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REPORT

SUMMER IN THE CITY:
IMPROVING COMMUNITY RESILIENCE TO EXTREME SUMMERTIME HEAT IN NORTHERN MANHATTAN

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DEDICATION

We dedicate this report to the late Cecil Corbin-Mark, Deputy Director and Director of Policy Initiatives at WE ACT for Environmental Justice. He spent his life fighting for environmental and climate justice, and was the driving force behind numerous legislative wins in New York City and New York State. He was also instrumental in developing this report, as well as the study upon which it is based. He passed away on October 15, 2020 at the age of 51. His work lives on.

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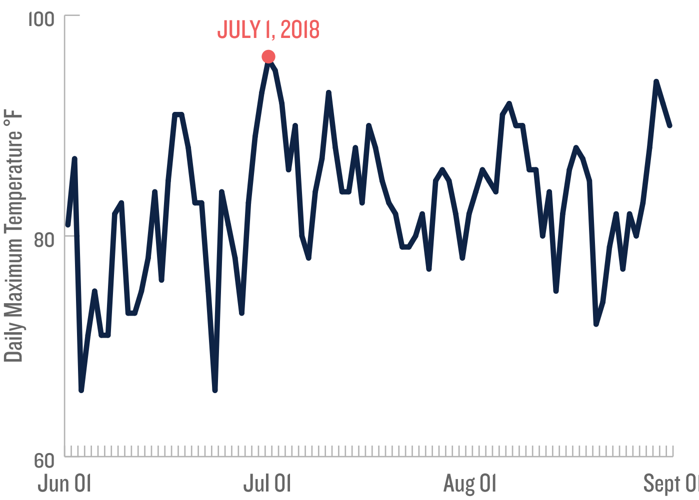
Introduction

New York City faced a brutally hot summer in 2018 (Figure 1). On July 1, the hottest day of the year, the Central Park weather station registered a maximum temperature of 96 °F. Between June and August of that year, there were three separate instances when the mercury rose above 90 °F three or more days in a row. A year later, in July of 2019, the Central Park weather station recorded 10 days with temperatures of 90 °F and over, four more than July of 2018. One of those July 2019 90 °F plus days witnessed more than 70,000 residents in New York City suffering in the extreme heat without electrical power because of a Con Edison equipment failure. It was likely even hotter in other areas of the city that lack the temperature-reducing vegetation of Central Park.[1]

FIGURE 1: JULY 1 MARKED THE HIGHEST MAXIMUM TEMPERATURE IN CENTRAL PARK IN 2018[2]



Because of climate change, extreme heat events like the episodes of July 2018 and 2019 are expected to increase in intensity, duration, and frequency.[3] These extreme heat events are dangerous to human health, especially among the most vulnerable populations such as the elderly, and among those with low incomes or preexisting medical conditions. In fact, extreme heat in New York City is often deadly: between 2000 and 2012, an average of 13 people died each year from extreme heat.[4]

Environmental justice communities and others on the front lines of climate impacts have long advocated for equity-focused solutions to the climate and health crisis. Understanding how vulnerable populations experience extreme heat—as well as devising equitable solutions that prioritize the well-being of those communities—requires meaningfully engaging with the concerns of impacted communities.

In New York City, NRDC has a long-standing partnership with WE ACT for Environmental Justice, an organization that advocates for communities in Northern Manhattan. Northern Manhattan encompasses 8.11 square miles and is composed of five distinct neighborhoods—West, Central, and East Harlem; Washington Heights; and Inwood—all of which are on the front lines of the climate crisis and challenged by a myriad of public health threats. NRDC and WE ACT's collaborative research is focused on mapping the people and places most vulnerable to extreme summertime heat in Northern Manhattan and understanding how people experience and cope with the hottest days in the summer.

In this report, we provide an overview of current and projected extreme heat impacts due to climate change in New York City; we look at how exposure to extreme summertime heat is distributed unevenly throughout the city; and we discuss the health burdens extreme heat imposes on environmental justice communities. We also report the findings of two studies focused on extreme summertime heat vulnerability in Northern Manhattan. In the first, quantitative study, we combined census data on race, poverty, age, and other markers of socioeconomic status with satellite data on the locations of trees and heat-absorbing surfaces in the city to map the demographics of those populations most vulnerable to extreme heat. In the second, qualitative study, we surveyed residents of Northern Manhattan on their recent experiences with extreme heat, including their perceptions of health risks associated with heat waves and urban heat islands.

Finally, we provide policy recommendations that reflect the concerns and experiences of those Northern Manhattan neighborhoods most affected by extreme heat. We hope that the policy recommendations presented here help motivate residents of impacted communities as well as policymakers in New York State and New York City to develop equitable solutions to the climate change crisis.

ENVIRONMENTAL JUSTICE COMMUNITIES

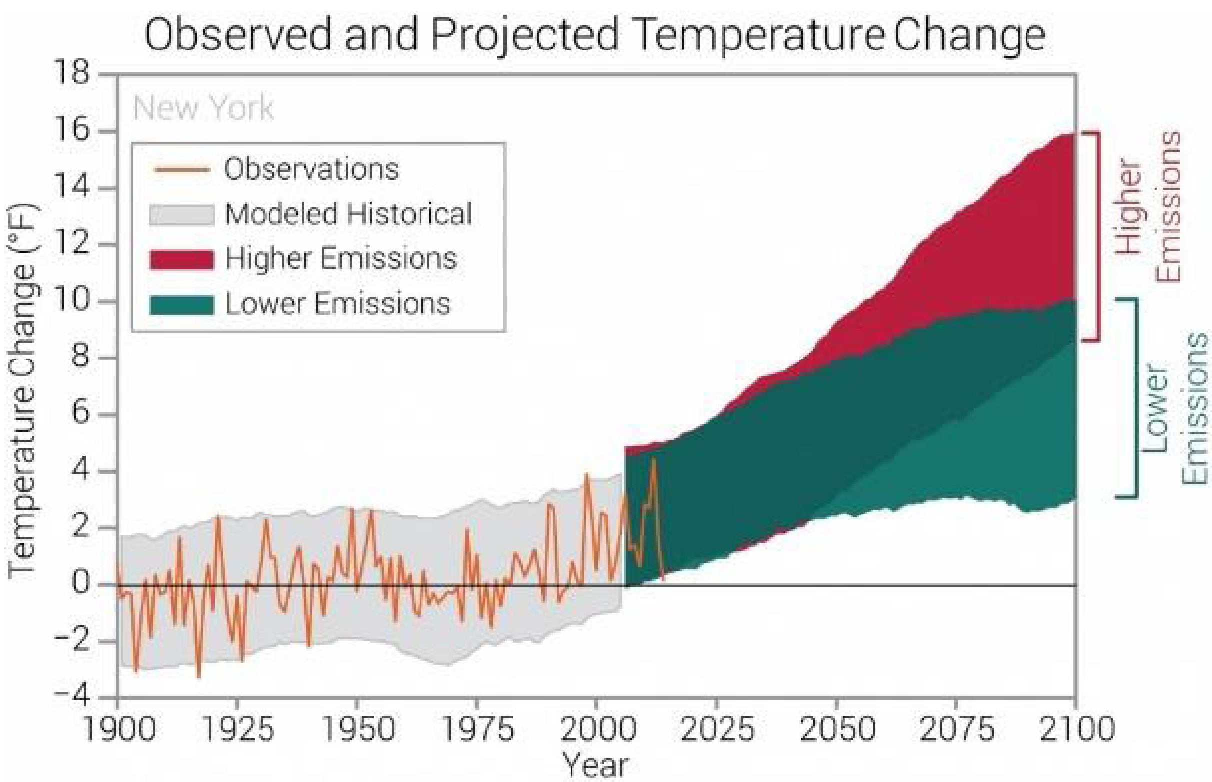
Environmental justice communities are those communities where a majority of the population are people of color, Indigenous peoples, and/or low-income persons who are overburdened with environmental hazards that jeopardize their health and livelihoods. Many environmental justice communities have long endured poverty, racial discrimination, residential redlining, or forced displacement, and those histories shape today's environmental injustices in New York City.

How is Climate Change Impacting New York State and New York City?

Average temperatures in New York State have increased by approximately 2 °F since the start of the 20th century (Figure 2).[5] Since 2000, statewide annual average temperatures have been higher than during any other historical period. Although the annual number of very hot summer days (with maximum temperatures above 95 °F) has actually been below the historical average in recent years, the number of warm nights (with lows above 70 °F) has increased.[6] Meanwhile, since 1900, New York City has warmed by 4.4 °F, more than double the amount of statewide warming.[7] Scientists warn that we must reduce global carbon emissions by 40 percent by the 2030s if we are to avoid catastrophic consequences.[8] However, even if we achieve drastic carbon emissions reductions, the warming that has already occurred will lead to more frequent extreme heat events. Climate models predict that even under the best emissions scenarios, by 2050 New York City could experience between four and seven heat waves each year, compared with an average of two annual heat waves between 1971 and 2000.[9]

Temperature increases are projected to significantly impact human health in New York City and the greater metropolitan area. Under a high-emissions scenario characterized by rapid human population growth, relatively little concern for the environment, and a lack of aggressive carbon pollution reductions, annual premature deaths due to extreme heat in the New York metropolitan area could increase by 83 percent by the 2050s relative to the 1990s.[10] This estimate could be reduced by 57 percent if New York City took measures, such as increased use of AC, heat alerts, and cooling centers, to adapt to the heat and protect the population.

FIGURE 2: OBSERVED AND PROJECTED TEMPERATURE CHANGE IN THE STATE OF NEW YORK. EMISSIONS SCENARIOS REFER TO REPRESENTATIVE CONCENTRATION PATHWAYS 4.5 (LOWER EMISSIONS) AND 8.5 (HIGHER EMISSIONS)[11]



URBAN HEAT ISLANDS, HEAT-HEALTH VULNERABILITY & THE COVID-19 PANDEMIC

Due to the COVID-19 pandemic, people were asked to stay at home as much as possible to prevent further spread of the virus. But while the stay-at-home directive protects against viral transmission, it also presented urgent new complications for communities of color and residents of low-income communities living in urban heat islands.

