Cool Policies for Cool Cities: Best Practices for Mitigating Urban Heat Islands in North American Cities

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ABSTRACT

The urban heat island (UHI) effect poses a significant and wide-ranging threat to cities. A city's public health, air quality, energy consumption, climate adaptation, quality of life, storm-water management, and environmental justice may be negatively affected. Many cities have recognized the central role that reducing excess heat will play in meeting a variety of community goals. UHI mitigation can be incorporated into cities' livability, sustainability, energy, or climate adaptation plans, and related initiatives have been launched. UHIs are experienced differently by each city, and approaches to tackling the problems can thus vary. Planning documents, goals, policies, and programs for UHI mitigation efforts differ across North America. This paper presents the results of a comprehensive review of the UHI mitigation strategies and programs in place in 26 large- and medium-sized North American cities. It includes an analysis of city goals, strategies, programs, policies, and other actions and, where possible, an evaluation of progress on UHI mitigation. Information was gathered through a literature review and a survey of city officials. The findings are categorized by type and city and synthesized into actionable recommendations for urban sustainability policymakers. Cities are beginning to recognize the impacts of UHI effects on their infrastructure and inhabitants. Our findings show that cities are taking action by developing strategies and policies to mitigate these effects. All of our sample cities have developed one or more strategies that include UHI mitigation and 25 have adopted at least one policy.

Introduction

Our cities are heating up. This trend is intensified by the urban heat island effect--a phenomenon in which the predominance of dark, impermeable surfaces and human activity causes urban temperatures to be several degrees hotter than surrounding rural areas. Urban heat islands (UHIs) have significant and wide-ranging effects that span many city policy priorities, including public health, air quality, energy consumption, climate adaptation, quality of life, storm-water management, and environmental justice. As a result, responsibility for policies and programs to reduce excess heat is often spread across a number of city agencies, each with its own strategy and priorities.

Mitigating the UHI effect can produce many benefits for buildings, neighborhoods, cities, suburban areas, and the globe. Air-conditioned buildings can see reduced energy bills and unconditioned buildings can be cooler in the summer months. Roofs can last longer due to reduced thermal expansion. Entire cities can shave peak electric demand during the summer months. During extreme heat events, there may be fewer instances of sickness or mortality. Local air and water quality can improve, as can a city's quality of life. Because disadvantaged neighborhoods are often the most vulnerable to heat, addressing a city's UHI can help improve social and environmental equity. Globally, cities can reduce their sources of atmospheric warming. If less peak electricity is required, fewer greenhouse gases (GHGs) will be emitted. Reflective surfaces and vegetation produce a localized cooling effect that helps cancel out some of the warming caused by GHGs.

This report elucidates the many ways cities deal with excess heat and provides the tools needed for another city or jurisdiction to adopt similar policies or programs. UHIs are experienced differently by each city, and approaches to tackling the problem can thus vary. For our research, we chose 26 large- and medium-sized cities from a full range of climate zones and geographic areas to make our analysis as accessible and broadly applicable as possible. We included cities where policymakers have a specific focus on urban heat reduction, and some cities in which urban heat mitigation is a positive by-product of action on other priorities, such as storm-water management or urban beautification. For each city, we conducted a literature review and sent a 31-question survey to city officials to collect information on UHI mitigation activities.

Background

The term "urban heat island" describes the phenomenon where urban areas specifically have higher surface, air, and atmospheric temperatures than their rural or suburban surroundings (Akbari 2005). On average, UHIs make cities 7°F hotter than rural surrounding areas. Some cities have UHIs that are 15–20°F hotter (Navigant 2009). During the day, sunlight shines on a city and is radiated back through the atmosphere by snow, clouds, or light surfaces or is absorbed by dark surfaces or air pollution (Trenberth et al. 2008). This surface heat warms the surrounding air and increases temperature.

Decreased air quality is one of the most broad-reaching effects of UHIs. An increase in temperature accelerates the rate at which ozone feedstocks (NOx and VOCs) cook into ozone. Akbari (2005) finds that for every 1.8°F that the temperature in Los Angeles rises above 71.6°F, smog increases by 5%. Surface heat in the urban environment can decrease water quality through warm runoff causing heat shock in rivers, harming all aquatic life. The hotter it gets, the more cooling demand there is overall. As a result, the UHI-related increase in air temperature is responsible for 5–10% of urban peak electric demand (Akbari 2005). As cities require increased electric load, especially during peak hours, power plants produce more electricity and release more GHGs into the air, creating more warming on a global scale.

