MAPC
METROPOLITAN AREA PLANNING COUNCIL

SMART GROWTH AND REGIONAL COLLABORATION

MEMORANDUM

From: MAPC
To: EEA
Subject: Summary of Cool Roofs Literature Review and Methodology Selection
Date: June 30, 2024

Overview

This memo summarizes the work conducted under subtask 4.1 (Literature Review of Methodologies) and subtask 4.2 (Methodology & Date Acquisition) of the MVP Metro Mayors Cool Roofs project. The scope of these tasks was to review the literature of cool roof feasibility assessments and identify an appropriate methodology to assess the cool roof potential of the Metro Mayors region.[1]

Literature Review

The project team reviewed a number of resources, such as "On the use of 'cool roofs' to reduce residential heat exposure disparities in Boston, MA (Smith, Lusk, Hutyra, 2022)". The team also examined cool roof assessments from other cities, such as Cambridge and New York City, to identify best practices in data collection and methodologies.

In addition to reviewing the literature, MAPC met with the Google Public & Environmental Health team, who are leading a detailed cool roof feasibility study for the City of Boston, to compare and discuss respective methodologies. MAPC also connected with Mehdi Heris, professor at the Urban Policy and Planning Department at Hunter College, who led the cool roof analysis for both New York City and Cambridge and is a member of the MVP Cool Roofs advisory group (Task 1). Mehdi Heris provided invaluable support in discussing different approaches to cool roof assessments and even shared the code used for the cool roofs assessment in Cambridge and New York City.

After completing the literature and stakeholder meetings, MAPC opted to adapt the Cambridge and New York City approach, described in more detail in the next section, to the MAPC region. As a final step, the MAPC team met with Caitlin Spence, Assistant Climate Scientist at the EEA Climate Science Office, to present the methodology and receive any final feedback before proceeding.

Data and Methods

In summary, the cool roof methodology uses LIDAR data, provided by MassGIS, to extract roof shapes and color intensity to identify flat and dark roofs on buildings in the 16 Metro Mayors communities. Early on in the project, MAPC met with representatives from Nearmap to explore the possibility of purchasing high-resolution aerial imagery, which could deliver more detailed building-level data, but the quote exceeded the reserved budget and was cost-prohibitive to do at a regional-scale. We determined that MassGIS' raw LIDAR point cloud data was the best option for

[1] Metro Mayors Coalition includes the sixteen cities and towns of Arlington, Boston, Braintree, Brookline, Cambridge, Chelsea, Everett, Malden, Medford, Melrose, Newton, Quincy, Revere, Somerville, Watertown, Winthrop.

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assessing both roof pitch and roof reflectivity. Once potential cool roof sites (i.e., flat, dark roofs) are identified, MAPC used Python to join the sites with parcel data and summarized statistics (e.g., total number and square footage of residential vs commercial vs municipal cool roof sites).

Criteria Development

The goal of Task 4 of the Metro Boston Cool Roofs Project is to develop a site suitability analysis that identifies prime locations for cool roof installations in the Metro Mayors region. The analysis assesses each rooftop based on key physical characteristics of the roofs themselves as well as the environmental, economic, and social characteristics of the land parcels and census geographies in which they reside. Based on a literature review and interviews with members of our advisory group and availability of data, we narrowed our set of suitability criteria to the following characteristics. Data sources and detailed methodology for data processing can be found in the table below.

Analyzing Roof Characteristics

The initial plan for analyzing rooftop characteristics involved purchasing high-resolution aerial imagery, such as Nearmap, which could deliver building-level data on slope, aspect, color, obstructions, mechanicals. However, this data proved to be cost prohibitive, so we sought other options and guidance for completing this part of the analysis in-house. We determined that MassGIS' raw Lidar point cloud data was the best option for assessing both roof pitch and roof reflectivity. This was based on existing literature on the use of Lidar to extract roof shape and reflectivity[6,7], as well as conversations with Dr. Mehdi Heris, professor at the Urban Policy and Planning Department at Hunter College, who led the cool roof analysis for both New York City and Cambridge and is a member of the MVP Cool Roofs advisory group, and Phillip John, Remote Sensing Analyst for the MA Executive Office of Technology Services and Security. MassGIS maintains this dataset and was generous in offering support for its acquisition and processing.