Data that emerged about the pandemic's toll in New York City showed that there is a striking overrepresentation of Black/African American and Latino/Latina residents among the most vulnerable to both contracting the virus and experiencing severe cases of it. Moreover, these communities endured disproportionately high COVID-19 mortality rates, due in part to institutional and systemic racism and injustices such as redlining, lack of equitable access to health care, a large racial wealth gap, and other social inequities tied to class that have left many with underlying health conditions. In New York City, for example, Black/African American people accounted for 29 percent of COVID-19 deaths recorded as of April 24, 2020, though they make up less than 25 percent of the city's population.[12] Indeed, Black/African American, Latino/Latina, and other communities of color have been experiencing a syndemic (that is, two or more concurrent epidemics) of COVID, climate, and economic, and racial impacts.[13]

Black/African American residents also accounted for nearly half of New York City's recorded heat-related fatalities from 2000 to 2012. Many of those especially vulnerable to contracting lethal illnesses like COVID-19 are also heat-vulnerable.[14] This includes older adults, people with existing lung, heart, or pre-existing diseases, and people living in poverty, among others. Furthermore, COVID-19 death rates are significantly higher in areas with even slightly higher levels of air pollution, where many communities of color are located.[15]

Policy choices play a significant role in determining which people are least protected from both the coronavirus pandemic and extreme heat. Given the data on morbidity and mortality to both threats in the most vulnerable communities, policies must be changed. WE ACT for Environmental Justice's mission is to build healthy communities by organizing communities of color to change environmental and environmental health policies and practices. To that end, WE ACT has launched a campaign—at both the federal and the state levels—to extend the Low-Income Home Energy Assistance Program (LIHEAP) so that it covers the purchase, installation, and operation of household air conditioners. Climate change–fueled extreme heat episodes intensify the need for lifesaving home cooling measures, triggering extra household expenses that many low-income families cannot afford.[16]

At the city level, WE ACT is working with the New York City Mayor's Office, the New York City Department of Health and Mental Hygiene (NYC DOHMH), other non-profit organizations, and New York City Council members to come up with solutions that will provide communities with cooling access, whether it be at home or in public spaces. WE ACT is also working at the state level to pass the Energy Efficiency Equity and Jobs Act, legislation designed to help more residents of communities of color and low-income communities benefit from increased energy efficiency measures to reduce their energy expenses.[17] The Energy Efficiency Equity and Jobs Act has passed the New York State Senate but not the State Assembly yet. WE ACT will continue working with the New York Energy Democracy Alliance and policy experts to get it passed in the next legislative session. With more measures in place, operating an AC unit to prevent heat-related morbidity or mortality would not result in greater financial burdens related to energy costs.

IN NEW YORK CITY, THE URBAN HEAT ISLAND INCREASES DISPARITIES IN HEAT-RELATED HEALTH RISKS

Temperatures are higher in dense cities—a phenomenon called the urban heat island—because the thermal signature of cities resembles an "island" of heat within a cooler "sea" of surrounding rural areas (Figure 3). The New York City urban heat island magnifies heat-related health threats in New York City, and this threat will only grow as climate change intensifies.

However, even within a city, temperatures can vary widely due to the variety of building materials that make up the horizontal and vertical surfaces of urban environments, such as the concrete, glass, asphalt, soil, and greenery of roadways, railyards, buildings, sidewalks, and parks. These surfaces absorb solar energy during the day and emit it back into the atmosphere at night, but they do so at different rates. Picture yourself standing on a patch of grass under a red maple tree in Central Park during a summer day. Now imagine that patch has been replaced with asphalt and there's not a tree in sight. The average person will feel a difference in temperature between the asphalt and the park—which is how people experience the urban heat island. Temperatures are not uniformly distributed throughout the city, meaning that people in different neighborhoods experience hot days very differently. In some neighborhoods the prevalence of heat-absorbing surfaces including rails, concrete, and asphalt can create a hot spot of high surface temperatures. For example, in the Inwood neighborhood, the area near the train yard at 207th Street had the highest surface temperature of Northern Manhattan between 2007 and 2011 (Figure 4). In contrast, green spaces like the St. Nicholas and Morningside parks in West Harlem and the Marcus Garvey and Thomas Jefferson parks in East Harlem have a cooling effect, creating an appropriately named "park cool island." Exposure to high temperatures thus varies considerably according to land surfaces within the city.

FIGURE 3: TEMPERATURES VARY WIDELY BETWEEN URBAN AND RURAL AREAS DUE TO THE URBAN HEAT ISLAND EFFECT[18]

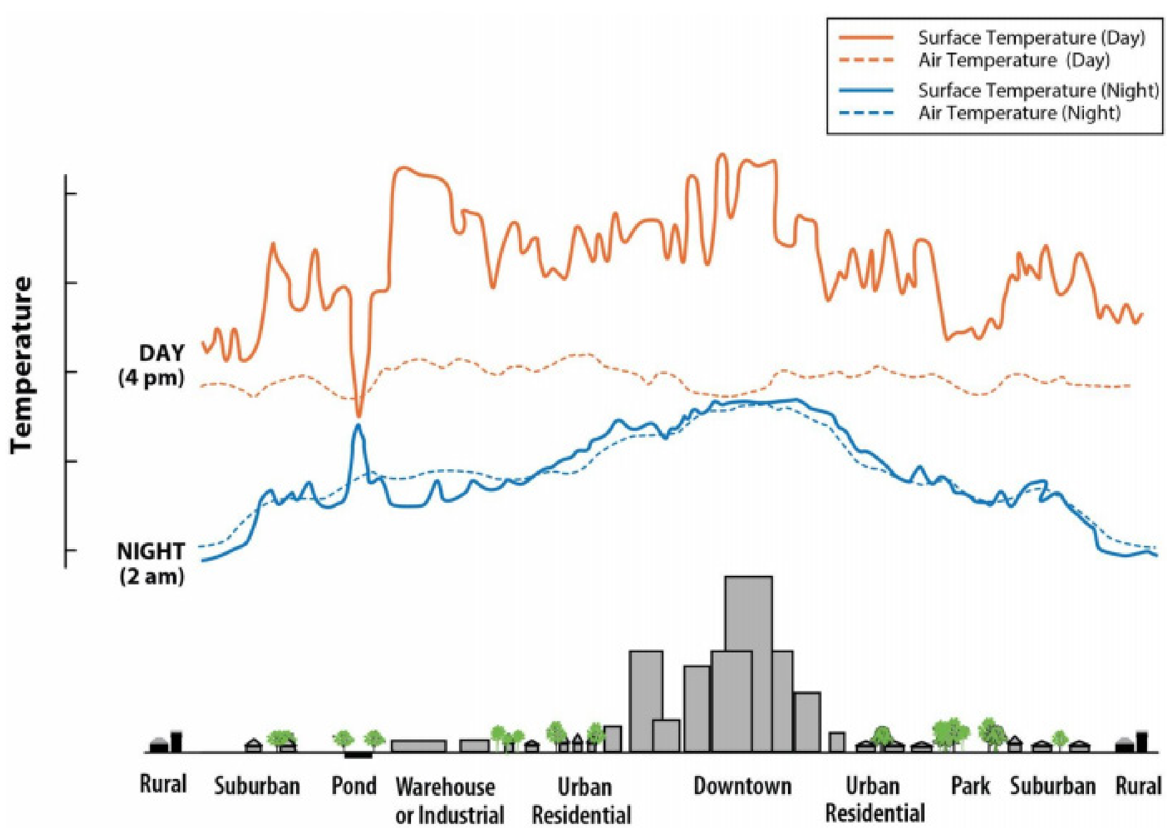
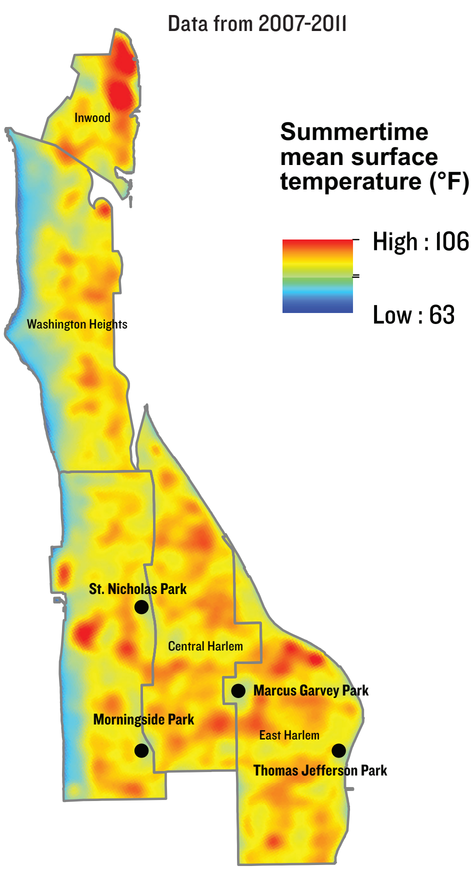


