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Using Green Solutions to Cover the Dark, Red History of Urban Heat Islands in New York City

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ABSTRACT

An urban heat island (UHI) is an area in a city that experiences higher temperatures relative to surrounding areas. New York City (NYC) experiences the UHI effect and is vulnerable to extreme heat and precipitation. Although multiple interventions were made on the issue, there exists a knowledge gap regarding the historical root of this phenomenon in present-day NYC. This paper uses secondary data, such as satellite images and climate databases, and conducts linear regressions to shed light on the interlink of heat and income inequality caused by redlining, the now-illegal practice by the federal government labeling non-white neighborhoods undesirable for real estate investment and depriving them of investment. The study analyzes the key issues of various stakeholders' past actions and ultimately proposes city-wide green remodeling as a sustainable intervention. This research seeks to propose the most effective and feasible method for NYC to reduce its UHI effect and to emphasize the importance of considering historical injustices when investigating environmental issues.

Introduction

An urban heat island (UHI) is an urban area that experiences higher temperatures relative to surrounding areas.[1] Infrastructure like buildings and roads that use conventional human-made construction materials absorb and re-emit the heat from the sun, in contrast to trees, vegetation, and water bodies that cool the air by giving shade by transpiring water from plant leaves, and evaporating surface water, respectively. With urban sprawl, cities tend to build more and design taller buildings. Denser buildings trap heat in lower levels, preventing it from rising into the atmosphere during the night. Denser populations mean more vehicles, buildings, and industrial facilities that emit waste heat into the urban environment. Therefore, urban areas with a great density of such structures, a lot of human activity, and limited greenery become "islands" of higher temperatures, thereby called urban heat islands.[2]

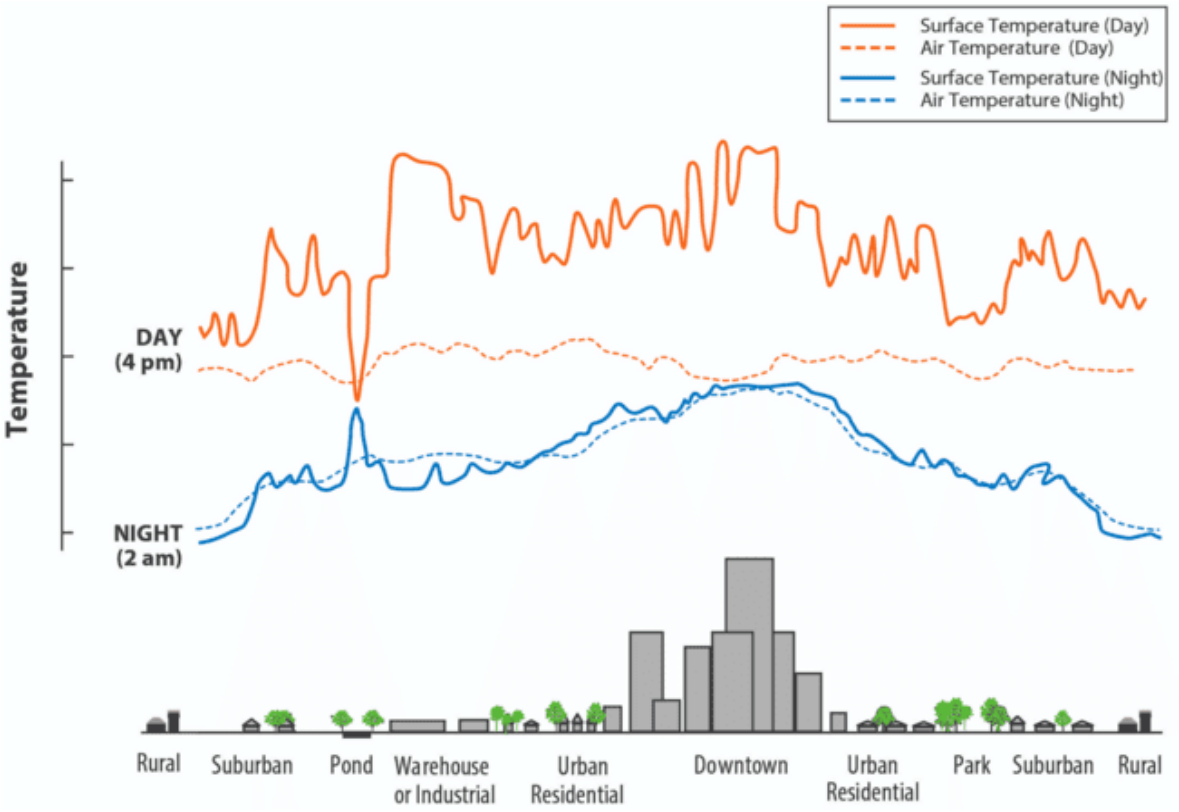

Figure 1. 2023 Heat Island Effect in the City and the Surroundings.

Figure 1 shows that surface temperatures fluctuate more and are higher than air temperatures during the day but are more constant at night. Suburban and rural areas have lower temperatures than downtown areas due to the lower density of buildings and level of human activity. In fact, the UHI effect results in daytime temperatures 0.5°C~4.0°C higher and nighttime temperatures 1.0°C~2.5°C higher in urban areas than surrounding rural areas.[3]

Heat hotspots within cities are called "intra-urban" heat islands. The primary cause of intra-urban heat islands is the inequitable land distribution in the urban landscape, which leaves certain areas with more heat-absorbing buildings and fewer cool spaces with greenery. Residents of intra-urban heat islands are more susceptible to heat-related illnesses, such as respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke, and even death.[4]

Furthermore, urban heat islands may have poorer air and water quality than their rural neighbors. This trait is often common in UHIs because densely populated and densely built areas produce more pollutants emitted by human activity. In particular, the primary source of contemporary air pollution is waste products from fossil fuel-powered vehicles.[5] The urban environment, full of buildings, roads, walkways, and parking lots, prevents these pollutants from dispersing and degrading in toxicity as well as water quality deteriorating. Increased water temperatures often cause eutrophication and excess algal growth, and these processes threaten native species that have evolved to survive in a colder aquatic environment.[4]

