Examining the Relationship Between Historic Redlining, Urban Heat Island Intensity, and Energy Burden Across Different Socioeconomic Regions in New York City

Members: Arya Gurumukhi, Sheila Micelli, Loli Koko
Mentors: Tanzia Ahmed, Olawale Oluwafemi, Kevin Czajkowski

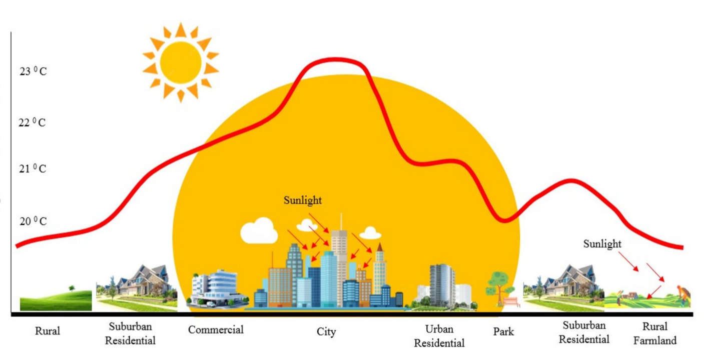
Introduction

The Urban Heat Island Effect: Urban heat island (UHI) is a phenomenon where urban areas are significantly hotter than nearby rural areas. This can be caused by city infrastructure such as concrete that traps heat. Some of the damaging effects can include increased energy consumption such as when needed for air conditioning, higher nighttime temperatures, and public health risks.

However, urban heat island disportionately impacts low-income and vulnerable groups within our nation. To truly visualize the impact, this research examines multiple aspects and visualizes how income correlates directly with urban heat island intensity but additionally with energy burden.

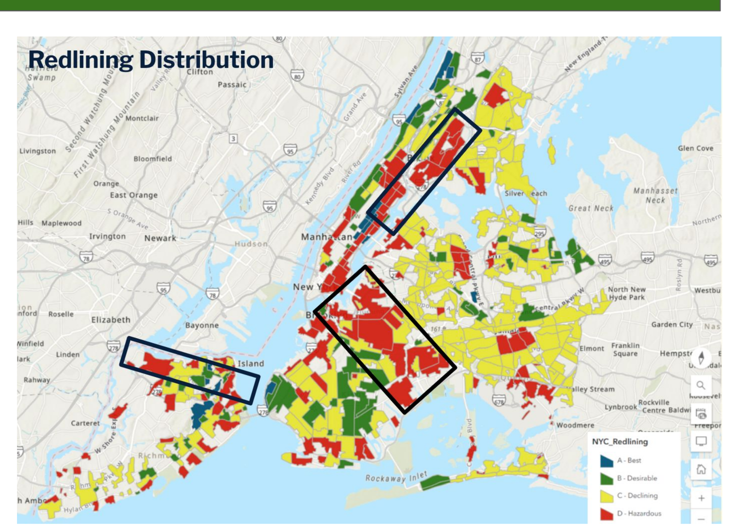
To measure and visualize this impact **median household income (MHI)** will be measured. MHI is the median household income level of a community and is an indicator of its economic well-being.

The study area will be **New York City** due to its large sample size and large range of income levels across the city. The data will be examined at the census tract level.



Redlining

Redlining is a discriminatory housing practice beginning in the 1930's that separated black, immigrant, and low income communities (by marking them in red) and **denied them opportunities for mortgages and investment.** This redlining has not only shaped economic and political decisions taken over time but changed the sociopolitical landscape. This can largely be seen in metropolitan areas like New York City. In the map above the boxed regions highlight heavily redlined areas in New York City that have been **disproportionately impacted over the past several decades**. These redlined regions give another lens to look through for UHI.



