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Adapting to Urban Heat:

A Tool Kit for Local Governments

GEORGETOWN CLIMATE CENTER
A Leading Resource for State and Federal Policy

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Foreword

The world is hot and getting hotter. Cities are already warmer than surrounding areas, and climate change is increasing not only average urban temperatures but also the frequency and intensity of heat waves and formation of ozone (smog). Individuals living and working within urban areas can suffer from heat stress and other heat-related illnesses and will face increased respiratory symptoms and disease. Buildings within heat islands require more air conditioning and thus use more energy, increasing emissions of greenhouse gases as well as conventional pollutants. Communities can respond to immediate health problems through emergency response plans and outreach to vulnerable neighborhoods, opening cooling centers, and providing other services. However, long-term changes in the natural and built environments are needed to keep residents, buildings, and communities cool and save energy and healthcare costs. States and local governments face challenges, however, in determining what to do given tight budgets, the complexity of options, the need to coordinate across agencies and jurisdictions, and more.

This Urban Heat Tool Kit is designed to help local governments reduce the effects of increased heat on their communities and citizens. It provides an analytic tool for policy makers to consider a combination of four built-environment changes (cool roofs, green roofs, cool pavements, and urban forestry), providing clear criteria for selecting among these approaches. It also examines the roles government can play in pursuing these changes: shaping government's own operations, mandating or providing incentives for private choices, and engaging in public education. The menu of options it provides does not prescribe a particular path for all communities. Instead, it offers a complete list of options and the means to select among them to fit particular circumstances.

Written by Harrison Institute Staff Attorney Sara Hoverter with contributions from clinical students (see author's note), each of the four main chapters provides examples of mandates, incentives, public education programs, and government operations for each strategy. Each chapter also concludes with a set of "no-regrets" policies that local officials may undertake that provide multiple benefits including public health, air quality, and energy efficiency, in addition to reducing urban heat impacts. Some of the options (e.g., cool or green roofs) also provide mitigation benefits (in the form of reduced energy use and emissions) as well as building resilience in communities affected by increased urban heat. Others, such as cool permeable pavements, curb storm-water runoff as well as heat.

The Georgetown Climate Center commissioned and oversaw the preparation of this Tool Kit as part of its effort to support adaptation to climate change by state and local governments. It follows the Sea-Level Rise Tool Kit, published in November 2011, and is informed by our work assisting local governments with their adaptation and mitigation efforts, as well as case studies and analyses performed by Center staff and students. Additional information can be found on our Center's website (www.georgetownclimate.org) and Adaptation Clearinghouse (www.adaptationclearinghouse.org).

We appreciate the support of our adaptation funders, the Rockefeller Foundation and Kresge Foundation, and of our core supporters, the Rockefeller Brothers Fund and the Emily Hall Tremaine Foundation, who make our work possible.

Vicki Arroyo, Executive Director   Peter Byrne, Faculty Director

Author's Note

Sara Pollock Hoverter (L.L.M., Georgetown University Law Center, 2007; J.D., *cum laude*, Georgetown University Law Center, 2005; B.A., Yale University, 1997) is a senior fellow and adjunct professor at Georgetown University Law Center's Harrison Institute for Public Law. Whole-hearted thanks to Yael Bortnick (J.D. candidate, Georgetown University Law Center, 2012; B.A., *magna cum laude*, University of Pennsylvania, 2009) and Laura Dziorny (J.D., Georgetown University Law Center, 2011; M.A., University of Nevada-Las Vegas, 2008; B.A., *summa cum laude*, Georgetown University, 2006) for their help researching and drafting portions of this Tool Kit.

The Georgetown Climate Center intends to update this Tool Kit to provide analysis of new tools and examples, as well as results of the efforts reflect in this version. We will continue to receive comments from government officials, planners, regulators, academics, and others in the field in order to ensure that this Tool Kit remains up-to-date. This study presents analysis by the author; it does not represent Georgetown University or any state or local agency.

The author is extremely grateful for insightful comments from Vicki Arroyo at the Georgetown Climate Center, Neelam Patel at EPA's Heat Island Program, Josh Foster at the Oregon State University/OCCRI, Natasha Prudent and Paul Schramm at CDC, Kara Reeve at National Wildlife Federation, Maia Davis at the Metropolitan Washington Council of Governments, Zoe Johnson at the Maryland Department of Natural Resources, and Laura Anderko at the Georgetown University School of Nursing and Health Studies. Special thanks to John Carey, Kate Zyla, and Bob Stumberg for their tireless editing to make this Tool Kit accurate, concise, and readable. Any remaining errors in this document are those of the author.

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Executive Summary

America's cities are warming and climate change will make already hot urban areas even hotter. Rising temperatures and urban heat islands increase the risk of illness and even death; the most vulnerable in our communities include the elderly, young children, and low-income residents. In addition to the public health problems, urban heat islands increase energy use and costs as well as pollution levels in cities, causing additional illness.

Local governments can adapt to the increased heat both by responding to heat emergencies and by changing their landscapes and physical structures in advance of a heat wave to lower temperatures. While emergency response measures are extremely important, this Tool Kit examines the built-environment strategy, which can 1) lessen the urban heat island, 2) protect the health of residents, 3) lower energy consumption and therefore reduce greenhouse gas emissions, and 4) potentially provide environmental co-benefits such as stormwater management and improved air quality. The Tool Kit analyzes four built-environment methods—cool roofs, green roofs, cool pavements, and urban forestry—and explains how and when local governments can adopt each method. Widespread surface changes can reduce the urban heat island effect, helping residents adapt to urban heat. Local governments face challenges in adapting to urban heat, however, including the complexity of the choices available, limited resources and authority, the need to coordinate among many local agencies, and in some cases skepticism about climate change.

This Tool Kit provides a decision-making framework for local governments to help overcome these barriers. The framework analyzes each of the four methods on the basis of several criteria: 1) outcome criteria, including effectiveness at reducing heat, improving public health, saving money, and providing environmental co-benefits; and 2) governance criteria, including administrative and legal considerations. Additionally, we apply the criteria to sets of tools with which local governments can put the methods into practice, including: 1) government operations, where government controls the land or buildings in question; 2) mandates, where local government require a particular action (i.e., building codes); 3) incentives, where local governments encourage a particular action (i.e., fee rebates or grant programs); and 4) education programs, where local governments provide information on the benefits of the methods to the public.

Individually, each tool can reduce the high temperatures that individuals would otherwise face; taken together, citywide adoption can drastically reduce the urban heat island effect itself, while providing many additional co-benefits. This Tool Kit provides guidelines for deciding under which circumstances each tool works best. By drawing on analytic criteria, the Tool Kit gives local governments a framework to compare tools and determine which will work best for them.

Introduction

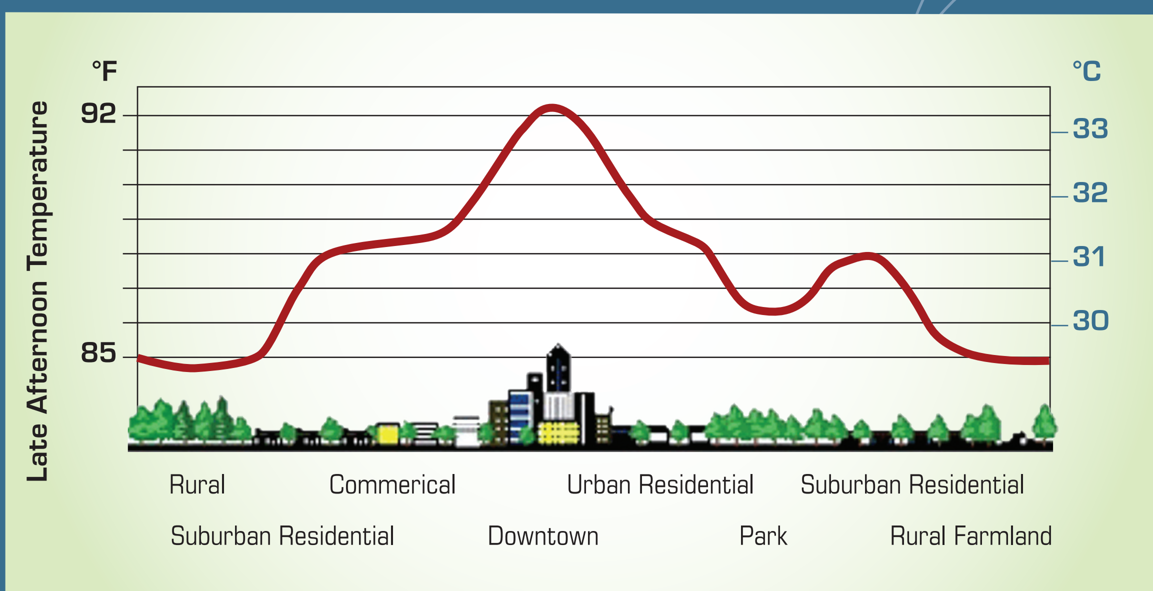
Urban Heat Islands

Urban Heat Is a Problem

The earth is warming.[1] Average temperatures in the northern hemisphere in the second half of the 20th century were "likely the highest in at least the past 1,300 years."[2] The period 2000-2009 was the hottest decade on record,[3] and the summer of 2011 was the second hottest ever, with average to above-average temperatures in 46 of the lower 48 states.[4] And that may be just the beginning. The United Nations Intergovernmental Panel on Climate Change (IPCC) predicts global temperatures to rise an additional two to 11.5 °F by the end of this century.[5] Even if the world dramatically scaled back emissions today, the earth would continue to warm for decades from the greenhouse gases already stored in the oceans and atmosphere.[6]

The projected temperature rise is likely to be even greater in urban areas, where over 80 percent of the United States population lives.[7] Even if the global climate were not warming, cities already have a heat problem—the *urban heat island effect*.[8] Cities are hotter than rural areas because the pavement, buildings, and other infrastructure 1) remove sources of shade and 2) retain heat during the day and release it overnight.

FIGURE 1: *The Urban Heat Island Effect*[9]



Source: Greater London Authority.

Traditional pavement and roof surfaces can be up to 90 °F hotter than the air, whereas vegetation and rural surfaces are more likely to be at or below air temperature.[10] On average, high surface temperatures make urban air two to five degrees F warmer than surrounding areas during the day and up to 22 °F warmer at night, though the difference is often less.[11]

Urban heat is already taking a toll on human health, while also increasing energy costs and environmental pollution. Reducing urban heat islands can both mitigate climate change (reduce greenhouse gas emissions) and adapt to climate change (prepare for the unavoidable impacts of climate change).

When heat kills

Between 1979 and 2003, extreme heat caused more deaths in the United States than hurricanes, lightning, tornadoes, floods, and earthquakes combined.[12] This threat will grow as temperatures rise. In the United States today, there are an average of 700 heat-related deaths per year, but if greenhouse gas emissions continue to rise at the current pace, that number is predicted to skyrocket to between 3,000 and 5,000 deaths annually by 2050.[13] Because the heat island effect is especially strong at night, residents will not be able to get overnight relief from heat in urban areas. During heat waves, the lack of nighttime relief is strongly correlated with increased mortality.[14]

Exposure to high temperatures can lead to heat stroke, heat exhaustion, heat cramps, heat rash, and general discomfort.[15] The severity of heat-related illnesses also increases with age: "[H]eat cramps in a 17-year-old may be heat exhaustion in a 40-year-old, and heat stroke in a person over 60."[16] Older people with fixed incomes, along with other lower-income people, are less able to afford air conditioning, making them more vulnerable.[17] Infants, children, and socially isolated residents are especially at risk of succumbing to heat-related diseases.[18] Outdoor workers, the mentally impaired, the homeless, and those with certain chronic conditions are also more vulnerable to heat than the average resident.[19]

When heat burns energy

Hotter days in urban areas lead to higher energy consumption for air conditioning, which increases fossil fuel emissions and pollution levels.[20] Researchers estimate that, nationally, one sixth of the electricity consumed in the United States is used to cool buildings, at a cost of $40 billion.[21] The summer of 2011 spiked energy demand by 22.3 percent above average.[22] In addition to the increased financial cost, the increased energy demand can lead to rolling brownouts or blackouts, which reduce the ability of residents to cool themselves with air conditioning and make emergency response difficult.[23]

When heat affects our lungs

Heat islands also harm the public's health by lowering air quality. The combination of increased pollution and higher temperatures results in more smog (ground-level ozone). Smog exacerbates respiratory diseases such as asthma, which are more prevalent among the same groups who are already vulnerable to heat-related illnesses: the elderly, young children, the poor, and people with preexisting chronic conditions.[24] According to a study by the Center for Health and the Global Environment at Harvard Medical School, "the combination of air pollutants, aeroallergens, heat waves and unhealthy air masses increasingly associated with a changing climate causes damage to the respiratory systems, particularly for growing children, and these impacts disproportionately affect poor and minority groups in the inner cities."[25]

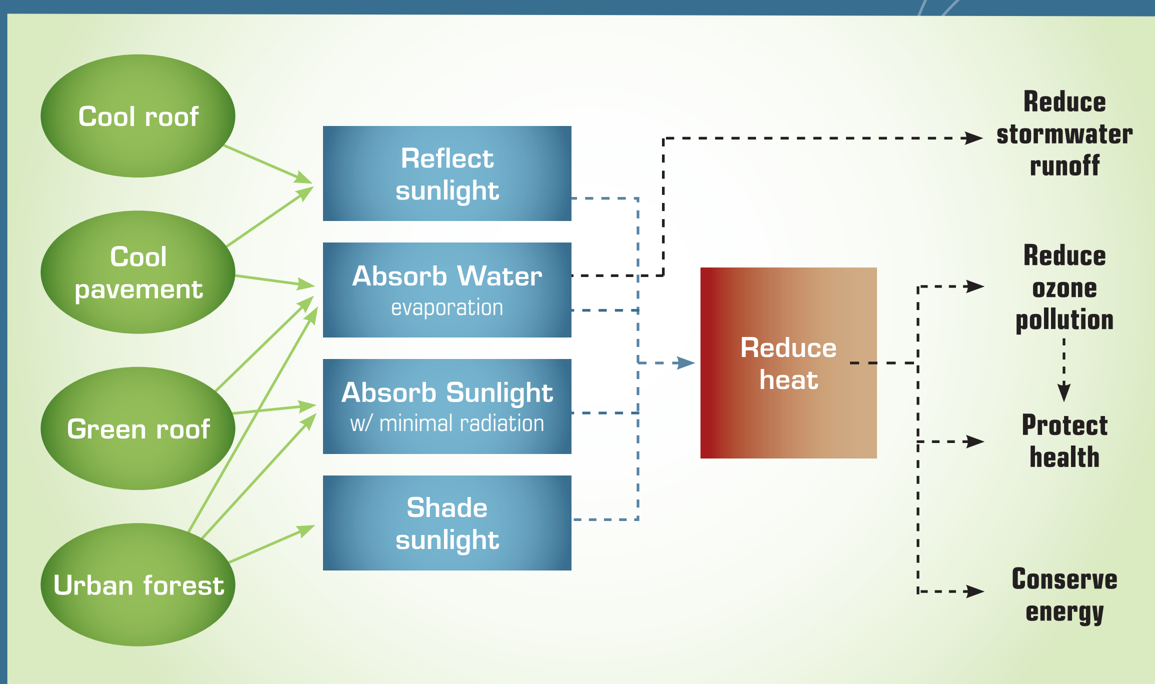
When heat pollutes the water

Heat islands can reduce water quality through thermal pollution. Just as hot surfaces in urban areas warm the ambient air, they also transfer heat to stormwater.[26] One study found that stormwater runoff in an urban area was as much as 30 °F hotter than runoff in a nearby rural area. Urban stormwater runoff heats streams, rivers, and lakes, potentially harming aquatic life and affecting other stream uses.[27] In combination with the fact that heat islands often have high percentages of impermeable surfaces, leading to more stormwater runoff, heat islands can have a serious adverse effect on local waterways.

Cities Can Adapt to Heat

Local governments can adapt to urban heat by 1) preparing for and responding to heat emergencies and 2) changing their landscapes and physical structures to lower local temperatures. Many local governments such as Philadelphia, Milwaukee, and Phoenix have developed effective heat emergency response plans.[28] These plans are a critical tool in the public health response to heat waves, especially within heat islands, and will save lives. However, emergency response alone will not save all of a community's most vulnerable residents. It also will not help residents when summer is merely hot and not at declared emergency levels. Last, emergency response fails to address other aspects of urban heat, including energy disruptions, air pollution, and economic costs of cooling residents. In short, an effective strategy for reducing heat needs both a strong emergency response and preparedness plan and a built-environment strategy.

