brooklyn	49,538	25%	2	13%	923	5,715	6,638
24	Flatbush	Brooklyn	60,706	21%	3	9%	793	4,913	5,706
25	Sheepshead Bay/Gravesend	Brooklyn	59,958	16%	2	5%	383	2,375	2,758
26	Brownsville/Ocean Hill	Brooklyn	43,084	37%	5	18%	1,096	6,789	7,884
27	East Flatbush	Brooklyn	44,098	16%	5	10%	625	3,873	4,498
28	Flatlands/Canarsie	Brooklyn	72,541	11%	4	8%	756	4,684	5,441
29	Greenwich Village/Financial District	Manhattan	85,219	8%	2	2%	31	1,588	1,619
30	Lower East Side/Chinatown	Manhattan	78,485	26%	2	9%	133	6,852	6,985
31	Chelsea/Clinton/Midtown	Manhattan	81,148	14%	2	2%	37	1,911	1,948
32	Stuyvesant Town/Turtle Bay	Manhattan	80,831	9%	2	6%	94	4,837	4,931
33	Upper West Side	Manhattan	104,989	10%	1	8%	156	8,034	8,189

Table 32 continued

	Neighborhood Name	Borough	Number of Homes	% Low Income	Heat Vulnerability Index (HVI)	% Homes Without Cooling	SF Homes w/o Cooling	MF Homes w/o Cooling	Total Homes w/o Cooling
34	Upper East Side	Manhattan	116,390	6%	1	4%	80	4,110	4,190
35	Morningside Heights/Hamilton Heights	Manhattan	48,861	25%	2	12%	113	5,848	5,961
36	Central Harlem	Manhattan	58,881	27%	5	18%	199	10,282	10,481
37	East Harlem	Manhattan	52,996	34%	4	15%	150	7,746	7,896
38	Washington Heights/Inwood	Manhattan	77,465	24%	3	8%	113	5,851	5,965
39	Astoria	Queens	80,690	16%	3	7%	1,614	4,276	5,890
40	Sunnyside/Woodside	Queens	52,666	13%	4	8%	1,169	3,097	4,266
41	Jackson Heights	Queens	56,111	17%	3	6%	907	2,403	3,311
42	Elmhurst/Corona	Queens	53,742	19%	4	4%	560	1,483	2,042
43	Middle Village/Ridgewood	Queens	70,115	11%	2	4%	826	2,189	3,015
44	Forest Hills/Rego Park	Queens	46,429	11%	1	8%	967	2,562	3,529
45	Flushing/Whitestone	Queens	82,997	16%	1	6%	1,342	3,555	4,897
46	Hillcrest/Fresh Meadows	Queens	53,319	14%	1	5%	745	1,974	2,719
47	Kew Gardens/Woodhaven	Queens	43,090	14%	2	8%	956	2,534	3,490
48	Howard Beach/South Ozone Park	Queens	39,661	13%	3	6%	619	1,641	2,261
49	Bayside/Little Neck	Queens	39,915	8%	1	6%	689	1,826	2,515
50	Jamaica	Queens	71,853	13%	4	16%	3,111	8,242	11,353

Table 32 continued

	Neighborhood Name	Borough	Number of Homes	% Low Income	Heat Vulnerability Index (HVI)	% Homes Without Cooling	SF Homes w/o Cooling	MF Homes w/o Cooling	Total Homes w/o Cooling
51	Bellerose/Rosedale	Queens	56,897	8%	3	7%	1,122	2,974	4,097
52	Rockaways	Queens	43,630	20%	3	17%	2,008	5,321	7,330
53	North Shore	Staten Island	64,278	20%	1	9%	3,599	2,379	5,978
54	Mid Island	Staten Island	50,305	11%	1	2%	485	320	805
55	South Shore	Staten Island	58,014	7%	1	3%	1,153	762	1,914

Neighborhoods with higher-than-average concentrations of key factors are highlighted in red cells. Neighborhoods with higher-than-average characteristics for all three factors are italicized.

Table 33 summarizes the available space to plant trees by borough basis, which the 2018 U.S. Forest Service report defines as open area of grass, shrubs, or bare soil. Queens and Staten Island have greater potential for additional tree cover, while Bronx, Brooklyn, and particularly Manhattan have less potential. It is assumed approximately 25% of available planting space would be suitable for tree planting. Applying 190 trees per acre (400 square feet per tree, assuming 20 feet x 20 feet branch to branch spacing) would be feasible, with the remaining for open parks and other green features. The 2018 U.S. Forest Service report provides estimates for the indirect space cooling benefits of NYC trees, which averages to 9.3 kWh/yr. per tree (provided in Table 13 of the Forest Service Report). Under these assumptions, it is estimated approximately 2.1 million additional trees could be planted in future years across NYC, which would provide an additional 20 GWh/yr. electricity savings. For comparison, this would represent approximately 0.6% of residential space cooling consumption in NYC today (3,338 GWh/yr. in 2020).

Table 33. Summary of Potential Trees and Avoided Cooling Consumption by Borough

Source: Space available for planting (i.e., open area of grass, shrubs, or bare soil) and per-tree avoided cooling consumption from Table 17 of 2018 U.S. Forest Service report,[120] *Guidehouse estimate of achievable tree-planting space and trees per acre.*

Borough	Space (Acres) Available for Planting	Achievable Space (25% of Space Available for Planting)	Potential Trees (109 Trees/Acre)	Avoided Cooling Consumption (MWh)
Bronx	10,928	2,732	297,788	2,770
Brooklyn	13,558	3,390	369,456	3,437
Manhattan	3,949	987	107,610	1,001
Queens	27,343	6,836	745,097	6,931
Staten Island	21,768	5,442	593,178	5,518
Total	**77,546**	**19,387**	**2,113,129**	**19,656**

These findings are impacted by NYC's recent Million Trees NYC initiative and large park areas (e.g., Central Park in Manhattan, Forest Park in Queens), but there still are opportunities to target smaller sections of neighborhoods. Figure 27 highlights NYC community districts with greater need for tree planting and urban greening from the 2018 U.S. Forest Service report. The figure highlights a critical need for additional tree cover in many parts of Manhattan, with some areas overlapping with the building-related characteristics of Table 32. In particular, Central and East Harlem show moderate-to-high need for tree cover. In the Bronx, the neighborhoods of Highbridge and University Heights show the greatest need. Brooklyn in general shows less of an acute need for additional tree cover, but there are still neighborhoods such as Brownsville and Ocean Hill that have moderate need.

Figure 27. Temperature Planting Index (TPI) Map by New York City Community District

Source: 2018 U.S. Forest Service report.[121]

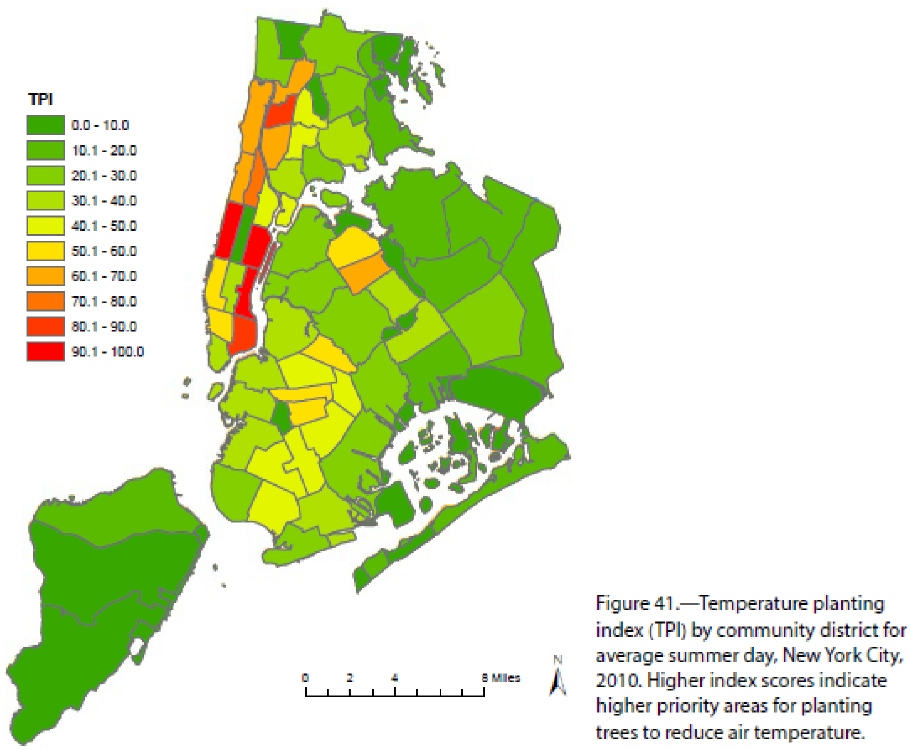


Table 34 summarizes the amount of pavement for streets by borough from the NYC Department of Transportation (DOT) Centerline Database. The analysis focuses on streets rather than highways, bridges, ramps, driveways, and other paved surfaces because streets consist of 90% of paved roadways and are most likely to be maintained by the NYC DOT rather than State or other entities. In total, NYC has 1,166 million square feet of roadway. Brooklyn and Queens have the greatest amount of street area—Bronx, Manhattan, and Staten Island have less. It is assumed that each road is resurfaced and/or replaced on a 20-year basis, which would suggest approximately 56 million square feet is upgraded each year. The Pomerantz et al. (2015)[122] paper cited in Shickman and Rodgers (2019),[123] found that increasing solar reflectance of urban surfaces would reduce indirect space cooling electricity demand by an average of 2 kWh/yr. per modified meter squared (0.185 kWh/yr. per square feet, 185 MWh/yr per million square feet). Upgrading 100% of NYC streets to cool pavements or other measures would reduce space cooling consumption by 216 GWh/yr. For comparison, this would represent approximately 6% of residential space cooling consumption in NYC today (3,338 GWh/yr in 2020). The cool pavement measure in the scenario analysis assumes that a portion of this resurfacing is done with cool pavements and sealants, and that the measure is targeted for the neediest areas (Table 32). If the technology proves successful in initial pilots and manufacturing volumes could increase, NYC could consider a larger deployment than what has been modeled in the scenarios—15 and 30 million square feet per year.

Table 34. Summary of Potential Street Area for Cool Pavements and Avoided Cooling Consumption by Borough

Source: Guidehouse.