Energy Cost Burden

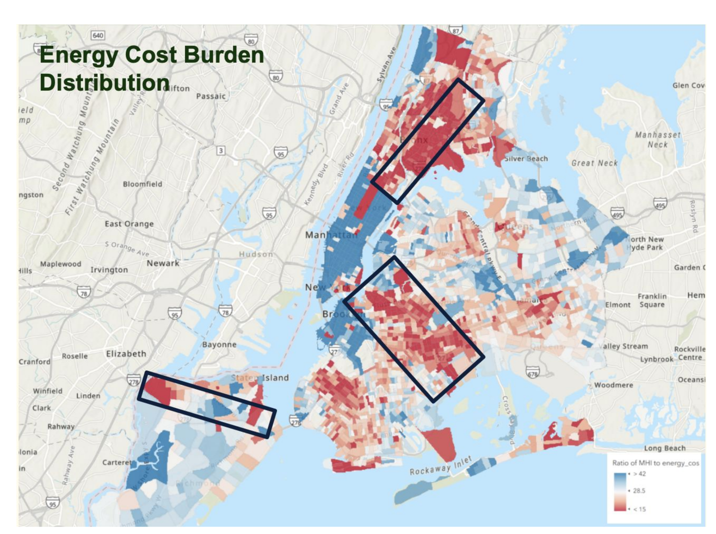
Energy cost burden refers to the **relative ratio of cost that residents have to pay in energy expenses relative to their income amount.** For this project we specifically used the formula: Energy Burden = (energy cos/median household income(MHI)). By mapping energy burden alongside urban heat island data in our research we aim to reveal how climate and economic inequities intersect in within New York City specifically. Energy burden traps several low-income communities within NYC annually. Infact, **more than a fifth (21%) of new yorkers have trouble paying their utility bills** due to the high price.

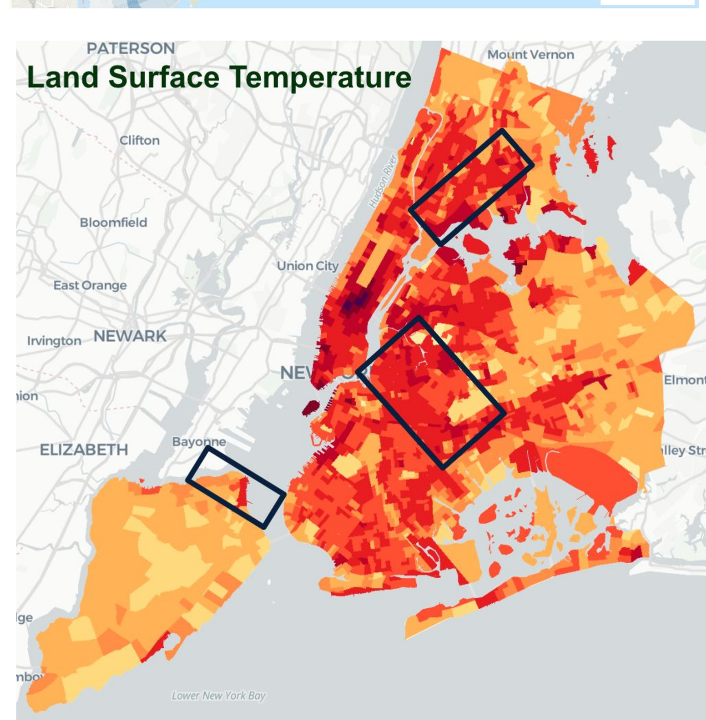
Methodology + Materials

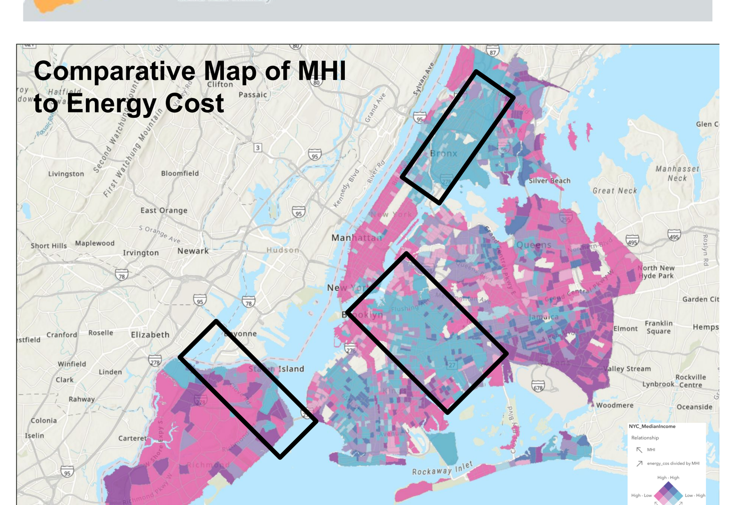
- **ARCGIS** software was used for map visualization and statistical analysis
- **Google Earth Engine** was used for land surface temperature
- **University of Richmond** Digital Scholarship Lab was used for redlining maps and redlining data
- U.S. **Census** Bureau (2020) was used for median household income data and socioeconomic data
- NYC **Open Data** / local government portals were used for information on the census tract level in NYC.