FIGURE 4: AVERAGE SUMMERTIME SURFACE TEMPERATURES SHOW DIFFERENCES IN URBAN HEAT ISLAND INTENSITY IN NORTHERN MANHATTAN

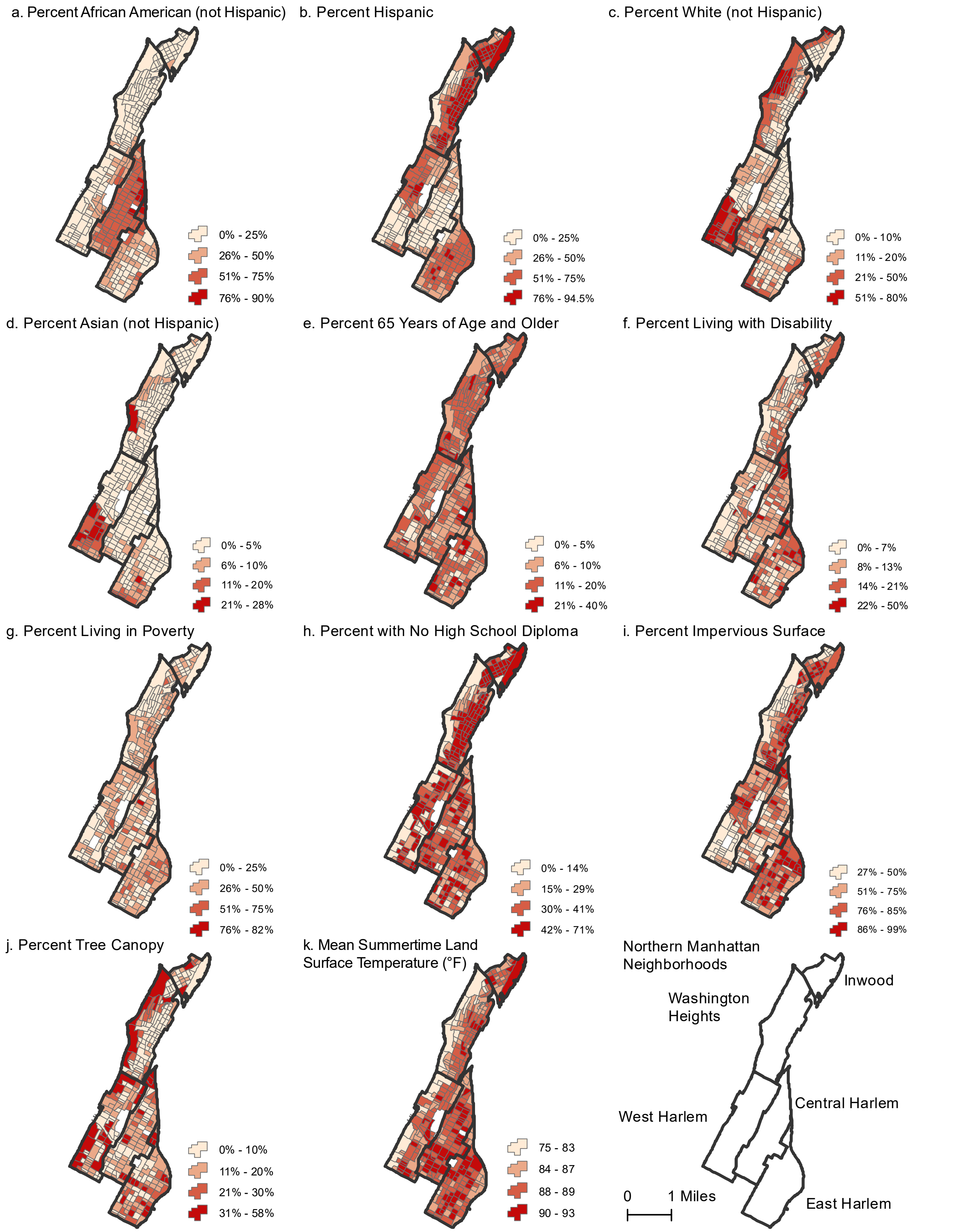


HEAT DISPROPORTIONATELY IMPACTS CERTAIN VULNERABLE POPULATIONS

In part due to historical and current patterns of racial discrimination and segregation, concentrated poverty, and public and private disinvestment, populations in New York City that are already vulnerable to poor health outcomes are also overburdened with higher death and illness rates from extreme heat. We already know that certain populations are more likely to face adverse outcomes from extreme heat, including people of color, people living in poverty, children, and the elderly. For example, people living with low income may not be able to run an AC unit in extreme heat because they cannot afford the resulting electric bills. Extreme heat can also aggravate conditions or trigger medical emergencies among individuals living with preexisting health problems, and low-income families may not have access to preventive health care that can avert these situations.[19] In New York City and many other cities across the United States, people of color often live in areas characterized by abundant heat-retaining surfaces and a lack of canopied vegetation (Figure 5).[20]

FIGURE 5: SOCIO-DEMOGRAPHIC AND BUILT ENVIRONMENT FACTORS RELATED TO EXTREME HEAT VULNERABILITY IN NORTHERN MANHATTAN[21]

Data from 2006-2011



DISPARITIES IN HEAT-RELATED DEATHS IN NEW YORK CITY

NYC DOHMH statistics on heat-related deaths for 2000 through 2011 revealed that in New York City:[22]

- Men between the ages of 35 and 64 accounted for 34 percent of all heat-related deaths, the highest percentage among age and gender groups.
- The elderly (65 years or older) made up a significant portion of all heat-related deaths, with elderly women accounting for 26 percent and elderly men accounting for 17 percent.
- Nearly half (48 percent) of all heat-related deaths were among people living in neighborhoods with high or very high poverty levels.
- Most heat-related deaths occurred in adults with an underlying chronic disease: cardiovascular (55 percent), diabetes (13 percent), substance use (11 percent), and cognitive/mental health (11 percent). Only 6 percent of heat-related deaths did not occur in adults with an underlying disease.

WHERE SCIENCE MEETS THE COMMUNITY: THE IMPORTANCE OF PARTNERING WITH ENVIRONMENTAL JUSTICE ADVOCATES

Communities of color and/or low-income communities have been historically excluded from important conversations and policy discussions that affect their lives and neighborhoods, meaning that decisions get made instead by private interests or government representatives without on-the-ground knowledge. The local and historical knowledge that these communities possess is invaluable, but they often lack access to the scientific and technical information necessary to push for policy changes.[23] Creating partnerships among scientists, environmental justice communities, local grassroots environmental organizations, and national environmental organizations is an important step toward reducing this gap, increasing democratic representation and community participation in critical decision making, and codeveloping solutions that prioritize the needs of impacted communities.

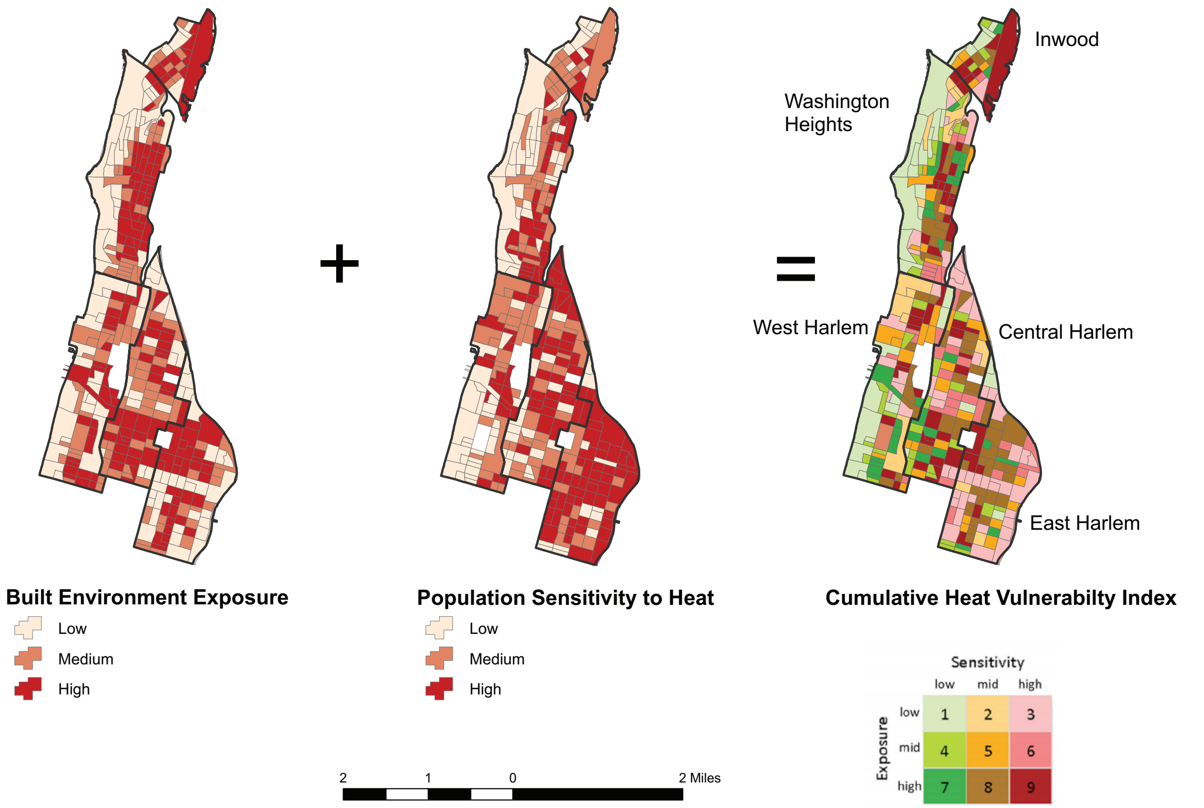
MAPPING HEAT VULNERABILITY IN NORTHERN MANHATTAN

Scientists often talk about *vulnerability* in terms of susceptibility to environmental stressors and the sensitivities of certain populations and communities.[24] However, vulnerability is not easily quantifiable or measurable in comparison with, for example, the amount of sea level rise in coastal areas over the past 30 years, or how much particulate pollution is in the air of a given city. Still, public health scientists have a good understanding of the individual risk factors that make people more sensitive to becoming ill or dying due to extreme heat, as well as the ecological characteristics that create extremely hot neighborhoods. We can use these data to create maps showing the locations of sensitive populations and extremely hot neighborhoods. These maps can be combined into a cumulative vulnerability map that helps us understand how the likelihood of heat-related illness or death can vary among neighborhoods with different levels of sensitivity and heat.

To create the first map in Figure 6, we combined a map of heat-retaining surfaces for the year 2010 with maps of summertime surface temperatures for 2007–2011 into a "built environment exposure" map to show which areas of the city were likely to be the most exposed—that is, the hottest—during the summer.[25] For the second map in Figure 6, we combined demographic maps that identified living locations of the elderly, disabled, those without a high school diploma, and impoverished populations in or around 2010.[26] We called the resulting map "population sensitivity to heat." Finally, we combined those two maps into a "cumulative heat vulnerability" map that identifies which census block groups in Northern Manhattan are most vulnerable to heat. For example, according to our analysis the southwestern portion of West Harlem (in light green colors) has both low sensitivity and low exposure, and therefore people in those neighborhoods have a lower likelihood of becoming ill from extreme heat. At the other extreme, most of Inwood (the northernmost neighborhood on the maps) has both high exposure and high sensitivity, and therefore its residents have a higher likelihood of suffering a heat-related health problem. Some places, like the pink areas in portions of East Harlem, tell us that while the sensitivity of the population is high, exposure is low, and therefore those areas are considered to have low to moderate cumulative heat vulnerability.