A study reported that each degree Celsius of temperature increase corresponds to the rise of the peak electricity load between 0.45% and 4.6%.[6] As residents of urban heat islands use electric fans and air conditioning to endure hot summers, the spikes in energy demand strains energy resources and cause rolling blackouts, an intentionally engineered electrical power shutdown executed to prevent power disruptions. The raised demand for electricity causes increased use of electricity supplied by fossil fuels, which in turn leads to an

expansion of both primary and secondary air pollutants. These pollutants harm human health and contribute to more significant air quality problems, such as the formation of fine dust, acid rain, and ground-level ozone. Increased use of fossil fuel-powered plants also increases emissions of greenhouse gasses (GHGs), contributing to global warming. Fundamentally, the UHI effect causes a vicious positive feedback loop of causing and dampening climate change effects. Scientists warn that this trajectory is dangerous: "Irreversible climate changes due to carbon dioxide emissions have already taken place, and going Business As Usual (BAU) would imply further irreversible effects on the planet."[7]

Hypothesis and Aim

The study discusses the research question, "How can green remodeling tackle the effects of urban heat islands caused by redlining in New York City?" Redlining is a now-illegal practice by the federal government labeling non-white neighborhoods undesirable for real estate investment and depriving them of investment.[8] In the United States, New York City was heavily affected by this practice, causing heat and income inequalities. This paper aims to develop a clear cause-and-effect relationship between the historical cause of redlining and the UHI effect. Based on the interlink, the study proposes green remodeling as a main intervention to effectively reduce urban heat islands' social, economic, health-related, and environmental harm to the residents.

Results and Discussion

Interlink of Heat and Income Inequality

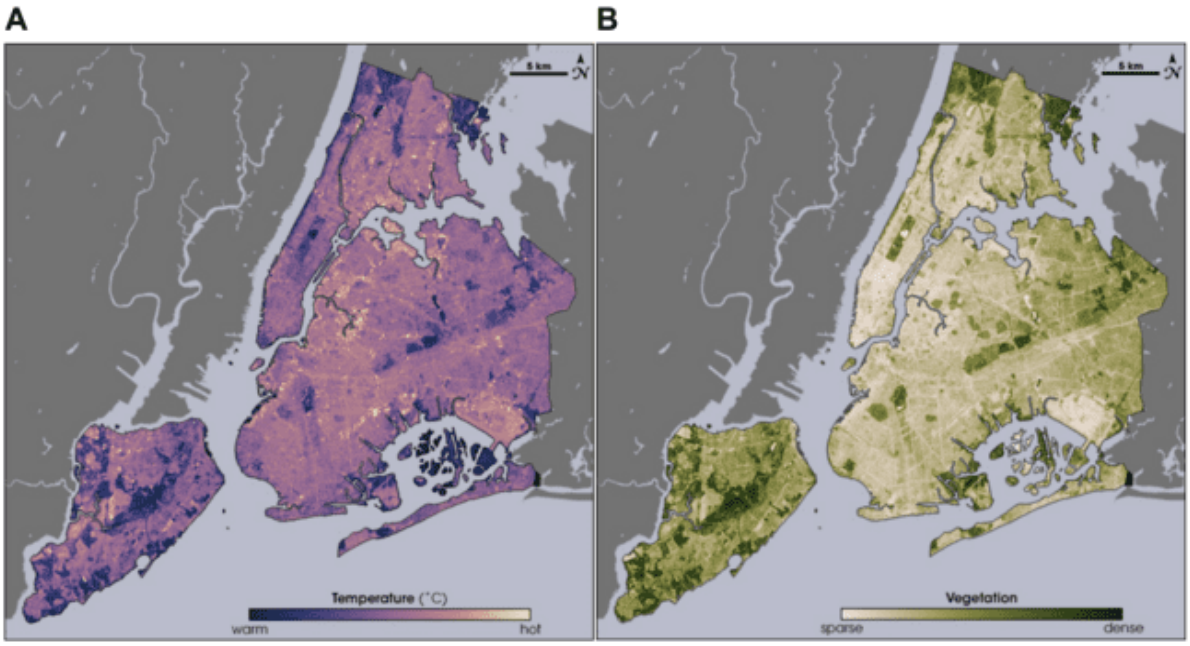

Figure 2. NASA's 2006 Landsat satellite imagery of temperature and vegetation spread in New York City. (https://earthobservatory.nasa.gov/images/6800/new-york-city-temperature-and-vegetation)

According to Climate Central's UHI index, after evaluating the land cover type, building height, and population density of 158 United States cities, New York City (NYC) is one of the five cities with the most intense urban heat islands.[9] Figure 2A shows the city's Land Surface Temperature (LST) index, with cooler temperatures in

blue and hotter temperatures in yellow. Figure 2B shows the Normalized Difference Vegetation Index (NDVI), with beige indicating sparse vegetation and dark green indicating dense vegetation. The maps demonstrate a strong correlation between dense vegetation and cool temperatures and between sparse vegetation and high for temperatures.

Table 1. Borough-Level Impervious Surface Area (ISA) Analysis of New York City.

Borough-Level Imperviousness Summary				
Borough	**Impervious**	**Semi-Pervious**	**Pervious**	**Open Water**
Manhattan	63.09%	1.67%	14.39%	20.85%
Bronx	57.58%	3.75%	30.41%	8.25%
Brooklyn	60.86%	3.00%	21.00%	15.13%
Queens	57.39%	2.15%	27.24%	13.22%
Staten Island	38.00%	6.29%	45.98%	9.73%

Note. Data from NYC Environmental Protection - DEP's Citywide Parcel-Based Impervious Area Study (https://www.nyc.gov/assets/dep/downloads/pdf/water/stormwater/dep-citywide-parcel-based-impervious-area-study-presentation.pdf)

As a coastal city, NYC has faced high urbanization and industrialization rates since the 17th century, and now, the majority of New York's boroughs are composed of impervious surfaces (Table 1). The high rates of impervious surfaces and human activity in those buildings cause abnormal patterns in LST.[10]

Since oceans absorb and radiate heat more slowly than land, NYC's coastal location makes it warmer, intensifying the UHI effect. In return, the UHI effect increases the intensity and frequency of extreme precipitation.[11] Climate Check Risk Ratings gave NY a 99/100 risk for storms and precipitation, which is 2nd highest in the country.[12] As such, the coastal location of NYC makes it vulnerable to extreme weather events and the exacerbation of the UHI effect.