Many aspects of the UHI effect increase health problems and mortality, especially among low-income and elderly populations. Wong (2012) reports that heat is the deadliest natural disaster, causing more casualties than hurricanes, floods, and tornadoes combined. The Centers for Disease Control and Prevention (2012) found that over a 12-year period (1999–2010), excessive heat caused 7,415 premature deaths in the United States. In 1999 alone, 1,050 deaths were caused by excessive heat. Residents of and visitors to cities suffering from excess urban heat or extreme heat events experience a decrease in quality of life. People are less likely to take advantage of outdoor amenities, to exercise, and to interact outdoors. Residents are more likely to suffer from health problems. Energy utility customers may experience higher bills.

Mitigation Strategies and Their Benefits

At least two of the three main causes of the UHI effect—dark surfaces and lack of vegetation—can be mitigated through policies and programs related to buildings and city planning. Installing reflective and light-colored surfaces on city roadways, walkways, and roofs is a primary UHI mitigation strategy. The EPA (2014a) reports that conventional pavement can reach summertime temperatures of 120–150°F. A "cool" pavement can be 50–70°F cooler. Though the primary benefit of installing reflective pavement is reducing the surface and air temperatures, it has many co-benefits as well. Reflective pavements may increase road or sidewalk visibility at night, improve water quality by reducing water heat pollution, and last longer than traditionally colored pavements due to decreased heat stress (EPA 2014a).

Dark roofs have the same properties of heat storage and radiation as do dark pavements. However, dark roofs become very dangerous during heat events, since they transfer the stored heat into the building. Roofs that reflect instead of absorb solar energy—i.e., "cool" roofs—reduce the demand for cooling within the building. The ambient temperature of the city decreases, as do ozone and smog formation. A secondary benefit of installing a reflective roof is that the roof's life span increases due to reduced heat stress (Akbari 2005).

Increasing the total vegetation of a city is another well-documented method for mitigating the UHI effect. Potential actions include installing green roofs, planting shade trees, and using grass pavers. The decision to vegetate an area should be considered by each city within the context of its climate situation and water availability. All types of vegetation have the potential to provide beneficial ecosystem services and many co-benefits to a city and the surrounding areas: storm-water filtration, groundwater recharge, reduced stress on combined sewer systems, improved public recreation spaces, and increased urban habitat.

Social and Institutional Context of City Action

There are many reasons a city is prompted to develop a UHI strategy or initiative. Some cities have experienced a traumatic heat wave. Others have experienced and tracked the characteristic effects more broadly over time. Some cities recognize their increased chance of experiencing extreme heat events and choose to preemptively develop policies and programs. Proactive policies hedge against possible UHI-related disasters. Some cities have not identified mitigating UHI effects as a priority, but are in fact doing so as a positive by-product of urban tree canopy or storm-water management initiatives. In this way, UHI mitigation policies and programs can be cost-effective and broad reaching, effecting positive change alongside many city priorities and goals.

UHIs have the potential to impact every resident of a city negatively, but some sectors of the population are disproportionately vulnerable to the impacts, which are imposed inequitably on the elderly, the homeless, those with low income, and those with preexisting health conditions. Low-income residents may be less able to afford air-conditioning or increase the amount of cooling they do use and are subjected to continual heat stress. Poor air quality negatively affects the health of the entire population and imposes detrimental effects on high-risk populations. Children, those with preexisting heart or lung disease (especially asthmatics), and the elderly are more susceptible to becoming sicker due to poor air quality (EPA 2014b). Additionally, poor air quality and extreme heat acutely affect those frequently exposed to the elements, such as outdoor laborers and the homeless.

Various levels of government have control over policies and programs relating to UHI mitigation. Building codes may be set on the state or local level. Land use ordinances, urban planning, and zoning are typically determined at the city or county level. Municipal construction and procurement requirements are mostly determined by the locality itself. Beyond government, there are a variety of private actors—such as utilities, developers, contractors, and building owners—that play important roles in incentivizing and mainstreaming the adoption of UHI mitigation measures. Therefore, implementation of UHI mitigation may require cooperation between multiple levels of government and a variety of private actors.

Though the UHI effect imposes acute and local impacts on affected areas, the issue is not confined to the political boundaries of a city proper. All causes and impacts of UHIs are regional as well as local. Urban areas outside of a particular city's jurisdiction still contribute to the region's UHI and increase temperatures within the city. Expressways, turnpikes, and highways ring many cities. These large paved areas fall under the jurisdiction of regional transportation authorities, or the state or federal government. Office and industrial parks outside of a city may have vast parking lots and many buildings that contribute to the regional effect. Suburbs are not subject to the codes and ordinances of their neighboring cities and may not have the same commitment to UHI mitigation. To fully combat the UHI effect, regional and multijurisdictional cooperation is needed.