Borough	Street Area (Million SF)	Avoided Cooling Consumption (MWh/yr.)	Percentage of Total
Bronx	165	30,600	14%
Brooklyn	305	56,468	26%
Manhattan	111	20,595	10%
Queens	418	77,326	36%
Staten Island	167	30,956	14%
Total	**1,166**	**215,945**	**100%**

5.6 Discussion of Scenario Modeling Results

- The analysis identifies that extending cooling access to all NYC homes will carry significant incremental operating and capital costs. Beyond the modeled solutions, policy support mechanisms for free or low-cost AC systems, weatherization upgrades, and bill assistance will be needed to shift the burden of this costs away from vulnerable populations. How these costs should be allocated across residents, property owners, utility customers, and taxpayers is outside the scope of the analysis.
- Increasing energy efficiency and UHI measures can reduce the operating cost but carry additional capital cost requirements. Assuming that electricity rates will continue to increase, adopting additional EE and UHI measures can minimize costs post-2030. NYC and NYS have already committed to strong EE policies, and per-home cooling consumption will reduce overtime absent of further measures.

- Energy efficiency measures are best deployed when the existing systems reach the end of their lifetime to minimize the incremental cost of installation (e.g., high-efficiency AC, cool roof codes during replacement). Deploying incremental measures (urban greening/tree planting) or retrofits (weatherization upgrades before end-of-life) would carry higher costs.
- UHI related measures such as tree planting, cool pavements, and cool roofs will have greater benefits to NYC residents than what is modeled for cooling energy consumption alone. The analysis does not consider the economic value of non-energy benefits related to avoided heat stress, heath impacts, carbon reductions, air quality, job development, livability, beautification, and other attributes. Including these would further increase the benefits and reduce the net program costs for extending cooling access.
- The annual incremental cost to deliver equitable cooling across NYC is estimated at $200 million per year, or approximately $700 per housing unit when including levelized capital cost and annual operating cost. Additional research is necessary to quantify the non-energy impacts and benefits of the equitable cooling program on health, comfort, and productivity of vulnerable residents. Assuming similar performance as low-income weatherization programs in Massachusetts, these non-energy impacts would partially or fully offset the capital and operating cost associated with the analyzed measures.

6 Conclusions and Recommendations

This report summarizes the major findings and insights from the Equitable Access to Cooling in New York City Under a Changing Climate study over the course of the entire project: fall 2020 through spring 2021, accounting for a pandemic-related pause over summer/fall 2020. This report builds on the Interim Report prepared in spring 2020.

Specifically, the team analyzed current cooling usage patterns across New York City and developed a spreadsheet model to project electricity consumption, demand, operating cost, capital cost, and other characteristics for residential space cooling systems under different climate scenarios. Guidehouse and researchers with the University at Buffalo conducted a literature review of public health research related to extreme heat as well as strategies to expand cooling access and mitigate heat risks. The study team then characterized current technology, policy, and market barriers related to the efficient use of, and equitable access to, cooling. The team also prioritized a list of technology and policy options to meet the cooling needs of vulnerable populations while minimizing increases in energy use and demand. The team then conducted structured dialogs and focus groups with key experts, community and environmental justice groups, utility administrators, and researchers in the areas of health, climate change, and vulnerable populations to refine the list of identified options. The team then prepared and analyzed three scenarios of prioritized technology and policy solutions to understand the overall impacts on cooling equity, electricity consumption, and cost for NYC residents. This report is intended to provide health, building, and policy stakeholders with research and insights to support their ongoing work to address New York City's challenges due to climate change.

A summary of Guidehouse's conclusions from the analysis is shown in section 7.1. Based on these findings and conclusions, Guidehouse prepared recommendations for NYSERDA and stakeholders to consider when evaluating potential strategies to promote and advance equitable cooling in NYC.

6.1 Conclusions

Guidehouse's key conclusions regarding future NYC cooling demand in a changing climate and strategies to address cooling inequity in vulnerable NYC residents are summarized below.

6.1.1 Future Cooling Demand in a Changing Climate

- **New York City Residential Cooling Demand Today**: Residential and commercial buildings consume approximately 7,254 GWh per year for space cooling systems or approximately 17% of total electricity consumption. Residential buildings account for 46% of building electricity demand in NYC, with single-family and multifamily buildings accounting for 13% and 33% respectively. Space cooling accounts for approximately 21% of annual home electricity consumption. Unlike many electrical appliances, space cooling demand is directly tied to weather, and its impacts for residential utility bills are largely concentrated in the summer months.
- **Cooling Impacts from Climate Change**: NYC will experience hotter summers, warmer winters, heavier rainfall, greater coastal flooding, and more extreme weather events due to future climate change. In relation to cooling demand, overall cooling degree days are expected to increase by 17% by 2050, whereas the number of days above 90°F, heat waves, and length of heat waves will have more substantial growth. Other factors that will increase cooling demand across NYC include population growth (0.3% annually) and greater AC adoption (91% saturation today).
- **Heat Risk for Vulnerable Populations**: Public health research finds that vulnerable populations in NYC currently face challenges related to heat stress during extreme heat events. Global climate change will exacerbate these challenges for residents concentrated in neighborhoods with poor housing conditions, less green space, lower incomes, and other exposure and sensitivity-related factors. Although the majority of NYC homes have AC systems today, many homes in vulnerable communities either do not have working AC systems or choose not to use the systems due to behavioral preferences, economic challenges, and/or low awareness of heat vulnerability. A range of available technology and policy solutions can help mitigate these impacts, but future strategies must address a large number of technical, market, and policy barriers that prevent equitable cooling access and building energy efficiency.
- **Future New York City Residential Cooling Demand**: Projected cooling electricity consumption impacts from climate change are largely offset by NYC aggressive energy efficiency targets which are implemented by public agency and utility programs. A variety of federal, State, and local policies outline prescriptive requirements for NYC residential buildings related to energy efficiency, safety, and other characteristics, and overtime improve the energy efficiency of the building stock. Furthermore, energy efficiency incentive programs offered by electric utilities and public organizations encourage the adoption of building technologies with performance above minimum codes and standards.
- **AC Adoption Impacts for Electricity Grid**: Installing AC systems in the homes of vulnerable residents is one of the more promising strategies to address cooling access across the City. The analysis suggests that increasing residential adoption of AC systems from 91% to 100% will have a modest impact on citywide energy consumption (1–2% of total NYC building consumption over 2020–2050). Similarly, extending access to AC systems for all NYC homes would increase future citywide peak demand by approximately 2.2% or 285 MW. High-efficiency AC systems with grid-interactive features would mitigate these electricity impacts, as well as statewide energy shifts through State GHG emissions policies.

- **AC Adoption Impacts for Vulnerable Residents**: Increasing access to AC systems for vulnerable populations can help mitigate health risks during extreme heat events, but the additional electric utility costs to operate the AC systems may create an additional economic burden if not managed correctly. The analysis suggests that an average residential cooling cost of $303 per year could be reasonable for most NYC residents. Nevertheless, vulnerable residents below the NYC poverty line would likely face challenges affording utility bills during the summer, even after available energy insecurity programs that limit energy spending to 6% of income.

6.1.2 Stakeholder Findings on Equitable Cooling Solutions

- **Technology and Policy Solutions**: Technology and policy solutions must be deployed to ensure that vulnerable populations have affordable access to cooling and are benefiting from energy efficiency and climate policies in New York State and New York City. At the household level, promising strategies center on providing financial access to AC through incentives or rebates. Promising building-level solutions include expanding access to both financial support for building shell improvements such as improved sealing and reflective walls/roofs, which can reduce indoor air temperatures. At the neighborhood level, cooling centers continue to be a promising option to provide access to cooling; through structured dialogs conducted by the team, improvements to cooling centers to make them more attractive were discussed, and include (1) the implementation of affordable transit, (2) development of amenities such as WiFi, and (3) marketing and outreach to raise awareness of cooling centers. Other promising solutions include those that mitigate the UHI effect, such as trees and green infrastructure, providing long-term cooling benefits at the street or neighborhood level.
- **Importance of In-Home Solutions**: Cooling in the home is of high priority due to the fact that residents feel most comfortable at home and are likely to spend significant quantities of time there. In addition, it can be inconvenient and challenging to get transportation to cooling centers due to factors such as affordability, medical devices, children, and pets. Due to cooling center closures because of COVID-19, it is even more apparent that in-home solutions are the most pressing need. Safety within residents' own homes will make people safe and comfortable without solely resorting to less effective options such as urban greening and cool roofs.
- **Strategies for Cooling Success**: Solutions must combine cooling systems with electricity bill relief for eligible residents—giving an AC without the means to operate will lead to poor operation and challenges with 2020 year program. Note about how the cooling equity programs should be deployed through existing programs that work (WAP/HEAP), not duplicate efforts, particularly on federal, State, city, and local levels. Role for Heating Electrification: Statewide goals for heating electrification and energy efficiency can support high-efficiency space heating and cooling, but cannot sacrifice short-term health needs for long-term GHG emissions goals.

- **Improving Cooling Centers**: Cooling centers can be improved by dedicated funding and spaces for cooling centers in communities. The structured dialogs revealed that today's cooling centers are mostly an add-on function to existing spaces without funding for staff, signage, activities, refreshments, and other items. Furthermore, more should be done to provide accessible and affordable transportation to the cooling centers, along with improved communication strategies so that residents can identify and travel to the nearest cooling center. Where possible, the cooling centers should be located within the communities (e.g., common areas of NYCHA housing, local churches and schools, community centers). Installing community solar systems with storage or auxiliary generation systems at dedicated cooling centers can also improve the resiliency of the facilities to ensure operation during extreme heat events that may cause local grid interruptions.