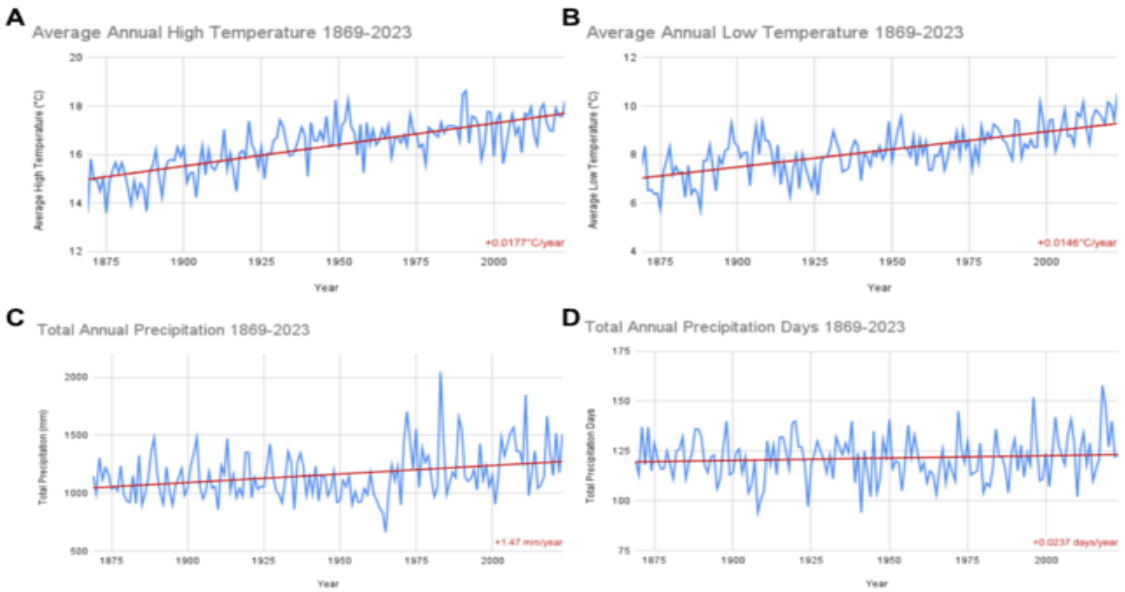

Figure 3. New York City's Average Annual Temperature and Precipitation Levels, 1869-2023. Figure 3A shows the increasing average annual high temperatures (°C); Figure 3B shows the increasing average annual low temperature (°C); Figure 3C shows the total annual precipitation (mm); Figure 3D shows the number of total annual precipitation days. (Source: Author Compiled - NYC temperature and precipitation level rise (2023))

The aforementioned are manifested in real NYC climate data. The average annual temperature and precipitation levels in NYC have been rising (Figure 3). The positive trend-lines indicate the increasing temperature and precipitation every year, which are consequences of global warming and the UHI effect created, in part, by redlining and exacerbated by NYC's coastal location.

Researchers have shown a correlation between today's hotter neighborhoods with higher concentrations of low-income and racial minorities.[13] Nearly three-quarters of families of color with children live in "nature-deprived" neighborhoods, which increases the possibility of the neighborhood experiencing great heat.[14] Noting the heat disparities across urban environments, why are communities of color and low incomes living in the hottest areas? Could a possible explanation be that prior urban planning initiatives and housing regulations have increased disproportionate exposure to intra-urban heat in American cities?

The 1990 book *Dumping in Dixie: Race, Class, and Environmental Quality* (R. D. Bullard) showed how environmental vulnerability and racial zoning practices, like redlining, were intimately related.[15] One study examined the relationship between demographics, historical redlining, the present temperature, and vegetative cover in Baltimore, Maryland; Dallas, Texas; and Kansas City, Missouri. The study discovered that historically redlined districts in all three cities experienced the UHI effect and were characterized by less vegetation, were hotter and had a significantly high percentage of low-income residents. Additionally, there were higher proportions of Hispanic and/or Black populations in the formerly redlined areas of all three cities.[16] Another study showed that formerly-redlined areas faced 94% of consistent patterns of elevated land surface temperatures relative to their non-redlined counterparts by as much as 7°C.[17] "Redlining" refers to a now-illegal practice by the federal government labeling non-white neighborhoods undesirable for real estate investment and depriving them of investment.[8] To stabilize the housing market during the Great Depression in the 1930s, the government-sponsored corporation Home Owners' Loan Corporation (HOLC) created color-coded maps of 202 United States cities according to lending risk. Neighborhoods were graded on a four-point scale: A (best), B (still desirable), C (definitely declining), and D (hazardous). These maps were driven mainly by racial segregation, with "D" areas colored in red, later termed "redlined" neighborhoods.[18]

Legacy of Redlining

Although redlining was banned under the Fair Housing Act of 1968, its legacy has persisted through entrenched segregation.[19] Areas deemed "hazardous" remain dominated by communities of color with/or low-to-moderate income. In contrast, those considered "desirable" remain primarily white with higher incomes.[20] The practice and legacy of redlining also apply to places outside the United States, albeit under different names, in countries like South Africa, Brazil, Australia, the United Kingdom, and Canada. This issue intersects with environmental justice and public health concerns such as disproportionate temperatures, impaired air and water quality, and heat-related illnesses.

Table 2. Economic Characteristics, by 1938 Home Owners' Loan Corporation (HOLC) Grade: New York City, 2013–2017.