Methodology

To gather information on the UHI mitigation activities employed by a sample of North American cities, we first undertook a literature review and then distributed a survey to local government contacts. The information collected describes how urban heat islands affect the cities and how each city is responding.

Many levels of local government can enact policies aimed at mitigating the UHI effect on their jurisdictions. Cities, counties, school districts, and metropolitan planning organizations all have authority over areas of land and portfolios of buildings. In the existing literature on UHIs and mitigation techniques, cities and metropolitan areas are commonly referenced affected areas. To narrow our scope of study, we chose to focus on city governments due to their direct authority over the building stock and land area. As a result, local governments have the authority to influence the adoption of UHI mitigation measures.

As our research sample, we selected 26 medium and large cities from the United States or Canada based on three criteria. Each city 1) has implemented some UHI mitigation actions or developed a UHI mitigation strategy, 2) has experience with strategy development that may be applicable to a broad sample of other North American cities, and 3) represents a diverse geography and climate. To satisfy the first criterion, we established a list of cities that we knew had implemented some UHI mitigation actions or had developed a mitigation strategy. We gathered this information through background research, industry knowledge, and familiarity with current practices on the local scale.

To satisfy the second criterion, we narrowed our scope of cities to those that had strong experience with strategy development that would be applicable to a broad sample of other North American cities. For example, cities in the *2013 City Energy Efficiency Scorecard* (Mackres et al. 2013) that proved to have strong strategy development were included in our study. To prove further applicability to other North American cities, we selected cities with a mixture of large (more than 800,000) and medium (between 240,000 and 800,000) resident populations. We included large cities to satisfy the first criterion because the existing literature notes that they have many UHI mitigation policies and programs in place already, some of which may be adaptable for use in smaller communities. We included medium-sized cities in our sample in hopes of identifying policies and practices that would be applicable to a large number of North American cities.

The third criterion was to represent a diversity of geographic locations and climate zones. We chose a mixture of cities that span the largest International Energy Conservation Code (IECC) climate regions of the continental United States, from 1 (tropical) to 7 (alpine or arctic). Figure 1 shows the number of cities surveyed within each climate zone. Additionally, we ensured that cities from every Census Region and Division were included. Figure 2 shows the geographic spread of the cities chosen for our study.

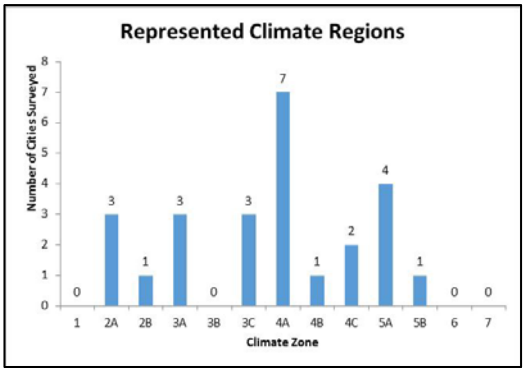

Figure 1. Number of cities in various regions (n = 26).

Figure 2. Map of the ciities included in our study International Energy Conservation Code.

We developed a 31-question survey to gather policy and program information from the selected cities. Prior to distributing the survey, we conducted a literature review of public documents, records, reports, and web pages. We used this research to prepopulate answers for many of the questions. To ensure accuracy and currency, we asked the respondents to review, correct, and update the prepopulated answers. For each city, we distributed the survey to a city staff person in either the city sustainability office or the department of the environment and asked that they complete the survey within two to three weeks. Eighteen cities returned a completed survey. For the remaining eight cities, we relied on publicly available data. All of the cities were given the opportunity to comment on the draft report.

Results and Discussion

This section discusses the findings related to the topics covered in the survey. We focused our background research and survey questions on the following topics:

- *History, origin, and motivations.* Background of events sparking the city's interest in UHI mitigation
- *Strategy types*. Strategy or plan with discrete goals for mitigating UHI effects
- *Goals.* Description of goals established for local government operations, across the community, and to achieve social benefit
- *Policies and programs.* Voluntary and mandatory policies and programs
- *Implementing agencies.* Agencies involved in program development and implementation
- *Market drivers.* Discussion of the market sectors and associated demand drivers

- *Tracking indicators.* Tracking of progress, UHI indicators, and heat trends
- *Funding and budgeting.* Level of spending by both city and non-city sources
- *Progress*. Respondent's subjective assessment of goal achievement, with specific consideration of perceived and actual aids and hindrances

History, Origin, and Motivations

We asked our survey respondents to think back to the origin of the UHI mitigation strategies. We asked, in an open-ended manner, if there was a particular event or series of events that triggered consideration of the UHI effect as the cause of city problems. The responses fell into seven categories. Table 1 identifies the categories and the number of cities that cited each origin. Some cities' responses were counted more than once because they spanned multiple categories.