6.1.3 Cooling Impacts and Costs for Equitable Cooling Solutions

- **Capital and Operating Costs**: The analysis identifies that extending cooling access to all NYC homes will carry significant incremental operating and capital costs. Beyond the modeled solutions, policy support mechanisms for free or low-cost AC systems, weatherization upgrades, and bill assistance will be needed to shift the burden of this costs away from vulnerable populations. The annual incremental cost to deliver equitable cooling across NYC is estimated at $200 million per year, or approximately $700 per housing unit when including levelized capital cost and annual operating cost. How these costs should be allocated across residents, property owners, utility customers, and taxpayers will require more detailed discussions and evaluation of impacts for different stakeholder groups.
- **Value of Direct Cooling Measures**: Direct cooling measures such as high-efficiency AC, envelope upgrades/weatherization, and expanding cool roof laws for residential buildings have a more significant impact on cooling energy consumption. UHI related measures such as tree planting, cool pavements, and cool roofs for non-residential buildings will have more limited, indirect impact on residential cooling electricity consumption. An optimal solution would combine both direct measures to each home as well as indirect measures at the neighborhood level.
- **Value of Indirect Cooling Measures**: Increasing energy efficiency and UHI measures can reduce the operating cost but carry additional capital cost requirements. Energy efficiency measures are best deployed when the existing systems reach the end of their lifetime to minimize the incremental cost of installation (e.g., high-efficiency AC, cool roof codes during replacement), particularly through building codes and ordinances. Deploying incremental measures (urban greening/tree planting) or retrofits (weatherization upgrades before end-of-life) would carry higher costs. Indirect cooling measures, such as tree planting, as well as supporting initiatives like community solar can be valuable for the community and has a lot of interest in community action stakeholders due to co-benefits (e.g., beautification, jobs). Nevertheless, these solutions must have the cooperation of the community to prevent gentrification, resident displacement, and imposing maintenance requirements on residents.

- **Capturing Non-Energy Benefits**: Equitable cooling solutions will provide greater benefits to NYC residents than what is modeled for cooling energy consumption alone. The analysis does not consider the economic value of non-energy benefits related to avoided heat stress, heath impacts, carbon reductions, air quality, job development, livability, beautification, and other attributes. Including these would further increase the benefits and reduce the net program costs for extending cooling access. Assuming similar performance as low-income weatherization programs in Massachusetts, these non-energy impacts would partially or fully offset the capital and operating cost associated with the analyzed measures.

In addition to evaluating citywide impacts, the analysis also modeled results by building type, borough, and neighborhood. Similar to the larger building stock, multifamily buildings consist of the majority of homes without AC systems today. Window/room or ductless mini-split AC systems are likely the most appropriate solution for these buildings unless ducts are available for forced-air heating or the building would soon require extensive upgrades to its heating system. Select Bronx, Brooklyn, Manhattan neighborhoods with higher-than-average concentration of low-income residents, homes without AC, and HVI represent the highest priority areas with over 106,000 homes in need of ACs and other equitable cooling solutions:

- Bronx (Mott Haven/Hunts Point, Morrisania/East Tremont, Highbridge/South Concourse, University Heights/Fordham, Kingsbridge Heights/Mosholu, Soundview/Parkchester): 51,357 homes.
- Brooklyn (Bedford Stuyvesant, Bushwick, East New York/Starret City, N. Crown Heights/Prospect Heights, South Crown Heights, Brownsville/Ocean Hill): 36,532 homes.
- Manhattan (Central Harlem, East Harlem): 18,377 homes.

6.2 Recommendations

Based on the conclusions summarized above, Guidehouse recommends the following actions to NYSERDA, its partners, and other stakeholders when evaluating potential strategies to promote and advance equitable cooling in NYC. While Guidehouse provides recommendations on how to improve equitable cooling in NYC, it is important to recognize that NYC has already developed a variety of comprehensive programs and policies, and the recommendations build on the successes in energy efficiency, cool roof, urban greening, subsidized AC systems, and other initiatives.

1. The environmental justice and public health aspects of cooling equity to key stakeholders should be communicated while also recognizing the significant investment that will be necessary to deliver equitable cooling for vulnerable populations. The analysis revealed that both direct and indirect strategies to achieve cooling equity within the home require large, continued investments in capital and operating costs, electricity consumption and demand, and other resources. Similar policy and financial discussions on how to achieve equitable climate mitigation through building energy efficiency, heating and transportation electrification, and other strategies are taking place today on a State and local level. The opportunities, impacts, and costs for achieving cooling equity should be considered in these tough discussions.
   A comprehensive analysis of the impacts of the 2020 Cooling Assistance program in NYC should be conducted to understand how the program may be continued and improved in future years, as well as extended to other parts of NYS. This analysis should include the types of AC systems installed, how residents used the systems, net impacts of the utility bill allowances, installer costs and challenges, and lessons learned from the program administration and deployment. The structured dialogs revealed some of the successes and challenges that stakeholders observed in the rollout of the 2020 program, but it is clear that there is more to learn about the program. Nevertheless, stakeholders suggested that the program had a meaningful impact during COVID-19 restrictions to deliver cooling to vulnerable populations and should be expanded and improved in future years.
2. A comprehensive program should be developed to deliver AC systems to remaining NYC residents with AC by 2030 or earlier and establish permanent cooling bill credit programs for eligible customers. The 2020 NYC program exemplified how AC systems could be deployed across approximately 20% of the homes without AC systems today in a short period of time. Building on the Local Law 84 benchmarking requirements for larger buildings, this program can also offer comprehensive assessments for eligibility for heating electrification, envelope upgrades, cool roofs, etc. for eligible buildings. These assessments will identify the opportunities and challenges for individual buildings, and inform future energy efficiency and GHG reduction projects, such as heating electrification.
3. Additional research should be conducted to quantify the non-energy impacts and benefits of the equitable cooling program (described above) on health, comfort, and productivity of vulnerable residents. The analysis focused on the capital and operating cost impacts to deliver cooling to vulnerable residents, but the value of extending cooling to all NYC residents would be substantial if monetizing on a similar basis. Guidehouse has not identified research that would monetize the impacts/benefits to vulnerable populations especially for Northeast U.S., but such research exists for several State energy efficiency programs related to low-income weatherization and other measures. Performing such an analysis would allow stakeholders to perform benefit-cost analyses on the same basis as more conventional utility programs, Climate Act-related programs, and State and local budget analyses.

4. Leaders across NYC government, electric utilities, community organizations, and other stakeholders should work together to discuss how to fund the equitable cooling program over the next 30 years. The analysis identified the capital and operating costs that will need to be invested annually to deliver equitable cooling for vulnerable populations. Nevertheless, further analysis and discussion is needed on how these costs should be allocated across residents, property owners, utility customers, and taxpayers, and the specific mechanisms to fund the programs. This research would need to evaluate whether vulnerable populations may experience unintended financial or other adverse impacts through the funding mechanism for the equitable cooling program.
5. The development of dedicated funding and spaces for climate-resilient cooling centers in communities should be encouraged. Guidehouse's structured dialogs revealed that today's cooling centers are mostly an add-on function to existing spaces without funding for staff, signage, activities, refreshments, and other items. Furthermore, more should be done to provide accessible and affordable transportation to the cooling centers, along with improved communication strategies so that residents can identify and travel to the nearest cooling center. Where possible, the cooling centers should be located within the communities (e.g., common area of NYCHA housing, local churches and schools, community centers) and have resilient features, such as community solar with storage or backup power systems to maintain operations during heat-related outages.
6. Existing programs for residential and commercial cool roofs, tree planting, and other UHI initiatives should be supported and expanded. Additional pilots around cool pavements and other emerging technologies should also be considered. As identified in this project, these programs can provide meaningful cooling benefits citywide even if they do not eliminate the need for AC systems in the home and can provide considerable non-energy benefits such as air quality, job development, livability, beautification, and other attributes. Many of these programs exist today in NYC and could be further expanded through additional funding and support.

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Appendix A. Public Health Literature Review

Researchers with the University at Buffalo reviewed available public health literature relating to heat risk for vulnerable populations, future impacts from climate change, and cooling mitigation strategies, with particular focus on New York City and the Northeast United States. Section 3.2 summarizes key findings from a subset of the approximately 50 public health research papers. This section provides full references for public health research resources collected during this literature review. Bold denotes resources that were most useful when preparing the report.

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Appendix B. Analysis Approach and Assumption

This appendix describes the analysis approach to characterize New York City cooling demand and identify potential technology and policy solutions:

- **B.1 Cooling Demand Modeling Approach**—The study team developed a spreadsheet model to characterize cooling demand and energy use in NYC today, project impacts from climate change, population growth, AC adoption and other factors for future years, and analyze the costs and benefits of different technology and policy solutions to improve cooling equity for vulnerable populations. This section provides an overview for the modeling approach, with additional details contained in the Excel spreadsheet provided to NYSERDA. Appendix C provides the results for the different cooling demand scenarios.
- **B.2 Technology and Policy Solutions Approach and Assumptions—**The study team identified a list of cooling technology options and policy strategies that could meet cooling needs of NYC residents, primarily vulnerable populations, while minimizing energy use. Appendix D provides the results for the technology and policy solution scenarios.

B.1 Cooling Demand Modeling Approach and Assumptions

First, Guidehouse collected past, current, and future forecasted information about energy consumption, peak demand, building stock, climate/weather data, electricity rates, resident characteristics, and other data for NYC. Using this data, the team disaggregated City cooling electricity consumption and other parameters on a per-home/per-building level for each of NYC's 55 neighborhoods. This methodology allows for future analysis by building segment (single-family versus multifamily), location (borough, neighborhood), cooling system type (split-system, window, central), efficiency level (below code, code, above code), and occupant characteristics (rent versus own, rent burdened, HVI score).
Figure B-1 provides an illustrative example for how building parameters and energy consumption on a neighborhood level were calculated. Each row of the model contains a long list of building stock parameters and calculated values in 5-year increments over 2020–2050, such as: HVI, share of homes with room AC, share of homes with envelope below code, and number of new AC systems sold. Guidehouse then defined future parameters from 2020–2050 for utility rates, population growth, CDD increase, appliance replacement rates, energy efficiency (EE) impacts, and other trends.