FIGURE 2: *How Built-Environment Changes Provide Benefits*



Source: Harrison Institute for Public Law, 2012.

This Tool Kit focuses on the built-environment strategy, which can 1) lessen the urban heat island, 2) protect the health of residents, 3) lower energy consumption and therefore reduce greenhouse gas emissions, and 4) potentially provide environmental co-benefits such as stormwater management and improved air quality.[29]

This Tool Kit examines four methods—cool roofs, green roofs, cool pavements, and urban forestry—and explains how and when local governments can adopt each method. Cool roofs reflect light and heat, unlike traditional dark surfaces that absorb heat, thus keeping buildings cooler. Likewise, cool pavements reduce temperatures either by reflecting energy or byabsorbing and then evaporating water, helping to cool city streets. Green roofs and urban forests absorb less heat than dark roofs or pavements, and also cool the surrounding air by evapotranspiration.[30] In addition, urban trees offer cooling shade. Local governments can require use of each method under certain circumstances, encourage its use through incentive programs, and/or educate the public about its use through education or demonstration programs.

> *If employed extensively and in combination, these methods indirectly cool all city residents by reducing the urban heat island.*

These four methods can directly cool individuals by decreasing temperatures of buildings and neighborhoods where those people reside. If employed extensively and in combination, these methods indirectly cool all city residents by reducing the urban heat island. Unlike emergency response alone, a built-environment strategy can reduce heat and prevent its adverse effects on health, the economy, and the environment.[31]

Governments Face Challenges

Many state and local governments have adaptation plans.[32] Most offer aspirational language and general policies; few provide concrete steps for action. Adaptation planning is complex; many choices exist for adapting, and deciding among them is challenging. When governments face intense budgetary pressures, adaptation planning competes with other priorities.[33] Yet another complication is that an effective strategy usually requires multiple agencies to cooperate, which can be difficult. Finally, many communities may be stymied by political barriers. They may prefer to wait for the federal or state government to take action first (or to direct communities to do so, preferably by providing some guidance and resources) or they may be sensitive to the prevailing sentiments about climate change in their communities.[34]

Complex choices

Once a local government decides to develop an adaptation plan, officials must decide which combination of built-environment options (changes to roofs, pavements, etc.) will best serve their objectives. Then, for each option, they must choose which combination of policy tools (e.g., zoning incentives or purchasing preferences) will work best. For example, if cool pavements would advance the heat adaptation goals, how can the government increase their use? Require agencies to use them? Encourage developers to use them through tax breaks or other incentives? Test them in small areas to gauge their effectiveness first? With at least 10 policy tools for each of the four methods to help cool communities, governments need a menu of choices and a summary of the cost and benefits for each item on the menu.

Local governments can maximize positive tradeoffs by considering that not all of their residents are equally affected by heat. As discussed above, low-income, elderly residents are most vulnerable, along with infants, children, and socially-isolated citizens.[35] Given limited resources, use of cool pavements and other tools in a city-wide effort would not have as much impact as concentrating on neighborhoods where areas of higher temperatures (caused by small-scale heat island effects) coincide with the highest proportion of vulnerable residents.

In order to prioritize neighborhoods or blocks where adaptation could begin, local governments can identify areas of most urgent need in several ways. First and most simply, local planners, social workers, and agencies on aging may have some idea of where their most vulnerable residents live. Second, GIS mapping is now commonly used by local governments and can identify targets based on census data such as age, socio-economic status, etc. Heat islands can be identified by surface temperature and air temperature measurements.[36] By overlaying the vulnerable areas with the heat islands, local governments can conserve resources for adaptation, protect the most vulnerable residents, and improve energy efficiency.

Limited resources and authority

Each of these decisions requires decision makers to assess trade-offs. Environmental and economic impacts, both in the short- and long-term, change with different methods and tools. Many local governments are unsure whether they have the legal authority to act without running afoul of state or federal laws.

Some governments are already using policy tools that reduce heat islands, although those tools may be directed primarily at different purposes. Milwaukee, for example, promotes green roofs as a tool to manage its stormwater.[37] By promoting green roofs in areas identified as heat islands, Milwaukee could solve two problems at once. The city does not need any new authority or funding to make this change, given the tools already in place. Many local governments already have urban forestry initiatives or other programs that can be expanded for adapting to urban heat.

Agency coordination

The diversity of built-environment methods for adapting to urban heat requires the coordination of several local agencies. Increasing urban tree canopy, for example, might require participation from the local urban forestry office as well as from the departments of transportation, parks and recreation, planning, and zoning. Local governments may struggle to align the interests and priorities of this many agencies. As with limited resources, building on existing partnerships and relationships may be a fruitful place for governments to begin their adaptation efforts before branching out to new efforts.

Climate skepticism

Many local governments may be faced with skepticism or outright hostility when talking about climate change with their staff and constituents. In some cases, they may feel that simply mentioning climate change will end the conversation about adaptation efforts. The measures discussed in this Tool Kit are important for addressing current weather variability and recognized risks and system stressors. Local government officials can choose to emphasize benefits such as energy efficiency, public health, sustainability, etc. For example, the Climate and Energy Project, a nonprofit group in Kansas, achieved a 5 percent reduction in energy use among six Kansas towns by starting a competition and focusing on the values of thrift, stewardship, and jobs.[38] The project deliberately never discussed global warming or climate change. Similarly, local governments can talk about adaptation to urban heat in terms of protecting their most vulnerable residents from weather extremes, saving energy and money, or creating jobs. Residents directly experience heat and may be more supportive of managing high temperatures to protect their health than they might be of other climate strategies.

Purpose and Methodology

Our purpose is to help local governments reduce the intensity of urban heat. Our methodology is to help them decide:

- Whether to use one or more of the built-environment methods, and
- Which policy tools they can use to implement the methods. They may already have authority to use a tool, or they may need new state or local legislation.

Different agencies usually manage the policies that govern the built-environment methods: roofs, pavements, and trees. This Tool Kit facilitates a multi-agency strategy. For example, a program to increase use of cool pavements might involve the department of health to identify areas of vulnerable residents, the department of transportation to set new policy about where and what type of cool pavements would work for roads and sometimes sidewalks, the office of procurement to set standards for evaluating bids, and the department of environment to coordinate efforts of all agencies.

Different agencies usually manage the policies that govern the built-environment methods… this Tool Kit facilitates a multi-agency strategy.

In this chapter, we introduce a framework that enables governments to decide whether and where they can promote use of cool roofs, green roofs, cool pavements, and urban forestry; the full descriptions of the criteria are located in Appendix 1 at the end of this Tool Kit. The framework uses two sets of criteria to weigh the pros and cons of each built-environment method:

- ***Outcome criteria:*** including heat reduction, public health improvement, energy cost reduction, and reduced environmental impact; and
- ***Governance criteria:*** including administrative and legal considerations.

Following the framework, we introduce four sets of policy tools—mandates, incentives, education, and infrastructure—that governments can use to implement their built-environment methods.

Subsequent chapters cover cool roofs, green roofs, cool pavements, and urban forestry. Each reviews the pros and cons of the method, applies the decision-making framework, and then outlines a menu of policy tools to implement that method. Within the four sets of tools, we explain under what circumstances each tool works best. Each chapter concludes with a list of "no regrets" tools—the tools for which the benefits outweigh the costs, regardless of whether the climate of your community is getting hotter, and regardless of your views about the causes of climate change.

The conclusion provides a summary and a comparison chart to show the circumstances for which each tool is best suited.

Framework for Decision-Making

We analyze each method in terms of four ***outcome criteria***: heat, economic, public health, and environmental; these criteria will correspond to decision makers' priorities and the physical realities of their urban areas. Additionally, we assess the impact of two ***governance criteria***: administrative and legal. With this governance analysis, local governments can determine whether a particular tool is within their current legal authority or administrative capacity.

Outcome Criteria

Our decision-making framework enables local governments to tailor the best heat adaptation strategies for their unique situations. This section describes both sets of decision criteria—outcomes and governance—and then outlines the sets of policy tools that we use in the following chapters. Following the lead set by our Sea-level Rise Adaptation Tool Kit[39], we organize the outcome criteria into four categories:

Heat: First and foremost, the built-environment method or policy tool must actually reduce heat. Considerations of geography and climate can influence whether cool roofs are economically viable as well as the levels of evaporative cooling from vegetation and permeable pavements. Land cover can guide local governments' choice to make pavements or roofs a higher priority. The proportion of new development versus established buildings will help to determine which method or tool (mandates, incentives, etc.) will most effectively reduce heat.

Public Health: Local governments' public health interest in reducing urban heat focuses primarily on equity and the needs of vulnerable populations. For a variety of reasons, low-income individuals and the elderly are more susceptible to heat-related illnesses,[40] and they may also suffer more from the effects of the urban heat island, such as poor air quality.[41] These residents may also have less access to air conditioning[42] or spend a higher percentage of their income on energy costs.[43] Therefore, local governments may choose to focus on identifying areas where heat islands are likely to affect vulnerable populations and then apply the heat-reducing methods to these high-need areas.

Environmental: All of the methods for reducing urban heat islands play a role in mitigating climate change as well as adapting, and several offer environmental co-benefits outside of their climate benefits. Three of the major co-benefits are lowering energy use, reducing air and water pollution, and improving stormwater management. These co-benefits will improve environmental conditions and public health.[44] Heat adaptation strategies can also help local governments address air pollution such as ground-level ozone and water quality from stormwater runoff.

Economic: When contemplating the financial impact of adaptation strategies, governments must take stock of the short- and long-term costs of each method, as well as the potential cost savings of each over time, and choose who will pay the costs. Some heat adaptation methods require large upfront investments; green roofs, for example, have initial costs ranging from $10 to $25 per square foot. However, building owners commonly offset this cost over time in energy savings and other co-benefits.[45] Incentive programs that encourage citizens to adapt may require more government funding than mandates, which would place the cost on private actors. Green roofs and some types of cool pavements may have greater maintenance costs over time as well. Local governments may draw from a variety of funds to pay for adaptation measures, including general funds as well as targeted taxes, fees, or charges.[46]

Governance Criteria

Governance criteria are grouped into two categories:

Administrative: Program administration and the city's current practices may influence which strategies are most likely to work. Government organization, coordination with outside groups, and the level of participation of citizens and interest groups can strongly affect the success of various strategies. Authority for the various strategies may be divided among a number of government agencies, such as planning, public works, health, and environmental departments; coordination among these agencies will lead to better outcomes. Governments might evaluate whether opposition from interest groups could delay or prevent implementation of certain adaptation measures, particularly those that are mandatory.[47] Because most local governments are not starting from nothing, they must consider how current policies fit with their adaptation goals. In order to capitalize on current programs and policies that may work well, local governments may choose to build upon an existing urban forestry program, for example, rather than beginning an entirely new program from scratch.

Legal: Local governments will need to consider which tools fall within the authority that agencies already possess and which may require further granting of authority from either the local legislative body or the state legislature. In addition, certain methods or tools could conflict with current state or local law. For instance, existing building or paving standards may conflict with heat adaptation priorities.[48] To improve current laws, governments can consider consolidating the laws on a particular topic[49] or revising existing ordinances to better address heat adaptation needs. We have attempted here to identify potential legal obstacles for each local government to consider.

This framework is a starting place for local officials and an aid in decision-making. It is not a sufficient guide to the intricacies of every potential cost and benefit. Each jurisdiction's strategy will be different than another's based on local law, politics, and geography. The chart below provides a first look at how the four methods interact with these evaluation and governance criteria. Each of the chapters in this Tool Kit explores the methods in more detail, including evaluation of how local governments might implement each one.

TABLE 1 *Urban Heat Methods: How Decision Criteria Affect Choices*

Method	Outcome Criteria				Governance Criteria	
	Heat	Economic	Public Health	Environmental	Administrative	Legal
Cool Roofs	+	+	+	+	~	~
Green Roofs	+	~	+	+	~	~
Cool Pavements	+	~	+	+	~	~
Urban Forestry	+	+	+	+	~	+

Advantageous (+) The choice maximizes benefits and is feasible.
Neutral (~) The choice may present may present mixed advantages and disadvantages.

Sets of Policy Tools

For each of the four heat-reducing methods (green roofs, cool roofs, cool pavements, and urban forestry), we identify the tools with which local governments can actually put the methods into practice. We organize the tools into four main sets: mandates, incentives, education, and government operations.

Government Operations are crucial when government is the owner and custodian of heat-sensitive assets: pavement, streetscapes, buildings, and urban forests. In this context, government can lead by example at the stages of land-use planning, building design, and choice of materials and landscaping. In most urban areas, the density of public paving and buildings means that an active government role– not merely acting as a role model– is crucial for reducing the heat island.

Mandates include tools that require public or private actors to perform an action or meet a set standard. Mandates are non-discretionary—i.e., an agency must use cool pavements for a certain project or property owners must include a cool roof on buildings over a certain size. Mandates can be implemented through building codes, zoning codes, procurement codes, etc.

- ***Incentives*** are used by governments to encourage a particular behavior. Incentives neither 1) set a particular standard to meet nor 2) specify only one way to meet it. For example, a local government could adopt a stormwater fee rebate for properties that build green roofs and thus reduce the amount of stormwater runoff. Grant programs would also fall under incentives.
- ***Education programs*** provide information on health, economic, and environmental benefits and costs. When benefits outweigh costs, education can be enough to stimulate voluntary adoption of heat-reducing methods. For example, a city could distribute information directly to homeowners about the energy savings they could realize from planting trees in optimal locations. The most influential audience is the development community: architects, engineers, commercial and residential developers, and construction companies. For them, governments can provide online information for heat-smart design and purchasing decisions. Demonstration projects—such as retrofitting government buildings—can test and validate the costs and benefits under local climate conditions.

There are scores of effective policy tools within these four categories. Choosing among them is difficult because (1) there are so many to choose from, (2) the tools are most likely to work in combination, as part of a coherent strategy, and (3) that strategy requires political will. It takes political will to coordinate multiple agencies. It takes political will to change last year's way of building streets and structures in order to achieve next year's reduction in heat and energy costs.

Starting with cool roofs, the next four chapters address each of these challenges. They provide an overview of benefits and costs, apply the framework for making local decisions about whether and where to use each method, and provide a menu of policy tools. We stress that this Tool Kit provides a framework and a menu, not cookie cutter solutions. In the short run, the local officials can use these tools to cool individuals and to save energy and lives on a small scale. In the long run, these tools will produce cooler, more livable cities.

Cool Roofs

Urban areas are projected to get hotter, which will exacerbate the urban heat island effect.[50] In urban areas, pavement has replaced vegetation and open areas—which provide shade and lower air temperatures—with pavement, buildings, and infrastructure—which absorb the sun's light energy as heat during the day and release it overnight. Consequently, urban areas are on average two to five degrees F warmer than surrounding areas; they will warm further as the overall climate changes.[51]

In this chapter, we focus on installing cool roofs to reduce the urban heat island effect.[52] Cool roofs reflect more light and absorb less heat than traditional roofs. Or in more technical terms, cool roofs have both a high solar reflectance (or albedo) and a high thermal emittance, so that much of the heat that is absorbed is quickly radiated back to the atmosphere. [53] As a result, cool roofs can be 50 to 60 °F cooler than traditional roofs.[54] Just as wearing light-colored clothing keeps people cooler, installing a cool roof lowers temperatures inside the building; attics and top floors receive the greatest cooling benefit from cool roof treatment.[55] In one study, cool roof treatment reduced the peak heat gain from the attic into the house by nearly 90 percent when combined with improved attic insulation.[56] The corresponding decrease in energy use for air conditioning may in turn help to mitigate the greenhouse gases emitted by the power generator.[57] According to Energy Secretary Steven Chu, "Cool roofs are one of the quickest and lowest-cost ways we can reduce our global carbon emissions and begin the hard work of slowing climate change."[58]

Cool roof materials come in a variety of colors from light to dark and are available for both low-sloped and steep-sloped roofs. They work for a variety of building types and aesthetic requirements.[59] Creating a cool roof can be as simple as spraying on a light-colored, paint-like coating. There are two basic types of coating that reflect more light and energy than a traditional roof.[60] Slightly more complex approaches include membranes that can be applied to the roof, roof tiles that reflect the sun much better than traditional tiles, cool-colored metal roofing, and asphalt shingles.[61]

Cool roofs mean cooler cities. A New York City study found that cool roofs on half of the available surfaces could lower the air temperature by 0.3 degrees F.[62] Even such a small change yields great reductions in energy use, the likelihood of blackouts, and threats to public health.[63]

Local governments have a wide variety of policy tools available to promote cool roofs, including building codes, grant programs, utility rebates, and others. Incorporating goals for increasing the number of cool roofs into a comprehensive or general plan can be an important prerequisite step to later changes to building or zoning codes. Comprehensive or general plans contain a jurisdiction's long-term vision for development and set zoning and other policies, goals, and objectives that direct future growth.[64] By incorporating cool-roof-friendly goals in these plans, local governments can guide zoning authorities in prioritizing cool roofs and other policies that lessen urban heat islands. Philadelphia's new cool roof law, for example, which will require cool roofs on all new residential and commercial construction, grew out of the city's goal to reduce energy consumption contained in the city's comprehensive sustainability plan.[65]

Likewise, the General Plan for the Town of Gilbert, Arizona includes an environmental planning element that "addresses anticipated effects on water quantity and quality, air quality, and cultural resources."[66] To achieve the town's vision of a sustainable economy and a high quality of life, the goals of the Gilbert General Plan include reducing the urban heat island effect. The plan further lists specific policies that can help achieve this goal, including forming partnerships to increase awareness of urban heat islands and promoting education and awareness of cool roof products and implementation mechanisms. Gilbert continues to adopt policies, including issuing design guidelines for cool roofs, in pursuit of this goal.[67] Adoption of some of these policies by local government sets the stage for collaboration by multiple agencies over the long term.