Variable	By HOLC Grade				
	A (Green)"Best," No. (%)	**B (Blue) "Still Desirable," No. (%)**	**C (Yellow) "Definitely Declining," No. (%)**	**D (Red) "Hazardous," No. (%)**	**Not Classified (Gray), No. (%)**
Poverty level, % below US poverty line (column %)					
Very low (< 10%)	30 (93.8)	101 (33.2)	223 (27.1)	86 (15.9)	224 (48.2)
Medium (10% to < 20%)	1 (3.1)	114 (37.5)	312 (37.9)	150 (27.7)	129 (27.7)
High (20% to < 30%)	1 (3.1)	52 (17.1)	167 (20.3)	142 (26.2)	50 (10.8)
Very high (≥ 30%)	0 (0.0)	37 (12.2)	122 (14.8)	163 (30.1)	62 (13.3)
ICE for racialized economic segregation[1] (column %)					
Tercile 1 (best off)	32 (100.0)	133 (43.8)	193 (23.5)	146 (27.0)	202 (48.0)
Tercile 2	0 (0.0)	89 (29.3)	370 (45.0)	132 (24.4)	116 (27.6)
Tercile (worst off)	0 (0.0)	82 (27.0)	259 (31.5)	262 (48.5)	103 (24.5)

Note. ICE = index of concentration at the extremes. Based on 2010 normalized census tract boundaries. Data from Am J Public Health - Structural Racism, Historical Redlining, and Risk of Preterm Birth in New York City, 2013–2017 (Krieger et al., 2020)

[1]High-income White households vs low-income Black households. Missing from analysis = 48 census tracts.

Table 2 is the most recent data for NYC by HOLO Grade (created in 1938) from the 2013-2017 study published in 2020. It shows how neighborhoods designated historically with an A grade fared most significant advantages in economic indicators, with A-graded census tracts having a mean household income approximately twice as high as that of tracts graded as B and C and nearly three times that of the D-graded tracts. Neighborhoods historically designated with a D grade fared worse on most contemporary indicators, including

a substantially lower determinant of health index (16.37) and the percentage of children living above the poverty line (54.62%).

Effect of Redlining on Heat Inequality in New York City

As with other environmental justice (EJ) issues, the causes of the disparities in the exposure of the UHI effect are complex and rooted in part in historical patterns of exclusion and discrimination. Multiple stakeholders are involved in the conflict, and the issue contains the effects of social stratification by race and class.[21] NYC's environmental injustice regarding urban heat islands concerns minorities' unequal rights and participation in decision-making, unfair risk distribution, and unfair resource use and allocation.

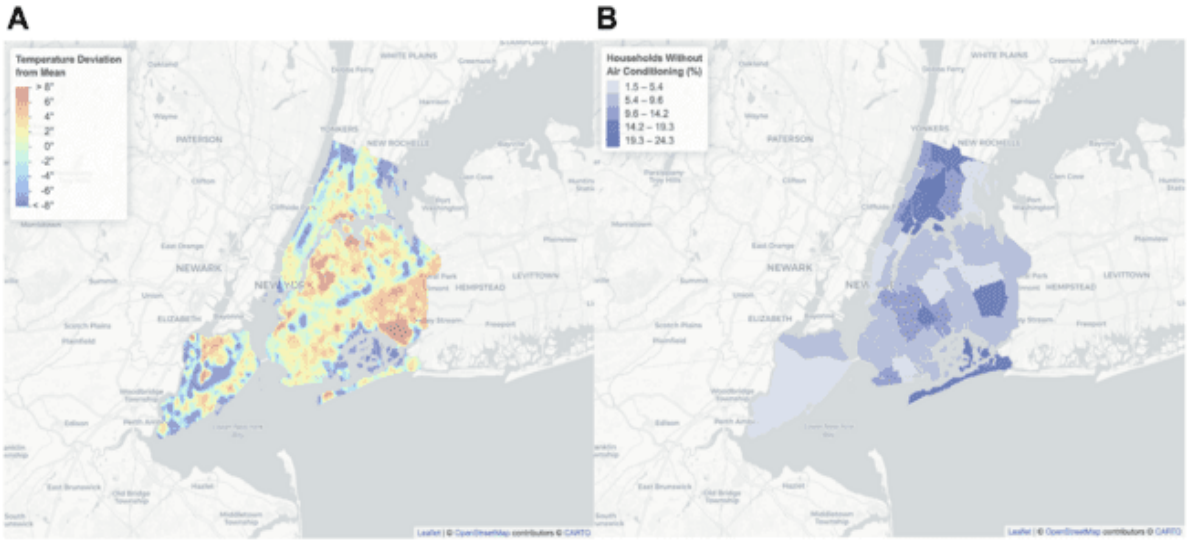

Figure 4. Map of Heat and Cool Inequality in New York. (Source: NYC Council Data Team - https://council.nyc.gov/data/heat/)