Figure B-1. Illustrative Example for Neighborhood-Level Characterization and Analysis

Building Type	Borough / Neighborhood	Average SF per Home / Building	Average Cooling EUI (kWh/SF)	Cooling Elec Consumption per Home / Building (kWh)	Number of Homes / Buildings in Neighborhood	Cooling Elec Consumption of Homes / Buildings in Neighborhood (GWh)	Sector Utility Rate ($/kWh)	Cooling Elec Cost per Home / Building ($/yr.)	Cooling Elec Cost of Homes / Buildings in Neighborhood ($M/yr.)
Single-Family (55 segments)	1 – Bronx, Mott Haven / Hunts Point	1,832	1.05	1,918	5,030	10	$0.26	$506	$2.5 M
	2 – Bronx, Morrisania / East Tremont	1,832	1.05	1,918	5,174	10	$0.26	$506	$2.6 M
	…	1,832	1.05	1,918	…	…	$0.26	$506	…
	55 – Staten Island, South Shore	1,832	1.05	1,918	31,750	61	$0.26	$506	$75.3 M
Multi-Family (55 segments)	1 – Bronx, Mott Haven / Hunts Point	953	1.05	997	42,420	42	$0.26	$263	$52.3 M
	2 – Bronx, Morrisania / East Tremont	953	1.05	997	43,639	44	$0.26	$263	$53.8 M
	…	953	1.05	997	…	…	$0.26	$263	…
	55 – Staten Island, South Shore	953	1.05	997	20,991	21	$0.26	$263	$25.9 M
Commercial (5 segments)	1 – Bronx	15,000	2.10	31,500	13,333	420	$0.19	$6,080	$555.8 M
	2 – Brooklyn	15,000	2.10	31,500	27,333	861	$0.19	$6,080	$1,139.5 M
	…	15,000	2.10	31,500	…		$0.19	$6,080	
	5 – Staten Island	15,000	2.10	31,500	4,000	126	$0.19	$6,080	$166.7 M

Illustrative

Guidehouse developed three modeling scenarios to understand the impacts for the key factors, as well as the potential technical and policy solutions. Figure B-2 highlights the differences between the three scenarios: Steady Progression, Current Policy, and Technology and Policy Solution. The Steady Progression scenario includes appliance turnover, and the Current Policy scenario includes the additional impacts of EE policies. The model can also project the impacts of increasing AC adoption to 100%, an increase from approximately 91% adoption today. For each five-year increment, the team updated the building stock and characterization for population growth, utility rates, and other parameters. Guidehouse then adjusted the average per-home cooling consumption based on projected changes in cooling demand, including climate change, share of buildings with AC systems, appliance and building technology replacements, and known EE impacts. Using the updated per-home cooling consumption value, Guidehouse then calculated operating cost, capital cost for the purchase of new AC, envelope, and roof systems, and other parameters. The outputs are summarized on a five-year basis over 2020–2050 for each scenario.

Figure B-2. Summary of Cooling Demand Modeling Scenarios

1. Steady Progression Scenario	2. Current Policy Scenario	3. Technology & Policy Solution Scenario
• Includes impacts of: o climate change, o population growth, o utility rates o normal appliance and building system turnover	• Same as Steady Progression scenario + • Additional impact of energy efficiency programs	• Same as Current Policy scenario + • Customized adjustments for technology parameters: o adoption rates, o energy savings o upfront cost

The modeling inputs, data granularity, and resources used can be found in Table B-1 through Table B-4 below. Appendix C provides the interim results for the different modeling scenarios.

Table B-1. Residential Building Stock Model Inputs and Resources

Key Metrics	Selected Data Granularity	Selected Resources
• Number of housing units. • Percentage of homes with AC systems. • Residential characteristics (age, income, rent burdened, etc.). • Heat Vulnerability Index.	• By neighborhood (55 across 5 boroughs).	• New York City Environment & Health Data Portal (Link). • Data confirmed or adjusted with 2017 New York City Housing and Vacancy Survey (Link) and 2018 American Community Survey (Link).
• Number of single-family vs. multifamily housing units. • Number of owner-occupied vs. rented housing units.	• By borough (5).	• American Community Survey 2018 - Selected Housing Characteristics (Link). • 2017 New York City Housing and Vacancy Survey (Link).
• Residential energy use intensity for space cooling (kWh/SF). • Residential energy use intensity for total electricity (kWh/SF).	• Average for total New York City, modeled as multifamily results from New York City benchmarking database (Local Law 84).	• 2017 Energy and Water Use Report (Link).
• Average housing unit square footage (SF) for single-family and multifamily housing units. • Cooling system type for single-family and multifamily housing units. • Percentage of building systems below code, at code, and above code.	• Average for New York City-region (climate zone 4). • Cooling system type (room, split-system, central building). • Building systems include cooling, envelope, roof.	• 2015 NYSERDA Residential Baseline Study (Link). • Guidehouse judgement where necessary.
• Energy savings, percentage from code and above code building technologies. • Lifetime of building systems.	• Cooling system type (room, split-system, central building) • Building systems include cooling, envelope, roof.	• 2019 New York State Technical Resource Manual (TRM), Version 7 (Link).
• Installed cost of code and above code building technologies.	• Cooling system type (room, split-system, central building). • Building systems include cooling, envelope, roof.	• 2019 Mid-Atlantic TRM, v 9 (Link). • EIA Appliance Cost Database (Link).

Table B-2. Commercial Building Stock Model Inputs and Resources

Key Metrics	Selected Data Granularity	Selected Resources
• Number of commercial buildings. • Total floorspace of commercial buildings.	• By borough (5)	• New York City Department of City Planning's (DCP) Primary Land Use Tax Lot Output (PLUTO) database (Link) .
• Commercial energy use intensity for space cooling (kWh/SF). • Commercial energy use intensity for total electricity (kWh/SF).	• Average for total New York City, modeled as office results from New York City benchmarking database (Local Law 84).	• 2017 Energy and Water Use Report (Link).
• Percentage of building systems below code, at code, and above code.	• Cooling system type (room, split-system, central building). • Building systems include cooling, envelope, and roof.	• Estimate similar percentages as residential.
• Energy savings percentage from code and above code building technologies.	• Cooling system type (room, split-system, central building). • Building systems include cooling, envelope, and roof.	• 2019 New York State TRM, Version 7 (Link).

Table B-3. Energy and Climate Parameters and Projections Model Inputs and Resources

Key Metrics	Selected Data Granularity	Selected Resources
• New York City total electricity consumption (GWh). • New York City total summer peak demand (MW).	• NYISO New York Control Area, Zone J, inclusive of New York City.	• NYISO load and capacity data "Gold Book" (Link).
• Current utility rates—residential and commercial.	• 2018 annual average residential and commercial rates for Con Edison, inclusive of all fixed costs, fees, and taxes.	• EIA. electric sales, revenue, and average price (October 2019) (Link).
• Future utility rates—residential and commercial.	• U.S. average 2020–2050 nominal and normalized growth rates for residential and commercial.	• EIA 2019 Annual Energy Outlook (Link).
• Population/building growth rate.	• Average population growth rate 2020–2040, by borough (5).	• New York City population projection by age/sex & borough, 2010-2040 (Link).
• Historical average cooling degree days. • Projected future cooling degree days.	• Average for New York City based on LaGuardia Airport weather station.	• NYSERDA monthly cooling and heating degree day data (Link). • New York City, one city built to last report, incorporating IPCC AR5 climate projections (Link).
• Future impact of existing EE programs and policies. • Future impact of public awareness of cooling demand.	• Average for New York City.	• 2019 NYISO GoldBook estimates an average annual energy savings of 0.6% over 2019-2039. • It is assumed approximately half of the savings are attributable to codes and standards, and half to incremental EE programs.
• Adoption of AC systems in homes that do not have them today.	• By neighborhood (55 across 5 boroughs).	• Selectable parameter to increase adoption to 100%.

Table B-4. Health and Technology Model Inputs and Resources

Key Metrics	Data Granularity	Resources
• Heat Vulnerability Index	• By New York City neighborhood except where data is unavailable.	• New York City Environment and Health Data Portal (Link) • New York City DOHMH provided updated values to Guidehouse for use in this study.
• Per unit cooling benefits. • Net unit energy consumption (+/- to baseline conditions). • Applicable market size (percentage of residents or buildings). • Upfront cost and annual operating costs. • Non-energy benefits • Barriers to implementation, access, or equity.	• Defined on a per person or per housing unit basis. • By New York City building segment. • Guidehouse will scale this data to New York City neighborhoods as appropriate.	• New York State TRM (Link). • New York City Energy and Water Use Report (Link). • Cool Neighborhoods New York City report (Link). • Additional research conducted by the study team and stakeholders.

The following list presents key assumptions for the building stock analysis in the baseline case.

- Total electricity and cooling electricity consumption are estimated for an average single-family and multifamily housing unit in NYC. Actual electricity usage for individual housing units will vary based on floorspace, building characteristics, and occupant behavior.
- All new buildings in future years will have an AC system and all building systems are code or above code efficiency.
- For each neighborhood, the number of new building systems installed includes both new buildings (100% of new buildings) and replacement of systems in existing buildings at the end of their useful life (e.g., assuming 25-year lifetime, 1/25 or 4% of existing buildings annually).
- For each building segment, the choice of AC system type in the future (split, room, or central chiller) is based on the current share of each AC system type.
- For each building segment, the choice of building system efficiency in the future (code, above code) is based on the current share of above code building systems (e.g., if 15% of existing buildings have above code AC, then 85% of new AC installs will be code and 15% will be above code).
- Technology and policy options considered in this study will adjust the energy consumption, energy savings, installed cost, and adoption rate of specific building technologies or other input parameters. For example:
    - Policies that promote high-efficiency ACs would increase the share of ACs sold each year that are above code.
    - Policies that raise minimum performance for building envelope and roof designs would increase the energy savings of annual installations that are code efficiency.
    - Policies that reduce the UHI effect through increased greenspace would reduce building energy consumption and/or limit the saturation rate for ACs in future years.

B.2. Technology and Policy Solutions: Approach and Assumptions

Guidehouse conducted an in-depth literature review of research on technology solutions to access to cooling, as well as a review of previous policy efforts and initiatives on equitable access to cooling. Through this literature review, the team created a list of roughly 60 technology and policy solutions. Through prioritization, the list was narrowed to about 20 options. Prioritization included consideration of costs, cost-effectiveness, feasibility, relative cooling and non-cooling benefits, and current adoption in NYC, based on details gathered from literature review.

This literature review and the list of potential solutions was used as a starting point to hold structured dialog and group discussions with experts and affected communities to understand the technology solutions available and the applicability, pros and cons, interactions, barriers, and non-energy impacts associated with each solution. Guidehouse also used these structured dialogs to investigate potential program mechanisms, regulatory constraints, and stakeholder considerations underlying successful policy implementation. Using the insights captured during the structured dialogs and literature review, the team revised the list of technology and policy options and prepared a further prioritized list of options to be modeled as scenarios using the spreadsheet model developed for this study. Finally, synthesizing the modeling outcomes, Guidehouse summarized the technology and policy findings in a matrix of options/combinations, evaluating their attractiveness to NYSERDA and NYC in general.