FIGURE 6: BUILT ENVIRONMENT EXPOSURE TO HEAT (LEFT MAP) AND POPULATION SENSITIVITY TO HEAT (CENTER MAP) COMBINE TO CREATE A CUMULATIVE HEAT VULNERABILITY INDEX (RIGHT MAP) IN CENSUS BLOCK GROUPS IN NORTHERN MANHATTAN

Data from 2006-2011



HEAT-RELATED VULNERABILITY IS HIGH IN PUBLIC HOUSING DEVELOPMENTS

The population living in public housing developments is particularly vulnerable to heat. Congressional District NY-13, which includes the Washington Heights and Inwood neighborhoods of Northern Manhattan, has the largest number of public housing units of any district nationwide. Currently about 564,000 people in New York City live in public housing provided by the New York City Housing Authority (NYCHA), and about 112,000 of those are in Manhattan.[27] According to a 2015 survey, 13 percent of NYCHA residents receive public assistance, and nearly 20 percent are 62 years of age or older. Black/African Americans and Latinos/Latinas account for 46 and 45 percent of residents, respectively, and 77 percent of NYCHA families have a female head of household.[28]

Looking at NYCHA developments provides an important example of the diverse variables that are required to get an accurate picture of heat vulnerability. On the one hand, census block groups with NYCHA developments have more trees (23 percent tree canopy on average) than do non-NYCHA census block groups (averaging 13 percent tree canopy), suggesting that NYCHA residents have more tree shade and likely experience lower outdoor temperatures. However, on the other hand there are important—and often overlooked—indoor heat risks for people in public housing: less than half of public housing residents in New York City have AC units. In New York City, most heatstroke deaths occur due to heat exposure in homes without an AC unit.[29] Disparities in AC access are prevalent throughout New York City: one study found that 82 percent of low-income neighborhoods have access to air conditioners, compared to 94 percent of more affluent neighborhoods.[30] There are also disparities in energy bill burdens that may cause low-income households to run an AC unit less often. Generally, the cutoff for energy affordability is 6 percent of annual household income, and the average in New York State is 3 percent. However, low-income households in New York State spend, on average, 13 percent of their annual income on energy.[31] Residents of public housing in Northern Manhattan may experience lower outdoor temperatures, but their lack of AC means that heat remains a potentially dangerous health threat.

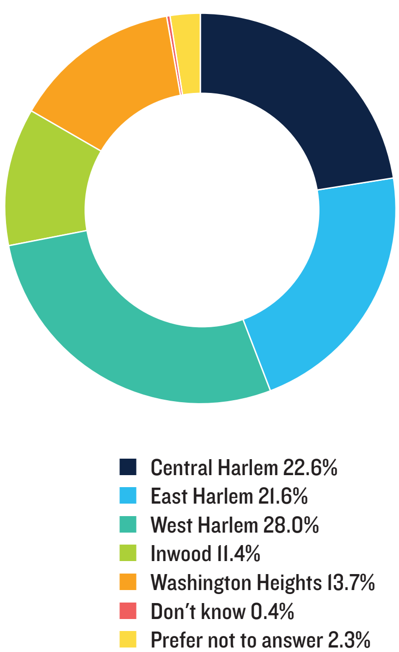
THE LIVED EXPERIENCE OF EXTREME SUMMERTIME HEAT IN NORTHERN MANHATTAN

While census and built environment data on neighborhoods can give us a general understanding of how likely it is that vulnerable populations will become ill or die from extreme heat, it does not tell us how individuals experience or cope with the heat. To fill this gap, we surveyed nearly 500 residents of Northern Manhattan neighborhoods during the summers of 2014 and 2015 and asked them questions about their experience with extreme heat (Figure 7).

Our respondents identified mostly as female (64 percent), single (51 percent), born in New York (52 percent), and Black/African American (53 percent) or Latino/Latina or Hispanic of any race (47 percent). Respondents ranged between 19 and 99 years of age, with an average age of 55. Nearly one-quarter worked full time (22 percent), and 28 percent were retired. Twenty-seven percent completed high school, and nearly one-third obtained a degree from a four-year institution, community college, or vocational/technical school. Respondents identified most frequently as being residents of West Harlem, followed by Central and East Harlem. One-third of the people who answered a question about income said they made $20,000 or less per year.

FIGURE 7: NEIGHBORHOOD OF RESIDENCE OF SURVEY RESPONDENTS

Data from 2014-2015



Unsurprisingly, most of the surveyed population recognized the threats that extreme summertime heat in the city pose for themselves and their families. Nearly 87 percent of respondents said that heat waves were very serious or somewhat serious risks, and nearly 81 percent thought that urban heat islands posed very serious or somewhat serious risks. Although less than one-fourth of those surveyed were routinely engaged in outdoor work during the summer, nearly 9 in 10 said that they were too hot when outdoors during the summers of 2014 and 2015. And 64 percent felt that their health in general was at higher risk when outdoors than when indoors.

Although most respondents (81 percent) had not required emergency medical attention for heat-related illnesses during the two previous summers, more than half (55 percent) of those surveyed experienced symptoms related to heat or high temperatures, such as dizziness or rapid heartbeat.[32]

People living in Northern Manhattan reported relying on multiple sources to obtain information on how to deal with heat. The most common source was television (mentioned by 72 percent of respondents), 23 percent also mentioned the radio, and nearly 19 percent said that they obtained information online. Friends, family, and neighbors were also mentioned as sources of information on heat by 23 percent of Northern Manhattan respondents, and nearly 22 percent cited doctors, nurses, and other medical sources of information. And people do go looking for that kind of information: more than half (54 percent) independently accessed heat-related information in the previous two summers.

Residents of Northern Manhattan used many different strategies to cope with summertime heat. People said they relied most often on AC window units at home, indoor fans, and drinking lots of fluids. To a lesser extent, using central AC (as opposed to a window unit), taking mass transit, closing indoor curtains or blinds, seeking cover under the shade of trees, going to parks or other outdoor areas, and wearing lighter or less clothing were also ways in which people in Northern Manhattan took refuge from the heat. Notably, the use of public cooling centers was mentioned by just 17 percent of respondents. While 40 percent of respondents said they had no issues with using AC to cool their homes, almost as many (37 percent) reported barriers such as lack of an air-conditioning unit or the cost to purchase, repair, or operate an AC unit at home (Figure 8).

FIGURE 8: BARRIERS TO USING AC DURING HOT WEATHER IN NORTHERN MANHATTAN

Data from 2014-2015

- Don't like the noise of AC 4%
- Don't know 5%
- Don't like the feeling of AC; not my preference 6%
- Prefer not to answer 8%
- Don't have a home AC unit, or not provided by landlord 9%
- Can't afford to operate/cost of electricity 10%
- Can't afford to purchase, fix, or repair an AC unit 18%
- Nothing prevents me; I use it 40%

We asked Northern Manhattan residents what new measures they would like to see implemented during heat waves and very hot days. Here are some of their responses.

- More cooling centers, with longer hours
- Distribution of free water
- More public drinking fountains
- Distribution of free fans
- More public pools, with longer hours
- Planting of more trees
- Free air conditioners for those in need, with vouchers for electricity bills
- More parks or green areas
- More help for the elderly
- More readily available information in residential buildings, such as posters in common areas listing symptoms to watch for and numbers to call for help
- Incentives for landlords to make modifications to reduce heat vulnerability
- Fans for subway platforms

Policy Recommendations and Paths for Action

ENVIRONMENTAL JUSTICE COMMUNITIES MUST BE EQUITABLE PARTNERS IN THE SEARCH FOR EXTREME OUTDOOR HEAT SOLUTIONS

Within New York City, there are significant disparities in exposure to high summertime temperatures, and vulnerable populations face greater risks of becoming ill or dying due to heat-related health complications. Urban heat islands and climate change are critical environmental and public health issues that threaten the health, well-being, and livelihoods of environmental justice communities. Extreme heat vulnerability in New York City is, quite simply, an environmental injustice, and policies to ameliorate it should be designed with equity in the foreground.

People in environmental justice communities possess a great deal of historical and contemporary local knowledge about their individual and collective experiences in dealing with climate vulnerabilities—knowledge that is valuable for informing climate mitigation policies. But the role of impacted communities should not be limited to providing data. An inclusive and participatory policy process that includes impacted communities in decision making is critical to producing policies and behaviors that will make Northern Manhattan a more resilient and healthy community.

SIX RECOMMENDATIONS FOR ACTION

On the basis of our findings on extreme-heat-vulnerable populations in Northern Manhattan, WE ACT and NRDC believe there are several policy steps that would ameliorate the effects of extreme heat among these city residents. They are:

1. **INCREASE VEGETATION AND TREE COVERAGE.** Increasing vegetation and the number of trees in high-heat-vulnerable neighborhoods in New York City can help mitigate the urban heat island.[33] The New York State Energy Research and Development Authority (NYSERDA) found that a combined strategy of adding vegetation—specifically, planting more trees along streets—and replacing dark-colored surfaces with lighter ones is the most cost-effective approach per degree of temperature reduction.[34] The city's *Cool Neighborhoods NYC* report (2017) identifies Northern Manhattan as a priority area for additional street trees, and $82 million has already been allocated by the city for this effort.[35] Other policies can be implemented to plant more trees in heat-vulnerable areas as well as to protect existing trees. Furthermore, the various additional benefits that tree planting provides, such as reducing air pollution and stormwater runoff (two pressing issues in New York City), make increasing vegetation and tree coverage an extremely promising solution.

   New York City should also ensure the prudent placement of street trees in heat-vulnerable neighborhoods, as described in the *Cool Neighborhoods NYC* report. The city should engage the Department of Parks and Recreation, the Mayor's Office of Recovery and Resiliency, and the Department of Health and Mental Hygiene (DOHMH), the departments assigned to this particular strategy in the report.

   Additionally, New York City should follow the lead of other major municipalities and implement tree-canopy-related zoning ordinances for new buildings and all other new development. For example, Austin, Texas, adopted a zoning ordinance requiring all new parking lots to have 50 percent canopy cover.[36]

2. **RAISE AWARENESS AND PREPARE FOR EXTREME HEAT.** Raising awareness is one of the most critical tools we have to help the most heat-vulnerable communities prepare for extreme heat events. Mayor Bill de Blasio and his administration deserve some praise for measures they have implemented to improve outreach to and communication with heat-vulnerable populations, like the Be a Buddy Program and the Home Health Aide Training initiatives. However, much more is needed to ensure that the city is effectively reaching out to environmental justice communities, seniors, low-income residents without access to air conditioning, and residents of the New York City Housing Authority (NYCHA). WE ACT and NRDC are therefore making the following recommendations for improvement:

   a. *Expand and permanently fund the Be a Buddy program.*[37] The city should also partner with members of the philanthropic community to increase the pool of resources available to support expansion of the program. Launched in 2017 as a two-year pilot initiative, this program provides funding to community-based organizations to develop and test strategies to protect the most at-risk residents of environmental justice and heat-vulnerable communities from the negative health effects of extreme heat. Strategies focus on building social cohesion within communities so that members are able to support and check on one another. They also focus on improving coordination among city agencies to increase capacity for climate preparedness and better communication. The initiative has been successful and should be continued and permanently funded.

   b. *Partner with local television and radio to disseminate extreme heat information.* The Mayor's Office of Emergency Management should develop a more robust partnership with local television and radio stations to get information out to those most at risk of the health impacts of extreme heat. Our survey of Northern Manhattan residents clearly showed that most people surveyed get their information about extreme heat from television, followed by radio. WE ACT and NRDC believe that more must be done to use both of these portals to get vital public health information about extreme heat to the most heat-vulnerable populations so they can better prepare for and protect themselves from extreme heat events. In 2016, as a member of the Urban Heat Island Working Group in the Mayor's Office, WE ACT recommended that the city build a partnership with health and medical reporters and meteorologists to improve communications about extreme heat and its public health impacts. In 2017 the city committed to hosting a workshop with these reporters. WE ACT and NRDC are recommending that more such workshops be held and that the city work with the local television and radio stations to formalize the partnership.

   c. *Continue and expand the partnership to train home health aides.* In 2017 the city announced that it would partner with three home care agencies to train aides to recognize and address early signs of heat-related illness. The idea for this initiative also grew out of the Urban Heat Island Working Group in the Mayor's Office that WE ACT was a member of. And in his 2022 budget, Mayor De Blasio included the launch of a $39.4-million Community Care Plan to support seniors living at home and in their communities, along with opening 25 more senior centers in underserved communities of color. WE ACT will work with the City to ensure that the distribution of heat safety information is part of this program.

   d. *Expand faith community partnerships.* Expand the partnership with the faith communities in New York City to share information about the public health impacts of extreme heat with those who regularly attend churches, mosques, temples, and other houses of worship.

e. Broadcast emergency alerts for extreme heat events. The National Weather Service should announce extreme heat emergencies through the emergency broadcast system in the same way that it provides information about flooding.