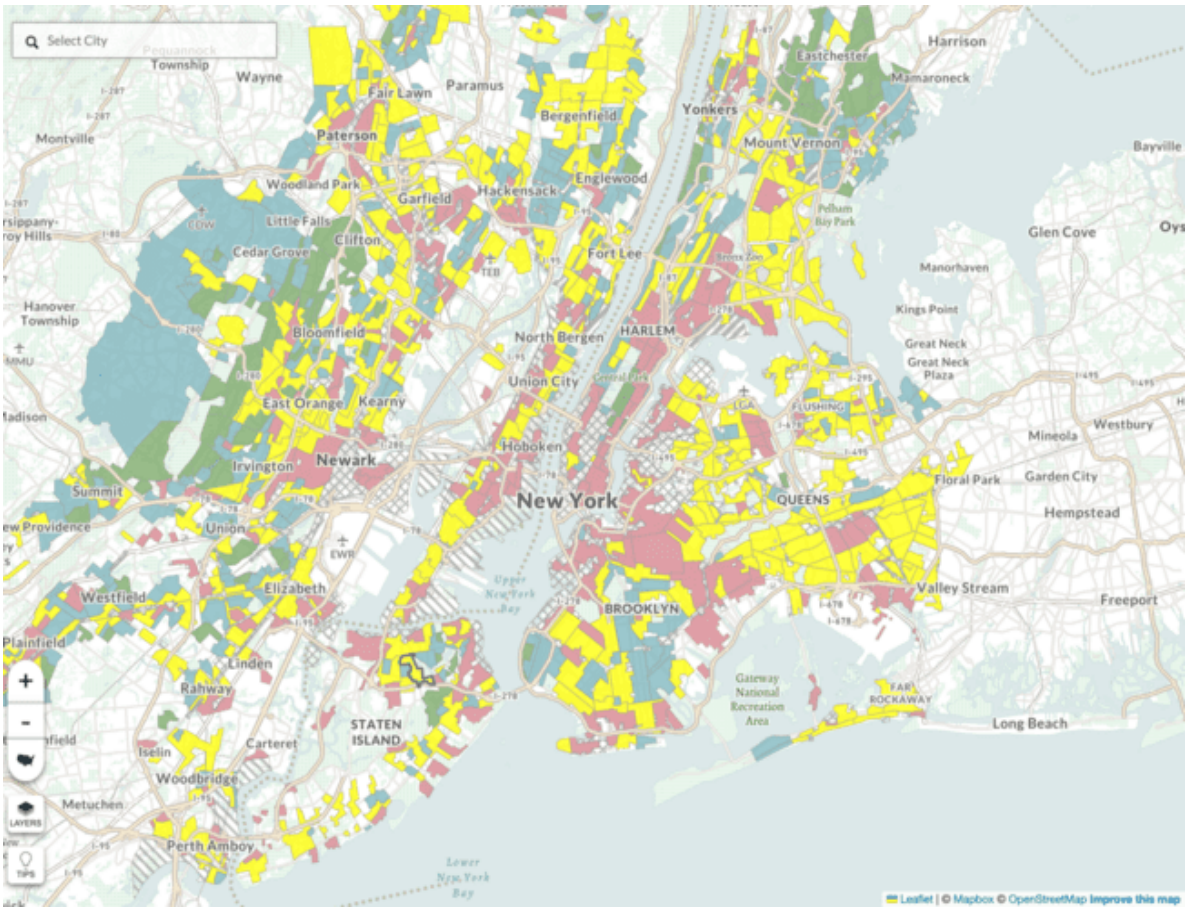

Figure 5. 1935-1940 HOLC (Redlining) Map of New York. (Source: University of Richmond - Mapping Inequality: Redlining in New Deal America (Nelson et al., 2023))

Figure 4a indicates areas experiencing extreme heat, and Figure 4b indicates proportion of households' access to air conditioning in different areas. Together shows that areas with higher temperatures also have relatively less access to air conditioning, demonstrating those populations' vulnerability to environmental harm. It also illustrates the population's lack of resilience to the environmental challenge, as people cannot fight back the extreme heat but rather cope with air conditioning. There are clear correlations between the "D" grade areas, as seen in Figure 5, and areas of vulnerable populations, i.e. areas with a higher deviation from the mean temperature and without air-conditioning as seen in the two maps of Figure 4. As such, the evidence above proves that historical redlining altered the urban landscape of U.S. cities so that communities of color were more vulnerable to rising heat. EJ expert Robert D. Bullard's quotes from *Confronting Environmental Racism: Voices from the Grassroots*, that "Racism influences the likelihood of exposure to environmental and health risks. Racism provides whites of all class levels with an 'edge' in gaining access to a healthy physical environment."[22]

Challenges of Tackling the UHI Effect Caused by Redlining

While the marginalized minority populations have suffered, the majority community, mostly comprised of high-income and/or white people, has benefited from marginalization and hence does little to alleviate the situation. White households are worth at least ten times as much as Black households;[23] only 15% of white households have zero or negative net worth, while a third of Blacks and Hispanics do.[24] This ignorance likely comes from

the "Not In My Back Yard (NIMBY)" phenomenon, as well as the invisibilities of not being able to see the damages of their actions to those in other places and to future generations.[25] It is challenging to tackle the grassroots of such a historical EJ issue that requires the willingness of the majority population to contribute to protecting the vulnerable. In 1992, Lavelle & Coyle unveiled glaring inequities of the EPA's practices: "There is a racial divide in the way the U.S. government cleans up toxic waste sites and punishes polluters. White communities see faster action, better results, and stiffer penalties than communities where minorities live." Accordingly, many policymakers are motivated to serve the interests of the majority population to be re-elected or are from white and/or high-income backgrounds themselves. Therefore, as aforementioned, people of color experience injustice in decision-making. On top of that, many of them cannot "vote with their feet" by leaving unhealthy physical environments due to socioeconomic barriers.

The environmental problem of urban heat islands caused by historical redlining in New York City is a complexity that delves into the social-environmental system involving various stakeholders. Amid the climate crisis, urban heat islands' positive loop hinders efforts to reduce GHG emissions and has significant environmental, social, and human health-related consequences. As the issue involves historical environmental racism, it necessitates inclusive interventions designed to advocate for the "right" of all individuals to be protected from environmental degradation and shift the burden of proof to those who cause harm, discriminate, or do not give equal protection to minorities. Therefore, it is important to advocate for the implementation of city-wide green remodeling, along with education, monitoring, and short-term cooling methods, to reduce the UHI effect while tackling environmental injustice.