The following list presents key assumptions for the consideration and prioritization of technology and policy options to provide equitable access to cooling to NYC residents.

- Policies and programs that are currently underway and in place are assumed to continue to operate and escalate at their current rate of growth if currently expanding.
- Programs are assumed to continue making the same impact on cooling availability that they do now.
- It is assumed that there are no radical changes in technology that would impact the list of technology options.
- It is assumed that no broad-sweeping federal level programs are introduced.
- The makeup of the vulnerable population is assumed to continue to be consistent with how it is currently characterized. COVID-19 and economic impacts that may change the prevalence and makeup of the vulnerable population are not considered.

The following list presents key limitations for the consideration and prioritization of technology and policy options to provide equitable access to cooling to NYC residents.

- Many cooling technologies, particularly for building envelope or neighborhood-level cooling, do not have a consistent cooling capacity, so cooing benefit for these options is estimated based on available data.
- Based on the current functioning of the economy and labor force; radical changes to the economy or workforce (such as recession) could change the viability and cost/benefit analysis of options.
- Adoption rates of cooling technologies or behaviors based on the introduction of a given program are estimated based on available data.
- Estimations of programmatic costs for some options are limited by data availability about costs for specific implementation in NYC.
- Identified technology options are limited to only technologies that are currently available.
- Events could change the social dynamics, desirability and efficacy of certain technology or policy options. (i.e., cooling centers will likely be less desirable/feasible due to social distancing instated for the COVID-19 pandemic).

Appendix C. Key Modeling Results

This section provides the final parameters for the spreadsheet model to characterize cooling demand and energy use, as well as the modeling results for residential cooling and electricity consumption in each scenario.

C.1 Final Input Parameters

Table C-1 provides the calculated values for per-home and per-building estimates for cooling electricity consumption and total electricity consumption for NYC building stock. Guidehouse relied on energy benchmarking data collected for Local Law 84 in 2014 and 2015[124] to establish a current baseline for average consumption per square foot for NYC residential and commercial buildings. The team then multiplied by the average floorspace per building to determine per-home and per-building estimates. The team then multiplied these values by the number of single-family and multifamily buildings in each neighborhood to determine total neighborhood cooling and total electricity consumption. Estimated number of buildings for each of the 55 neighborhoods was provided by the 2017 New York City Housing and Vacancy Survey [125] and 2018 American Community Survey.[126]

Table C-1. Estimated Cooling Electricity Consumption per Home/Building

Source: Energy and Water Use Report,[127] NYSERDA Residential Baseline Study,[128] and New York City Department of City Planning's (DCP) Primary Land Use Tax Lot Output (PLUTO) database.[129]

Input Parameter	Building Segment	Units	2020 Values	Notes
Average Floorspace per Home/Building	Single-Family	sq. ft. per home	1832	New York State average
	Multifamily	sq. ft. per home	953	New York City average
	Commercial	sq. ft. per building	15,000	Approximate value based on New York City PLUTO database
Total Electricity Consumption per Square Foot	Single-Family	kWh/SF	4.9	Assume same as multifamily benchmarked value
	Multifamily	kWh/SF	4.9	
	Commercial	kWh/SF	14.4	Office benchmark value
Cooling Electricity Consumption per Square Foot	Single-Family	kWh/SF	1.05	Assume same as multifamily benchmarked value
	Multifamily	kWh/SF	1.05	
	Commercial	kWh/SF	2.14	Office benchmark value
Total Electricity Consumption per Home/Building	Single-Family	kWh/home	8,987	Calculated
	Multifamily	kWh/home	4,673	
	Commercial	kWh/building	216,000	
Cooling Energy Consumption per Home/Building	Single-Family	kWh/home	1,918	Calculated
	Multifamily	kWh/home	997	
	Commercial	kWh/building	32,100	

Table C-2 provides the estimated values for AC system type for single-family and multifamily buildings today. The NYSERDA Residential Baseline study provides these estimates for downstate New York (Zone 4); values were normalized for homes with AC systems. It is assumed that all new construction homes have an AC system, and the choice of AC system type in the future (split, room, or central chiller) is based on the current share of each AC system type for each building segment.

Table C-2. AC System Type by Residential Building Category

Source: NYSERDA Residential Baseline Study.[130]

Input Parameter	Building Segment	2020 Values	Notes
AC System Type (Single-Family)	Split-System	42.5%	Includes AC and heat pump systems.
	Window/Room	57.5%	Includes PTACs
	Central Building	0.0%	Includes chillers and other central systems.
AC System Type (Multifamily)	Split-System	5.2%	Includes AC and heat pump systems.
	Window/Room	86.4%	Includes PTACs
	Central Building	8.4%	Includes chillers and other systems.

Table C-3 provides the estimated market saturation by efficiency level for AC, envelope, and roof systems across the NYC building stock for 2020. Guidehouse developed these estimates based on the NYSERDA Residential Baseline Study and expert judgement based on previous Guidehouse EE potential studies in NYS and the Northeast U.S. The Cool Roof market saturation is based on the assumed compliance with a Local Law 21 of 2011[131] which updated the NYC building code to require cool roofing materials (16% market adoption based on 4% annual replacement for 8 years, and 50% of roofs are covered by the building codes). The team assumes the same values for both single-family and multifamily homes. Guidehouse assumes that building systems are replaced at the end of their lifetime with new systems with either code or above code efficiency level, so that the number of below code systems decreases over time. The assumptions for building system efficiency in the future (code, above code) are based on the current share of above code building systems (e.g., if 15% of existing buildings have above code AC, then 85% of new AC installs will be code and 15% will be above code).

Table C-3. Estimated Saturation of Building System by Efficiency Level

Source: NYSERDA Residential Baseline Study[132] and Guidehouse assumptions.

Input Parameter	Efficiency Level	2020 Values	Efficiency Level
Saturation of AC System by Efficiency Level	Below Code	70%	12 SEER
	Code	20%	14 SEER
	Above Code	10%	17 SEER
Saturation of Envelope System by Efficiency Level	Below Code	70%	R-11 wall, R-19 ceiling, no air sealing
	Code	25%	R-21 wall, R-49 ceiling, no air sealing
	Above Code	5%	R-27 wall, R-60 ceiling, with air sealing
Saturation of Roof System by Efficiency Level	Below Code	84%	No Cool Roof
	Code	16%	Cool Roof
	Above Code	n/a	n/a

Table C-4 provides the lifetime values for AC, envelope, and roof systems across the NYC building stock for 2020. Average lifetime values were used within the NYS TRM 2019. To determine an average value for AC systems, Guidehouse calculated the weighted average of split-system (15 years), window (13.5 years based on 12 years for room AC and 15 years for PTAC), and central (20 years) AC systems.

Table C-4. Estimated Lifetime for Building Systems

Source: 2019 New York State TRM.[133]

Building Segment	Lifetime (Years)	Annual Replacement Rate (%)	Notes
AC System Lifetime	14	7%	Weighted average of split-system, window, and central AC systems.
Envelope Lifetime	25	4%	Many buildings will forego upgrades until well past the useful life of building systems.
Roof Lifetime	25	4%	

Table C-5 provides the estimated installed cost for code and above code AC, envelope, and roof systems across the NYC building stock for 2020. These estimates were developed based on the EIA Appliance Cost database, NEEP Mid-Atlantic TRM, and expert judgement based on previous Guidehouse EE potential studies in NYS and the northeast. The capital costs represent upgrades or replacements for homes with existing systems and will have a wide variation in per-home costs based on the existing building characteristics. The AC system costs represent a three-ton split-system AC, without furnace or furnace fan. Window, room, and PTAC AC systems would likely have lower capital costs for replacements of existing units and potentially new installations. Cool roof costs are difficult to project on a per-home basis since multifamily buildings with many units share a common roof.

Table C-5. Estimated Capital Cost for Building Systems

Source: EIA Appliance Cost Database,[134] NEEP Mid-Atlantic TRM,[135] Guidehouse assumptions.

<table>
<tr><th>Input Parameter</th><th>Building Segment</th><th>Units</th><th>Estimated Capital Cost</th><th>Notes</th></tr>
<tr><td rowspan="2">AC System Capital Cost</td><td>Code</td><td>$/home</td><td>$3,650</td><td>Three-ton, coil only, without fan or furnace.</td></tr>
<tr><td>Above Code</td><td>$/home</td><td>$4,650</td><td>Mid-Atlantic TRM estimates approximately $300/ton incremental cost.</td></tr>
<tr><td rowspan="2">Envelope System Capital Cost</td><td>Code</td><td>$/home</td><td>$2,700</td><td>Upgrade to R-21 wall, R-49 ceiling, no air sealing.</td></tr>
<tr><td>Above Code</td><td>$/home</td><td>$3,490</td><td>Upgrade to R-27 wall, R-60 ceiling, with air sealing.</td></tr>
<tr><td rowspan="2">Roof System Capital Cost</td><td>Code</td><td>$/home</td><td colspan="2" rowspan="2">• The capital costs and impacts for upgrading roofing systems are typically applied across an entire building based on the amount of shared roof space, which poses challenges when assessing the impacts for individual housing units within larger multifamily buildings.
• It is assumed that the majority of cool roofs will be deployed through building codes when replacing an existing roof, which minimizes or negates any incremental cost.</td></tr>
<tr><td>Above Code</td><td>$/home</td></tr>
</table>

C.2. Modeling Results for Residential Cooling and Electricity Consumption

Table C-6, Table C-7, and Table C-8 provide the modeling results for residential cooling and electricity consumption across 2020–2050 under the Steady Progression and Current Policy scenarios, including assumptions for 91% and 100% AC adoption in NYC. The residential results include both single-family and multifamily homes. The Technology and Policy Solution scenario results show the impact for 50% adoption of high-efficiency AC systems.