3. PASS AND SIGN INTO LAW EXTREME HEAT BILLS.

a. New York City Council Introduction 1563-2019. WE ACT worked with former City Council Member Costa Constantinides, who chaired the Environmental Protection Committee, on Introduction 1563-2019. This bill proposes to codify the city's cooling center program and to set a minimum number of centers located where heat vulnerable populations reside. It would also institute a process for engaging local communities in determining how best to access cooling infrastructure in their neighborhoods, by implementing wayfinding best practices based on research by the Centers for Disease Control and Prevention Healthy Aging Network and the Institute for Transportation Engineers.[38] In addition, the proposed legislation would require the DOHMH to conduct an annual survey of program utilization and report its findings annually to the mayor and the City Council.

WE ACT and NRDC call on the New York City Council to pass Introduction 1563 and the mayor to sign it into law expeditiously to protect heat vulnerable populations in New York City. Delaying this legislation from becoming law could result in residents in the most heat vulnerable neighborhoods being stricken by heat-related illnesses or, worse, death.

b. Green roofs/rooftop solar bills. According to a 2017 study conducted by researchers at UC San Diego Jacobs School of Engineering, solar panels reduced the amount of heat reaching the roof by an incredible 38 percent, keeping a building's roof 5 °F cooler than portions of a roof exposed to sunlight directly.[39] Likewise, WE ACT worked with the late Stuart Gaffin, Ph.D., a climatologist at Columbia University's Center for Climate Systems Research, whose research demonstrated that green roofs can cool near-surface air temperatures by an average of 29.5 °F (16.4 °C) per unit area—slightly behind street trees in terms of heat island mitigation potential, according to a 2006 report from the New York City Regional Heat Island Initiative.[40]

WE ACT and NRDC call on the New York City Council to introduce bills that survey the level of green roof and solar roof penetration in environmental justice and heat vulnerable communities in New York City annually, and to make that report available to both the City Council and the Mayor. Furthermore, we call on the Mayor to sign such bills into law.

c. New York City Council Introduction 1945. Now that this legislation has been signed into law, thanks to the sponsorship of New York City Council Member Justin Brannan, WE ACT will continue its advocacy to ensure that it is properly enacted. This law requires the NYC DOHMH to collect and make heat vulnerability data available on an annual basis. The information reported must capture cumulative impacts. Data that highlight the spatial distribution of sociodemographic indicators and New York City's heat vulnerability index can be used to identify the most at-risk populations. Programs and policies should be designed according to this information.

WE ACT and NRDC thank the New York City Council for passing this legislation in late July, and we now urge the mayor to sign it into law.

4. PROTECT NYCHA'S MOST HEAT VULNERABLE RESIDENTS.

a. Implement the findings of its Sheltering Seniors from Extreme Heat *study.* This agency is New York City's largest landlord, with 326 housing developments. As stated in the study's report, the approximately 564,000 New Yorkers who currently live in these developments are particularly vulnerable to heat, especially the 62,000 seniors who reside in NYCHA housing. NYCHA contracted with Arup to conduct a series of studies to identify what physical and strategic improvements NYCHA could make to better enable residents of NYCHA senior housing to shelter in place safely, considering that New York City will likely continue to experience extreme heat events, and in increasing numbers.[41] The study, which was conducted between spring and winter of 2019, focused on two NYCHA senior developments, Meltzer Towers in Lower Manhattan and Fort Independence Houses in Brooklyn. It aimed to identify physical retrofits that could ensure safe indoor air temperatures even during a citywide or localized power outage.

Arup's study revealed that upgrading building envelopes to meet or exceed current code requirements for insulation and installing high-performance windows and air sealing could reduce the outdoor/indoor temperature differential to 3 °F from its current 6 °F.
(In other words, if those improvements were made and the outdoor temperature reached 96 °F, the indoor temperature would be 99 °F instead of the expected 102 °F without the upgrades.) Furthermore, adding indoor or outdoor shading to a building with a high-performance envelope could keep indoor temperatures below peak outdoor temperatures. However, Arup recommended that for NYCHA to accomplish its goal of protecting NYCHA's seniors, it needed to both make the upgrades *and* provide reliable AC. And for AC to be reliable, the report recommended that NYCHA install generator backup systems with 100 percent backup capability.[42]

WE ACT and NRDC urge NYCHA to move forward with the recommendations outlined in the *Sheltering Seniors from Extreme Heat* report to protect the seniors in NYCHA senior housing.

b. *Develop an emergency management plan for extreme heat.* In the aftermath of Superstorm Sandy, then NYCHA chairman John Rhea revealed at a City Council hearing that the cash-strapped agency had failed to adequately prepare for it. The superstorm left 80,000 NYCHA tenants without heat or power for several weeks or even months, exposing the weak infrastructure and fragility of more than 250 buildings, not to mention the agency's disorganization.[43] NYCHA has an opportunity to get out ahead of the climate crisis and develop an emergency management plan to help its most heat-vulnerable residents get ready for the negative impacts of extreme heat.

WE ACT and NRDC call on NYCHA to develop an emergency response plan for extreme heat and ensure that it is effectively communicated to all NYCHA residents immediately.

5. ENGAGE AT THE STATE LEVEL TO CREATE OR IMPROVE EXISTING POLICIES OR PROGRAMS.

a. *Home Energy Assistance Program subsidies for AC use.* Approximately 86 percent of households in Northern Manhattan have access to at least one AC unit.[44] While this figure is lower than in wealthier neighborhoods—for example, 97 percent of households on the Upper East Side have access to AC—it is still a relatively high share of households with access.[45] However, many households in Northern Manhattan are unable to run their units as often as they would like. New York State has some of the highest electricity rates in the nation, and the New York metropolitan area's average electricity price is about 7¢/kWh higher than the national average.[46] The 30-day cost for a 1,440-watt window AC unit running eight hours per day is about $45.60, and the cost may be even higher in poorly insulated apartments and hotter areas of the city.[47] WE ACT identified this cost burden as a deterrent for AC usage in some households.

The state-run Home Energy Assistance Program (HEAP) provides AC units (one per household) to low-income individuals with a documented medical condition that is exacerbated by heat.[48] However, in New York State, only 4 percent of HEAP funding goes toward cooling, while 65 percent went toward heating, largely in the form of heating bill assistance. WE ACT, the City, and its statewide partners hope to expand and restructure the funding from this program to provide more aid for cooling. Specifically, a press release notes that "The City will also work with health departments and other stakeholders across New York State to support an expansion of the Home Energy Assistance Program (HEAP) to assist qualified households in paying utility bills related to the operation of air conditioners."[49] In its 2020 OneNYC progress report, the City stated that it plans to work with WE ACT's Heat, Health, and Equity Initiative to achieve this goal.[50]

We urge New York State, the New York City Mayor's Office of Recovery and Resiliency, the NYC DOHMH, and the New York City Human Resources Department to allocate a portion of the HEAP budget to expand the provision of bill assistance to low- and moderate-income households during summer months. This would help rectify the imbalance in the use of HEAP funds, which disproportionately help upstate households pay their heating bills.(Downstate customers have heat included in their rent, so they have a higher rent burden but are ineligible for higher HEAP support.) The additional funds for AC should not come from the HEAP money used for the Weatherization Assistance Program or EmPower New York.

b. *WE ACT's Energy Efficiency Equity and Jobs legislation.* Low-income households, many of which include people of color, spend a greater percentage of their income on energy and live in disproportionately inefficient, unaffordable, and unhealthy homes.[51] The expense of maintaining a comfortable, functioning home therefore often competes with other health and wellness expenses, leading to poorer health and perpetuating the cycle of poverty. Further, because low-income families tend to live in less energy-efficient homes, they are disproportionately threatened by the heat waves that are becoming increasingly common.

   The Energy Efficiency Equity and Jobs bill has passed the New York State Senate, and WE ACT is working with the New York Energy Democracy Alliance and policy experts to get it passed by the State Assembly. The legislation would require:

   - establishment of cost-effective energy use reduction targets and a term for review and adjustment of such targets;
   - equitable allocation of residential and small commercial energy use reduction funding to Potential Environmental Justice Areas;[52]
   - that NYSERDA capture, track, and publish data regarding nonenergy benefits (NEBs) of home and building-scale energy efficiency spending; and
   - institution of proportional job training and hiring practices for state-funded efficiency work.

c. *State energy spending study proposal.* In January 2018, New York Governor Andrew Cuomo declared that the state's spending on energy programs must serve all New Yorkers, regardless of zip code. The 2019 Climate Leadership and Community Protection Act also requires that 35 to 40 percent of the overall benefits of spending on state climate and clean energy programs, such as NYSERDA energy programs and the Regional Greenhouse Gas Initiative, go to disadvantaged communities in the state. Without understanding where energy dollars are allocated, funding cannot be distributed equitably to low-income communities and communities of color. The communities most at risk from climate change may be receiving less than their fair share of state assistance for renewable energy and energy efficiency projects. DEC and NYSERDA should transparently report the geographic location of state energy spending to ensure that funds intended to be spent on low-income communities actually go where they are most needed.

d. *Energy efficiency and urban heat island connection.* State programs should also consider green infrastructure and other urban heat island mitigation strategies as part of their mandate, because adding green infrastructure and street trees will have health and community benefits.

e. *Home health aide training.* New York State must require that as part of their certification, home health aides get training in how to recognize and address the signs of heat-related illness. Home health aides who are already certified when the new requirement is imposed should be compensated by the state for the time required for the additional training.

f. *Maximum indoor temperature threshold.* New York State must establish a maximum indoor temperature threshold for facilities that house heat-vulnerable populations, such as domestic violence and homeless shelters, senior citizen housing, and prisons/jails. The threshold could be consistent with the one established by Medicaid: Under the federal law [42 CFR Part 483. 483.15(h)(6)], facilities initially certified after October 1, 1990, must maintain a temperature range of 71 to 81 °F.