1. **Data Collection**
   - We collected land surface temperature (LST), socioeconomic data, redlining maps and energy consumption data from the census tract. For the LST data we collected it from the summer of 2023 and all other data was based off of the 2020 census data.
2. **Data Cleaning**
   - The data collected had several null values so the data was cleaned in Excel. During the cleaning the null values were removed & the data was ensured to have numerical formats for every value.
3. **GIS Analysis**
   - For the GIS analysis all of it was conducted in ARCGIS. To do this CSV and shapefile data layers were imported and then spatial joins were conducted. By overlaying different layers more in-depth analysis could be conducted.
4. **Visualization**
   - In ARCGIS heat maps were generated and a multivariate map was created showcasing energy cost paired up with MHI. Several other maps were also created to showcase the socio economic landscape
5. **Statistical Analysis**
   - To find the correlation and strength of the correlation of all variables that were studied a Pearson Correlation was conducted.

Results







Using spatial analysis in ArcGIS, the geographic patterns of energy burden distribution, land surface temperature (LST), and median household income (MHI) were examined and compared to different socio economic regions across New York City. Since NYC is quite large and with multiple variable results, for this research result analysis we **specifically focused on three regions.** These three regions have been boxed in black on each map.

The **first map reveals clear geographic disparities in energy burden** across NYC census tracts. Energy burden was calculated and then mapped in comparison to median household income. The darker red areas indicate a higher energy burden essentially a greater percentage of income spent on energy.

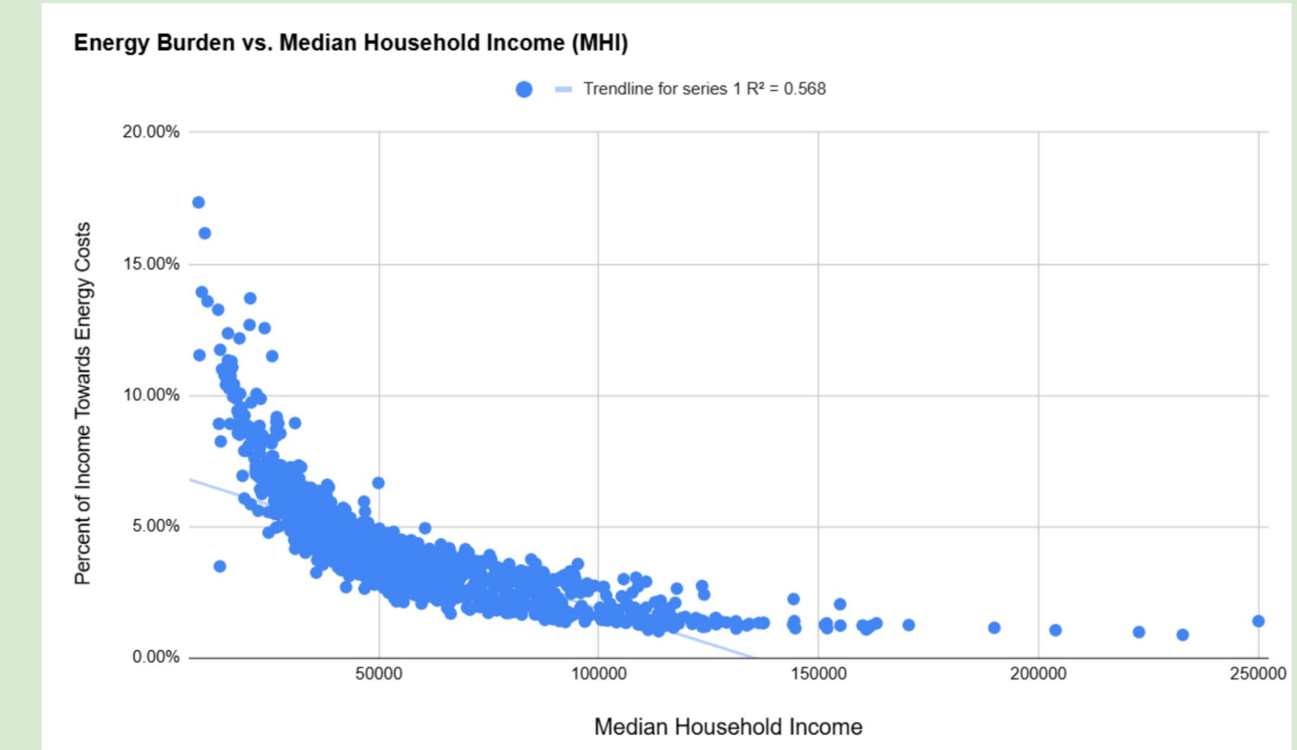
When put in comparison with the second map, we can see that the the hottest areas are concentrated in Central Brooklyn, the South Bronx, and parts of Queens, aligning with dense urban regions with limited tree canopy and high impervious surface cover.