Table C-6. Steady Progression Scenario with 91% AC Adoption—Residential (Single-Family and Multifamily)

Key Values	Units	2020	2025	2030	2035	2040	2045	2050
Annual Values—Residential (Single-Family and Multifamily)								
Cooling Degree Days (CDD)	Base 65F	1,502	1,545	1,589	1,632	1,676	1,719	1,763
Number of Homes	1,000 Units	3,198	3,242	3,288	3,334	3,380	3,428	3,476
Percentage of Homes with AC	%	91%	91%	91%	91%	91%	92%	92%
Cooling Elec Consumption per Home	kWh/yr.	1,147	1,105	1,066	1,034	1,021	1,009	1,019
Total Elec Consumption per Home	kWh/yr.	5375	5,266	5,207	5,156	5,127	5,098	5,091
Residential Utility Rate	$/kWh	$0.26	$0.29	$0.33	$0.37	$0.41	$0.45	$0.51
Cooling Elec Cost per Home	$/yr.	$303	$325	$350	$378	$417	$459	$517
Total Cooling Elec Consumption	GWh/yr.	3,338	3,255	3,176	3,115	3,125	3,134	3,213
Total Cooling Elec Cost	$MM/yr.	$881	$958	$1,042	$1,140	$1,275	$1,426	$1,630
Total Elec Consumption	GWh/yr.	16,859	16,756	16,862	16,990	17,192	17,396	17,673
Total Electricity Cost	$MM/yr.	$4,451	$4,932	$5,534	$6,217	$7,014	$7,913	$8,963
Five-Year Values (Costs Incurred Over Five-Year Increments)								
Total Cooling Operating Cost	$MM per 5 years	n/a	$4,790	$5,211	$5,699	$6,374	$7,128	$8,148
Total Capital Cost	$MM per 5 years	n/a	$5,011	$5,087	$5,164	$5,243	$5,322	$5,403
Total Cooling Related Costs	$MM per 5 years	n/a	$9,801	$10,298	$10,863	$11,616	$12,450	$13,552

Assumes current adoption of AC systems in NYC (91% of homes).

Table C-7. Current Policy Scenario with 91% AC Adoption—Residential (Single-Family and Multifamily)

Key Values	Units	2020	2025	2030	2035	2040	2045	2050
Annual Values—Residential (Single-Family and Multifamily)								
Cooling Degree Days (CDD)	Base 65F	1,502	1,545	1,589	1,632	1,676	1,719	1,763
Number of Homes	1,000 Units	3,198	3,242	3,288	3,334	3,380	3,428	3,476
Percentage of Homes with AC	%	91%	91%	91%	91%	91%	92%	92%
Cooling Elec Consumption per Home	kWh/yr.	1,147	1,105	1,066	1,034	1,021	1,009	1,019
Total Elec Consumption per Home	kWh/yr.	5,375	5,266	5,207	5,156	5,127	5,098	5,091
Residential Utility Rate	$/kWh	$0.26	$0.29	$0.33	$0.37	$0.41	$0.45	$0.51
Cooling Elec Cost per Home	$/yr.	$303	$325	$350	$378	$417	$459	$517
Total Cooling Elec Consumption	GWh/yr.	3,338	3,255	3,176	3,115	3,125	3,134	3,213
Total Cooling Elec Cost	$MM/yr	$881	$958	$1,042	$1,140	$1,275	$1,426	$1,630
Total Elec Consumption	GWh/yr	16,859	16,756	16,862	16,990	17,192	17,396	17,673
Total Electricity Cost	$MM/yr	$4,451	$4,932	$5,534	$6,217	$7,014	$7,913	$8,963
Five-Year Values (Costs Incurred Over Five-Year Increments)								
Total Cooling Operating Cost	$MM per 5 years	n/a	$4,790	$5,211	$5,699	$6,374	$7,128	$8,148
Total Capital Cost	$MM per 5 years	n/a	$5,011	$5,087	$5,164	$5,243	$5,322	$5,403
Total Cooling Related Costs	$MM per 5 years	n/a	$9,801	$10,298	$10,863	$11,616	$12,450	$13,552

Assumes current adoption of AC systems in NYC (91% of homes).

Table C-8. Current Policy Scenario with 100% AC Adoption—Residential (Single-Family and Multifamily)

Key Values	Units	2020	2025	2030	2035	2040	2045	2050
Annual Values—Residential (Single-Family and Multifamily)								
Cooling Degree Days (CDD)	Base 65F	1,502	1,545	1,589	1,632	1,676	1,719	1,763
Number of Homes	1,000 Units	3,198	3,242	3,288	3,334	3,380	3,428	3,476
Percentage of Homes with AC	%	100%	100%	100%	100%	100%	100%	100%
Cooling Elec Consumption per Home	kWh/yr.	1,147	1,097	1,051	1,014	1,003	992	1,002
Total Elec Consumption per Home	kWh/yr.	5,375	5,261	5,198	5,143	5,115	5,087	5,080
Residential Utility Rate	$/kWh	$0.26	$0.29	$0.33	$0.37	$0.41	$0.45	$0.51
Cooling Elec Cost per Home	$/yr.	$303	$323	$345	$371	$409	$451	$508
Total Cooling Elec Consumption	GWh/yr.	3,668	3,562	3,462	3,385	3,391	3,398	3,480
Total Cooling Elec Cost	$MM/yr.	$968	$1,048	$1,136	$1,238	$1,383	$1,545	$1,765
Total Elec Consumption	GWh/yr.	17,188	17,063	17,149	17,260	17,458	17,660	17,940
Total Electricity Cost	$MM/yr.	$4,538	$5,022	$5,628	$6,316	$7,122	$8,033	$9,098
Five-Year Values (Costs Incurred Over Five-Year Increments)								
Total Cooling Operating Cost	$MM per 5 years	n/a	$5,242	$5,681	$6,192	$6,917	$7,727	$8,824
Total Capital Cost	$MM per 5 years	n/a	$5,401	$5,477	$5,554	$5,633	$5,713	$5,794
Total Cooling Related Costs	$MM per 5 years	n/a	$10,643	$11,158	$11,747	$12,550	$13,440	$14,618

Assumes 100% of homes have AC systems (i.e., vulnerable residents also have AC systems)

Appendix D. Modeling Results for Equitable Cooling Strategies

Table D-1 outlines the key characteristics for the modeling scenarios to extend cooling access to vulnerable populations. Each scenario provides AC systems and other measures for the roughly 300,000 homes without cooling today. The initiatives were applied to all residents to estimate the overall citywide impacts and understand how activities for the majority of NYC's building stock will minimize the energy impacts of extending AC access to all residents. Tables D-2 through D-4 provide the modeling results for residential cooling and electricity consumption across 2020–2050 under the Targeted Cooling Relief, Expanded System-Wide Cooling, and Accelerated System-Wide Cooling scenarios.

Table D-1. Key Characteristics by Modeling Scenario

Source: Guidehouse analysis.

Key Characteristics by Modeling Scenario	Baseline/ Current Policy Scenario (Reference)	100% AC Saturation (Reference)	Targeted Cooling Relief Scenario	Expanded System-Wide Cooling Scenario	Accelerated System-Wide Cooling Scenario
Percentage of Homes with ACs*	91%	100%	100%	100%	100%
Percentage of Above Code AC	10%	10%	10%	25%	35%
Percentage of Above Code Envelope	5%	5%	5%	15%	25%
Cool Roof Deployment	Assumes current cool roof codes may eventually impact 50% of NYC roofs.				Modified cool roof codes impact 100% of NYC roofs
Incremental Weatherization Projects	n/a	n/a	30,000 per year (target 300,000 by 2030)	30,000 per year (target 300,000 by 2030)	30,000 per year (target 300,000 by 2030)
Incremental Cool Pavement Installations	n/a	n/a	n/a	15 million SF per year	30 million SF per year
Incremental Tree Planting/ Urban Greening	n/a	n/a	n/a	10,000 trees per year**	20,000 trees per year**
Cooling Centers***	n/a	n/a	Targeted improvements in the cooling center strategy for NYC by 2025.		
Community Solar***				Piloting community solar initiatives and rates by 2025 with targeted rollout in key neighborhoods over 2020–2050.	

Each scenario incorporates progressively more technology and policy measures.

*Approximately 3.2 million housing units in NYC, of which approximately 300,000 do not have cooling systems as of most recent data.

** Tree planting was found to have high cost and limited impact on building AC consumption, so Guidehouse also modeled the Expanded and Accelerated scenarios excluding tree programs.

*** cooling centers and community solar are supporting measures that can theoretically offset cooling electricity consumption and cost at the home level, but it is highly uncertain what impact these solutions may have.

Table D-2. Targeted Cooling Relief Scenario—Residential (Single-Family and Multifamily)

Key Values	Units	2020	2025	2030	2035	2040	2045	2050
Annual Values—Residential (Single-Family and Multifamily)								
Cooling Degree Days (CDD)	Base 65F	1,502	1,545	1,589	1,632	1,676	1,719	1,763
Number of Homes	1,000 Units	3,198	3,242	3,288	3,334	3,380	3,428	3,476
Percentage of Homes with AC	%	100%	100%	100%	100%	100%	100%	100%
Cooling Elec Consumption per Home	kWh/yr.	1,147	1,097	1,051	1,014	1,003	992	1,002
Total Elec Consumption per Home	kWh/yr.	5,375	5,261	5,198	5,143	5,115	5,087	5,080
Residential Utility Rate	$/kWh	$0.26	$0.29	$0.33	$0.37	$0.41	$0.45	$0.51
Cooling Elec Cost per Home	$/yr.	$303	$323	$345	$371	$409	$451	$508
Total Cooling Elec Consumption	GWh/yr.	3,668	3,531	3,431	3,354	3,360	3,367	3,449
Total Cooling Elec Cost	$MM/yr.	$968	$1,039	$1,126	$1,227	$1,371	$1,531	$1,749
Total Elec Consumption	GWh/yr.	17,188	17,032	17,118	17,229	17,427	17,629	17,909
Total Electricity Cost	$MM/yr.	$4,538	$5,013	$5,618	$6,304	$7,110	$8,019	$9,082
Five-Year Values (Costs Incurred Over Five-Year Increments)								
Total Cooling Operating Cost	$MM per 5 years	n/a	$5,196	$5,630	$6,136	$6,854	$7,657	$8,745
Total Capital Cost	$MM per 5 years	n/a	$5,461	$5,537	$5,614	$5,692	$5,772	$5,853
Total Cooling Related Costs	$MM per 5 years	n/a	$10,657	$11,166	$11,749	$12,546	$13,429	$14,598

Table D-3. Expanded System-Wide Cooling Scenario—Residential (Single-Family and Multifamily)