Table 1. Origins of UHI strategies

Trigger for UHI mitigation actions	Cities
Increased number of high-heat days	7
Extreme heat events with documented mortality	6
Results of an academic study or research	5
Increased (non-heat) extreme weather	4
Extreme loss of trees	4
Overwhelming past power outages	2
Result of community involvement/stakeholder working groups	2

Some of the most common triggers reported were an increased number of high-heat days, extreme heat or non-heat weather events, and loss of trees. An example of a city that suffered an extreme heat event is Austin, TX, in 2010. A summer of record-breaking heat and drought lead to wildfires that burned over 30,000 acres, killed two people, and destroyed approximately 1,600 homes. Austin has developed many programs in response to this event, including replanting lost trees and building greener, energy-efficient buildings and resilient infrastructure.

Each city surveyed is situated in a unique geographic, political, and social context. As a result, UHIs have the potential to affect cities differently, prompting them to pursue UHI mitigation actions that are in line with their disparate motivations. For example, New Orleans, situated in the low-lying Mississippi Delta, is motivated strongly by storm-water management. Denver, situated near the Rocky Mountains, is motivated to keep its infrastructure resilient in the face of extreme temperature fluctuations. Dallas is situated in northern Texas, on the Great Plains of the Midwest. Rainfall is rare and the summers are especially hot and dry. Due to these conditions, the buildings of Dallas are air-conditioned much of the year. The city therefore is motivated by building energy savings. Employing cool technologies on a single building or portfolio of buildings decreases energy usage for cooling, potentially increasing cost savings.

We asked each city to indicate all of its motivations. The major categories were as follows, along with the number of cities that cited each motivation: building energy savings (22), public health and resilience (16), storm-water management (17), climate adaptation (12), quality of life (11), general sustainability (9), disaster preparedness (7), and improving affordable housing (5). We allowed cities to write in additional motivations. Results included poor air quality and the need to reduce citywide power draw, rehabilitate brownfields, and reduce crime. Some cities also mentioned place-specific motivations. Denver mentioned that reduced snowpack and earlier snowmelt were key motivations for their moving to mitigate the UHI effect. Finally, we asked each city to indicate their *primary* motivation for developing UHI mitigation policies and programs. Figure 3 shows the results for the 16 responses available.

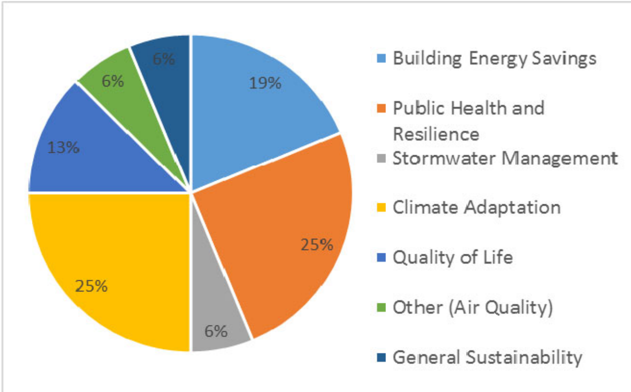

Figure 3. The primary motivations for development of UHI mitigation goals (n = 16).

The most common primary motivations were climate adaptation, public health and resilience, and building energy savings. The frequency of these motivations and "quality of life" shows that cities consider the UHI effect not only an *environmental* issue, but also a core health, safety, and service delivery issue.

Strategy Types

Cities plan and organize their strategies for mitigating the UHI effect in a variety of ways. Figure 4 describes the strategy types used in implementing UHI mitigation in the cities we studied. For cities that implement UHI mitigation as part of more than one strategy, each strategy was counted.

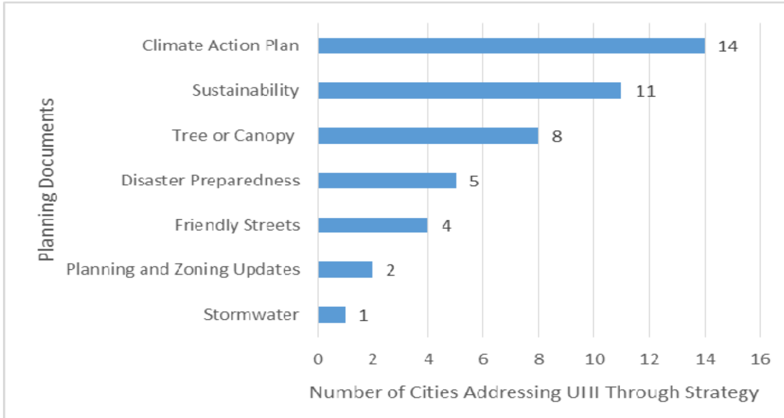

Figure 4. Strategies chosen by cities to govern UHI mitigation policies (n = 24).