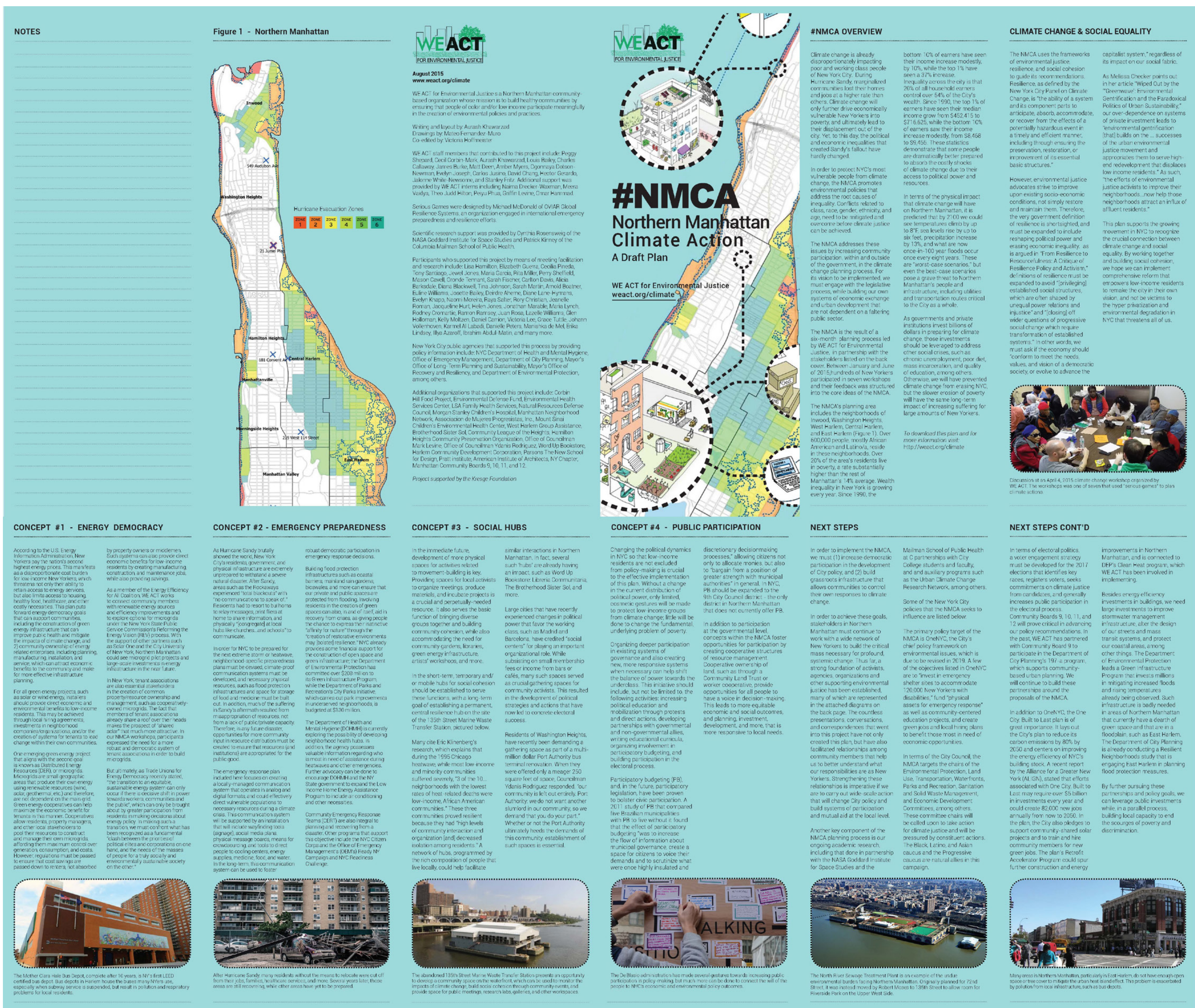
6. **SUPPORT HEAT-VULNERABLE COMMUNITIES IN PARTICIPATORY VISIONING PROCESSES TO DEVELOP PLANS FOR RESILIENCE TO EXTREME HEAT, AND IMPLEMENT THE NORTHERN MANHATTAN CLIMATE ACTION PLAN AND AGENDA.** In 2014, with support from the Kresge Foundation, WE ACT launched a six-month community planning process to hear from its members and other key stakeholders in Northern Manhattan—including many residents who were heat vulnerable—on what policy or physical changes they believed were needed to make their communities climate resilient. In 2016 WE ACT published the Northern Manhattan Climate Action (NMCA) Plan, which arose out of the community planning process, and which presents an integrated set of community-driven resiliency projects designed to confront and mitigate the climate crisis.[53] The NMCA's suite of policy recommendations emerged out of consultations with WE ACT's members and other allied stakeholders and are guided by the frameworks of environmental justice, resilience, and social cohesion.

   Key elements of the NMCA Plan and Agenda for mitigating the urban heat island include:

   - Expanding urban agriculture in Northern Manhattan through the existing community gardens program.

Local agriculture is an integral part of climate resiliency, as it both reduces the footprint of impervious surfaces—which in turn can lead to reduced surface temperatures—and promotes local community self-reliance. The city is slowly getting behind the idea of expanding urban agriculture. At the end of 2017, the New York City Council unanimously passed Introduction 1661-A, a bill that directs the Department of City Planning and other relevant agencies to launch a website that will provide New Yorkers with information about urban agriculture across the five boroughs. The goal is to create a comprehensive database of existing urban agriculture organizations and businesses and provide guidance to those who are interested in becoming involved in urban farming.

- Deploying kiosks to inform the public about cooling center locations and times of operation, and other important resources. Since the NMCA Plan and Agenda were published in 2016, New York City inked a deal to replace old pay phones across the city with 7,500 kiosks offering high-speed Wi-Fi and other digital services. The program, known as LinkNYC, has installed kiosks with 55-inch digital screens at several locations in Northern Manhattan. They offer free phone calls anywhere in the United States, map functions on their tablets, access to NYC 311 (NYC Information), a 911 button, and a USB phone charger, but they do not provide information about cooling centers in the vicinity of the kiosk. WE ACT is working with LinkNYC and the Mayor's Office of Emergency Management to address this shortcoming.



#NMCA RESILIENCE CONCEPTS

The following concepts were generated by project participants as measures that can protect our environment while reducing socio-economic inequality. Logos indicate potential partnerships, not formal agreements.

Writing and layout by Aurash Khawarzad (@khawarzad), Drawings by: Mateo Fernandez-Muro (@Matufis)

Download at: http://weact.org/climate

Coastal Protection
Coastal areas, particularly those in the floodplain shown in Figure 1, are in need of green infrastructure that provides ecosystem and flood protections. NYC is currently implementing a coastal protection project worth $3.7 billion and has released its first-ever comprehensive coastal protection plan, A Stronger, More Resilient New York. The plan seeks to deepen public participation in waterfront restoration and protection by expanding the Waterfront Management Advisory Board and includes pledges to undertake feasibility studies for construction and restoration of flood-prone areas. DEP has also spent over $40 million to-date on wetlands restoration and other coastal protections. What remains to be seen is the extent to which developments will encompass community-based plans or be leveraged to gentrify waterfront areas.

Community Land Trusts (CLT)
Organizing property ownership through a CLT is one way to preserve affordable housing by removing properties from the speculative market. CLTs also allow participants to collectively use space for local agriculture, energy production, recreation, and even social services such as childcare. Such shared governance structures can help rebuild the commons in terms of how we use space/resources.

Affordable Cooperative Housing
The City plans to create and/or preserve 200,000 units of affordable housing between 2015 and 2025. This will be done by maximizing use of City-owned land, mandating inclusionary zoning, and providing tax incentives to developers, among other things. However, many are skeptical that these efforts will provide the necessary amount of housing at truly affordable prices (particularly for vulnerable populations such as the homeless, criminalized populations, the elderly, etc.). Therefore, new cooperative homeownership mechanisms such as community land trusts must be explored.

Social Hubs
Community meeting spaces are crucial to support ongoing planning efforts, as they are necessary for local organizations to host educational programs, hold meetings, produce materials, use for storage, etc. Having a local hub open for community use can support centralized planning and production activities while remaining grounded in local needs and capacities.

Design for Pedestrians + Bicyclists
OneNYC calls for a bike lanes in areas "with limited bike infrastructure". This includes bike lanes on the Harlem River bridges and on other auto-oriented streets. The City's privately-owned bikeshare service, CitiBike, should be expanded to encompass Uptown areas, while taking on a more public nature. For example, equipments should be manufactured locally.

Cooperatively Owned Microgrids
Both the City and state government have called for an expansion of distributed generation (DG) technology, including wind, solar, and geothermal. This plan supports the implementation of DG in the form of microgrids that are deployed in vulnerable areas and/or are managed by local stakeholders. The City is currently undertaking a microgrid feasibility study and removing policy roadblocks to microgrid construction by working with ConEd and the Public Service Corps to revise "ConEd's standby tariffs to lessen economic impediments to DG". Microgrids provide multiple benefits, including reliable power when the main grid experiences a blackout, reductions in energy costs, more control for residents over their own energy consumption, and employment opportunities.

Community Bank
Financial services should be provided by local institutions connected with the community. Locally-run finance can shift the focus of banks away from their short-term profit, towards long-term investment in infrastructure, development of small businesses, and other much-needed investments in shared resources that will benefit the community.

Places of Worship
Churches, mosques, synagogues, and other religious institutions provide flexible spaces for community planning and emergency services, while conveying important climate-related messages through religious practices. Many churches, urged on by Pope Francis, are joining the struggle for climate justice.