This chapter discusses the various policy tools available to local governments, along with the benefits and challenges of these tools, and provides guidelines to help governments decide how and when to use mandates, incentives, education, and public buildings to promote cool roofs. The chapter concludes with a comparison chart to help select policy tools.

Benefits and Challenges of Cool Roofs

Benefits of Cool Roofs

Cool roofs have many private and public benefits. Public benefits include reducing urban heat and decreasing smog formation,[68] thus improving the health of the community's residents—especially for seniors, children, and people with asthma.[69] By lowering energy use, cool roofs also ultimately reduce air pollution and greenhouse gas emissions.[70] Private property owners benefit from lower energy costs,[71] and cool roofs can extend the life of roofs by reducing the variability of roof temperatures, which damages traditional roofs.[72]

Cool roofs' versatility makes them applicable for many types of buildings. Roofs typically make up an average of 20-25 percent of a city's land cover.[73] The National Aeronautics and Space Administration (NASA) concluded that cities such as New York may have more rooftops with the potential to adopt cool roofs than green roofs.[74] Green roofs (see next chapter) require greater structural support than traditional roofs and relatively low slopes, cool roofs do not impose such structural requirements. [75] Cool roofs are also cheaper. The added cost of installing a cool roof instead of a traditional roof is only five to twenty cents per square foot,[76] whereas green roofs might cost ten to twenty five dollars more per square foot.[77]

Challenges of Cool Roofs

Weathering, location within a city (relative to a heat island), and climate (northern latitude) can all lessen the benefits that cool roofs offer.[78] While cool roofs require less upkeep than green roofs, they are not maintenance-free. Cool roofs generally have initial reflectance levels of 55 to 90 percent, compared to traditional roofs' five to 25 percent.[79] Unfortunately, weathering and dirt accumulation can lower the solar reflectance of cool roofs over time; studies have found an average decline of 15 percent in solar reflectance after the first year, with less significant additional declines over the next five years.[80] However, studies also have found that washing can restore nearly all of the original solar reflectance. Whether the energy savings are larger than the costs of washing depends on the local climate and building insulation levels.[81] Yet even after weathering, cool roofs are usually more reflective than traditional roofs, suggesting that they are worth the slight cost premium.

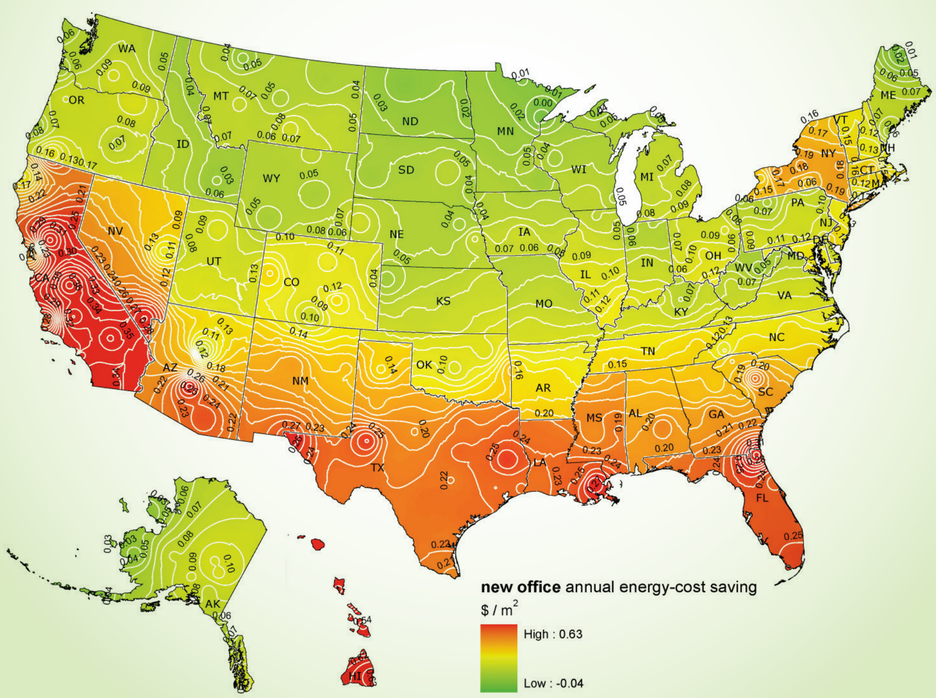
Cool roofs pose different benefits and challenges than do green roofs. First, while cool roofs keep buildings cooler than do traditional roofs, they still trap more heat than green roofs.[82] As Stuart Gaffin, a scientist at Columbia University's Earth Institute, points out, cool roofs reflect sunlight away from themselves, but they can bounce the light onto taller neighboring buildings, warming those buildings instead.[83] They can also cause unwanted glare.[84] Cool roofs therefore might best be used sparingly on shorter buildings. Where roof height is uniform, cool roofs have a consistently beneficial effect. Also in comparison with green roofs, cool roofs provide fewer environmental benefits such as reducing stormwater runoff, lessening pollution runoff, and capturing greenhouse gases and particulate matter.

The amount of benefits that building owners and communities receive from cool roofs also varies with regional location. Cool roofs make more economic sense where energy prices are high. For example, Baltimore, Maryland, and Richmond, Virginia, have similar climates, but the price of electricity in Baltimore is 60 percent higher than in Richmond.[85] An equivalent percentage reduction in energy use will therefore save more money in Baltimore.

Recent research suggests that cool roofs may not provide as much global cooling as earlier studies had posited. A new study by Stanford professor Mark Z. Jacobson modeled the outcomes of converting every roof in the world to a cool roof and found 1) that urban heat islands provide approximately 2 to 4 percent of gross global warming[86] and 2) that heat islands can be lessened on a local level by incorporating cool roofs.[87] The study also found that global adoption of cool roofs would change the way clouds develop locally and may not decrease global temperatures.[89] The model did not, however, factor in reduction of energy use due to cooler indoor temperatures, which in warm climates is significant.[90] These conclusions have been challenged by others in the field as making perhaps questionable assumptions and potentially drawing conclusions from numbers that are statistically insignificant.[91]

FIGURE 3 *Potential Net Energy Savings From Installing Cool Roofs*

Measured in dollars, net savings reflect the benefit of summer cooling minus the penalty of winter heating. Dr. Ronnen Levinson, 2010.[88]



Source: Lawrence Berkeley Laboratory, Heat Island Group.

Another study confirms that cool roofs do not provide a net economic or environmental benefit in areas with extremely cold winters and relatively mild summers. These areas would experience higher heating costs in winter, because of the heat-reflecting effect of cool roofs. The added winter costs would be greater than any savings from reduced cooling costs in summer.[92] However, cool roofs usually reflect less light and heat in winter than in summer, due to the lower position of the sun in the sky, increased cloud cover, decreased daylight hours, and snow cover.[93] Moreover, changes in climate in the future may make cool roofs economically attractive even in these areas because of rising temperatures.

Cool roofs can extend the life of roofs, reduce energy costs, and help residents stay healthy during periods of high urban temperatures.

Cool roofs can extend the life of roofs, reduce energy costs, and help residents stay healthy during periods of high urban temperatures. However, cool roofs only provide these benefits when used in appropriate locations in appropriate manners. Cool roofs may work best in neighborhoods with uniform building height in hot, sunny areas. Being aware of these geographic constraints allows governments to choose the best policies for their particular circumstances.

Decision-Making and Cool Roofs

Cool roofs are cost effective in most temperate-to-warm locales, but governments must still answer two specific questions: First, in which neighborhoods are cool roofs beneficial? Second, which policy tools are optimal for the community? The local climate and neighborhood characteristics will inform where adopting cool roofs will be most appropriate.

Outcome Criteria

Heat: Local weather patterns have a major impact on where cool roofs make economic sense. As discussed above, governments need to weigh the lower summer cooling costs against potentially higher winter heating costs. In most U.S. climates, the summertime benefits of cool roofs are greater than the winter heating penalties, particularly in areas where the roofs are likely to be covered with snow for much of the winter.[94] However, in some cold, cloudy northern climates, cool roofs will not be the best option.[95] But governments must also consider expected changes in climate. In many parts of the United States, temperatures will rise and precipitation patterns will change. So evaluating cool roofs based purely on current conditions may fail to consider their ability to help in the future.

Cool roofs can work on many buildings that cannot bear the weight of green roofs or which are too steep for green roofs. However, although cool roofs can physically work on many structures, they are best used in particular neighborhoods and with certain building combinations. For example, cool roofs on relatively short buildings surrounded by higher buildings may reflect light and transfer heat to the taller buildings.[96] Additionally, they can lead to unwanted glare for residents or workers in those taller buildings.[97] The cooling effect of cool roofs is also largely limited to levels just below the roof. Lower floors in tall buildings get little or no benefit. So cool roofs are especially beneficial in areas with one- or two-story buildings.[98]

Economic: In temperate-to-warm climates, cool roofs are cost-beneficial because of their relatively low cost and their potential for longer-term cost savings in energy use. Depending on type, cool roofs can cost zero to 20 cents more per square foot (zero to five or ten cents for most types of cool roofs) compared to traditional roofing.[99] The savings in energy typically outweigh this upfront investment. One California study found average savings of 47 cents per square foot, even after accounting for a slight increase in heating costs.[100]

Public Health: Local governments can use cool roofing programs to fulfill environmental justice needs by identifying neighborhoods with vulnerable populations and promoting cool roofs in those areas. Local officials can use GIS mapping and their own local knowledge to identify concentrations of their most vulnerable citizens (elderly, low socio-economic status, children, and those with chronic respiratory disease) and to find where those concentrations intersect with urban heat islands. In times of tight budgets, targeting cool roof initiatives to help the most vulnerable people can ensure that any money spent is highly effective.

Environmental: Cool roofs reduce energy consumption and therefore help to mitigate climate change. In addition, the reduced urban heat helps curb ozone formation and the reduction in electricity use lowers emissions of several air pollutants including air toxics. However, cool roofs do not help to manage stormwater as green roofs do.

Governance Criteria

Administrative: Cool roofing materials are similar in cost and design to traditional roofs and so are easy to incorporate with current practices.[101] Increasing the construction of cool roofs may require government spending (likely in the form of tax breaks, grants, or rebates) or a mandatory requirement in the local building code. While incentives require money, mandates may be politically unpopular with property owners and developers, and are less likely to cause cool roofs to be built in older and highly-developed neighborhoods. Current practice within the jurisdiction, including whether builders are familiar with cool roof installation, may influence whether cool roofs are a priority for local governments to encourage and/or require.

Legal: Any action local governments take clearly has to be within the scope of their authority. Mandatory requirements in building codes are likely to require a legislative change by the local council, as will a new tax incentive or fee rebate. If local governments remain within their scope of authority, however, and if they are careful not to impose mandatory requirements on existing buildings (barring substantial renovations), they should face few legal challenges to promoting cool roofs.[102] Local governments with cool roof incentive programs or zoning bonuses already in place may be able to target cool roofs more closely to urban heat islands, thus increasing the "bang for the buck."

TABLE 2 *Cool Roofs: Summary of Benefits & Costs*

Method	Outcome Criteria				Governance Criteria	
	Heat	Economic	Public Health	Environmental	Administrative	Legal
Cool Roofs	+	+	+	+	~	~

Advantageous (+) The choice maximizes benefits and is feasible.
Neutral (~) The choice may present may present mixed advantages and disadvantages.

Policy Tools to Increase the Use of Cool Roofs

A city or county can increase the use of cool roofs through changes in government operations, public education programs, incentives, mandates, or combinations of these. A local government has the most control over its own operations, making this category a logical place to begin.

Government Operations

Using cool roofs on government buildings can save money in energy costs. In addition, government action can also have the important effect of demonstrating the cool roof techniques and benefits to developers and residents (see Public Education below for more detail).

For example, Tucson, Arizona, installed a cool roof on the Thomas O. Price Service Center in June 2001 to "help educate residents along with representatives of industry and local government …"[103] The Price Center is a one-story office building with a 28,000 square foot roof that the city retrofitted with a white coating.[104] Even though the Price Center had already lowered its energy usage through internal upgrades, such as efficient lighting systems, the roof resulted in a nearly 50 percent reduction in the energy used to cool the building.[105]

TABLE 3 *Government Operations for Cool Roofs*

Pros	Cons
Direct control over facilities	Facility may not be within a heat island
Saves money over time	Requires upfront investment

The city is saving $4,000 a year and expects to recoup the cost of the roof, $24,993, in about six years.[106] The relevant policy tool here is procurement; governments will need to write their bid specifications to include cool-roof materials or performance characteristics.

Mandates

Many local governments require property owners to build cool roofs by setting standards in their building codes or green building programs. Focusing on new development is cost-effective because installing a cool roof on a new building is comparable in cost to a traditional roof, whereas retrofitting an existing roof with a cool roof can be more expensive.[107]

TABLE 4 *Mandates for Cool Roofs*

Pros	Cons
Ensures use in new buildings	Excludes most existing buildings
Low cost for government	Additional cost for property owner
Requires standard setting	

Building Codes and Green Building Programs

Building codes are the primary vehicle for mandating that new construction projects include reflective roofs. Local governments use building codes to set standards for individual building types (i.e., residential, commercial, etc.).[108] Green building programs prioritize methods of building that preserve and protect human and environmental health.[109] Building codes apply mainly to new development; however, local governments can incorporate requirements for retrofits or repairs into building codes as well. Including a cool roof requirement in a building code places the cost of installing a cool roof primarily on the building owner; however, for new development this cost is similar to that of a traditional roof.[110] Whether a roof is new or retrofit, its cost is usually financed over period of years to match the savings.

Several building standards include cool roofs among their options to earn points for certification. The American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE), promotes the sustainable use of heating, ventilating, and air-conditioning. ASHRAE developed energy-efficient design standards for commercial and residential buildings in response to the 1970s energy crisis. Today, many local and state governments incorporate these standards, which include points for cool roofs, into their building and energy codes.[111] The U.S. Green Building Council has developed a green building certification and rating system called LEED (for Leadership in Energy and Environmental Design); some local governments use LEED standards in creating incentives for private property owners or requirements for publicly owned buildings.[112] The International Code Council (ICC), a standard-setting body for many building and other codes, released the International Green Construction Code (IgCC) in draft form in 2010. The IgCC is intended to provide a model for state and local governments to adopt sustainable and green building practices; a new version will be released in spring 2012.[113] All of these standards incorporate cool roofs and can be incorporated into the building code as either mandatory or voluntary standards. Following are some examples of mandatory standards that require cool roofs specifically.