Notably, 14 cities mentioned that their UHI mitigation policies and programs are found within an overarching climate action plan and 11 are found within a sustainability plan, both through mayoral initiative. None of the cities that we surveyed had developed a stand-alone UHI mitigation planning document encompassing all of their UHI mitigation efforts. This finding indicates that UHI issues are of consideration to cities, but that they have not yet risen to the level of prominence that they are considered a topical issue on their own.

Goals

In our survey, we asked cities if they had set one or more goals related to these five categories: temperature reduction, reflective roofing, vegetated roofing, urban fabric permeability, and urban canopy. Some cities have quantitative goals, and others have qualitative goals. A city may set either, with its political landscape and dedication to an issue defining the goal type. Qualitative goals do not have a deadline and allow for on-demand participation. A city may set a qualitative goal to introduce an issue or technology to the city. For example, Baltimore, MD, set a quantitative goal that "30% of the city's commercial buildings and 10% of homes will have reflective roofs by 2020," whereas Albuquerque, NM, qualitatively aims to "incorporate reflective roofing materials whenever possible." Figure 5 shows the number of city goals in each category. Some cities reported multiple goals, each of which we counted.

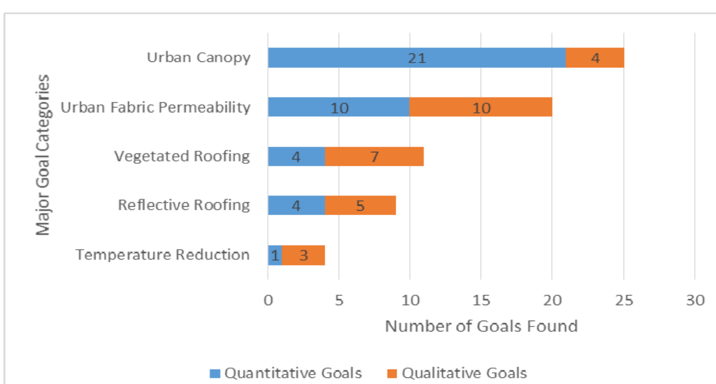

Figure 5. Number of goals by category and type (n = 26).

The most common goal category is urban canopies. Twenty-one cities have a quantitative goal for developing an urban canopy. Vancouver, BC, set a 2012 goal to plant 150,000 new city trees by 2020. Four cities have qualitative urban canopy goals. The least mentioned goal was city temperature reduction, with only three cities having a qualitative goal in place: Baltimore, Washington, DC, and Chicago. One city, New York, has the quantitative goal of reducing the average ambient temperature by 1°F. The prevalence of urban canopy goals illustrates a preference for easily measurable and highly visible projects.

Some cities also mentioned goals outside of these five categories. They included reducing GHG emissions (14), achieving community-wide energy efficiency (6), improving air quality (5), focusing on climate mitigation (4), reducing the energy use of local government buildings (3), developing new green building standards or requirements (3), increasing urban agriculture (3), participating in an education campaign (2), improving on a variety of public health indicators (2), and recharging groundwater (1).

One of the key goal areas in UHI mitigation is socio-environmental equity. Cities can set goals to mitigate heat, reduce building energy use, or improve public health. These goals can encompass either the entire community or only specific areas. We counted the number of cities that include social issues in their mitigation strategies. Three-fifths (18) incorporate consideration of social and environmental equity in their UHI mitigation efforts. Many cities have identified their vulnerable populations and geographies and developed strategies to ensure that the needs of the particularly vulnerable are addressed. We found that four cities have specific goals to mitigate heat in their affordable housing stocks: New York City; Chula Vista, CA; Washington, DC; and Philadelphia. Eight cities (Boston; New York; Philadelphia; Baltimore; St. Louis, MO; Phoenix, AZ; Portland, OR; and Los Angeles) have goals to mitigate heat in vulnerable neighborhoods.

Policies and Programs

Cities have a variety of policy options available to increase the adoption of UHI mitigation measures both within government and by the private sector. Local governments may opt to establish procurement requirements to enhance their response to UHI effects. UHI-sensitive municipal construction and procurement choices are some of the easiest policies for a city to implement and can simultaneously reduce costs and emissions. When local governments lead by example, they can also catalyze mitigation actions by the community.