Key Values	Units	2020	2025	2030	2035	2040	2045	2050
Annual Values—Residential (Single-Family and Multifamily)								
Cooling Degree Days (CDD)	Base 65F	1,502	1,545	1,589	1,632	1,676	1,719	1,763
Number of Homes	1,000 Units	3,198	3,242	3,288	3,334	3,380	3,428	3,476
Percentage of Homes with AC	%	100%	100%	100%	100%	100%	100%	100%
Cooling Elec Consumption per Home	kWh/yr.	1,147	1,087	1,033	989	977	965	975
Total Elec Consumption per Home	kWh/yr.	5,375	5,251	5,179	5,118	5,089	5,060	5,053
Residential Utility Rate	$/kWh	$0.26	$0.29	$0.33	$0.37	$0.41	$0.45	$0.51
Cooling Elec Cost per Home	$/yr.	$303	$320	$339	$362	$399	$439	$494
Total Cooling Elec Consumption	GWh/yr.	3,668	3,485	3,357	3,257	3,260	3,262	3,342
Total Cooling Elec Cost	$MM/yr.	$968	$1,026	$1,102	$1,192	$1,330	$1,484	$1,695
Total Elec Consumption	GWh/yr.	17,188	16,986	17,043	17,132	17,327	17,524	17,802
Total Electricity Cost	$MM/yr.	$4,538	$5,000	$5,593	$6,269	$7,069	$7,971	$9,028
Five-Year Values (Costs Incurred Over Five-Year Increments)								
Total Cooling Operating Cost	$MM per 5 years	n/a	$5,129	$5,508	$5,959	$6,649	$7,419	$8,474
Total Capital Cost	$MM per 5 years	n/a	$5,792	$5,871	$5,951	$6,032	$6,115	$6,199
Total Cooling Related Costs	$MM per 5 years	n/a	$10,921	$11,378	$11,910	$12,681	$13,534	$14,672

Tables D-4 through D-6 summarize the Incremental Operating Cost, Capital Cost, and Total Cost (Operating and Capital to deliver equitable cooling to all NYC residents including capital and operating cost impacts for a combination of AC systems, energy efficiency measures, and UHI initiatives. These scenarios are compared against the reference of Current Policy with 91% AC adoption (Table C-7).

Table D-4. Incremental Operating Cost to Deliver Equitable Cooling, Annual Values 2020–2050

Key Values	Units	2020–2025	2025–2030	2030–2035	2035–2040	2040–2045	2045–2050
Current Policy, 100% AC Adoption	$MM per year	$90	$94	$99	$109	$120	$135
Targeted Cooling Relief	$MM per year	$81	$84	$87	$96	$106	$119
Expanded System-Wide Cooling	$MM per year	$68	$59	$52	$55	$58	$65
Expanded System-Wide Cooling w/o Trees	$MM per year	$68	$60	$52	$55	$59	$65
Accelerated System-Wide Cooling	$MM per year	$47	$20	-$7	-$23	-$42	-$49
Accelerated System-Wide Cooling w/o Trees	$MM per year	$47	$21	-$7	-$22	-$41	-$49

Table D-5. Incremental Capital Cost to Deliver Equitable Cooling, Annual Values 2020–2050

Key Values	Units	2020–2025	2025–2030	2030–2035	2035–2040	2040–2045	2045–2050
Current Policy, 100% AC Adoption	$MM per year	$78	$78	$78	$78	$78	$78
Targeted Cooling Relief	$MM per year	$90	$90	$90	$90	$90	$90
Expanded System-Wide Cooling	$MM per year	$156	$157	$157	$158	$158	$159
Expanded System-Wide Cooling w/o Trees	$MM per year	$129	$130	$130	$131	$131	$132
Accelerated System-Wide Cooling	$MM per year	$211	$212	$213	$214	$215	$216
Accelerated System-Wide Cooling w/o Trees	$MM per year	$157	$158	$159	$160	$161	$162

Table D-6. Total Incremental Cost (Capital & Operating) to Deliver Equitable Cooling, Annual Values 2020–2050

Key Values	Units	2020–2025	2025–2030	2030–2035	2035–2040	2040–2045	2045–2050
Current Policy, 100% AC Adoption	$MM per year	$168	$172	$177	$187	$198	$213
Targeted Cooling Relief	$MM per year	$171	$174	$177	$186	$196	$209
Expanded System-Wide Cooling	$MM per year	$224	$216	$209	$213	$217	$224
Expanded System-Wide Cooling w/o Trees	$MM per year	$197	$189	$182	$186	$190	$197
Accelerated System-Wide Cooling	$MM per year	$259	$232	$206	$191	$173	$167
Accelerated System-Wide Cooling w/o Trees	$MM per year	$205	$179	$153	$138	$120	$113

Appendix E. Additional Technology and Policy Measures

In addition to the prioritized, recommended technology and policy solutions detailed in sections 5–7, Guidehouse has included deprioritized but potentially useful technology and policy measures. Some details that contribute to their unsuitability include timeline, intensive costs, and lack of research of the measure's feasibility in the climate and cityscape of NYC. Despite these drawbacks, the team feels that these resources may be helpful in the future should conditions change.

E.1 Additional Measure List

- Comprehensive Heat Plan:
  - Heat health warning system
  - Pre-summer risk identification
  - Preventative messaging
  - Realtime health surveillance
  - Expand beabuddy nyc
  - Climate risk training
  - Extreme heat evacuation plan
  - Increase awareness of using fans/ac during heat
- Water Installations
  - Pavement watering
- Cooling Oases
- Green Roofs
  - Extensive green roofs
  - Intensive green roofs

E.2. Comprehensive Heat Plan

E.2.1 Measure Summary

Comprehensive Heat Plans (CHP) are national and regional scale efforts to orchestrate short, mid-, and long-term strategies across a variety of agencies in preparation for, and reaction to, extreme heat emergencies, particularly to protect vulnerable populations. Components vary, but may include alert system protocols, pre-summer identification of and contact with high-risk individuals, preventative health and safety messaging, education and awareness campaigns on the risk of heat-induced illness and benefits of cooling, training of home health providers, emergency evacuation plans and real time health surveillance technologies and protocols.

E.2.2 Rationale for De-prioritization

While CHPs can play a key role in a jurisdiction's resiliency, adaptation and emergency preparedness planning around extreme heat events and climate change, they do not fulfill the primary goal of this study which is to provide equitable access to cooling. CHPs help avoid and reduce heat-related mortality and illness, but do not deliver more equitable access to cooling. Rather, they are a set of preventative and during-crisis interventions intended to mitigate suffering and loss of life. Even if equitable access to safe in-home cooling was achieved for all NYC residents, this package of measures would still benefit the most vulnerable who, due to language, age, income, physical, mental, or other constraints and barriers, might not utilize cooling optimally and therefore still face increased risk of heat-related illness or death.

E.2.3 Technology and Policy Sub-components

- Heat Health Warning Systems (HHWS) are mechanisms that communicate extreme heat events to residents and emergency organizations. Though most relevant to extreme heat for this project, these warning systems can also be used in the case of extreme cold, heavy precipitation, and other emergency events. HHWSs require collaboration with meteorological services, a threshold to determine when a warning should be triggered, a mode of communication, and effective messaging on the risks associated with the event. Successful HHWSs are timely, local, accurate, and catered to the characteristics of the target population.
- Pre-summer risk identification is a preventative approach that identifies individuals who have a high risk of death, illness, or suffering during extreme heat events. By pinpointing who the high-risk individuals are before the summer, community organizations, doctors, and care providers are able to advise those individuals before any serious consequences occur and follow up with them throughout the season as needed. Pre-summer risk identification helps mitigate unexpected heat-related health emergencies by determining those who are most at risk and preparing them ahead of time.
- Preventative messaging is a proactive approach to increasing awareness of heat risk through mass communication systems. Unlike HHWSs, preventative messaging seeks to inform vulnerable individuals of the risks associated with and strategies to combat extreme heat events before they occur.
- Realtime health surveillance is a strategy that detects and tracks the early impacts of extreme heat events to appropriately formulate and modify interventions. Realtime health surveillance leverages real-time data on mortality, emergency calls, emergency room visits, hotline calls, and doctors' records and must be available within 1–2 days to be impactful.

- Climate risk training equips home health aides, family members, care providers, and interest/community organizations with the tools and knowledge to understand risks posed by extreme heat to help prevent health emergencies. Training may include recognizing early signs of heat stroke, how to cool down affected individuals, and how to transport medication at appropriate temperatures.
- Extreme heat evacuation plans provide a blueprint for evacuating extremely vulnerable individuals to cooling centers during lengthy heat waves. Accurate and timely identification, communication, and transportation are key for these plans to be effective.
- Fan/AC use awareness campaigns use public marketing to broadcast the importance of using air conditioning and fans during extreme heat events. Often a component of preventative messaging, these awareness campaigns serve to provide a concrete strategy for preventing health issues caused by extreme heat. However, vulnerable residents may not be able to afford operating their fans and AC units during these events, thus indicating that another form of intervention needs to be employed to ensure that these types of campaigns are effective at reaching the most at-risk communities.

E.2.4 Related Existing Policy

BaB NYC is a program that facilitates partnership between community members and individuals who are the most vulnerable to urban heat (e.g., the elderly). This program was introduced in 2017 as part of the Cool Neighborhoods NYC program through Mayor Bill DeBlasio's Office for Sustainability. This is a two-year pilot involving many stakeholders including community groups to promote community cohesion. The program develops and tests strategies for protecting at-risk NYC residents in the South Bronx, Central Brooklyn and Northern Manhattan from heat-related health impacts. In addition to other services the BaB program creates inventories of at-risk individuals in order to conduct outreach, education and intervention both before and in the case of extreme heat events in the city.

E.2.5 Non-Energy Impacts

Non-energy Benefits (NEB) include improved community cohesion, reduced risk of heat-related mortality and illness, reduced strain on emergency rooms and emergency responders, reduced hospitalization and medical intervention costs, improved societal climate change resilience.

E.2.6 Barriers to Implementation, Access, or Equity

A key barrier to implementing CHPs involves identifying and communicating with the vulnerable populations that these measures hope to address. The target population for CHPs can often be difficult to reach due to obstacles concerning language, age, income, and physical or mental impairment. Conducting assessments within these population is an essential step in effectively rolling out a CHP but can be stalled when met with apprehension or misunderstanding by the community. Some of the most vulnerable individuals also lack access to a television or internet connection, indicating that another method of communication (i.e., phone call or text) would be required to adequately reach target audiences.