Environmental justice expert Robert D. Bullard writes in *Confronting Environmental Racism: Voices from the Grassroots,* "It is unlikely that this nation [United States] will ever achieve lasting solutions to its environmental problems unless it also addresses the system of racial injustice that helps sustain the existence of powerless communities forced to bear disproportionate environmental costs."[22] Similarly, the National Environmental Justice Advisory Council, a Federal Advisory Committee to the U.S. Environmental Protection Agency, recommends that "all stakeholders should have the opportunity for meaningful involvement in redevelopment and revitalization projects."[26] To curate a sustainable society, we must challenge the Not In My Back Yard (NIMBY) mentality, exposing privileged communities to vulnerable populations nearby. In order to foster stakeholder collaboration and equitable contribution, breaking the system of racial injustice, the intervention strategy will be based on Ostrom's Design Principles (Appendix).[27]

Past Actions by Various Stakeholders

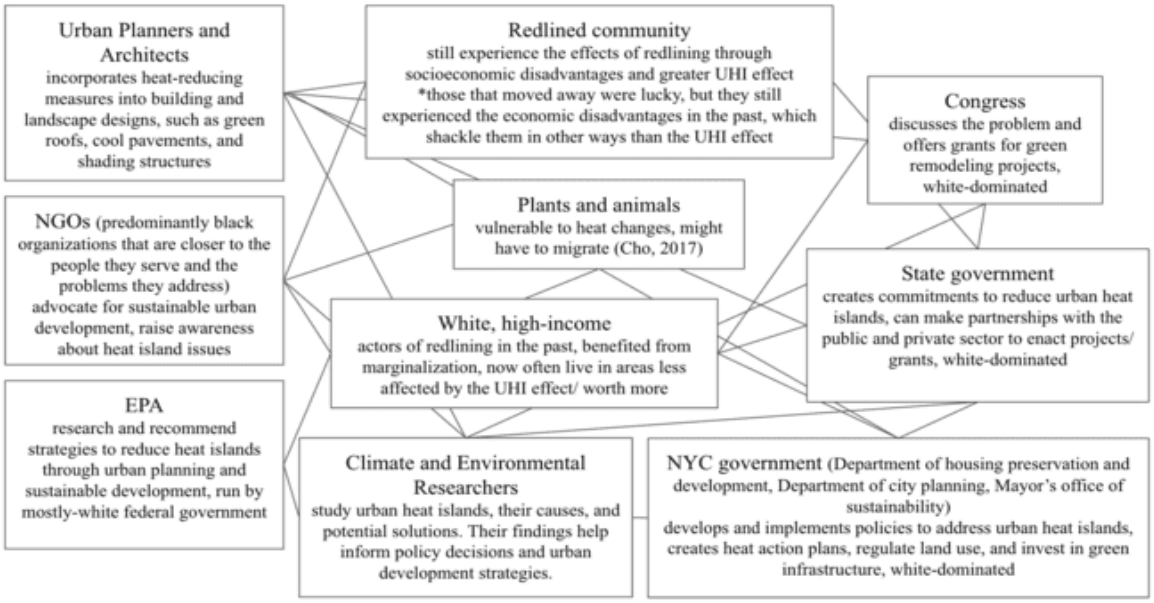

Figure 6. Stakeholder map identifying existing stakeholders of the UHI effect caused by redlining in NYC. (Source: Author Compiled - Stakeholder map (2023))

State Action

Previous attempts to solve the problem had mixed results. At a state level, the NY State Senate passed the Climate Leadership and Community Protection Act (Bill S6599) to "reduce New York's greenhouse gas emissions by 85% by 2050 and net zero emissions overall"[28]in the 2019-2020 Legislative Session. The values of this bill are the promises of regular hearings, a public statewide GHG emissions report, identification of vulnerable populations to climate change, and the publication of the criteria for identifying disadvantaged communities. However, there are inadequate drastic reduction measures to meet the ambitious goal, and the plan does not provide specific and distinct plans for different sources of emissions. The EPA awarded Urban Forestry Grants totaling $2.24 million to communities and organizations across New York for tree inventories, community forest management plans, tree planting, and tree maintenance.[29] While increasing vegetation is proven to be beneficial in cooling down areas, the downsides of individual tree-planting programs are opportunity cost, carbon footprint, time to grow, cost efficiency, greenwashing, one-frame narrative, and potential conflicts with native species (Introduction to Environmental Problems and Solutions discussion, July 11, 2023).

City Action

One city-run program is the NYC Cool Roofs, which provides free or low-cost installation of energy-saving reflective rooftops to reach carbon neutrality by 2050. Another is the NYC Green Infrastructure Grant Program, which is an application-based green roof retrofit funding for private property.[30] Both programs help residents save utility costs in the long run, preserve roof structure and cooling equipment, reduce energy consumption and carbon emissions, and combat the urban heat island effect. Still, the limitations are that they are voluntary and require residents to apply or request the program's implementation.

International Action

Internationally, the United Nations Environment Programme (UNEP) published guidance to address warming in cities. With study findings and city cooling case studies, this guide is intended for city officials and planners to use as an encyclopedia of proven options to help cool cities. In the publication, UNEP advocates for increasing tree cover in cities by saying, "Heat reduction services from urban tree cover in the United States are estimated to be worth USD 5.3 billion to USD 12.1 billion annually."[31] Nonetheless, this is just a guide, not a binding international law, i.e., countries can choose whether or not to utilize it.

Analysis of Past Actions

The common drawbacks of these existing solutions are strict eligibility requirements despite non-strict regulations and huge commitments without a precise roadmap. They also do not focus on the grassroots of the issue, which is environmental injustice that shackles marginalized communities from accessing such programs or moving to safer living environments. Thus, there are loopholes for the wealthy to get away with regulations or utilize expensive emissions-cutting technology as a simpler and quicker solution. Meanwhile, the vulnerable populations would face the same emissions reduction requirements with a lower reduction capability.

Proposed Intervention: Green Remodeling

The proposed idea improves the existing solutions and attends to each key issue outlined at the beginning of the paper. Green remodeling is the act of changing the interior or exterior of buildings using processes that are environmentally responsible and resource-efficient. It is both an adaptation and mitigation technique because it helps residents build resilience to the warmer climate by providing a cooler environment and reducing buildings' heat emissions. There are various methods of green remodeling and benefits. Increasing vegetation provides shade, absorbs heat, and cools the air through evapotranspiration. Subsidizing the use of renewable energy and installing roof solar panels, for example, would help low-income families overcome the burden of energy expenses. A case study of implementing cool roofs in Boston, Massachusetts, reports that these roofs reduce roof and internal building temperatures, improve air quality by reducing power demand, and reduce the UHI effect.[32] Although green remodeling cannot change the city layout to reduce the density of buildings, it has the potential to significantly reduce the UHI effect caused by the density. Some factors that will favor the implementation of green solutions, effectively in the redlining areas, are community engagement, inclusion of the previously underrepresented voices in decision-making, educational programs, policy support, monitoring and evaluation methods, and long-term planning.