> *Building codes apply mainly to new development; however, local governments can incorporate requirements for retrofits or repairs into building codes as well.*

Frisco, Texas, became the first city in the United States to adopt a program to require green building practices for residences in May 2001, followed by a commercial green building program in 2004.[114] In 2006, Frisco expanded its commercial green building program.[115] Frisco chose a mandatory program over voluntary in order to "to give future generations the legacy of environmental sensitivity, functionally efficient homes, and a commitment to conservation."[116] The program requires that "100% of all [commercial] roof areas shall comply with the specifications of the Environmental Protection Agency's Energy Star Cool Roof Program, as it exists or may be amended."[117] Projects can also be recognized as energy efficient and earn an Energy Star designation from the federal EPA by using Energy Star approved products, among other criteria.[118] By November 2009, city officials estimate that nearly 13,000 green or Energy Star homes had been built in Frisco, with an average annual energy savings of over $400 per home.[119]

Other cities have followed Frisco's example. In May 2010, citing the environmental and financial benefits, Philadelphia passed a law that requires many new residential and commercial buildings to include cool roofs, a law that the Council considers to be relatively cost-neutral.[120] The city limited the law to roofs with low or no slope, which covers many row houses and commercial buildings but excludes many single-family homes.[121]

Incentives

In addition to mandates, governments can promote cool roofs through incentive programs, such as grants, which offset initial costs of cool roof installations, or rebates, which offset ongoing energy costs. Incentives reduce the costs borne by property owners; however, they can potentially be expensive for local governments compared to mandatory programs, depending on the size of the incentives and the scope of property owners and developers who qualify. Their political viability will likely depend on the size and status of the city budget, along with these other factors.

Governments can target incentive programs to both new development and existing structures, which are harder for mandates to reach because it is not feasible for governments to require private building owners to retrofit their roofs. Likewise, governments can target incentive programs to types of buildings to reduce the unwanted glare sometimes associated with cool roofs, or to particular neighborhoods to focus on the community's most vulnerable residents.

TABLE 5 *Incentives for Cool Roofs*

Pros	Cons
Applies to existing and new buildings	May result in less use than mandates
Property owners bear less cost	Government has to pay for incentives
May be more politically feasible than mandates	

Grant Programs

Grant programs require governments to have funds on hand for distribution. However, governments can limit both the amount of money available for grants and the duration of the grant program in order to control costs. The Toronto Eco-Roof Incentive Program provides grants for private individuals to retrofit existing structures with cool or green roofs, and to include green roofs on some new developments.[122] The program, created in 2009 and set to run for three years, has already approved over 50 grants, leading to over 90,000 square meters of "eco-roofs," a term that encompasses cool and green roofs. The program defines cool roofs as systems to reduce the urban heat island effect; they can be either a coating applied over an existing roof system or a new waterproofing membrane, a sheet that is fastened over the entire roof. Standards vary by the slope of the roof, with low-sloped roofs needing higher reflectance ratings.[123] Eligible cool roof projects can receive two to five dollars per square meter, up to a total of $50,000.[124]

Rebate Programs

Many local utilities offer rebate programs to building owners who install cool roofs. The rebate is essentially a payment or reduction in the building owner's utility bill and helps to pay for some of the costs of installation. The Cool Roof Rating Council, a neutral non-profit organization that rates the radiative properties of roofing materials, lists 30 such programs.[125] Utilities can limit their programs by duration, type of building, type of structure, or type of roof in order to target particular structures or to limit costs.[126]

Unlike grant programs, which require governments to set aside money from the outset, utility rebates have relatively few upfront costs and directly link the private incentive to the public benefit of reducing energy use. Rebates may be particularly useful in urban areas with a high potential for energy conservation but with low electricity rates. The rebates translate the energy conserved into a financial incentive that is otherwise lacking for the building owner to switch to a cool roof.

For example, the Sacramento Municipal Utility District (SMUD) operated the United States' first cool roof program for commercial buildings from 2001 through 2005. During this period, the State of California issued a state requirement for nonresidential buildings with low-slope roofs to include cool roofs or additional roof installation.[127] In 2007, SMUD initiated a residential cool roof program as well, under which customers receive energy rebates if they retrofit their roofs with Energy Star rated cool roof products and have an electric central air conditioning system. New construction is not eligible for the rebates, likely because cool roofs on new construction make financial sense without rebates.[128] Cool roofs can earn rebates of 10 to 20 cents per square foot depending on the slope of the roof.[129] Local governments will need to negotiate with utility companies (public or private) or the public utility commission to establish a rebate program; it may require state legislation.

Public Education Programs

Public education programs include training, direct outreach to contractors and the public, and demonstration projects. Even if a city decides to primarily use incentives or mandates, education programs can support a comprehensive cool roof strategy. A public that understands the potential benefits of cool roofs and the dangers of the urban heat island helps to build support for mandatory programs and to raise the necessary awareness to make incentives more widespread. Governments can also raise public awareness through direct campaigns to educate citizens on cool roofs, including explaining the technologies available and the potential benefits of implementation. These campaigns can take the form of seminars, workshops, short videos, or direct mailings. Governments can also use education programs in public schools to teach the next generation of leaders about the importance of cool roofs.

TABLE 6 *Public Education for Cool Roofs*

Pros	Cons
Low cost for government	Less direct means of increasing use
Relatively low administrative effort for government	Lower results if used alone

Demonstration Projects

The Price Center in Tucson (noted above) serves as a demonstration project for the city. After retrofitting the office building with a cool roof, the city commissioned a study to evaluate the energy savings. The findings of significant energy savings (50 percent reduction in cooling costs) prompted the city to continue to retrofit other buildings and to promote adoption of cool roofs more broadly.[130]

Training

Local governments can help building owners reduce expenses in switching to cool roofs by training them to install the roofs. NYC °CoolRoofs aimed to coat one million square feet of rooftop in the city with a reflective white coating by October 2010.[131] Working with teams of volunteers, the program coated city building roofs, worked with non-profits to coat their roofs, and provided private building owners with a "do it yourself kit" and a list of vendors who supply coating material at a discounted rate.[132] The city surpassed its goal and coated 1,168,369 square feet.[133]

Public Education and Media Campaigns

Governments can also use public education and media campaigns to raise awareness about cool roofs. The Houston Advanced Research Center (HARC) is a nonprofit organization that promotes sustainable development and sponsors the Cool Houston! Program. The program published a plan to reduce the heat island effect by changing the surface of Houston, in part through the use of cool technology on flat roofs.[135] Of the plan's six components, three are education-based: creating visible public partnerships, providing information on cool roofing, and increasing public awareness.[136]

Mayor Bloomberg and former Vice President Al Gore paint rooftops of participating buildings white.

Image from NYC Service.

HARC hopes to lead by example by installing cool roofs on public buildings. It is also raising public awareness by targeting information to building owners and managers.[137] Toward this goal, Cool Houston! has developed a direct mail campaign that provides information on three methods to cool the city—cool pavements, reflective roofing, and urban trees. The flyer explains the importance of adopting each strategy, lists the strategy's benefits, and provides an example of a location that has adopted the option.[138]

Conclusion

Cool roofs assist with adaptation to climate change by reflecting sunlight away from buildings to make them cooler and to reduce urban heat.[139] While cool roofs are beneficial in temperate climates, there are some neighborhoods, structures, and northern climates where they may not be cost-beneficial. However, for most urban areas and neighborhoods, there are several "no-regrets" policies that all local governments facing increases in heat may wish to consider. These policies are beneficial even under current climate conditions, regardless of projected changes.

- ***Help establish utility rebate programs for cool roofs.*** Cool roofs lower peak energy demand and reduce the likelihood of brownouts and blackouts. Utilities benefit enough from cool roofs that the utilities may be willing to grant rebates for the roofs' installation (assuming that rate-base authority is in place). In essence, a rebate is self-financing. Local governments can reap the benefits with relatively little direct expenditure, while supporting the reliability of the electricity grid and reducing emissions from power generation, particularly during peak cooling times.
- ***Building code standards for new buildings with low-slope roofs.*** Flat and low-slope roofs can be retrofitted with cool roofs without risk of glare to neighboring buildings; changes to the building code ensure that new construction will be more energy efficient and will help to reduce the heat island effect. The requirement can be

tailored to particular building types (commercial, residential, etc.) and/or buildings over a certain size. A revision of this type will likely require local legislation.

- ***Guidelines in general plans.*** Inclusion in design guidelines or general plans will likely lead to future adoption of cool roofs.
- ***Use on city-owned buildings with low-slope roofs.*** Local governments can lead by example to demonstrate the benefits of cool roofs to private residents. The governments will recoup the cost premium with energy savings over a short period of time.

TABLE 7 *Decision-Making and Cool Roofs: How the Criteria Affect Tool Choices*

	Outcome Criteria				Governance Criteria	
	Heat	Economic	Public Health	Environmental	Administrative	Legal
Government Operations						
Government Facilities	+	+	+	+	~	+
Mandates						
Building Codes & Green Building Programs	+	+	+	+	~	~
Incentives						
Grant Programs	~	~	+	+	~	~
Rebate Programs	~	~	+	+	~	~
Public Education						
Demonstration Projects	~	+	+	+	~	+
Training	~	+	+	+	+	+
Media Campaigns	~	+	+	+	+	+

Advantageous (+) The choice maximizes benefits and is feasible.
Neutral (~) The choice may present may present mixed advantages and disadvantages.

Green Roofs

Traditional roofs absorb sunlight and radiate heat into the surrounding air.[140] Vegetation on green roofs shades the roof and cools the air through evapotranspiration.[141] These effects cool green roofs by 100 °F compared to traditional black roofs.[142] The cooler roofs transfer less heat to the ambient air.[143] Green roofs do not have as great a cooling effect on air temperatures as ground-level vegetation does, but they have the advantage of not taking up additional land and of keeping building occupants cooler.[144]

Green roofs are increasingly being installed by local and state governments. Chicago City Hall, which installed its green roof in 2001, was one of the first municipal buildings to feature a green roof. In 2012, local governments from Roanoke, Virginia, to Lake Station, Indiana, have installed green roofs to save energy costs, reduce stormwater runoff, and reduce heat islands.[145]

After introducing the two types of green roofs—intensive and extensive—this chapter applies the decision-making criteria to show under what criteria green roofs work best, and summarizes the benefits and challenges of installing green roofs. Finally, the chapter provides guidelines for implementing green roof policies through government operations, education programs, mandates, and incentives. The chapter concludes with a list of "no regrets" policies that are beneficial regardless of the impacts of climate change.

Types of Green Roofs

Green roofs are made up of several layers: a waterproof membrane to protect the underlying roof, a drainage layer, a growing medium such as soil, and the plants themselves.[146] The two basic types of green roofs—extensive and intensive—vary in the depth of growing medium and the amount of vegetation.[147]

Extensive green roofs have a thinner layer of soil and vegetation and are the simpler, lower-maintenance option. Plants used on these roofs include sedum (a hardy flowering plant) and/or herbs[148] that have minimal maintenance requirements.[149] Extensive green roofs can be up to seventy pounds lighter per square foot than intensive green roofs; they are a good option for buildings that cannot support an intensive green roof.[150] Green roofs need flat or low-slopes (up to 30 degrees) in order to support the vegetation.[151] Because of their thin growing medium and vegetation layer, extensive green roofs cannot capture as much water as intensive green roofs, which means that extensive roofs do not manage stormwater to the same degree.[152] Water retention decreases with the slope of the roof. [153] Roofs that are accessible to the public often require safety precautions such as handrails. Extensive roofs are less likely to be publicly accessible, which reduces their complexity and costs. [154]

Intensive green roofs have deep layers of growing media that can support a diverse array of plants from herbs and sedum up to full-grown trees.[155] Intensive green roofs are much heavier than extensive roofs because of their added depth, heftier plants, and retained water. As a result, they require more structural support. They also require irrigation and fertilization to maintain the plants.[156] Intensive green roofs work well for commercial buildings or parking garages that have the necessary structural strength.[157]

Benefits and Challenges of Green Roofs

In addition to lessening urban heat, green roofs help decrease energy use, improve air quality, and reduce stormwater runoff.[158] Whether or not urban areas continue to warm, these benefits can make green roofs a valuable investment. This section explains these benefits, which vary by region, type of roof, and design. Green roofs, however, are not without challenges: They require greater structural support than cool roofs, are expensive, and may provide somewhat less global cooling effect than cool roofs, although they may be more effective for local cooling.

Benefits to Residents and Building Owners

Cool roofs decrease summer cooling costs, but they can increase winter heating costs because they reflect heat year-round. In contrast, green roofs act as insulation and so can lower energy costs in both summer and winter.[159] Because green roofs retain heat indoors when the air is cold outside, they can be used in more northern climates where cool roofs are not recommended. The amount of energy savings will vary with the number of heating and cooling days in a locality and with local electricity costs.[160] By choosing appropriate vegetation for the region and type of roof, green roofs can be viable in many climates.[161] Furthermore, green roofs lessen the temperature variability of roof surfaces and protect the waterproofing membrane from UV-radiation and ozone, which accelerate aging of traditional roofs' waterproofing.[162] Therefore, green roofs can increase or even double the lifespan of a roof, saving the building owner money in the long term.[163]

Additionally, green roofs improve human health.[164] Green roofs reduce the need for heating and air conditioning in the buildings below and provide a cooler and safer environment for residents. [165] This saves property owners money and reduces greenhouse gas emissions. In addition, green roofs act as sound buffers, reducing sound levels by as much as 50 decibels, depending on the roof depth.[166] In urban environments where residences are located near noisy airports, bars, or industrial parks, this reduction in outside sound is particularly beneficial. The roofs can also provide residents with space for meetings, gardening, and recreation, providing additional benefits to health and well being.[167] Some hotels are taking advantage of the extra growing space to cultivate herbs, flowers, and vegetables. The Fairmount Waterfront Hotel in Vancouver, for example, saves $30,000 a year on food costs thanks to its rooftop garden.[168] Guests can tour the garden as well, benefiting from the exposure to green space in the city.[169]

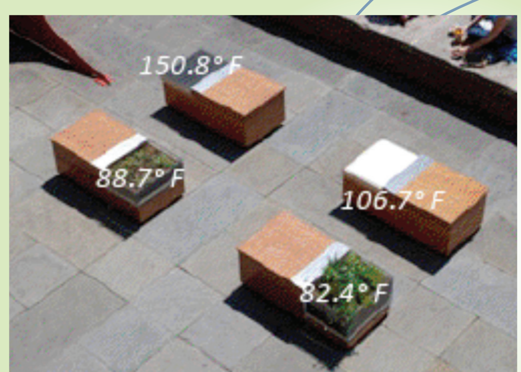


Image showing (clockwise from top left) samples of a traditional black roof (150.8 °F), cool roof (106.7 °F), intensive green roof (82.4 °F), and extensive green roof (88.7 °F), on an 85 °F day.[172]

Public Benefits

The public also benefits from the ability of green roofs to improve air and water quality and reduce urban heat. [170] A demonstration project in Philadelphia found green roofs were actually cooler than the surrounding air, while a traditional roof was 65 °F hotter.[171]

By lowering the surface temperature, green roofs transmit less heat to the air above the roof. [173] While an individual green roof will help residents of that building adapt to urban heat, targeted adoption of multiple green roofs in a specific area can reduce the heat island effect.[174]

Unlike cool roofs, green roofs also reduce stormwater runoff because, depending on the vegetation and time of year, they retain up to 90 percent of rainfall.[175] In urban areas that have combined sewer systems, green roofs help prevent heavy rain from overwhelming the systems and causing untreated human waste to be discharged into waterways.[176] Such combined sewer overflows are increasing with increased precipitation levels that are resulting from warming, at great costs to communities. Green roofs can reduce these costs as well.

In addition to improving stormwater management, green roofs improve air quality and reduce greenhouse gas emissions, which in turn improve public health.[177] Green roofs filter air pollutants and capture greenhouse gases. One study estimated that a green roof measuring roughly 1,000 square feet could annually remove the particulate matter equivalent to taking 15 cars off the road for a year. [178] Green roofs also improve air quality indirectly by lowering energy demand, which reduces conventional air pollution and greenhouse gases.[179] But green roofs could increase pollen production, potentially exacerbating allergies and respiratory disease; careful weeding until plants are established can keep this harm to a minimum.[180]

One study estimated that a green roof measuring roughly 1,000 square feet could annually remove the particulate matter equivalent to taking 15 cars off the road for a year.

Some ecological benefits vary with type of roof. Extensive roofs that do not have public access to sensitive areas create safe habitats off the ground for insects, birds, and fragile flora.[181] Intensive roofs can provide opportunities for urban food production, increasing access to fresh and healthy foods in traditionally underserved areas.[182] Providing space for urban agriculture can help the local economy, increase access to fresh produce, and, in turn, reduce the greenhouse gases associated with shipping food.[183] It can also build social capital through multigenerational community engagement in a neighborhood setting and help overcome the "nature deficit" that affects many urban youth and others.