Urban Agriculture
Local agriculture is an integral component of climate resiliency, as it helps build communities' self-reliance while reducing the massive petro-chemical footprint of existing industrialized food systems. The City plans to increase its number of community gardens by partnering with schools, helping gardeners sell their produce at farm stands, and supporting urban farms through

(cont'd from Urban Agriculture) the multiagency Building Healthy Communities Initiative. NYCHA's Gardening and Greening program is also working to expand accessibility to community gardens. Our partners, such as the Corbin Hill Food Project, are deeply engaged with these issues and are mapping out an effective model for a sustainable food system in Northern Manhattan.

Participatory Budgeting
In April 2015, over 51,000 NYC residents voted on how to allocate $32 million to various locally-developed capital projects across 24 NYC Council Districts. Participatory budgeting is a clear example of how residents can be made to engage directly with governance systems to tailor policy to their needs. Given the level of site specificity essential to effectively address climate change issues, PB should be expanded to encompass more of the City's budget, green projects, and longer-term investments.

Councilman Ydanis Rodriguez · Councilman Mark Levine · Councilwoman Melissa Mark-Viverito

Resilient Housing
True victory in the climate struggle is not simply based on the preservation of physical conditions, but also on the achievement of lasting security for communities that are now under threat of displacement. Therefore, affordable housing should be a priority for climate advocates, just as it is for the Mayor's office and many NYers. Supporting NYCHA by reinvesting in its infrastructure is a necessary first step, but we must also ensure that further price hikes do not happen and that NYCHA property leased to private developers does not cause further gentrification. Simultaneously, alternative models for transitional housing, such as the Sugarhill development by Broadway Housing Communities should be explored.

It is particularly important to ensure that homes are cool enough for the elderly. Between 2000 and 2011, 85% of those who died from heat in NYC died in their own homes.

"NYCHA has an important role to play in reducing this city's carbon footprint and I look forward to [making] our public housing more efficient and resilient"
–Council Member Ritchie Torres

3333 Broadway · Drew Hamilton Houses · Wagner Houses · Sugarhill Houses · Dyckman Houses · Jackie Robinson Houses

Healthcare
Healthcare services should not only be expanded to provide aid to more people; they must also be made resilient enough to continue to function during the next superstorm, heatwave or other crisis. Post-Sandy healthcare resilience efforts include installing infrastructure to protect against flooding, building distributed generation systems (and microgrids), and connecting precarious demographic groups with health services. Healthcare providers should establish connections with local emergency response systems so that people who need special health services during a crisis can be reached and treated quickly.

Multipurpose Infrastructure
New design guidelines should be implemented so that waterfronts promote industrial activities while remaining accessible to the public. This can be done through constructing green spaces that both mitigate flood damage and support water-based transportation should be constructed. These spaces are also important for cooling the urban heat island and supporting physical activity, local agriculture, and more.

Tech Incubator
By working with universities, public agencies, community organizations and members of the "maker" community, a tech incubator can be built to help local activists and entrepreneurs develop socially responsible products, such as improved software for running green technologies. OneNYC plans to support "Clean Tech" industries by creating an Advanced Manufacturing Network that will provide affordable workspaces, business support services and workforce training programs. NYCEDC has also funded several business incubators, including one that focuses on renewable energy.

Space for Social Services
Flexible space within residential buildings can be used for social services such as childcare and healthcare, as a meeting space for local groups, and for other activities that can build social cohesion while allowing more freedom for working class people to pursue employment and engage in other forms of social reproduction.

Local Brewery
A local brewery in the manufacturing district can build on local tradition and culture while creating a local craft food industry.

Local Markets
Manufacturers, farmers, and other "makers" within the hub can sell their goods at local markets, which support non-conventional commerce, including bartering networks and alternative currencies.

Ferry Service
The West Harlem Piers (pictured below) is a good location to add ferry services for daily commuters and to create alternate evacuation routes. OneNYC calls for several new ferry routes.

Food from the Hudson Valley
Farms in the Hudson Valley can make use of improved waterfront infrastructures to ship food into NYC, which can strengthen NY state's economy while providing healthier food options for local food deserts. OneNYC plans to invest $100 million in marine terminals for freight movements.

Local Media Production
Dedicated space for critical media outlets, training for citizen journalism, and cooperatively owned equipment for digital and print copy media production.

Manufacturing Facilities
Northern Manhattan's coastal and interior areas provide many opportunities for light industrial activities (manufacturing of consumer goods), which can both provide jobs for low-income residents and produce tools for local climate resilience. Public and private financial institutions, organized labor, and local organizations that focuses on workforce development can work together to create local employment opportunities, develop green energy technology (solar, wind, etc.), green transport equipment (bikeshare systems) and other basic necessities such as textiles and foodstuffs. Organized labor is already exerting a strong influence on City climate policies. The City Council has announced that it will fund 22 new cooperatively owned businesses in FY 2016.

Live/Work Spaces
One of the most effective (yet currently underutilized) tools for communication in relation to climate change is the arts. However, it is difficult for young artists to secure live/work spaces in NYC, forcing them to leave NYC for other cities. As a result, OneNYC pledges to develop 1,500 live/work spaces, including 500 affordable units, by 2024.

Affordable Public Transport
In recent years, bicycle lanes, bus system facilities, and subway routes have been constructed in Northern Manhattan. These services can provide important transportation options should other transportation resources be damaged in a storm. However, rising transportation costs are also increasingly limiting transportation access for low-income groups. Transportation options should be made more affordable, perhaps by means of more public investments, expansion of the bikeshare system, and reduced costs for subway and bus services. Transportation services should also be made free to low-income residents during emergency situations.

135th Street Marine Waste Transfer Station
For several decades, the Marine Waste Transfer Station at 135th Street polluted the Hudson River alongside West Harlem, the neighborhood of Hamilton Heights, and other nearby areas with a 24-hour stream of garbage trucks and barges. The now-abandoned facility represents an exciting opportunity to create a permanent climate resilience center that can support local organizations, educational/cultural programs, freight movement, citizen science, and other climate-related efforts. Several City Council members, Manhattan's Borough President, the Parks Commissioner, local Community Board representatives and others have formally stated that they are in support of such a project.

Community Board 9 · Sanitation Comissoner Kathryn Garcia · Parks Commissioner Mitchell Silver · Borough President Gale Brewer · Councilman Mark Levine

Information Kiosks
After Hurricane Sandy, locally-produced signage played an important role in connecting people with networks and resources that supported recovery efforts. Public signs and stands should be created across the City to provide information on cooling center locations, evacuation zones, and other important resources.

Flooding Barriers
The thirteen-plus miles of coastline in Northern Manhattan are home to thousands of residents, small businesses, manufacturing spaces and important pieces of municipal infrastructure. Many of these, particularly in East Harlem, are located within the Hurricane Evacuation Zone and should therefore be hardened against flooding. Flood protections should be planned using design guidelines that prioritize the creation of public space, access to the waterfront, and bicycle route connectivity.

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APPENDIX A: HEAT VULNERABILITY MAPPING METHODOLOGY

To identify outdoor heat vulnerability in New York City, we first created and mapped two separate indicies of population sensitivity and built environment exposure using variables known to influence heat-related mortality and morbidity in census block groups (CBG) in Northern Manhattan. We then aggregated the sensitivity and exposure indexes into a cumulative index of heat vulnerability. We chose CBGs because these are the smallest enumeration units at which the U.S. Census Bureau reports socioeconomic and demographic variables that represent heat-related health risk factors. In this report, we subscribed to the model of "determinants of vulnerability" of human health to climate change composed of exposure, sensitivity, and adaptive (or coping) capacity used by the U.S. Global Change Research Program's scientific assessment of climate change and others.[54] We mapped the sensitivity and exposure components of heat vulnerability but excluded adaptive capacity due to lack of available data on household coping mechanisms, typically the scale at which individuals learn to adapt to environmental hazards.[55] The variables used and their sources are listed in Table A1.

We now describe the sensitivity and exposure components, followed by a description of the utility and construction of indicies at small geographical scales for identifying climate change-related hazards.

TABLE A1: SOCIOECONOMIC AND BUILT ENVIRONMENT DESCRIPTOR VARIABLES USED IN HEAT VULNERABILITY MAPPING

VARIABLE	DESCRIPTION	SOURCE	TIME PERIOD	SPATIAL SCALE
Sensitivity				
Percent White (not Hispanic)	Percentage of the population of the White race and not of Hispanic or Latino/Latina origin/ethnicity	U.S. 2010 Census	2010	Census Block Group
Percent Black/African American (not Hispanic)	Percentage of the population of the Black/African American race and not of Hispanic or Latino/Latina origin/ethnicity	U.S. 2010 Census	2010	Census Block Group
Percent Hispanic	Percentage of the population that is of Cuban, Mexican, Puerto Rican, South or Central American (except for Brazil) origin	U.S. 2010 Census	2010	Census Block Group
Percent Asian (not Hispanic)	Percentage of the population of the Asian race and not of Hispanic or Latino/Latina origin/ethnicity	U.S. 2010 Census	2010	Census Block Group
Percent 65 or Older	Percentage of the population that is 65 of years of age or older	U.S. 2010 Census	2010	Census Block Group
Percent Living Alone	Percentage of households that contain exactly one person	U.S. 2010 Census	2010	Census Block Group
Percent with Disability	Percentage of the population 16 to 64 years of age with at least one mental or physical disability	2010 ACS*	2006-2010	Census Block Group
Percent No High School Diploma	Percentage of the population over 25 years of age that has not obtained at least a High School Diploma or GED equivalent	2010 ACS*	2006-2010	Census Block Group
Percent in Poverty	Percentage of the households whose ratio of income to poverty level is less than one	2010 ACS*	2006-2010	Census Block Group
Exposure				
Percent Trees	Percentage of all pixels in Census Block Group that are classified as trees	MacFaden et al. (2012)	2010	3-ft^2 pixel aggregated to CBG
Percent Impervious	Percentage of all pixels in Census Block Group that are classified as roads, buildings, or other paved surfaces	MacFaden et al. (2012)	2010	3-ft^2 pixel aggregated to CBG
Land Surface Temperature				
Mean and Standard Deviation LST for May-September 2007-2011	Mean and standard deviation surface temperature (°C) at the time of diurnal satellite overpass	Landsat 2007-2011	summer months 2007-2011	30-m^2 pixel aggregated to CBG

*American Community Survey: 5-Year Data

Sensitivity to extreme heat

As an exploratory first step, we calculated the Pearson's correlations matrix of land surface temperature (LST) with 1) the four most common race/ethnicity categories in Northern Manhattan available in the 2010 U.S. Census: percentages of the white, African American (not Hispanic), Hispanic, and Asian (not Hispanic) populations; and 2) percentages of individuals 65 years of age or older, living alone, with at least one mental or physical disability, without a high school diploma, and living at or below the poverty threshold (Table A2). With the exception of the white population, each of these demographic variables is known to be individually correlated with adverse heat-related health outcomes.[56] The white and Asian populations showed negative and statistically significant correlation with LST; the African American, disability, no high school diploma, and poverty variables showed slight but statistically significant positive correlations with LST. The remaining sensitivity variables did not show statistically significant correlations. In the final selection step of variables for the sensitivity index, we excluded all race/ethnicity variables because initial mapping of the percentage of non-whites (i.e., African American, Asian, and Hispanic populations together) showed that most CBGs were between 75 and 99 percent non-white, suggesting that the high degree of racial/ethnic diversity would mask other key sensitivity variables in the index.