E.2.7 Additional Considerations

Because communication is an essential component of CHPs, an understanding of existing public beliefs and available communication channels is imperative for messaging to be successful. Coordination with news organizations, trusted community members, and meteorological services help set the foundation for effective messaging. Active communication that invites dialogue, rather than passive messaging that takes a one-size-fits-all approach, are much more impactful when addressing vulnerable communities through CHPs.

E.2.8 Proven Success Examples

From 2005 to 2007, public health experts, meteorologists, and other stakeholders were consulted to inform EuroHEAT, a project that assessed health impacts and provided solutions in response to extreme heat. Heat and health action plans were created in response to this project that included coordinated responses of institutions, alert systems, strategies to reduce heat exposure, improved urban planning, and real time surveillance among other measures. An essential outcome of this work involved annually evaluating the successes and failures of the plans in order to improve them as data came in.

Other European examples include a Catalonian initiative that collaborates with the Red Cross to transport people to cooling centers, a Roman program that uses GPS to make contact with identified vulnerable patients in advance of heat waves and during follow-up, and an English initiative that asks individuals to sign up to be contacted and with provided information and help during a heat wave.

In 2017, New York City launched an extreme heat awareness campaign focused on older individuals as well training modules for home health aides. The campaign noted that it was challenging to identify and reach some vulnerable individuals, emphasizing the need for a systematic way to identify, reach, and affect the elderly and the physically and mentally impaired. The training modules provided targeted education to medical professionals in contact with vulnerable populations to mitigate the heat-related health emergencies.

E.3. Water Installations

E.3.1 Measure Description

Water installations reduce urban heat island intensity through the use of evaporative cooling. Effective in low humidity environments, evaporative cooling works by leveraging the cooling effect caused by evaporating water whereby surrounding air is directly or indirectly cooled. Because water has a greater specific heat capacity than physical material and takes longer to warm up, water installations are able to further mitigate urban heat islands. Water installations include fountains, pools, misters, ponds, and pavement watering, which uses water spraying systems to reduce pavement temperatures.

E.3.2 Rationale for De-prioritization

Because NYC has a humid summer climate, water installations are not an effective form of cooling and would instead lead to feelings of increased humidity. Furthermore, the high-water usage, energy consumption, and expenses required to build and operate these installations render this measure less cost-effective and more harmful to the environment than other measures. Water installations also do not provide equitable access to cooling in people's homes, a priority within this study.

E.3.3 Related Existing Policy

Although there is no existing policy related to water installations for cooling within New York City, there are initiatives related to stormwater management (specifically the Green Infrastructure Grant Program) where installations like rain gardens and retention ponds provide ancillary benefits of evaporative cooling.

E.3.4 Non-Energy Impacts

Non-energy impacts of water installations include stormwater management, new habitat for wildlife, and increased water and energy consumption along with the associated greenhouse gas emissions. Pavement watering can also reduce surface albedo and reflection of UV radiation, leading to increased pedestrian comfort.

E.3.5 Barriers to Implementation, Access, or Equity

A major barrier to implementing water installations in NYC concerns the large water footprint required to enable it at scale. Attached to the water footprint is the high cost of building, transporting, and operating installations. These factors coupled with the unsuitability of NYC's climate present challenges to using this measure to provide equitable access to cooling.

E.3.6 Additional Considerations

There are no additional considerations for this measure.

E.3.7 Proven Success Examples

A study in Paris found that pavement watering was able to achieve cooling effects at an average of 0.5°C, with maximums of 1–2°C seen during the day.

A study in Suzhou, China analyzed the cooling effects of the nearby Suzhou Bay and found that cooling effects were experienced up to 800 meters away from the water source and up to a maximum of 3°C.

E.4. Cooling Islands

E.4.1. Measure Description

Cooling islands are outdoor structures with a canopy for shading and seating connected to a district cooling network. These islands are modular, reusable, and can be built in varying shapes and sizes. They can be built anywhere in a city where a district cooling connection is available and create environments where perceived temperatures are 5°C lower than ambient air. As free, public structures, they allow individuals to cool off during the day, or night, as needed.

E.4.2. Rationale for De-prioritization

While cooling islands present a free public option for cooling, the large investment in district cooling infrastructure required to enable their use led to their de-prioritization. These islands have been piloted only in Paris where a robust district cooling network already exists; this is not the case for NYC. Furthermore, instead of accomplishing the priority of equitable access to cooling within people's homes, cooling islands provide temporary relief from heat within communities.

E.4.3. Technology and Policy Sub-components

District cooling is an underground network that generates chilled water at a plant, then distributes the water to connected buildings as a form of cooling. Water in the system is reused and rechilled (via steam or refrigerants) before making its way through the network again. District cooling is often present on campuses, such as universities and hospitals, but can also be seen at the city scale. District cooling can be up to 50% more energy efficient and generate 50% less CO_2 emissions than traditional cooling units.

E.4.4. Related Existing Policy

Although there is no direct policy related to cooling islands and district cooling, Con Edison operates a district steam system in Manhattan that provides heating and cooling to over 3 million New Yorkers from downtown up to 96th street.

E.4.5. Non-energy Impacts

District cooling can generate 50% less emissions, consume 65% less water, and emit 90% less refrigerants than traditional AC systems. Cooling islands beautify neighborhoods and provide free spaces for public and social interactions.

E.4.6. Barriers to Implementation, Access, or Equity

The need for district cooling infrastructure presents a major challenge for implementing cooling islands. Although district cooling itself has multiple benefits, it is a costly, long-term endeavor that does not address immediate cooling needs. Additionally, with stay-at-home orders and social distancing in place due to the coronavirus, cooling islands would not be as relevant or utilized should a similar situation arise in the future.

E.4.7. Additional Considerations

Effective communication is key to ensuring that cooling island benefits are recognized. By informing users what the island is, how it works, and why it differs from traditional outdoor seating structures, cooling islands could be effective in reaching target audiences and being highly utilized.

Considerations for where the islands are located is also important. Areas with high traffic (e.g., near an office district or train station), high need, and limitations around planting greenery are good candidates for a cooling island site.

E.4.8. Proven Success

In the summer of 2018, energy company ENGIE piloted cooling islands in three locations across Paris. They reported generally positive feedback from users and measured temperature differences of 5°C on the islands when compared to ambient air temperature. Incorporating feedback from the previous year (regarding comfort, education, and siting), in 2019 four new cooling islands were set up at other locales in Paris leveraging different materials and architectures. An evaluation of the 2019 cooling islands has yet to be provided.

E.5. Green Roofs

E.5.1. Measure Description

Green roofs are vegetative systems located on building rooftops that include a waterproof membrane, drainage layer, optional irrigation system, growing medium, and vegetation. Because of the greenery and evaporative cooling properties associated with it, green roofs can provide shade, mitigate urban heat island effect, and provide cooling to the internal structure of their building. In addition to reducing building energy usage by 0.7%, studies have found that green roofs can lower indoor temperatures by 4°F (2°C) during the day and increase indoor temperatures by 0.5°F (0.3°C) at night compared to conventional roofs.

E.5.2. Rationale for De-prioritization

While green roofs reduce urban heat island effect and provide cooling at the building level, they are also less cost-effective and require more maintenance than cool/reflective roofs. The increased complexity, cost, and maintenance of green roofs led to the measure's de-prioritization in favor of cool roofs which occurs at the same unit of intervention and provides similar benefits.

E.5.3. Technology and Policy Sub-components

- Extensive green roofs use shallow-rooted, drought-resistant plants within a thin planting medium (1–4 inches). These systems are simple, lightweight (typically 15–50 pounds per square feet), and low maintenance. Due to these factors, extensive green roofs are typically cheaper to install than intensive green roofs.

- Intensive green roofs are more complex structures that can support a variety of different plants, including trees, flowers, grasses, shrubs, and food crops. Weighing in an average range between 80–100 pounds per square feet, intensive roofs require a deeper planting medium as well as engineering to ensure that roofs can bear the heavier load. While intensive roofs are more expensive and require more maintenance than extensive roofs, they also provide additional benefits including potential for community gardening, outdoor space for building residents, and increased aesthetic value.

E.5.4. Related Existing Policy

In 2016, there were approximately 730 buildings (60 acres of rooftop) with green roofs, which represented less than 0.1% of NYC's building stock. Passed in 2019, the Climate Mobilization Act and Local Laws 92 and 94 together require solar panels or green roofs for all new construction and major renovations. Incentives are also available in the form of subsidies through NYC's Green Infrastructure Grant Program and a tax abatement of up to $15/square feet from NYS.

E.5.5. Non-energy Impacts

The non-energy impacts of green roofs are extensive, including potential food production, aesthetic value, improved air quality, increased animal habitat, stormwater management, and reduced lifetime building costs through protecting against UV degradation and extending the life of roof waterproof membranes by up to 40 years. Additionally, although green roofs have the potential to reduce stormwater runoff by 50–90%, they can also discharge nutrients and chemicals used to support the plants when runoff does escape the roof.

E.5.6. Barriers to Implementation, Access, or Equity

Key to the efficacy of green roofs are the amount of space available to implement these systems and the structural suitability of the rooftops. The more space that is allotted to green roofs, the more effective they will be. However, not all roofs in NYC can easily be adapted into green roofs and although current policies require them for new buildings and large retrofits, older buildings that often house vulnerable populations have the potential to be left behind in the absence of other interventions.

E.5.7. Additional Considerations

In addition to the size of the roof itself, the size of the building affects the magnitude of cooling benefits received inside the structure. While a skyscraper with a green roof could see cooling demand reductions as little as 1%, a single-story building with the same roof area could see as much as a 20% reduction. Further, because green roofs can be installed on public and private buildings, different incentives and policy mechanisms could be considered to incentivize the installation of green roofs across sectors and industries.

E.5.8. Proven Success Examples

In Queens, a study found that in comparison to black roofs, green roofs had 34% lower winter heat loss rates and 84% summer heat gain rates. In addition to NYC, various cities across the world have mandated green roofs with varying levels of stringency. Toronto, Copenhagen, Córdoba, and San Francisco are some of the few cities that have passed laws requiring green roof installations. As of 2019, Toronto has seen the installation of 640 green roofs (approximately 5 million square feet) since their law's passing in 2009. Research in Toronto has shown a reduction in surface air temperature of 2°C achieved when green roofs with irrigation were implemented on 50% of building surfaces.

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