In total, green roofs improve air and water quality and reduce energy consumption. They improve human health by lowering building temperatures and reducing unwanted sound. Green roofs provide aesthetic benefits, space for recreation and meetings, and opportunities for urban food production.[184]

Challenges of Green Roofs

Green roofs need structural support for the weight of the plants, soil, and water. They do not work well on steep-sloped roofs and are generally more expensive than cool roofs.

Structural requirements limit the number of buildings that can support green roofs. [185] Green roofs weigh anywhere from 13 pounds per square foot for an extensive roof up to 100 pounds per square foot for an intensive roof.[186] To support this weight, existing structures may need upgrades to decking, roof trusses, joists, columns, or foundations; new construction needs to be engineered to support the full weight of a green roof.[187] To hold vegetation, a roof cannot exceed a slope of 45 degrees,[188] and intensive roofs with public access will need even lower slopes.[189] For buildings with too steep a slope, vertical gardens (or "green walls") might be another option. Similar to green roofs, green walls are installed on the sides on buildings and can insulate a building and reduce runoff. An Anthropologie store in Huntsville, Alabama, installed a 2,000 square foot green wall on its south and southeast facades to protect the interior from heat transfer.[190]

Apart from structural requirements, the largest barrier to installation of green roofs is the expense compared to cool roofs and traditional roofs. [191] The price of an extensive green roof starts at $10 per square foot and goes up to $25 for intensive roofs. [192] Annual maintenance ranges from $0.75 to $1.50 per square foot.[193] Maintenance costs drop for extensive roofs as the plants mature, but costs remain steady for intensive roofs, which require more care.[194] Repair costs for a green roof when leaks occur are also higher than for traditional roofing, because the green roofs have to be removed and reinstalled. Costs of repairs are similar to initial installation costs of $3 to $8 dollars per square foot.[195]

Although green roofs cost more to install and maintain, owners can recoup some of these costs through energy savings and the increased longevity of the roof. A University of Michigan study found that while a 21,000 square foot commercial green roof cost $464,000 to install (compared with $335,000 for a traditional roof), it saved about $200,000 through reduced energy costs over its life span.[196] Those who can afford the initial cost premium of green roofs may therefore save money in the long run.

Finally, some evidence suggests that green roofs do not provide as much global cooling as cool roofs might. Cool roofs reflect the sun's energy into the upper atmosphere, thus cooling not only the surrounding area but the planet as a whole through the albedo effect.[197] Green roofs, by contrast, absorb water from their soil and emit it back into the air, where ambient heat converts the water into vapor, a process known as evapotranspiration.[198] While this cools both individual buildings and surrounding areas, the heat can be trapped near the earth by greenhouse gases.[199]

Decision-Making and Green Roofs

The evaluation and governance criteria in this Tool Kit, in combination with the particular circumstances and priorities within each urban area, will guide local governments' decision-making regarding the best use of green roofs. Green roofs are a good fit for some but not all settings; governments can use the outcome criteria to discern where they work. Urban areas where most roofs do not meet the structural and roof slope requirements may not be able to encourage the widespread adoption of green roofs, at least on existing building stock; for instance, only a few of the 800 city buildings in Los Angeles are suitable for green roofs due to considerations of cost, engineering, and fire safety.[200]

Outcome Criteria

Heat: Because green roofs insulate buildings, the buildings are warmer in winter and cooler in summer; cool roofs, by contrast can raise winter heating costs in cold climates.[201]

Economic: When considering green roof policies, local governments will need to consider who will be bearing the additional costs, depending on the policy tool. For example, requiring green roofs on new construction over a certain size clearly places the initial costs on the property owners, while incentivizing their use shares the cost between government and property owners. Regardless of who pays the upfront costs, however, the property owner captures the long-term savings. Because high cost can be a significant barrier to use of green roofs, local governments may want to support some of the financial burden of their construction.

Public Health: Although green roofs have many public health benefits, if financial support is not available, their high cost may result in relatively little installation and therefore less protection for the most vulnerable members of a community. Low-income residents are also more likely to live in older housing stock that is not structurally sound enough to support the weight of a green roof.

Environmental: Like many green infrastructure tools, green roofs are often encouraged and constructed for a particular purpose: stormwater management, heat island reduction, etc.[202] But like other green infrastructure, green roofs can improve air and water quality by filtering air pollutants, lowering energy use, reducing stormwater runoff, filtering pollutants in stormwater such as nitrogen, and delaying stormwater runoff.[203] Because green roofs fulfill these functions, they are particularly valuable in areas that struggle with smog, pollution, or stormwater management—likely most large urban areas. By lessening heat islands, green roofs help to mitigate climate as well as adapt to it.[204]

Governance Criteria

Administrative: Supporting increased use of green roofs may require either government funding (due to the up-front costs), assistance with financing, or changes to the city's building or tax codes, depending on the preferred tool. Proposing to require green roofs on new construction may be met with resistance from property owners and developers, and such requirements are likely to be effective only in areas with significant levels of new construction. For urban areas with older building stock located in their heat islands, requirements for new buildings to have green roofs may simply be irrelevant. Conversely, providing financial incentives for green roofs may be more viable politically but would require a stronger financial commitment.

Legal: Legal considerations are not likely to be a barrier to increasing use of green roofs as long as 1) governments do not try to impose requirements on property owners to retrofit their existing buildings with green roofs, and 2) local governments act within the scope of their authority. However, some policy tools may well require legislative changes to the local building code, tax code, or regulatory processes.[205] Local governments with green roof incentive programs already in place should be able to target them more closely to areas that are heat islands, thus increasing the "bang for the buck" and protecting residents' health while reaping all of the environmental and energy conservation benefits of green roofs.

TABLE 8 *Green Roofs: Summary of Benefits & Costs*

Method	Outcome Criteria				Governance Criteria	
	Heat	Economic	Public Health	Environmental	Administrative	Legal
Green Roofs	+	~	+	+	~	~

Advantageous (+) The choice maximizes benefits and is feasible.
Neutral (~) The choice may present may present mixed advantages and disadvantages.

Policy Tools to Increase the Use of Green Roofs

Local governments can promote the use of green roofs through government operations, mandates, incentives, educational programs, or some combination of these mechanisms. This section discusses how local governments can use the four sets of tools listed above to encourage green roof development, applies the evaluation criteria to determine when each tool works best, and provides examples of current implementations.

Government Operations

Local governments can build green roofs on government buildings in order to 1) reduce heat in targeted areas of the city; 2) save the government money in energy costs; 3) manage stormwater in the areas where it owns and manages property; and 4) serve as an example for private property owners.

TABLE 9 *Government Operations for Green Roofs*

Pros	Cons
Direct control over facilities	Facility may not be within a heat island
Saves money over time	Requires upfront investment
Manages stormwater in targeted area	Requires upfront investment
Also serves as demonstration project	

Government Facilities

Chicago's City Hall Rooftop Garden saves the city over $3,500 in annual energy costs.[206] Chicagoans can see the roof from many taller buildings in the vicinity, which allows the public to view the roof and increases awareness of the garden.[207] The garden incorporates both intensive and extensive systems, as well as over 150 varieties of plants. [208] Chicago monitors air quality benefits and the temperature of the roof, which is almost 100 °F cooler than nearby roofs. [209] The project helps the city better advise private developers who are interested in adopting green roofs because the city has tested the technology in Chicago's climate. A benefit of working primarily on city-owned buildings is also that such changes are unlikely to require legislative action or changes in code.

Design Guidelines

Local governments can also incorporate green roofs into their design guidelines, which serve as a bridge between the general principles in comprehensive plans and the specific regulations contained in zoning and building codes. Design guidelines describe desired qualities for a district or building type and set quality standards that permitting agencies must use in reviewing proposals for new development or renovations.[210] Portland's Central City Fundamental Design Guidelines call for buildings to "develop rooftop terraces, gardens, and associated landscaped areas to be effective stormwater management tools."[211] Portland agencies must consider rooftop integration among other approval criteria in evaluating

This visual shows the green roof on Chicago's City Hall juxtaposed with the traditional roof of the county building next door, where temperatures are approximately 75°F warmer.

Source: Chicago Climate Action Plan, 2008.

building proposals;[212] green roofs are among the options that developers must incorporate into their designs. Although green roofs were originally enacted in Portland as a stormwater management tool, they can be used by local governments to lessen urban heat islands as well.

Mandates

Mandates to require green roofs can be incorporated into zoning and building codes, either on a widespread basis or applied only to particular building types or districts. Mandates on new construction or substantial rehabilitation should result in a greater number of green roofs than incentives alone are likely to produce.

Because green roofs are costly to install, an unfunded mandate may be politically difficult compared to creating voluntary incentive programs. If the political climate is less hospitable for a broad mandate, local governments can lead by example and demonstrate how the requirements work on public buildings or projects receiving public funds. Alternatively, they could require that public buildings consider installing green roofs when repairing or retrofitting roofs.

TABLE 10 *Mandates for Green Roofs*

Pros	Cons
Ensures use in new buildings	Excludes most existing buildings
Low cost for government	Potential high cost for property owner
Requires standard setting	Can be politically tricky

Zoning Codes

Local governments use zoning codes to determine land use and development within delineated districts.[213] In many cases, imposing such a green roof requirement will necessitate a legislative change to the zoning code for the targeted zoning districts (residential, commercial, etc.). While local governments have used zoning codes in the past to provide development bonuses for green roofs, Seattle is one of the first cities to mandate green buildings under certain circumstances.[214] The Seattle City Council passed the Green Factor ordinance in 2006 (and expanded it in 2010) requiring new construction in commercial, neighborhood commercial, and multifamily residential zones to include additional planted area, which can include green roofs. Buildings accumulate points through the inclusion of various elements, such as green roofs, permeable pavements, or vegetated walls equivalent to a LEED silver status.[215] Building designers can fulfill the Green Factor requirement by including either an intensive green roof or an extensive green roof in combination with other elements such as permeable pavements and vegetated walls. [216] Giving green roofs proportionately higher points than other elements within such a system will help increase their numbers best.

Building Codes

Governments might choose to require green roofs through building codes, rather than zoning regulations, if they want to target a particular type of building in all districts, whereas zoning codes let cities target specific districts or land uses. [217] As with zoning codes, a change to a building code is likely to require local legislation.

In 2009, Toronto became the first city in North America to change its building code to mandate green roofs on all new development over a certain size. Under the Green Roof Bylaw, all new residential, commercial, institutional, and industrial development must incorporate a green roof. The law exempts buildings that are less than 2,000 square meters in ground area and residential buildings with fewer than six stories.[218] Developers are required to include green roof coverage on a sliding scale (depending on the size of the building), ranging from 20 percent coverage of available roof space for buildings with under 5,000 square meters of floor area up to 60 percent coverage for buildings with greater than 20,000 square meters.[219] Furthermore, Toronto, along with Portland, Oregon, requires a minimum percentage of green roof coverage for all new city-owned buildings where practical.[220]

Incentives

Some local governments currently use a wide variety of incentives to encourage private building owners to adopt green roofs, including financial incentives, such as grants and tax credits; administrative incentives, such as allowing more buildable space than normally permitted for a given area (known as a floor-area-ratio, or FAR, bonus); and expedited permitting.[221] Because incentives allow individuals to choose whether or not to adopt a green roof and take advantage of the policy, they are less politically divisive than mandates. Additionally, incentive-based tools have the potential to reach both new construction and existing buildings, in contrast to a mandatory program's limitation to new construction and to substantial renovations of existing buildings. The downside to using an incentive program, of course, is its voluntary nature—property owners can install green roofs or not, depending on whether the incentive is enough to shift their decision-making.[222]

Incentives directly address one of the biggest challenges to voluntary adoption: the added expense of adopting a green roof.[223] Although financial incentives involve some upfront costs to the city, the community stands to benefit directly through lower stormwater runoff (therefore less need for water treatment or less risk of costly combined sewer overflows) and reductions in regional pollution that affects attainment of air quality standards and economic development. Administrative incentives have little to no government costs while still encouraging interested parties to adopt green roofs through time-saving measures and indirect financial benefits. On the other hand, administrative incentives will only apply to new development and to substantial renovations that are subject to permitting and zoning regulations, whereas financial incentives can reach existing structures as well. A combination of incentives can reach different types of structures at different stages of development.

To the extent that budgets allow, local governments can target incentives to specific areas or place conditions on funding to put a focus on the most vulnerable residents. For example, cities could encourage green roofs on nursing homes or schools in order to target at-risk groups, or they could target grant programs to low-income areas of the city with a high concentration of socially-isolated elderly and/or low-income residents. This section explains how each of the above tools operates and provides examples of how cities are using them. Local governments can incentivize green roofs using any of several local government powers, including the powers to tax, zone, permit, and spend public money.

TABLE 11 *Incentives for Green Roofs*

Pros	Cons
Applies to existing and new buildings	May result in less use than mandates
May be more politically feasible than mandates	Government has to pay for incentives if financial
Property owners bear less cost	

Grant Programs

Grant programs help private property owners by defraying some of the cost of installation. Ongoing maintenance is usually covered by the property owner. Grant programs require city governments to expend money up front. A government can limit the number of grants or the amount and the manner of spending for green roofs in advance.[224] Chicago's Green Roof Grants Program awarded 72 grants of up to $5,000 to residential and small commercial green roof projects during the program's three-year run.[225]

Toronto operates an Eco-Roof Incentive Program, which gives priority to projects within heat islands that threaten communities that are vulnerable to negative health effects. The program provides grants for green and cool roof installations on new or existing commercial, industrial, and institutional buildings in those areas. Green roof projects can receive public funds of $50 per square meter, up to a maximum of $100,000.[226] This formula maximizes roof size, not just the number of green roofs.

Tax credits can be more difficult to tailor to the specific public health needs, because local governments generally tax property uniformly across neighborhoods.

Tax Credits

Tax credits offset some of the private costs associated with green roofs and do not require the government to expend funds directly. Local governments have less control over the budgetary costs of tax credits than they have with direct grants. In fact, Toronto chose other incentive options over property tax credits because credits would continue indefinitely and make the city budget hard to control.[227] But it is possible to limit the size of the credit and the duration of the program. Philadelphia and New York, for instance, limited building owners to a one-time credit, lessening the long-term negative impact on the city's tax revenue.[228] Tax credits can be more difficult to tailor to the specific public health needs, because local governments generally tax property uniformly across neighborhoods; in order to target a particular neighborhood, a local government would most likely need to set up a special taxation district.[229]

Since 2007, Philadelphia has had a green roof tax credit for the city's business privilege tax (a tax on all individuals, partnerships, associations, and corporations that engage in for-profit activity).[230] Businesses can receive a one-time credit equal to 25 percent of the cost of installing a green roof, up to a maximum of $100,000. The green roof must cover at least 50 percent of the roof space, and the recipient must maintain the roof for five years. A recipient that fails to meet these requirements must pay back the tax credit.[231] In 2008, the state of New York passed a similar pilot program providing a property tax abatement for green roofs; it focused on New York City and will expire in 2013.[232] Green roof installations that cover at least 50 percent of a building's roof can earn a $4.50 per square foot tax abatement, up to $100,000 for one year. The recipient must maintain the green roof for four years. The program provides no additional assistance for maintenance. As seen in both of these examples, changes to the tax code by the legislature are necessary to authorize a new tax credit.

Floor-Area-Ratio Bonuses

Some local governments offer bonuses to builders using green roofs by amending the local zoning code to allow more square footage than the applicable zone would otherwise allow. [233] These floor-area-ratio bonuses are primarily designed to target new, large-scale developments because greater square footage can be a strong incentive for developers without incurring significant cost to the city. For example, in Portland, Oregon, developers can build an extra one to three square feet for every one square foot of green roof they include, depending on the percentage of total coverage of the available roof area.[234] For example, one developer was able to build an additional 12,000 square feet, or six condominiums, by installing

4,000 square feet of green roof.[235] The profits from the sale of these extra condominiums greatly outweighed the additional cost of the green roof for the developer, without any cost to the Portland government.[236] The additional square footage does not increase the amount of impermeable surface for the new development or exacerbate stormwater management problems.

Expedited Permitting

An incentive that local governments with restricted budgets can use is offering an express or expedited permitting process for construction projects that include green roofs.[237] Expedited permitting can save developers and property owners time, if not money. Chicago has successfully adopted an expedited permitting program for green projects, including developments with green roofs.[238] Under this program, construction projects receive their permits in as few as 15 or 30 days.[239] In combination with other incentives, this program has advanced hundreds of green projects in the Chicago area.[240]

Public Education Programs

Because education programs do not impose any requirements on private parties and can entail few costs for governments or for private parties alike, they can be politically attractive. Demonstration projects in which local governments install green roofs on municipal buildings may have some up-front costs but also result in energy savings for the municipality. When governments conduct these demonstration projects, they can test different types of vegetation and green roof systems, measure the results, and promote the advantages of green roofs for the precise mix of precipitation, temperature, etc., for that particular area.