Data Processing

The following table describes the processing steps and data source for each indicator included in the Cool Roofs Suitability Analysis.

Criteria	Description/reason for including	Processing steps	Data Source
Low-Slope Roofs	The shape of a building's roof determines what kinds of interventions are possible. Low-slope roofs are well suited for cool roof conversion as they can more easily be coated with high solar reflective index (SRI)[2] materials. In contrast, pitched roofs require more specialized materials to become cool roofs.[3,4]	Using Lidar point cloud data and an ArcGIS-based methodology, a 0.8 meter resolution raster was created to cover each building in MMC, with each raster pixel approximating the slope of the building at that location. A "flat roof" for this analysis is defined as a rooftop where the majority of pixels within the roof's boundaries are less than or equal to a 17% rise. This threshold was determined based on a baseline from visual inspection, trial and error, and existing practices.	MassGIS Lidar point cloud data (2021)
Dark Roofs	Because dark roofs have a lower solar reflectiveness and higher thermal emittance, they absorb more heat from sunlight. As a result, converting dark roofs to cool roofs can significantly reduce heat exposure. Dark roofs are often concentrated in areas of higher heat exposure.	Lidar instruments also measure the intensity of every point in the point cloud. Intensity is "based, in part, on the reflectivity of the object struck by the laser pulse (Esri)." Lidar intensity values are used as a proxy for approximating roof albedo, or reflectivity, in this analysis (Source) A 0.8 meter-resolution raster was created to cover every building in each municipality, with each pixel approximating the intensity of the roof at that location. The intensity raster was rescaled to a 1-10 scale using percentile rankings, with pixels scoring a 1 representing the 10% lowest (least reflective) rooftop intensity levels in the municipality, and	MassGIS Lidar point cloud data (2021)

[2] Solar Reflective Index is a measure of how well a surface reflects sunlight and heat instead of absorbing it.
[3] Ian A. Smith, Katharine Lusk, and Lucy R. Hutyra. (2022). "On the Use of 'Cool Roofs' to reduce residential heat exposure disparities in Boston, MA." *BU Initiative on Cities,* 1-6, https://media.wbur.org/wp/2022/11/Smith_Lusk_Hutyra_2022.pdf.
[4] Cambridge, MA Community Development Department (CCD). "Cambridge Roofscapes, 'Why do we care about roof types?'" https://storymaps.arcgis.com/stories/fc3df29578784b8693417b9626cd1ce4.

		pixels scoring a 10 representing the 10% highest (most reflective) rooftop intensity levels in the municipality. A "dark" roof for this tool is defined as a rooftop where the majority of pixels within the roof's boundaries rank in the top 50th percentile for intensity values.	
Public or Municipal Ownership	As part of this effort, we specifically want to identify municipally owned buildings that are candidates for cool roof conversion.	Buildings were joined with the parcel in which it resides. Public and municipal parcels were identified based on whether the building's Land Use Code [USE_CODE] *OR* Owner Name [OWNER] meet a list of pre-defined responses or criteria developed by MAPC (link here).	MassGIS Assessor's Data (dates vary depending on town)
Building Type	Understanding general building type (single family, large multifamily, industrial, commercial, etc) is a useful way to filter and/or understand what buildings are suitable for cool roof conversion.	MAPC maintains a Land Parcel Database to assemble, standardize, and enrich the town-by-town assessor's data MassGIS provides. This includes a "Real Estate Type" that categorizes groups of land use codes into nine simpler and more readable categories. These types are used in this tool to provide summary information about what general types of buildings are suitable for cool roof conversion. More details on the methodology can be found here.	MAPC's Land Parcel Database (2023)
EJ Communities	Communities that meet the Commonwealth's Environmental Justice Population criteria have less capacity to adapt to the impacts of extreme heat. Higher income increases ability to adapt and recover from climate impacts[5]. Racialization of society and racism leads to differentially distributed opportunities and risks, which can negatively impact the adaptive capacity of communities of	Buildings were joined to MassGIS Environmental Justice census block groups. If the building is within a block group, it receives a value of "yes". If not, it receives a value of "no".	MassGIS Environmental Justice Populations