We asked respondents if any of the following UHI mitigation technologies were required in the procurement policies of the city government: reflective roofs, vegetated roofs, reflective pavement, porous pavement, shade trees, and revegetation of paved areas. We found that 13 required at least one. The most common were for reflective and/or vegetated roofs, which were in place in 8 and 9 cities, respectively. We speculate that these mitigation policies are the most common due to their ease of adoption and visibility in the community.

To engage the private sector, cities may offer voluntary policies and programs, or demand compliance over aspects of construction and management of private buildings. Potential voluntary measures include offering financial or nonfinancial incentives, connecting citizens with contractors or loan products that engage large sectors of the city, and public awareness and education campaigns. Examples of incentives include rebates for construction or purchase of a desirable technology, tax abatement for constructing in a certain way, and preferential permitting to fast-track designs and construction that push the city toward its UHI mitigation goals.

In some cases, the identified economic, environmental, or social benefits of UHI may be deemed so important that requirements in the forms of building codes and mandates are adopted. Examples of mandatory policies a city or state can require include building, zoning, land use, or resource protection codes or ordinances. Figures 6 and 7 break down how many of our surveyed cities engage the private sector with voluntary and with mandatory policies, respectively.

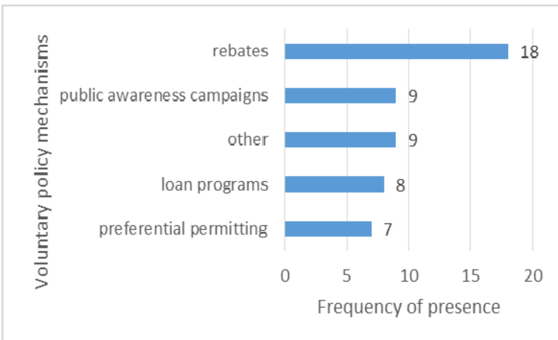

Figure 6. Voluntary policies for private construction.

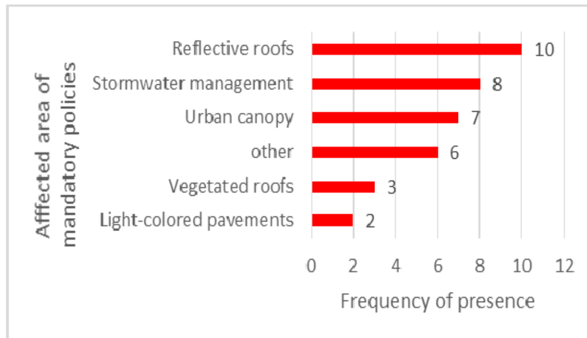

Figure 7. Mandatory policies for private construction.

Voluntary mechanisms include incentives, connecting citizens with contractors or loan products, and public campaigns. Incentives include rebates, tax abatement, and preferential permitting. Mandatory policies a city or state may employ through building, zoning, land use, or resource protection codes or ordinances include requiring cool or green roofs, shade trees, green landscaping, and cool pavements. We found that 24 cities surveyed have established at least one voluntary policy or program, and 20 have established at least one mandatory policy. Rebates are the most common policy in place, in 18 cities. For example, the Portland Water Bureau offers customers a "treebate" of a $15–50 credit on their water bill for purchasing and planting a tree. The next most popular policies are mandatory codes or ordinances for reflective roofs. Many cities, such as Houston, have reflectance requirements for roofs: low slope roofs up to 2:12 must have a minimum solar reflectance of 0.70 and thermal emittance of 0.75 across the entire roof surface, with the exception of green roofs, roof-top decks, or solar panels (Houston Commercial Energy Conservation Code of 2008).

Cost–benefit analysis plays a major role in developing beneficial citywide programs. Whenever a city makes an investment, it should want to see a return on that investment, either financially or in societal benefit. Understanding the cost of replacing infrastructure against the opportunity cost of keeping existing infrastructure helps a city decide when to act. Fifteen of our studied cities indicated that cost–benefit analyses were run on their programs. If an analysis had been run, its type varied. The city of Phoenix reported that for every $1 it spends on planting or caring for city trees, the city saves $2.23 in ecosystem services.

Implementing Agencies

Irrespective of the strategy framing, motivation, or planning, no city relied on a single department to run all UHI programs and their implementation. However, three cities did indicate that a single agency is the lead for UHI plans and strategies. Cincinnati's strategies focus on revegetation and rehabilitation of city land. Therefore, it is easy to see why the Park Board is the lead agency. Houston focuses very strongly on cool roofs. The agency that runs the roofing program and enforces the building energy codes is the Department of Building Code Enforcement. Every city mentioned that multiple agencies are engaged in developing goals or implementing programs for UHI mitigation. When one agency has purview over a program, the administrative burden may ease. A single agency with full ownership may lead a program to success, though for only one or a small number of goals. Some cities have combined the efforts of agencies to increase funding, staff time, and participation in a single or suite of programs. By assigning more than one agency joint responsibility, a program may reach a larger citizen base or meet multiple goals. Having one lead agency responsible for guiding citywide strategy while assigning sector-specific responsibilities to multiple agencies may also be effective.