To achieve this project, the city should first create a task force or committee comprising representatives from the identified stakeholders (Figure 6). Community buy-in is key for the long-term success of government initiatives. "Activists of color are more experientially equipped to perceive the injustice in the distribution of environmental hazards"[33] and "alliances formed between grass-roots and national groups can produce positive results, breaking down stereotypes and mistrust on both sides."[34] This diverse group of stakeholders will lead the planning and monitoring of implementing green remodeling and education initiatives. The executive decisions from the committee will then be reinforced by the city government. The formation of this committee not only tackles the grassroots issue of marginalization and under-representation by bringing more voices to the decision-making table but also ensures well-informed decision-making by involving climate and environmental researchers, non-governmental organizations (NGOs), and other experts.

Case Study of Cooling Distribution Program in Boston

A more immediate solution to accompany the long-term green remodeling is an air conditioning and fan distribution program run by environmental NGOs. In Boston, this program gave direct support to residents facing

increasingly high average temperatures and extreme heat events, for those who did not have the resources to stay healthy and cool during heat waves, and who were more sensitive to heat stress due to their age and chronic health conditions like asthma. While this program may incur high upfront costs, such as utility costs, it advances resilience and sustainability goals by empowering marginalized populations to gain adaptation capability. Additionally, involving volunteers and NGOs in the hands-on solution will raise general awareness and engage more residents in the change-making process.

Pop-Up Cooling Centers

Another possible short-term intervention is the creation of pop-up cooling centers near the previously redlined areas that suffer from the UHI effect to provide immediate relief during heat waves. These measures can ensure that vulnerable populations have access to cooling facilities and are aware of the dangers of extreme heat. This also brings employment opportunities to support the local economy by inviting small businesses and community organizations and an opportunity to celebrate culture, heritage, and identity at each site.

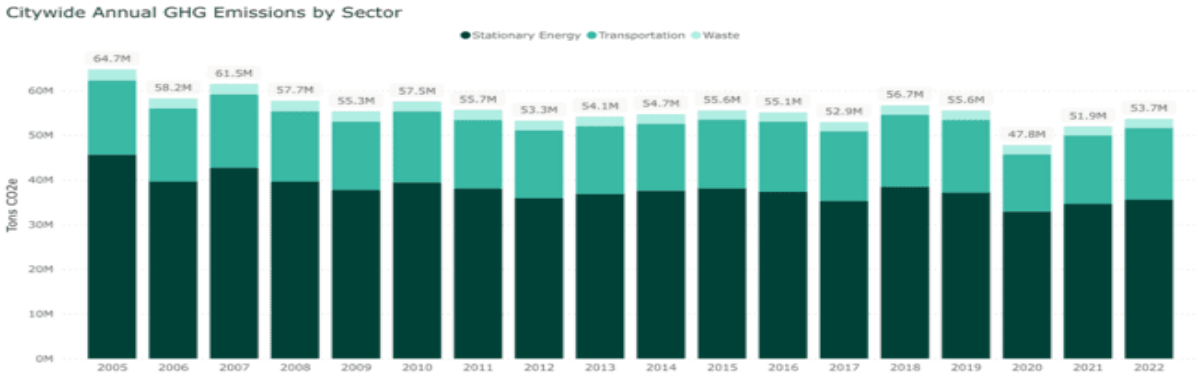

Figure 7. NYC's Citywide Annual GHG Emissions by Sector, 2022. (Source: New York City Mayor's Office of Climate & Environmental Justice - NYC Greenhouse Gas Inventories (2022))

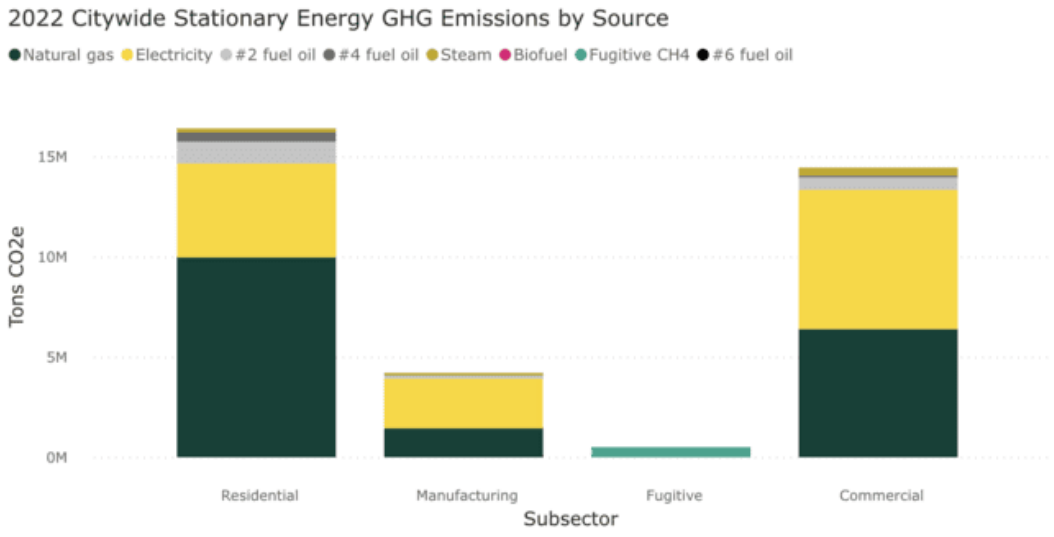

Figure 8. NYC's Citywide Stationary Energy GHG Emissions by Source, 2022. (Source: New York City Mayor's Office of Climate & Environmental Justice - NYC Greenhouse Gas Inventories (2022))

Evaluation of the Proposal

This holistic intervention is better than previous attempts to address the UHI effect caused by redlining because it is less voluntary, has a monitoring system run by a diverse task force, and targets the grassroots issue more directly. Furthermore, it also has a clear focus on buildings as a source of greenhouse gas emissions. Stationary energy, defined by the New York City Mayor's Office of Climate & Environmental Justice as "energy used by buildings and other stationary sources," contributes most to citywide GHG emissions (Figure 7). Buildings, especially residential ones, make up the largest portion of greenhouse gas emissions in NYC (Figure 8). By involving a wide range of stakeholders, the intervention aims to build back better together.