Cooler regions which are the lighter shades are seen in areas with higher vegetation and lower building density, such as parts of Staten Island and wealthier Manhattan neighborhoods.

When visually compared with the energy burden map, a spatial overlap emerges. **Many of the high-LST areas also exhibit high energy burdens,** suggesting residents in these neighborhoods face compounding challenges of heat exposure and high energy costs, often due to increased cooling needs during summer months.

The third map overlays median household income against energy costs across the city. The higher MHI areas (lighter shades) show lower relative energy costs, while lower MHI areas (darker shades) exhibit higher energy expenses relative to income.

Data Analysis & Conclusion




```
-0.7512286361
=CORREL (A2:A2202, C2:C2202)
```

Statistical analysis was conducted to find a Pearson correlation. Supporting the spatial patterns observed in the results section, the Pearson correlation analysis between Energy Burden and MHI produced a value of -0.75, indicating a strong negative correlation. This statistically confirms that **as median household income increases, energy cost burden decreases significantly.** Essentially, low-income communities are disproportionately affected by higher relative energy costs. These same communities often reside in urban heat islands with high intensities, exacerbating cooling demands and financial strain. The scatterplot above also further backs up this claim as there is a clear trend and association between income and energy burden. As the income increases the energy burden decreases exponentially. The combination of these datasets and maps illustrates the **intersectionality of climate vulnerability, energy burden, and socioeconomic disparities.** Communities that are low-income (high energy burden), living in high LST (heat islands) and facing systemic underinvestment are the most vulnerable to climate-related health impacts and financial strain. Using this information, **future policy plans can be shaped accordingly** to allocate more materials to specific communities. Additionally, investment can be made to increase green land cover in specific regions. The integration of redlining history into climate risk assessments to ensure affected communities are included in urban resilience planning and decision-making is another step towards the right direction.

Citations

Sharifi, Ehsan, and Steffen Lehmann. "CORRELATION ANALYSIS OF SURFACE TEMPERATURE OF ROOFTOPS, STREETSCAPES AND URBAN HEAT ISLAND EFFECT: CASE STUDY OF CENTRAL SYDNEY." Journal of Urban and Environmental Engineering, vol. 9, no. 1, 2015, pp. 3–11. JSTOR, http://www.jstor.org/stable/26203432. Accessed 17 July 2025.

Aalbers, Manuel B. "What Types of Neighbourhoods Are Redlined?" Journal of Housing and the Built Environment, vol. 22, no. 2, 2007, pp. 177–98. JSTOR, http://www.jstor.org/stable/41107379. Accessed 17 July 2025.

Duncan, Marcia, et al. "Redlining Practices, Racial Resegregation, and Urban Decay: Neighborhood Housing Services as A Viable Alternative." The Urban Lawyer, vol. 7, no. 3, 1975, pp. 510–39. JSTOR, http://www.jstor.org/stable/27893068. Accessed 17 July 2025.

Jacobs, Stephanie J., et al. "Use of Cool Roofs and Vegetation to Mitigate Urban Heat and Improve Human Thermal Stress in Melbourne, Australia." Journal of Applied Meteorology and Climatology, vol. 57, no. 8, 2018, pp. 1747–64. JSTOR, https://www.jstor.org/stable/26501140. Accessed 17 July 2025.

Rosenbaum, Emily. "Racial/Ethnic Differences in Home Ownership and Housing Quality, 1991." Social Problems, vol. 43, no. 4, 1996, pp. 403–26. JSTOR, https://doi.org/10.2307/3096952. Accessed 17 July 2025

Hillier, Amy E. "Spatial Analysis of Historical Redlining: A Methodological Exploration." Journal of Housing Research, vol. 14, no. 1, 2003, pp. 137–67. JSTOR, http://www.jstor.org/stable/44944777. Accessed 17 July 2025..

KAPLAN, Gordana. "Evaluating the Roles of Green and Built-up Areas in Reducing a Surface Urban Heat Island Using Remote Sensing Data." Urbani Izziv, vol. 30, no. 2, 2019, pp. 105–12. JSTOR, https://www.jstor.org/stable/26843926. Accessed 17 July 2025.

Shmaefsky, Brian R. "One Hot Demonstration: The Urban Heat Island Effect." Journal of College Science Teaching, vol. 35, no. 7, 2006, pp. 52–54. JSTOR, http://www.jstor.org/stable/42992461. Accessed 17 July 2025.