Green roofs require more complex design and engineering than traditional roofs, so information programs targeted at private individuals and contractors raise public awareness about green roof technologies and benefits with the hope that this will lead to voluntary adoption. Information efforts can include direct public outreach, green roof tours, and green roof resource centers. These programs make it easier for interested private individuals to adopt green roofs and work well in combination with either incentives or mandates.

TABLE 12 *Public Education Programs for Green Roofs*

Pros	Cons
Low cost for government	Less direct means of increasing use
Administrative effort for government	Lower results if used alone
Little likelihood of legal challenge	

Demonstration Projects

Chicago's green roof on City Hall serves as a demonstration project for the rest of city government as well as for the public. It has also garnered positive national attention and identified the city as a leader in sustainability.[241] In addition to permanent green roofs, smaller scale temporary demonstration projects that bring green roof ideas down to eye level are possible. One such project was done at the University of Pennsylvania, where students built four benches that demonstrated four roofing systems: a conventional black roof, a cool roof, an extensive green roof, and an intensive green roof.[242] The roofing materials were contained in clear acrylic boxes so onlookers could see all layers of the roof systems and compare the benches.[243]

Green Roof Tours

Tours allow people to see firsthand a broad range of ways in which buildings use green roofs. Seattle published a map with a self-guided tour of over twenty public and private green roofs that are open to public viewing.[244] Portland also publishes a list of green roofs, including the addresses and contacts to organize a viewing.[245] By publicizing the roofs, the cities hope to overcome the information barriers to green roof construction and to inspire others to adopt green roofs.

Online Resource Centers

Websites dedicated to green roof resources can reach a wide audience at a relatively low cost; after the initial setup, online resource centers require minimal expense or effort. Toronto, Chicago, and Portland each have comprehensive green roof resources available online. [246] Portland's website, for example, includes over 60 videos with information on when to consider a green roof, plant installation techniques, documents on cost benefit evaluations, guidelines for plant selection for the Portland area, and data from existing green roofs in the city, along with information on design, construction, maintenance, and additional resources. [247] In addition to online resources, local governments increasingly have sustainability coordinators who can answer questions, explain the permitting process, and direct individuals to experienced contractors and/or available resources.[248]

Conclusion

Cities are hotter than ever before due to the combined effects of climate change and the urban heat island effect. This puts the eighty percent of the American public that lives in urban areas at risk for many heat-related diseases.[249] Green roofs can help urban dwellers adapt to high temperatures, making buildings cooler through insulation and cooling the air through evapotranspiration.[250] Targeted green roof adoption within a given area reduces the heat island effect, helping to cool all citizens in addition to the building inhabitants.[251]

Governments can use outcome criteria to determine which policy tools will work under their specific circumstances. Several "no-regrets" policies are beneficial even under current conditions, regardless of climate change:

- ***Incorporate green roofs into design guidelines and general plans.*** Design guidelines and general plans encourage direct implementation of green roofs and adoption of policies that promote green roofs. Guidelines require no government expenditures aside from staff time to develop, disseminate, and include them in site plan review.
- ***Create tax credits for building owners who install green roofs and maintain them for a minimum time.*** Tax credits, unlike grants, have no upfront cost to the city, but still encourage green roof adoption by reducing the property owner's taxes based on the size and cost of their green roofs. In the long run, both the city and the property owners will reap benefits. Concerns regarding long-term revenue can be alleviated by limiting the tax credits to a specific time period. However, instituting a new tax credit is likely to require legislative action to amend the tax code.
- ***Offer floor-area-ratio (FAR) bonuses to buildings that install green roofs.*** FAR bonuses have little to no cost for the city, while providing a valuable incentive to developers who can use the additional building space to make more units or bigger, more expensive units. This particular strategy applies primarily to new construction.
- ***Create expedited permitting timelines for projects that incorporate green roofs.*** This is an incentive that local governments can provide at little or no cost to building owners and developers that will save owners and developers time and money. The permitting can be tailored to encourage other green building techniques as well; it requires little spending by the local government.

TABLE 13 *Decision-Making and Green Roofs: How the Criteria Affect Tool Choices*

	Outcome Criteria				Governance Criteria	
	Heat	Economic	Public Health	Environmental	Administrative	Legal
Government Operations						
Government Facilities	+	~	~	+	~	+
Design Guidelines	+	+	~	+	~	~
Mandates						
Zoning Codes	+	+	~	+	~	~
Building Codes	+	+	~	+	~	~
Incentives						
Grant Programs	+	~	+	+	~	~
Tax Credits	+	~	+	+	~	~
Floor Area Ratio Bonuses	+	+	~	+	~	~
Expedited Permitting	+	+	~	+	~	+
Public Education						
Demonstration Projects	~	+	+	+	~	+
Green Roof Tours	~	+	+	+	+	+
Online Resources	~	+	+	+	+	+

Advantageous (+) The choice maximizes benefits and is feasible.
Neutral (~) The choice may present may present mixed advantages and disadvantages.

Cool Pavements

Most pavements are asphalt[252] which absorbs sunlight almost completely.

Because of its dark color, low reflectance, and high heat retention, asphalt pavements reach temperatures up to 150 °F on summer days and in turn raise surrounding air temperatures.[253] Pavements release this trapped heat and keep neighborhoods warmer through the night.[254] Elevated nighttime temperature has a major negative impact on residents' health.[255] Local governments can reduce the contributions of pavements in one of two basic ways: 1) minimize the amount of paved surfaces, and 2) use cool pavements for surfaces that must be paved.

By reducing both surface and air temperatures, cool pavements reduce the heat island effect. Cool pavements typically fall into two categories: 1) permeable or porous pavements and 2) light-colored pavements.[256] Porous pavements have voids for air and water to pass through; the voids allow evaporation to occur through the pavement, cooling the pavement and the air above it.[257] Asphalt and concrete can both be made porous by omitting the smaller aggregates that are usual components.[258] More specialized forms of porous pavements include interlocking concrete pavers, in which water drains through the gaps between precast blocks,[259] and grass or gravel pavers, in which fill materials are laid on top of a plastic grid.[260]

The second category is light-colored pavements, which have high solar reflectance (also called albedo). They reflect the sun's radiation rather than storing it. Albedo is expressed on a scale from 0 (complete solar absorption) to 1 (complete solar reflectance); according to one study, raising solar reflectance by 0.1 can reduce surface temperature by 7 °F.[261] Usually, to be considered a cool pavement, a material must have an albedo over 0.29,[262] while the most reflective pavements have albedos over 0.75.[263] In contrast, new black asphalt has a low albedo, between 0.05 and 0.12.[264] The most common type of light-colored pavement is Portland cement concrete, which has an albedo between 0.35 and 0.40 when first applied.[265] Using a light-colored aggregate in asphalt[266] or adding a light-colored overlay to an existing pavement will also produce lighter, cooler pavements than traditional asphalt.[267]

Local governments do most of the paving, so they have a high degree of control over what paving materials are used. This chapter first describes the benefits and challenges of using cool pavements to reduce the heat island effect. It then examines the factors that local governments consider when choosing pavements, and it offers criteria for deciding whether and how to use cool paving. Finally, it compares a variety of policy tools to adopt or encourage cool pavements.

Benefits and Challenges of Cool Pavements

Benefits of Cool Pavements

All cool pavements mitigate the heat island effect, leading to lower surface and air temperatures. Cool pavements also lead to lower car temperatures and therefore less fuel evaporation and fewer NOx tailpipe emissions when starting car engines[268] and reduce the temperature of stormwater runoff into local water bodies. Minimizing overheated runoff can preserve aquatic ecosystems and especially protect wildlife vulnerable to temperature increases.[269]

Porous pavement stays cool through evaporation and reduced heat storage[270] and helps control the quality and quantity of stormwater runoff by filtering through its surface. The porosity prevents stormwater from running over the ground to storm drains and picking up harmful pollutants, [271] while also allowing more water to reach tree roots. Developers using porous pavements can save money by reducing or avoiding the installation of stormwater infrastructure, such as pipes, gutters, and drains. In one example, a parking lot developer saved $400,000 by installing permeable pavement rather than purchasing additional land and constructing a stormwater retention basin.[272] Finally, porous pavements can improve roadway safety because they produce greater traction, less standing water,[273] and fewer potholes[274]; they may also require fewer de-icing chemicals in cold weather because of greater heat transfer from the earth below.[275]

Light-colored pavements also have many benefits beyond lower temperature. Concrete is the strongest pavement available, less likely than asphalt to develop ruts or cracks.[276] Light-colored pavements also last longer than asphalt pavements, saving local governments money on long-term maintenance and replacement. The reflective surfaces of light-colored pavements also improve nighttime visibility, thereby improving safety, reducing lighting needs, and saving money on lighting construction and energy costs.[277] Of course, concrete has its own environmental and climate drawbacks, which are discussed below.[278]

Challenges of Cool Pavements

Despite their benefits, cool pavements present significant challenges. First, cool pavements are still being tested in a variety of locations, as their performance depends heavily on local conditions such as traffic, shadiness, and the specific use of the paved area.[279] This uncertainty can make local governments reluctant to use cool paving technologies, particularly for high-traffic areas. Second, pavements do not directly cool buildings, but instead reduce building temperatures indirectly by cooling the surrounding area. Because cool pavements do not affect the habitability or energy use of particular structures, their benefits are more difficult for local governments to quantify. As a result, governments are likely to give a higher priority to other heat-reducing strategies.[280]

Other challenges include local climate characteristics, natural conditions, and higher costs than traditional pavements. Some soils, especially fine or clay soils, may not allow for adequate drainage with porous pavements,[281] and urban areas with cold climates must take care that water does not freeze within porous pavements and cause cracking.[282] Some studies counsel against using porous pavements in high-traffic areas.[283] Anecdotal evidence, however, suggests that porous pavements may work on highly-traveled roads; a porous asphalt highway in Arizona has performed well for over 20 years.[284]

Finally, porous pavements are more costly to install. The Federal Highway Administration estimates that porous asphalt is 10 to 15 percent more expensive than traditional asphalt, and porous concrete is 25 percent more expensive than traditional concrete.[285] Meanwhile, annual maintenance to prevent clogging, including vacuuming or sweeping, costs around $200 per acre.[286] On the other hand, the cost of porous pavement may decrease significantly as it becomes more widely used. In Chicago, the price of locally produced porous concrete dropped from $145 per cubic yard to just $45 per cubic yard over the course of a year due to investment by the city in this technology.[287]

Light-colored pavements present their own set of challenges. Construction materials and equipment cost more for concrete than they do for asphalt.[288] New concrete pavements take several days to cure before they can open to traffic, unlike new asphalt roads that can open in a few hours.[289] Concrete's rigidity also makes it more difficult and expensive for utilities to remove sections and access buried infrastructure for maintenance and repairs.[290] Concrete highways may leach toxins into surrounding environments.[291] While using asphalt with a light-colored aggregate, such as limestone, can surmount some of these challenges, the light aggregate must be locally available. Shipping aggregate over long distances both is cost-prohibitive and adds to the greenhouse gas emissions of producing the asphalt.[292] Light-colored pavements may require pressure-washing to maintain their color and reflectance,[293] and many people prefer black, "new-looking" pavements to light-colored pavements, which may appear old and worn.[294]

From a climate change mitigation perspective, using light-colored concrete can be a complex calculation. Concrete production has traditionally been a significant source of greenhouse gas emissions.[295] In recent years, however, concrete manufacturers have increasingly been incorporating slag (an iron refining by product) or fly ash (a coal-combustion byproduct) into the concrete mixture,[296] both reducing waste and reducing the greenhouse gas emissions associated with producing the concrete.[297]

Decision-Making and Cool Pavements

Pavement decisions generally involve a number of stakeholders: local government officials (including transportation, public works, planning, and aviation officials)[298]; contractors and suppliers; and private pavement owners (especially parking lot owners).[299] Local governments usually have long-term responsibility for public (non-state) roads,[300] and they tend to rely on three factors in making pavement decisions: current local practice, costs, and performance. This section discusses criteria that could lead local governments to make greater use of cool pavements for heat reduction. It also describes factors that could help governments to chose between porous and light-colored pavements.

Outcome Criteria

Outcome criteria for cool pavements, like those for green roofs and cool roofs, include considerations of heat reduction, economics, public health, and environmental co-benefits. The potential benefits of various types of cool pavements vary with each criterion; the chart at the end of this section summarizes the trade-offs for each type of cool pavement and compares each to traditional pavements.

Heat: Use of cool pavements can be influenced by a local government's mix of physical factors including the soil, climate, and the percentage of the city surface that is paved as opposed to vegetation or rooftops. Porous pavements may be a better choice than light-colored pavements in urban areas with wet climates, sandy soils, and severe nighttime heat island effects. Urban areas in wet climates derive greater benefits from porous pavements than those in dry climates because evaporation through the pavement cools surface and air temperatures.[301] Sandy or well-draining soils allow governments to use porous pavements without installing costly drainage structures.[302] A high proportion of paved surface in a particular jurisdiction may also lead the local government to choose cool pavements over other adaptation strategies. Pavement is a primary form of urban land cover (along with vegetation and roofs). The percentage of paved surfaces varies widely: in a survey of four cities, pavement ranged from 29 to 45 percent of overall land cover.[303] In addition, local governments with many low-traffic areas will have more options for applying cool pavements than those where most paved surfaces are streets or highways.[304] A wider variety of cool paving materials can be used to repave lightly traveled areas, such as parking lots, alleys, and driveways.[305] Finally, growing jurisdictions can benefit from cool pavement strategies, because pavements often cover a large percentage of land cover in rapidly growing urban areas.[306]

Economic: Up-front cost can often be determinative for local governments on tight budgets.[307] Cool pavements have higher installation costs than traditional pavements, but they can also save money on stormwater management systems or lighting of roadways, as discussed above. Contractors, who construct roadways but do not maintain them, have an incentive to minimize initial paving costs and ignore long-term savings.[308] A few states, including Washington, Michigan, Iowa, and California, have required life-cycle analyses of pavement options[309] to assess the cost of a pavement project over the pavement's lifespan, accounting for maintenance costs and environmental impact.[310] Even with such analyses, however, officials may still make decisions based on initial cost.[311] Additionally, local governments looking to use porous pavements must ensure that they have sufficient ongoing funds and personnel to inspect and maintain those pavements. Light-colored pavements are most practical and cost-effective when light-colored aggregate is locally available.[312]

Public Health: Porous pavements help reduce the nighttime heat island effect by emitting stored heat more rapidly than other pavements.[313] By comparison, light-colored pavements provide a more consistent cooling benefit than porous pavements in dry regions,[314] especially in sunny areas where the higher albedo of light-colored pavements significantly reduces daytime surface temperatures. If nighttime heat islands are prevalent where vulnerable residents live, cool pavements may be an especially beneficial strategy.[315]

Environmental: Assessing the environmental co-benefits of cool pavements can help local governments determine whether to give this strategy a higher priority than other heat adaptation tools. For instance, cool pavements are a stronger option when governments have significant concerns over stormwater management and runoff. Permeable pavements can protect local water bodies and also reduce the cost of stormwater management. A recent study found that, for areas with soil that allows good infiltration, porous pavements reduced stormwater runoff by the greatest amount compared to several other stormwater management tools (green roofs, rain gardens, etc.).[316] The permeable pavement model in the study reduced runoff between 83 and 99.8 percent; by contrast, the next-best LID tool reduced runoff between 45 and 88 percent.[317] This may be an especially important co-benefit for areas with aging stormwater infrastructure,[318] those near vulnerable ecosystems,[319] and those worried about groundwater quality or Clean Water Act compliance. For instance, Chicago has focused on cool pavements because of problems with its outdated sewer system,[320] and sensitive areas around the Chesapeake Bay, Great Lakes, and Everglades have benefitted from porous pavement that reduces runoff.[321] Finally, porous pavements may be more beneficial than light-colored pavements in locations with urban forests, since porous pavements allow water to soak through to tree roots.[322]

Assessing the environmental co-benefits of cool pavements can help local governments determine whether to give this strategy a higher priority than other heat adaptation tools.

Governance Criteria

Governance criteria for evaluating cool pavement options include ease of administration, the local government's past and current practices, and legal feasibility.