Nevertheless, trade-offs and drawbacks exist with green remodeling. To offset those disadvantages, below are outlined solutions and benefits of the proposal:

Table 3. Evaluation of the intervention proposal to reduce the UHI effect in NYC.

Trade-off / Drawback	Solution / Benefit
High cost of implementation, which equals high opportunity cost that could be used for other immediate or impactful solutions	Reduced energy bills, improved comfort, healthier air, and lower maintenance costs until being remodeled again.[35]
Difficult stakeholder buy-in, opposition to change	Education[1] about the real racial history of the United States and how green remodeling reduces the UHI effect, community mobilization through the committee and volunteering, an incentive to make NYC a leading figure in combating urban heat
Not an immediate relief; it takes time for the effects to show	Short-term solutions such as pop-up cooling centers and air conditioning and fan distribution will accompany
Perception of "green" as less aesthetically pleasing	Education as a tool to change people's mindsets to realize the importance of and accept "green," involvement of green urban planners to make green remodeling as aesthetically pleasing as possible
Although redlining explicitly targeted the Black community, the current redlined areas are not Black-concentrated (Figure 9), so focusing on the present redlined areas only would fail to indemnify the damages redlining did to the Black community.	The project's target is the whole city, not just redlined areas, so the previously redlined Black community that moved away, as well as people of other races or ethnicities that were deemed "risky" by the government in the 1930s, could still reap benefits.

Note. Author Compiled (2023)

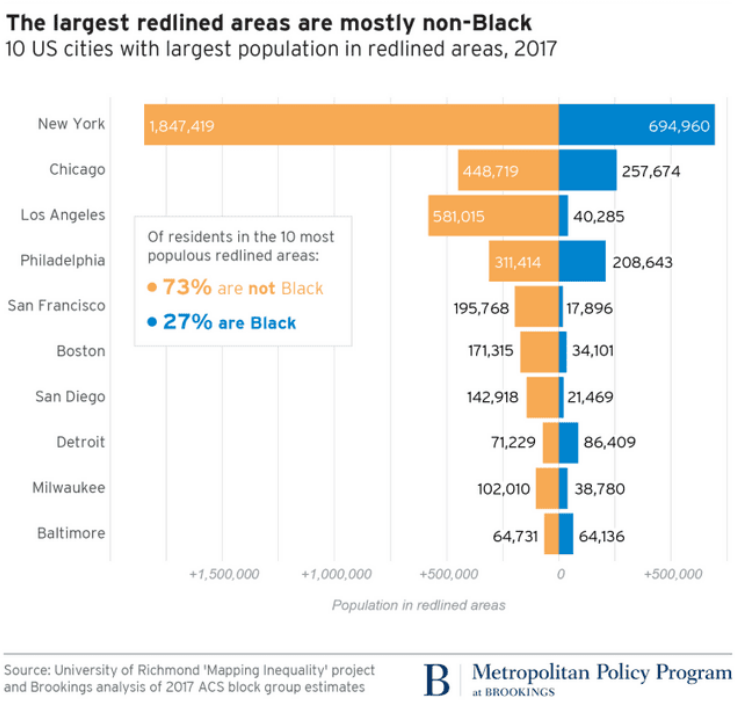

Figure 9. The Black and non-Black population distribution of the U.S.'s largest redlined areas. (Source: Brookings Institution - America's formerly redlined neighborhoods have changed, and so must solutions to rectify them (https://www.brookings.edu/articles/americas-formerly-redlines-areas-changed-so-must-solutions/))

Successful Case Studies of Green Remodeling

Some case studies demonstrate the effectiveness of green remodeling and community engagement in alleviating extreme heat from urban heat islands. China transformed Zhuhai, a city in the Guangdong-Hong Kong-Macao Greater Bay Area, into a "sponge city," where it replaced hard surfaces like roads with permeable pavement that can store water for longer and absorb less heat. Porous bricks and porous concrete are environmentally friendly, as they reduce pavement surface temperature by 12 and 20°C, respectively, and the air temperature by up to 1°C.

In another case, Newark and Camden, New Jersey, and Baltimore, Maryland, have prioritized community engagement and nonprofit partnerships to increase trees on private property and cool heat islands equitably. Newark's Office of Sustainability leveraged technology using the i-Tree tool to prioritize underserved neighborhoods for planting, and Tree Baltimore, a community-based organization, created a street tree inventory that informed the city's planting map. Leaders of the three cities cite the importance of community outreach for reaching their goals.[36]

Conclusion

The combination of city-wide green remodeling, a representative committee, education, monitoring, and short-term relief programs provides a holistic approach to reducing the UHI effect in NYC. Green remodeling is researched and proven through case studies to be effective in drastically cutting heat and GHG emissions radiating from buildings. The side projects proposed in the paper will elevate green remodeling's potential even more. By starting with green remodeling residential buildings only, New York City can expand its initiative to

other types of buildings later and become a model example of combatting the UHI effect. By having a diverse task force at its core, this intervention tackles the grassroots problem of environmental racism caused by historical redlining and "moves the needle" toward a more sustainable pathway, both environmentally and socioeconomically.

Limitations

This paper derives conclusions from analyzing secondary research and making observations. Primary research, such as surveying the residents of NYC about their views on green remodeling and collecting anecdotes from them about the daily consequences of redlining, could lead to more nuanced and tailored conclusions about the solution choice and discussion about the feasibility of implementing city-wide green remodeling in NYC. Further research in this area that identifies the costs and time frame required for implementation would also benefit from expanded survey efforts that compile stakeholders' experiences and views.

Authors

Jihyeon Sung is a junior at Chadwick International School. She is interested in the environmental injustice and is hoping that this research paper will expand her knowledge in further becoming a better global leader.

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