Market Drivers

A technology becomes fully implemented quickly and easily if there is demand within the private market. In the private sector of existing buildings and new construction, the market can be divided into two categories, residential and commercial. We asked our survey respondents to reflect on the level of market demand in their cities for various mitigation technologies. Of our respondents, 15 indicated that demand exists for cool (white or reflective) roofs, 6 indicated that demand exists for vegetated roofs, and 6 indicated that demand exists for cool (porous or reflective) pavements. Beyond these predefined categories, five cities indicated that there is private demand for street trees and two cities indicated that there is strong demand for engaging in city-run programs. Each of the respondents that indicated private sector demand exists in their cities mentioned that it exists in the commercial sector. Only three cities indicated that demand also exists in the residential sector.

Phoenix and Baltimore both indicated that the private sector demands cool technologies on its own, nine cities indicated that policy is the main driver of implementation, and four respondents indicated that a mixture of both demand and policy drives the cool technology markets in their cities. We also asked if investing in UHI technologies produced any perceived negative impacts in the local market. Nine of our respondents indicated that their markets held one or more perceived negative impact for cool technologies. Five cities noted that the public perceives cool technologies to have a high cost burden. Three cities cited worry about the effectiveness of current technologies to solve UHI issues. Four cities have citizenry that worry that reflective building materials may create increased glare and daytime brightness. Four cities perceive cool technologies as less durable than traditional alternatives, or as requiring increased maintenance. Finally, one city cited the low market penetration of cool technologies as being due to the public’s lack of knowledge of their importance.

To understand the private demand in the market for cool technologies, we asked our respondents about their perceived cost. Close to half of our responding cities believe their market sees cool technologies as more expensive than traditional, and half believe their market sees cool technologies as having a cost equal to traditional technologies. Interestingly, Los Angeles noted that their market sees cool roofs as cheaper than traditional roofs, which may be due to the tax levied on nonreflective roofs.

Tracking Indicators

To gauge success relative to goals, many cities track and report on progress. In the cities surveyed, 21 track progress toward goals in some way. Eighteen reported also publishing their tracked data. We asked if the city tracked urban heat trends, such as change in vegetation. Fourteen of the cities do, and many track more than one. Table 2 outlines the types of trends monitored.

Table 2. Urban heat trends tracked by cities (n = 26)

Tracked Urban Heat Trends	Cities
Temperature variation	7
Change in vegetation	6
Hospital visits	3
Precipitation rates	2
Environmental public health	2
NAAQS non-attainment days	1
Change in albedo	1
Carbon emissions	1

Tracking heat trends is a critical component of understanding the effect heat has on a city. The most tracked heat trend is temperature variation. This finding does not align with the finding that only three cities have temperature-related goals. Recording the daily temperature is one of the easiest trends to track. Cities can track this trend themselves or obtain data from a third party. The second most tracked trend is change in vegetation. Cities can monitor the amount of vegetation planted and destroyed. Citywide surveys and aerial mapping techniques allow comparison of the amounts of vegetation across time.

To better understand how these trends and indicators are tracked, we asked about the scale on which data are collected and reported, based on one of five categories. Of the cities that track data, responses included city block (2), census tract (3), citywide (1), neighborhood (4), and building (2).

Funding and Budgeting

Within our data set, eight respondents reported some or most of their city funding for UHI mitigation policies and programs. Many of our respondents indicated that the city did not track mitigation expenditures, or that they were so tightly interwoven with other city projects that the funds used for UHI mitigation were not quantifiable. However, local governments are not the only entities funding UHI mitigation programs. Many cities (19) indicated that funding to run policies and programs is available from noncity sources. A few examples include nonprofit groups, local utilities, philanthropic foundations, and a local university. Portland partners with Friends of Trees, and Philadelphia's TreePhilly (Philadelphia Department of Parks and Recreation) partners with the Tookany/Tacony Frankford Watershed Partnership, both of which aid in tree planting and maintenance programs. Other cities engage with their states by taking loans and dedicating the funds to environmentally beneficial projects. For example, PENNVEST loans funded a $30 million green streets project in Philadelphia. Further, many cities are served by energy or water utility programs that include funding for UHI mitigation measures. Georgia

Power provides its customers with rebates for installing reflective roofs as part of an energy-efficiency measure. In Baltimore, Exelon's purchase of Constellation provided funding for the construction of 22 cool roofs in 2013.