Administrative: Local governments may be more likely to use cool pavements when such pavements fit well with current programs and laws. For instance, local governments may be more willing to bear the increased up-front cost of cool pavements when their states require the use of life-cycle analyses for pavement decisions, since these analyses could reveal long-term savings that recoup the high initial cost.[323] In addition, cool paving strategies are more likely to succeed in states where cool pavements are already in wide use in other applications: Georgia and Oregon, for instance, commonly use porous overlays on highways, and the demonstrated success of these pavements may make them seem like a less risky investment.[324] In these states, contractors have more experience with a variety of paving materials.

Local governments may also want to use cool pavements when they have systems or procedures in place to plan for pavement needs, rather than make case-by-case decisions about where to pave next.[325] This will allow local governments to use cool pavements to their full potential and economies of scale.[326]

Legal: Where lands are publicly owned or under public control, local governments are constrained only by their procurement codes, which usually require awards to the lowest responsible bidder.[327] This is not an insurmountable impediment, but it does require bid instructions that are specific to the cool paving material or heat-related performance.

Where lands are privately owned, local governments can use permitting processes to require or encourage use of cool pavements. Both mandates and incentives may require legislative action, depending on the scope of authority of the agency setting the permitting processes. Incentives are generally more likely to survive the political process.

The following two charts capture 1) the benefits and costs of cool pavements, and 2) the benefits and costs of each type of cool pavement as compared to traditional pavement.

TABLE 14 *Cool Pavements: Summary of Benefits & Costs*

Method	Outcome Criteria				Governance Criteria	
	Heat	Economic	Public Health	Environmental	Administrative	Legal
Cool Pavements	+	~	+	+	~	~

Advantageous (+) The choice maximizes benefits and is feasible.
Neutral (~) The choice may present may present mixed advantages and disadvantages.

TABLE 15 *Decision-Making and Pavements: Traditional vs. Porous vs. Light-Colored*

Benefit	Traditional	Porous	Light-Colored
Reduce heat	!	+	+
Stormwater management	!	+	!
Upfront direct cost	+	~	~
Long-term maintenance costs	~	!	~
Roadway safety	~	+	~
Strength for heavy use	+	!	+
Use in cold climates	+	~	+
Access for utility work	!	~	!
Environmental concerns with production	~	~	~

Advantageous (+) The choice maximizes benefits and is feasible.
Neutral (~) The choice may present may present mixed advantages and disadvantages.
Disadvantageous (!) The choice maximizes benefits and is feasible.

Policy Tools to Increase the Use of Cool Pavements

Local governments can adopt or encourage cool pavement through mandates, incentives, education programs, and/or changes in government operations. Mandates are measures that set non-negotiable requirements and include building and zoning codes, among others. Incentives are programs and policies that encourage communities to use cool pavements without imposing direct requirements. Education programs teach the public about cool pavements, either by providing information or by demonstrating cool pavements. Government operations involve changes in the way government does business, including changes to procuring pavement and paving city streets and sidewalks. This section first outlines the steps to prepare before implementing a cool pavement strategy. It then describes how local governments can promote cool pavement using the four sets of policy tools, including the criteria they can consider to decide among the four.

Preparing to Adopt Cool Pavements

Before using cool pavements to reduce urban heat, local governments may wish to ensure that they have the necessary information, funding, and legal framework. To have the best information to target their efforts, local governments could inventory their percentage of paved surfaces and note the governing bodies responsible for each type. Having an up-to-date description of the city's land cover can help officials determine priorities and measure progress as changes take place.[328] In addition, local governments should geographically map their heat islands, vulnerable populations, and stormwater infrastructure. This would help city officials identify areas with the greatest need for cool pavements, whether because of elevated temperatures, public health risks, or excessive stormwater runoff and flooding.

After compiling the necessary information, local governments will likely want to consider their available funding sources for supporting cool pavements. Along with general revenues, such as bonds and levies,[329] local governments may be able to use special fees, such as inspection fees, to fund enforcement.[330] State or federal programs may provide another source of revenue.[331] Moreover, officials might consider revising any existing codes that might prohibit porous pavements in street paving[332] and regulations that omit porous pavements as a stormwater management option.[333] Finally, as a low-cost companion strategy, governments can use mandates and incentives to minimize the amount of paved surface in general.[334]

Government Operations

Local governments are likely to control much of the paving done in an urban area, including roads, intersections, medians, sidewalks, and some parking lots. Government operations offer a crucial set of tools for increasing use of cool pavements.

TABLE 16 *Government Operations for Cool Pavements*

Pros	Cons
Direct control over large portion of pavement	Requires upfront investment
Saves money over time	

Paving of Publicly Owned Land

Because a great deal of paving is done on publicly owned properties, local governments directly control many local paving decisions.[335] For public projects, governments can set regulations that favor or require cool pavements.[336] For instance, California's transportation department requires all construction projects to contain at least 25 percent fly ash, a waste product from coal burning that can be light in color (depending on the source).[337] Local governments may also consider prohibiting the use of coloring agents like carbon black that only serve to darken pavement for aesthetic reasons.[338] Local governments could further require life-cycle analyses for public paving decisions.

Because cool pavements can have slightly higher up-front costs than traditional pavements, officials may be more likely to select cool pavements if regulations require them to examine the long-term financial or environmental costs of pavements.[339] Even if not, local agencies may be able to set their purchasing specifications to include performance with respect to heat reduction, stormwater benefits, and life-cycle savings.

Mandates

To mandate cool pavements, local governments can require cool pavements in new construction, which could address public, private, or both types of property. This section discusses use of zoning to do so.

TABLE 17 *Mandates for Cool Pavements*

Pros	Cons
Ensures use in new buildings	Excludes most existing buildings
Low cost for government	Marginal cost for property owner
Requires standard setting	

Local governments could impose a requirement to use cool pavement by amending municipal zoning codes[340] and enforce it through site review of new construction.[341] For example, Novato, California, included a recommendation in its climate action plan to "[r]equire the use of high albedo material for future outdoor surfaces such as parking lots, …roadway improvements, and sidewalks in order to reduce the urban heat island effect and save energy."[342] Novato subsequently incorporated use of permeable pavements and vegetated roofs in their green building point system for single-family residential properties.[343] Some local governments and states have also modified their zoning codes to require cool pavements in specific locations. North Carolina, for example, requires porous pavements for at least 20 percent of parking lots larger than one acre.[344] Highland, Utah designated a 50-acre town center and mandated reflective parking surfaces within this zone.[345]

While mandates can apply to all kinds of property, they tend to be more effective in areas with high levels of new construction because it triggers the requirements through the permitting process.[346] Cool pavement mandates are especially beneficial when local contractors and suppliers already possess the knowledge and equipment to apply cool pavements.

Incentives

Incentives encourage property-owners to use cool pavements, whether by providing a reward for using cool pavements or by allowing cool pavements to meet other preexisting zoning or building requirements.[347] Cool pavement incentives include three basic types: financial, zoning, and green building incentives.

TABLE 18 *Incentives for Cool Pavements*

Pros	Cons
Applies to existing and new development	May result in less use than mandates
Property owners bear less cost	Government has to pay for incentives
May be more politically feasible than mandates	
Also serves as demonstration project	

Financial Incentives: Rebates

Financial incentives provide a payment or rebate to property owners or developers for using cool pavements. One common type is a rebate of stormwater management fees. Local governments collect these fees based on a property's contribution to stormwater runoff[348] and use the money to operate the local stormwater system.[349] Many governments offer property owners a partial or full refund of stormwater fees for installing porous pavements, which reduce runoff and lessen a property's impact on the system. In Newport News, Virginia, property owners can earn fee rebates of 5 to 15 percent for reducing runoff in various ways.[350] Similarly, some governments use revenue from stormwater management fees to offer direct, one-time payments to property owners who install porous pavements.[351] Des Moines, Iowa, offers $1 per square foot of porous pavement.[352] Advocates in Houston have proposed offering a similar rebate for light-colored pavements; they have also proposed other financial incentives such as reducing property taxes for parking lots that use cool pavements and lowering sales taxes on reflective paving installation as ways to encourage broader use.[353] These financial incentives are designed to at least partially offset the initial cost premium of cool pavements, helping to overcome the financial barrier to cool pavements' adoption. These incentives may require legislative change in local ordinances or codes.

Zoning Incentives

With zoning incentives, cool pavements can be used to meet existing requirements or rewards in the local governments' zoning code. Some local governments' zoning provisions require new construction projects to have a certain percentage of pervious groundcover; for example, Chicago requires large redeveloped properties to increase pervious surfaces by 15 percent compared to earlier conditions.[354] Porous pavements can be used to meet the requirement, although they may only count as 75 percent pervious when calculating the pervious surface area.[355] Local governments may also adopt zoning provisions that encourage light-colored pavements on a portion of new or redeveloped lots. Few local governments have done so yet; the City of Sacramento, California, convened a Green Building Task Force from 2009-11 to advise the City Council on potential green building practices it could adopt.[356] The Task Force recommended that the Council amend the city's zoning code and green building program to include incentives and requirements for light-colored pavement, among other options.[357]

Green Building Incentives

Local governments nationwide are increasingly integrating green building standards into their codes, especially the Leadership in Energy and Environmental Design (LEED) standards put out by the U.S. Green Building Council. Dallas, for instance, has adopted LEED criteria in its development standards.[358] Under the LEED program, developers earn points for using environmentally sound designs and practices, and buildings gain LEED certification when they reach a certain point threshold.[359] Some cool pavements earn LEED points, for example, for open-grid pavements and those with an albedo of at least 0.29.[360] Within LEED and similar programs, however, developers have many options for earning points besides cool pavements. Changes to local building codes also likely require legislative changes, even for voluntary measures.

Like mandates, incentives are most effective when local contractors and suppliers already know how to install cool pavements, so the contractors can immediately help residents take advantage of incentive programs. However, unlike mandates, incentives can apply to both new and existing structures, since property owners can earn rewards by voluntarily replacing their existing pavements with permeable materials.[361] In addition, incentives may in some localities be less politically sensitive than mandates,[362] and they can be incorporated into existing landscaping or stormwater systems. Urban areas with many elderly or low-income residents may want to supplement incentive programs with other initiatives because elderly and low-income populations may have less ability and capital to use the programs.

Public Education Programs

Education and demonstration projects contribute significantly to knowledge about cool pavements and how they perform in a particular climate and location.[363]

TABLE 19 *Public Education for Cool Pavements*

Pros	Cons
Low cost for government	Less direct means of increasing use
Administrative effort for government	Marginal cost for property owner
Can prove effectiveness of new technology	Lower results if used alone

Demonstration Projects

In Kansas City's Parking Lots to Parks project, pervious concrete was used in a converted parking lot to test how the material responded to cold weather.[364] Chicago's Green Alley program installed porous pavements in over 80 alleys.[365] By stamping "Green Alley" images in the new pavements, Chicago increased the project's public visibility as well as the public's awareness of cool pavements.[366] Other local governments have used cool pavements in bike and parking lanes,[367] pedestrian areas, and stadiums.[368]

Demonstration projects are especially important when the cool pavements are relatively untested for the locality's weather. In cold regions, for example, local governments are still testing whether porous pavements remain effective after the abuse of a few hard winters. Local government-sponsored demonstration projects can be particularly useful in low-traffic areas, such as parking lots and alleys, because these areas can support a wider variety of cool paving materials than heavily traveled roads. Demonstration projects are useful when cool pavements have an easily identifiable co-benefit, such as improved stormwater management or reduced energy costs. For example, Chicago used porous pavements to reconstruct alleys prone to flooding.[369]

Public Education

After demonstration projects are completed, local governments can use a variety of methods to share the results, including websites with project photographs and descriptions, a cool materials database, and product workshops.[370] Local governments can focus on educating contractors, who influence pavement decisions for both public and private projects.[371]

Conclusion

The proliferation of dark, paved, and impervious surfaces contributes substantially to the heat island effect. Using porous or light-colored pavements can lower surface and air temperatures. Local governments can use a variety of mandates, incentives, and education programs to increase the use of cool pavements, depending on the local climate and infrastructure. For instance, urban areas with wet climates or stormwater management problems may wish to use porous pavements, while sunny cities or those with dry climates may wish to use light-colored pavements. Mandatory requirements to apply cool pavements are more effective in areas with a lot of new development, while incentives and education programs can be useful in both situations. The chart below summarizes the factors that can influence local governments to choose one policy tool over another.

Regardless of local conditions, several "no-regrets" strategies exist that may be appropriate for all local governments:

- ***Minimize paved surfaces.*** As a companion strategy to implementing cool pavements, local governments can modify regulations on the amount of required parking to impose a cap on parking or a maximum size for parking spaces. Lessening the overall amount of paved surface will cool an area.
- ***Examine the environmental impact of public paving projects.*** Local governments can limit use of pavements containing dark pigments like carbon black or set a preference for light-colored and porous pavements. Local governments must carefully balance the "hidden" environmental costs associated with production with light-colored concrete, however.
- ***Encourage porous pavements for stormwater management.*** Along with removing any zoning provisions that limit or prohibit the use of porous pavements, local governments can include porous pavements among their best management practices. They can also institute a rebate program for stormwater management fees.

TABLE 20 *Decision-Making and Cool Pavements: How the Criteria Affect Tool Choices*

	Outcome Criteria				Governance Criteria	
	Heat	Economic	Public Health	Environmental	Administrative	Legal
Government Operations						
Publicly-Owned Land	+	~	~	+	~	+
Mandates						
Zoning Codes	+	+	~	+	~	~
Incentives						
Financial–Rebates	+	~	+	+	~	~
Zoning Incentives	+	+	+	+	~	~
Green Building Incentives	+	+	~	+	~	~
Public Education						
Demonstration Projects	~	+	+	+	~	+
Public Education	~	+	+	+	+	+

Advantageous (+) The choice maximizes benefits and is feasible.
Neutral (~) The choice may present may present mixed advantages and disadvantages.

Urban Forestry

As urban areas develop, trees and vegetation are often removed to make way for buildings and streets. Removing vegetation exacerbates the effects of an urban heat island, including heat-related illnesses, energy use, and pollution. These negative effects will worsen as temperatures increase due to climate change. Urban forestry can reduce heat and provide a variety of environmental and other co-benefits. This chapter first discusses the benefits and challenges of developing and maintaining an urban forest. It then offers criteria to help local governments determine whether to protect and increase their tree canopies. Finally, it describes how local governments can do so through a variety of policy tools.

Benefits and Challenges of Urban Forestry

Benefits of Urban Forestry

Trees reduce heat in two ways. First, trees shade buildings, pavements, and other surfaces. In one study, tree shade reduced the surface temperatures of walls and buildings by 20 to 45 °F.[372] Shading works by preventing solar radiation from reaching walls and pavements, decreasing the heat conducted into the buildings and into the surrounding air.[373] Trees also reduce air temperatures indirectly through evapotranspiration. In this process, trees absorb water through their roots and emit it back into the air. Ambient heat converts the water into vapor, thus dissipating the energy.[374] Overall, the cooling benefits of trees can be quite dramatic: according to one study, planting 10 million new trees in the Los Angeles basin (a vegetation increase of approximately 1 percent) could reduce afternoon air temperatures by up to 3.6 ºF.[375]

Besides their effects on urban heat, trees provide many other related benefits. By reducing temperatures, trees can reduce the need for air conditioning and decrease energy use and costs.[376] One study estimates that the energy needed to cool the adjacent part of a building decreases by 7 percent per shade tree.[377] Shading air conditioning units also saves energy, since cool air conditioners consume less energy than hot ones.[378] Trees can also bring down winter heating costs, especially evergreen trees planted to the north of buildings to block winter winds.[379]

Second, trees help prevent pollution and damage to ecosystems. By reducing energy use, trees reduce carbon emissions from electricity generation; they also reduce auto emissions by keeping parked cars cool, and they capture atmospheric carbon dioxide.[380] By trapping pollution and lowering temperatures, trees also slow production of ground-level ozone,[381] thus alleviating respiratory illnesses such as asthma.[382] Tree roots reduce water pollution by slowing and filtering runoff,[383] trees' shade protects vulnerable aquatic ecosystems by lowering the temperature of runoff,[384] and their trunks and branches provide wildlife habitats.[385] Trees also provide contact with nature, which has been shown to improve people's mental health and quality of life.[386]

Beyond these environmental and health benefits, trees offer an array of social and economic benefits. Street trees help slow traffic, reduce highway noise, and reduce the need for pavement maintenance.[387] By creating pleasant landscapes, they can also attract business and tourism, and even induce shoppers to pay more for products.[388] Trees also raise real estate values, perhaps as much as 10 percent for developed properties, thereby boosting municipal tax revenues.[389] With this multitude of benefits, the monetary value of trees is huge; Chicago estimated that its trees are collectively worth $2.315 billion.[390]

Challenges of Urban Forestry

Despite the many benefits of trees, urban forestry poses a number of challenges. First, maintaining trees in cramped, congested urban environments is costly and time-consuming.[391] Planting and pruning are usually the largest expenses, but litter management, watering, stump removal, inspection, and administration also require expenditures.[392] Because of these needs, local governments often rely on community members to help maintain trees; this reliance may prove difficult when community members lack the necessary knowledge, motivation, or resources. Given that heat islands tend to overlap with low-income and disadvantaged areas, this lack of resources can be a significant barrier. Trees may also present safety hazards: in some locations they might increase the risk of fire,[393] and broken branches can damage property or cause injury, particularly in heavy storms.[394] With expected increases in storms and fires, tree management will be an issue for these reasons as well as heat islands, and urban forestry planning should reflect these multiple concerns.