Built environment exposure to extreme heat

We conducted Pearson's correlations for the mean percentage of trees and impervious surfaces of all pixels in each CBG versus LST (Table A2). We obtained raster images of land cover in 2010 in New York City from a high-resolution (3-square-foot pixel size) urban tree canopy assessment.[57] We reclassified land cover areas representing roads, buildings, and other impervious surfaces into an "impervious surfaces" category. We then summarized the areas representing trees and impervious surfaces as the mean percentage of each category in all pixels in each CBG in Northern Manhattan.

In urban areas, trees and impervious surfaces are two land covers negatively and positively related to LST, respectively; that is, higher fractional cover of trees is correlated with lower LST, while higher fractional cover of impervious surfaces correlates with higher LST.[58] As expected, trees showed strong negative and statistically significant correlations with LST, and impervious surfaces showed strong positive and statistically significant correlations with LST. In the final selection of variables, we included only LST and impervious surfaces in order to express the exposure index in increasing order of vulnerability—in other words, the higher the index, the higher the exposure. In Northern Manhattan, impervious surfaces and trees are very highly and negatively correlated (–0.97; see Table A2), suggesting that the inclusion of both variables in an index would artificially inflate its explanatory power.

TABLE A2: PEARSON'S CORRELATIONS OF LAND SURFACE TEMPERATURE AND SENSITIVITY AND EXPOSURE VARIABLES IN CENSUS BLOCK GROUPS IN NORTHERN MANHATTAN

	Land Surface Temp. (mean, °C)	Per. White	Per. African American	Per Hispanic	Per. Asian	Per. 65 or Older	Per. Living Alone	Per. with Disability	Per. no HS Diploma	Per. in Poverty	Per. Trees
Land Surface Temp. (mean, °C)											
Per. White	-0.31****										
Per. African American	0.16**	-0.36****									
Per Hispanic	0.1	-0.50****	-0.62****								
Per. Asian	-0.14**	0.62****	-0.23****	-0.42****							
Per. 65 or Older	-0.1	-0.01	0.03	-0.02	0						
Per. Living Alone	0.04	0.35****	0.43****	-0.69****	0.27****	0.20***					
Per. with Disability	0.12*	-0.39****	0.26****	0.1	-0.29****	0.09	-0.09				
Per. no HS Diploma	0.19***	-0.67****	-0.15**	0.69****	-0.47****	0.06	-0.52****	0.38****			
Per. in Poverty	0.18***	-0.45****	0.07	0.31****	-0.29****	-0.11*	-0.24****	0.31****	0.49****		
Per. Trees	-0.43****	0.1	0.20***	-0.27****	0.15**	0.20***	0.14*	0.13*	-0.15**	0.02	
Per. Impervious	0.40****	-0.08	-0.24****	0.30****	-0.17**	-0.19***	-0.16**	-0.16**	0.15**	-0.02	-0.97****

Asterisks denote significance level: *p ≤ 0.05; **p ≤ 0.01;***p ≤ 0.001; ****p ≤ 0.0001

Sensitivity and exposure index construction

We then combined the variables in each vulnerability dimension into a spatially explicit index representing the magnitude of exposure and sensitivity in CBGs. Constructing and mapping small-scale indexes is useful to "locate spatially the distributions of social disadvantages and environmental hazards" in order to facilitate the identification and deployment of effective adaptation strategies for vulnerable populations.[59] For each of the two indices, we first standardized all variables by calculating z-scores for each variable in order to express them as unit-less quantities. We then added variable z-scores together for each dimension to obtain index scores. We recoded each of the two index scores into "low," "medium," and "high" categories based on the first, second, and third tertiles, respectively.

Construction of cumulative heat vulnerability index

In the last stage of mapping vulnerability to heat, we combined the sensitivity and exposure indices into a cumulative heat vulnerability index (HVI).[60] To construct the HVI, we mapped the nine possible combinations of the tertile-coded values of the exposure and sensitivity indices to show how vulnerability changes along both dimensions. Combining the two individual indexes in this way facilitates communicating the interactions between exposure and sensitivity that shape heat-related vulnerability.

APPENDIX B: "LIVED EXPERIENCE OF HEAT" COMMUNITY SURVEY

To understand individual perceptions and coping mechanisms around extreme heat and urban heat islands, we designed and administered a survey to residents of Northern Manhattan. We received authorization to perform research involving human subjects from Western Institutional Review Board (WIRB), a federally approved Institutional Review Board (IRB) registered with the Office for Human Research Protections and the U.S. Food and Drug Administration, with IRB registration number IRB00000533 and parent organization number IORG0000432. The WIRB protocol number for our research is 20151739. An abridged version of the protocol approved by WIRB is reproduced below; the full protocol can be obtained by contacting this report's authors.

Research design

To test the hypotheses that individuals engage in multiple strategies to cope with heat and possess and make use of different resources to cope, we asked survey participants to answer questions in two broad rubrics: "lived experience of extreme heat" and "coping with summertime heat." These questions probed respondents' experiences with summertime heat, such as environmental risk perceptions, job-related heat exposure, heat-related illnesses, access to heat-warning information, modifications to dwelling units to reduce extreme heat, use of resources to cool, and collective action to mitigate extreme heat. To test the third hypothesis, that the availability and use of coping resources is differentiated across race/ethnicity and socioeconomic status, we asked survey respondents to answer basic demographic questions on neighborhood of residence, income, race/ethnicity, gender, educational achievement, transportation, employment, and marital status. In addition, a GPS latitude and longitude coordinate of the location where the survey participant was located at the time the survey was administered was be collected.

Participants were asked to answer approximately 30 questions, most of which were multiple choice. Eligible participants were individuals 18 years of age or older who were residents of one of the five Northern Manhattan neighborhoods of Central Harlem, West Harlem, East Harlem, Washington Heights, or Inwood.

The survey instrument was administered in three different platforms. The main medium for administering the survey to participants was an electronic tablet loaded with a questionnaire designed in QuickTapSurvey, a commercial survey software for electronic tablets. We expected this in-person method to allow us to capture around 75 percent of the total target sample size. To acquire the remaining 25 percent, we deployed the same questionnaire in SurveyMonkey, a web-based online survey service.

As a backup to the electronic versions, we also provided paper copies of the survey. After participants answer the paper version of the survey, responses were entered into the QuickTapSurvey interface by surveyors. In the QuickTapSurvey version, there was an initial question (before the survey began) for the surveyor to indicate if the survey was being taken by a participant directly on the tablet, or if the surveyor was entering the responses manually.

Study population description

The general population that we sampled from was the five Northern Manhattan neighborhoods: Central Harlem, West Harlem, East Harlem, Washington Heights, and Inwood. The total 2010 population in the neighborhoods is 560,305 (Table B1).

Sampling plan

Based on the total Northern Manhattan population of 560,305 (Table B1), an acceptable error margin of 5.0 percent, a 95 percent confidence interval, and a response rate of 50.0 percent, we established a desired sample size of n=400. We stratified the sample size according to two criteria: the percent of the total population in each of the five neighborhoods, and the racial/ethnic composition of each neighborhood. As shown in Table B2, the five Northern Manhattan neighborhoods have markedly different racial/ethnic distributions. In order for our sample to reflect the racial/ethnic distribution in each neighborhood, we aimed to recruit participants according to the distribution shown in Table B3. Due to the small percentages of Native Americans, Hawaiian/Pacific Islanders, and those in the "Other" racial category, we eliminated those categories from our stratified sampling scheme.

Analysis plan

We tabulated frequencies of responses for each survey item. We linked participants' neighborhood of residence to Census demographics and built-environment data such as land use/land cover and land surface temperature. To assess variability in the lived experience of heat and coping strategies and resources among race/ethnicity, socioeconomic status, and neighborhoods, we subset responses in these categories and conducted analysis of variance (ANOVA) on the frequencies of responses.

TABLE B1: POPULATION DISTRIBUTION IN NORTHERN MANHATTAN NEIGHBORHOODS

NEIGHBORHOOD	TOTAL POPULATION	PERCENT OF TOTAL
Central Harlem	118,665	21.18%
East Harlem	115,921	20.69%
Inwood	46,746	8.34%
Washington Heights	151,574	27.05%
West Harlem	127,399	22.74%
Total	**560,305**	**100.0%**

TABLE B2: ETHNIC/RACIAL BREAKDOWN IN NEIGHBORHOODS IN NORTHERN MANHATTAN STUDY AREA

NEIGHBORHOOD	PERCENT WHITE	PERCENT HISPANIC	PERCENT AFRICAN AMERICAN	PERCENT ASIAN	PERCENT NATIVE AMERICAN	PERCENT HAWAIIAN OR PACIFIC ISLANDER	PERCENT OTHER
Central Harlem	10.4	23.4	61.7	2.9	1.0	0.1	0.6
East Harlem	12.3	51.2	29.4	5.9	0.6	0.1	0.5
Inwood	14.7	73.5	8.9	2.1	0.3	0.0	0.5
Washington Heights	17.0	71.7	7.5	2.9	0.3	0.0	0.5
West Harlem	25.7	42.8	22.6	7.6	0.6	0.1	0.5

TABLE B3: ESTIMATION OF STRATIFIED SAMPLE SIZES BY NEIGHBORHOOD BY RACE/ETHNICITY IN NORTHERN MANHATTAN STUDY AREA (N = 400 FOR ALL FIVE NEIGHBORHOODS)

NEIGHBORHOOD	TOTAL	WHITE	HISPANIC	AFRICAN AMERICAN	ASIAN
Central Harlem	85	9	20	52	2
East Harlem	83	10	42	24	5
Inwood	33	5	25	3	1
Washington Heights	108	18	78	8	3
West Harlem	91	23	39	21	7
Total	**400**	**66**	**203**	**108**	**18**

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