[5] Chow WTL, C. W.-C. (2012). "Vulnerability to Extreme Heat in Metropolitan Phoenix: Spatial, Temporal, and Demographic Dimensions." *The Professional Geographer*, 64(2), 286-302.

	color.[6] Linguistically isolated households have a limited ability to adequately prepare for and respond to climate events, especially if climate hazard warnings and information on available resources are only made available in English.[7]		
Within hottest 20% of areas in municipality/MMC	As our climate warms, all of metropolitan Boston can expect higher temperatures and more very hot days. Areas covered by dark and impervious surfaces heat up more than areas covered in reflective surfaces and vegetation, resulting in even more extreme "heat islands" on days that are already very hot. While hot days affect the entire region, people who live in areas prone to heat island effects are exposed to even greater temperatures.[8]	Zonal statistics were used to calculate an average heat index score across each census block in either MMC or each municipality. Percentile ranking was then used to give each block in MMC or the municipality a score from 0 - 1 based on the relative average index. Census blocks scoring closer to 1 represent the hottest census blocks in MMC/the municipality	MAPC's Land Surface Temperature Index (2021)
Roof prints	Base geography	The MassGIS Building Structures serves as a base geography for this analysis.	MassGIS Building Structures (2023)

[6] USGCRP. (2016). "The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment." Washington, DC: U.S. Global Change Research Program. doi:10.7930/J0R49NQX.

[7] Ibed.

[8] Seleeke Flingai and Caitlin Spence. (2019). "Climate Vulnerability in Greater Boston Technical Documentation." *Metropolitan Area Planning Council,* https://climate-vulnerability.mapc.org/assets/data/MAPC_ClimateVulnerability_Technical-Documentation_2019-12-10.pdf.

Tool Development

ESRI's ArcGIS Online Experience Builder was used to begin the initial buildout of a suitability analysis tool. Ultimately, we determined that rather than creating our own scoring/threshold system for the analysis, we would create a tool that allows a user to determine thresholds and filters on their own. This provides greater flexibility for users to set their own priorities and preferences.

Expansion/Next Steps

This methodology offers an exciting pathway to assess cool roof potential across Greater Boston using statewide, publicly-available datasets. This work could be expanded to refine the roof shape/reflectivity metrics; machine learning models could be applied that would improve the accuracy of the analysis. This method could also be expanded to other parts of the region and State.

Data on roof condition or date of last repair would help to further identify roofs with the highest potential for conversion. Takeaways from our research and focus groups and research illuminated that cool roof replacements were most likely to take place on roofs that were already slated for repair or re-surfacing. Nearmap provides this type of data to public sector entities, but at a cost that exceeded the capacity of this project.

This work could be expanded to align with other data tools, like the upcoming Cost Benefit Analytic Tool from the Smart Surfaces Coalitions (currently being expanded to include Metro Boston), Google's Cool Roofs tool (currently only available for the City of Boston), or the Trust for Public Land's Climate-Smart Cities tool (also expanding to include Metro Boston). These tools could be leveraged to understand how heat (and associated health and economic impacts of heat) would change if roofs identified by the site suitability tool were converted into cool roofs.

This online tool will be accompanied by a Site Suitability Self- Assessment to further assist building owners and managers in determining if a cool roof is both feasible and beneficial for their properties.

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