Progress Toward Goals

To wrap up our survey, we asked our respondents to consider their city's goals and to reflect on the progress made. For each main goal type, the respondents could gauge progress on a sliding scale from "no plan" and "implementation" to "goal achieved." Not every city responded to this section, but for the cities that did, replies ranged from minimal implementation to significant implementation. No cities indicated that they had fully met any of their stated goals.

Though the majority of cities that track heat indicators mentioned tracking temperature data, no city mentioned having measured movement toward a goal for temperature decrease. Only three cities have qualitative goals in place for temperature reduction. Since these goals are qualitative, there is no end goal toward which to measure movement. A common goal is to increase urban canopy. This goal type was the most frequently mentioned as showing progress.

To help cities begin implementing programs or expanding preexisting programs, we asked for respondents' reflections on what furthered progress and, conversely, what hindered it. One city specifically mentioned that progress is instigated by a "strong and immediate" need for policy. Some cities indicated that city council adoption of green building codes was the driving force behind implementing green or cool roofs. Some cities mentioned that the interconnected nature of their initiatives is especially helpful for driving progress across the board. For example, a single educational campaign can cover many aspects of UHI mitigation, and a community retrofit program can incorporate stakeholder interaction. The cities noted that these elements enabled program progress: mayoral commitment, community commitment, green building codes, interconnected initiatives, city–university partnership, and "Tree City USA" designation by the Arbor Day Foundation.

Conversely, some respondents noted that having too many city priorities is detrimental to the progress of any single priority. The lack of funding was the most frequently mentioned hindrance. These factors were said to hinder program progress: lack of data on "cool" technologies, lack of knowledge of the city's specific needs, lack of funding, too many competing priorities, lack of citizen UHI education, need for helpful policies, and inertia.

Recommendations

This report presented the current landscape of UHI mitigation policies and programs in North American cities. We hope that city sustainability managers and other leaders are able to draw parallels between some of what is reported here and their own cities. To pull best practices together in an actionable way, we offer the following recommendations:

- *Establish goals related to specific strategies.* We recommend that cities consider setting goals across many sectors, even those that might be difficult to meet or monitor.
- *Establish quantitative goals.* We recommend that cities develop quantitative goals, which establish a specific unit of measurement and level to be reached by a hard and fast deadline.

- *Track heat indicators.* We recommend collecting granular data on a variety of urban heat indicators in the short term and long term.
- *Use cost-effectiveness testing.* We recommend that cities employ some form of cost-effectiveness testing for programs, and that the test used be tailored to the type of program and investment.
- *Develop both mandatory and voluntary policies.* We recommend that cities consider a mix of voluntary and mandatory programs and policies to create a suite of tools to encourage technology adoption in ways that are conducive to varied market sectors.
- *Lead by example.* We recommend that local governments incorporate into procurement policies as many mitigation practices and technologies as possible and as are effective for the city. Further, we recommend that local governments document their experiences with these practices.
- *Identify a lead agency.* We recommend that local governments identify a lead agency to take responsibility for the city's UHI mitigation policies and programs.
- *Partner with local institutions.* We recommend partnering with local institutions as a mutually beneficial best practice.
- *Engage citizens.* We recommend that cities include stakeholder engagement in advance and during implementation of both mandatory and voluntary policies to both correct false perceptions and garner wider citizen support.
- *Use third-party data.* We recommend that cities engage in data-sharing partnerships with third parties. We ask that third parties that collect granular heat-related data make these data available to localities as a public service.
- *Develop multiple sources of funding.* We recommend that cities leverage a wide range of funders.
- *Adopt up-to-date cool roof and pavement standards on the state and regional level.* We recommend that cities share performance data from their programs and work with relevant state agencies to ensure their smooth adoption.

Conclusion

An urban heat island may affect all cities with similar impacts, yet each city can expect to experience differing levels of intensity with each impact. Each city studied is uniquely positioned in terms of climate zone, population demographics, and sociopolitical context. Therefore, the priorities and goals for mitigating each UHI effect differ in accordance with each specific situation. Cities seeking to translate the policies and goals from this report to their own localities should consider their individual situations and match and adapt policies to their needs to be most efficient and effective. Ultimately, we hope that cities, counties, and other jurisdictions will be able to identify some similarities they share with the cities studied in this report. Implementing some of the outlined practices in locally appropriate ways will constitute the beginnings of a strategy to mitigate the impacts of UHIs in their communities.

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