In addition, the urban forest can damage pavements, utility lines, and other parts of the built environment. Trees can cover security cameras, block business and traffic signs, and impede motorist or pedestrian visibility.[395] Excavating buried utility lines can damage roots, while tree branches can interfere with overhead power lines.[396] Tree roots can damage sidewalks, foundations, and underground pipes, especially in older areas with large trees and deteriorated infrastructure.[397] The challenge of promoting the urban forest also may increase when combined with the projected increase in severe weather, particularly for coastal communities; [398] utility lines and property may be increasingly vulnerable to damage from trees. Larger numbers of certain trees may also produce more pollen, potentially worsening respiratory diseases and allergies among some of the area's vulnerable residents.

Decision-Making and Urban Forestry

Certain urban areas with particular climate and other characteristics are well-positioned to take advantage of the benefits of urban forests. This section describes the criteria that help local governments decide whether to employ urban forestry as a method of adapting to heat.

Outcome Criteria

Heat: Local governments with dry climates benefit more from evapotranspiration (cooling from water evaporation) than those with wet climates, since humid areas allow less evaporative cooling than dry areas.[399] However, dry urban areas may need to choose native species that require less water, and some irrigation may still be necessary.[400] Local governments may also want to think about choosing species that are likely to survive in the climate conditions projected for the future as well as the present; as precipitation patterns and temperatures change, the species considered "native" for an area may change. An urban forest strategy works best when there is sufficient space for planting near streets and buildings, since this will provide shade that directly reduces surface temperatures.[401] In addition, low-rise buildings derive greater cooling benefits and energy savings from trees than high-rise buildings, since trees tend to shade a greater proportion of the walls and roof. Therefore, local governments with mostly low-rise construction in their urban heat islands will likely derive greater cooling benefits from urban forestry than those with many tall buildings.

Economics: Trees cost money, both up-front for purchase and planting and over time for maintenance. Trees can, however, potentially save money over time by lessening the need for stormwater infrastructure and reducing energy costs within heat islands.[402] Local governments looking to make a long-term investment in trees must have funding for ongoing maintenance and monitoring, because urban forestry requires long-term commitment of staff for planting, pruning, maintenance, and enforcement.[403]

Public Health: Urban forestry can be a valuable strategy for communities concerned about the health and well-being of their vulnerable elderly and low-income populations; these individuals often live in neighborhoods with few trees, so adding shade trees can provide large cooling and energy-saving benefits.[404] Because large-scale planting provides more cooling and pollution benefits than small-scale planting, urban forestry is especially useful for communities that have the means to collaborate with neighboring communities. For example, Oregon Community Trees brings together representatives from across the state to work together, network, and lobby for urban forests.[405]

Environmental: Local governments located near fragile or important aquatic ecosystems benefit from trees that help reduce the quantity and improve the quality of stormwater runoff.[406] Meanwhile, areas with poor air quality may want to make urban forestry a high priority because trees capture pollutants and reduce ozone production; this may be especially helpful for urban areas with ozone levels above or approaching those allowed under the Clean Air Act.[407]

Governance Criteria

Administrative and legal criteria may help local governments decide where and when to increase their urban forest canopies as well. Local governments may want to consider whether they have or want to create a way to deal with the tree debris from a new planting program, such as composting or recycling programs for yard waste.[408] From a legal perspective, governments will want to think about the potential liability from trees or limbs falling in the future and damaging property or injuring residents.

TABLE 21 *Urban Forestry: Summary of Benefits & Costs*

Method	Outcome Criteria				Governance Criteria	
	Heat	Economic	Public Health	Environmental	Administrative	Legal
Urban Forestry	+	+	+	+	~	+

Advantageous (+) The choice maximizes benefits and is feasible.
Neutral (~) The choice may present may present mixed advantages and disadvantages.

Policy Tools to Increase the Urban Forest

Mandates, incentives, and education programs can all be used to increase the tree canopy. Mandates are measures that set requirements for private actors. Incentives encourage but do not require specific behavior; they may be established by local governments, utilities, or private organizations. Finally, education programs aim to teach the public, either by providing information or by offering examples and demonstrating results. This section first describes steps that local governments can take to foster an urban forestry program. It then provides examples of how local governments have already used these tools for urban forestry. Finally, it describes how our criteria can help governments choose the tools that best meet their needs.

Preparing to Expand the Urban Forest

Before undertaking a new urban forestry program, local governments may wish to examine their planning capability, their available information and funding, and whether they can incorporate urban forestry into ongoing environmental initiatives. First, governments can determine which departments currently have responsibility for trees and planting. In many urban areas, tree regulations are divided among public works, parks, and other departments that may have overlapping or contradictory views of the urban forest.[409] By creating an inter-departmental task force or tree board, governments can harmonize urban forestry efforts.[410] Task force members could also communicate with utility representatives,[411] facility managers,[412] and environmental organizations to coordinate efforts with the work of outside entities. The urban forestry tree committee in Spokane, Washington, "reviews City plans and policies which contain matters relating to urban forestry" and "recommends legislation regarding the urban forest."[413]

Next, local governments can create an urban forestry plan. Creating an inventory of existing trees provides a baseline for planning[414] and for tapping into the resources available for maintenance within programs or laws covering urban forestry.[415] Based on this information, officials can set goals for tree planting, particularly a target for "the percentage of land area covered by tree canopies."[416] Goals for canopy cover can be community-wide as well as specific to neighborhoods or zones (such as single-family residential, industrial, or commercial).[417] The goals can also define priority planting regions, including areas with intense heat islands, low tree canopy,[418] or poor air quality. For example, New York City has designated six areas as "Trees for Public Health" neighborhoods because they have few street trees and high rates of asthma among young people.[419]

To fund urban forestry, some local governments have collected tax-deductible donations through non-profit partners or a city parks foundation. [420] Funds can also come from corporate sponsorships,[421] bonds or taxes.[422] In addition, local governments can charge fees that are dedicated to Municipal Tree Districts[423] or seek state grants, such as Oregon's Urban and Community Forestry Assistance Program.[424] When planning to fund urban forestry, local governments can set aside a contingency fund for storm damage or hazard mitigation, so the cost of any emergency response does not reduce forestry funding.[425]

Finally, local governments may want to investigate using urban forestry to meet federal environmental standards.[426] In particular, states that fail to meet air quality standards for certain pollutants, including ozone, must submit legally binding State Implementation Plans (SIPs) to EPA describing how they will reduce emissions.[427] States can include large-scale tree planting in a SIP, subject to certain limitations.[428] California, for example, lists parking lot trees as a form of air quality improvement because they help reduce car emissions.[429]

Government Operations

Local governments often control a sizable area within an urban district. This includes land for public facilities as well as the public right of way that borders most public streets and sidewalk. Any new trees will add to the shade for paved streets and sidewalks, reducing temperatures.

TABLE 22 *Government Operations for Urban Forestry*

Pros	Cons
Direct control over land	Requires upfront investment
Public right-of-way borders streets and sidewalks	Only applies to land under public control

Local governments can also require planting in public spaces and facilities. For instance, governments can mandate that a small percentage (perhaps one-half to one percent) of the capital budget for public projects be set aside for landscaping.[430] Local governments can also require that two or three trees be planted for every one tree removed from city property.[431]

Mandates

Mandates have the advantage of ensuring a desired behavior (e.g., planting new trees, protecting existing trees); the challenge is that they usually require the local legislature to pass a new ordinance. The following mandates promote an urban forest and lessen the heat island effect.

TABLE 23 *Mandates for Urban Forestry*

Pros	Cons
Protects existing mature trees	Some administrative challenges
Low cost for government	Some responsibility for property owners

Tree Protection Mandates

Tree protection mandates do not expand the forest; they impose penalties for removing existing trees that are protected because of their species, size, or location.[432] Seattle's tree protection ordinance protects trees over six inches in diameter as well as "exceptional trees" of unique size, species, or value.[433] Tree protection mandates may contain exceptions to allow removal of trees that interfere with visibility, utility infrastructure, or street access;[434] they also allow removing trees in poor condition.[435] Some tree protection mandates allow the removal of protected trees through a permitting process,[436] while all include penalties for non-compliance, such as replacement requirements and fines.[437]

Tree protection poses some challenges. It can be difficult and costly for local governments to establish culpability for removing protected trees.[438] Mandates may create a disincentive for landowners' planting trees or an incentive to remove trees before they become protected.[439] Moreover, these mandates do not help governments increase their tree canopy cover if it is currently sparse.

Landscaping Mandates

Landscaping mandates require developers to install or retain trees on properties during construction; they usually take the form of local ordinances and/or permitting requirements. Because these mandates may require retaining existing trees, they overlap with tree protection mandates.

Landscaping ordinances may require a specific number of trees per lot or per acre or a certain percentage of canopy over a particular property.[440] Landscaping mandates may also incorporate flexible standards in which properties must earn a minimum number of tree credits based on tree size, age, or species.[441] Seattle's Green Factor applies to new development in the city's business districts. To gain approval for new construction, developers must earn a certain number of points by planting vegetation, with more points for beneficial practices such as layering plants and using large trees.[442]

Landscaping ordinances generally require developers or property owners applying for building permits to submit landscaping plans that include utility lines, pavements, and other features.[443] In reviewing these plans, local governments can encourage developers to plant trees that provide shade, reduce heat, and save energy. Miami-Dade County requires that at least two of the three required trees for each single-family residence be placed in an "Energy Conservation Zone" near the house.[444] To ensure compliance with landscaping mandates, zoning inspectors visit completed sites before issuing Certificates of Occupancy.[445] Alternatively, landscaping mandates often allow developers to plant off-site or pay a fee if the required planting cannot be done on-site.[446] A local government that wishes to target heat islands may wish to encourage developers within the heat island to plant nearby if not on-site; the government can encourage developers in other areas of the city to plant there as well.

Local governments may have special landscaping requirements, such as mandating that trees be included in parking lots or near streets. Parking lot mandates generally require that every parking space be within a certain distance from a tree,[447] or that a certain percentage of the surface be landscaped or shaded.[448] A 1983 Sacramento ordinance required that 50 percent of the paved area in new parking lots be shaded within fifteen years.[449] Landscaping mandates often require planting trees along streets or sidewalks. In some cases, local governments and property owners divide the maintenance of street trees; for instance, governments may plant the trees, require that property owners maintain them for five years, and then take over responsibility for them.[450] Requiring street and parking lot trees may cost more in snowy climates, where salt and snowplows are likely to damage trees and necessitate replacement.[451] Urban areas prone to flooding may want to mandate street and parking lot trees, which can help manage runoff from impermeable pavements.[452]

Tree protection and landscaping mandates are not mutually exclusive, and many local governments use both types of policies.

Tree protection and landscaping mandates are not mutually exclusive, and many local governments use both types of policies. However, tree protection mandates may not be appropriate for tightly-packed multi-family and commercial zones, where trees could reduce the already limited space for light, air, open space, and parking.[453] In addition, governments looking to increase tree canopy may want to rely more on landscaping mandates, which often require new planting. Landscaping mandates are most beneficial in urban areas with building set-backs and rights-of-way that are sufficiently wide to allow street planting, so that street trees can shade roads and sidewalks.[454]

In general, tree protection mandates may be especially useful in urban areas with high turnover rates for properties, since existing trees may be most vulnerable when property changes hands.[455] Landscaping ordinances tend to be more effective in urban areas with high levels of new development, since new construction triggers their tree planting requirements.

Building Requirements and Other Mandates

Local governments can increase the urban forest through the use of green building standards, especially the Leadership in Energy and Environmental Design (LEED) standards put out by the U.S. Green Building Council. These standards recognize environmentally friendly practices in new and existing buildings; many local governments, including Dallas and Chicago, have incorporated LEED standards into their building requirements.[456] LEED standards support urban forestry by including protection of native habitats and water-efficient landscaping as options to earn points for certification.[457]

Other options include setting a statutory priority for trees over street improvements and defining who must take corrective measures when the two conflict.[458] A California statute provides, "Where sidewalk or curb damage due to tree roots occurs, every effort shall be made to correct the problem without removing or damaging the tree."[459] Local governments can indirectly require that property owners take care of trees by designating diseased or overgrown trees as public nuisances.[460] Finally, governments can require permits for activities that may harm street trees, such as paving near root zones[461] and transporting large items along city streets.[462]

Incentives

Urban forestry incentives offer rewards to encourage, rather than require, tree planting and protection. Tree-donation programs and development incentives are the major forms of incentives, but local governments can also support urban forestry by adopting green building standards or offering landscaping grants. By not requiring a particular behavior, incentive-based programs can be politically more viable than strict mandatory requirements, but they may result in fewer new trees.

TABLE 24 *Incentives for Urban Forestry*

Pros	Cons
Can target to particular areas	May result in less use than mandates
Property owners bear less cost	Government has to pay for incentives
May be more politically feasible than mandates	

Tree Planting Programs

Tree-planting programs are generally run either by local governments or local utilities. In government-run programs, the government provides trees to residents either for free or at a discounted rate, and the government and property owners share maintenance requirements or costs.[463] For example, in Charleston, South Carolina, the city sells trees at wholesale prices and plants them, citizens maintain them for a year, and then the city takes over maintenance.[464] These programs may be part of citywide tree-planting initiatives, like the Million Trees programs in Los Angeles, New York City, and other cities.[465]

Utility companies encourage urban forestry in order to reduce energy demand and thus to save money on electricity generation.[466] In utility-sponsored programs, consumers can request trees and utilities can provide them, often through non-profit organizations.[467] Some utilities require that homeowners attend a training session or sign a tree care pledge before receiving their trees;[468] utilities may also require that citizens use the trees to shade buildings, thereby reducing energy use.[469] Utilities may be more likely to sponsor incentive programs when state law requires them to fund energy efficiency measures.[470] In general, tree-planting programs tend to produce better results in highly engaged communities, since these programs often place some burden on citizens to care for trees. Thus, civic groups and volunteer organizations may be useful partners in creating any incentive program for urban forestry.

Financial Incentives

Local governments can also offer financial incentives to property owners to encourage urban forestry. Since plants help reduce runoff, local governments can reduce stormwater fees for properties with a high percentage of vegetative land cover.[471] Governments can provide tax credits for protecting large and significant trees[472] or use tax increment financing to freeze property values when owners add to the urban forest.[473] Governments can establish grant programs to fund urban forestry projects or promote planting in high-need areas. In Sacramento, groups can compete for grants of $1,000 to $15,000 to plant trees in public spaces.[474]

Development Incentives

Offering land use density bonuses[475] and expedited permitting for properties that retain large trees saves developers money while encouraging tree preservation.[476] While few jurisdictions have adopted these incentives for tree preservation, they are familiar to developers for other purposes including environmental design.

Tree giveaway programs can add to the urban forest where there is existing development, whereas expedited permitting, land use density bonuses, and green building standards are only applicable to new development. Therefore, urban areas with little new development may want to focus on tree giveaways.

As a final consideration, local governments looking to reduce the effects of heat on vulnerable populations may want to make mandates a higher priority than incentives. Given the cost and effort involved in tree maintenance, voluntary planting programs will likely be less effective in areas with many low-income or elderly residents, although financial assistance for low-income residents may help mitigate this problem. On the other hand, local governments can use mandates to ensure that trees benefit all city residents; for instance, mandates can help to ensure that trees are planted in all neighborhoods.[477]

Public Education Programs

Education programs aim to communicate the benefits of urban forestry to the public and to community groups who can help support forestry efforts.

TABLE 25 *Public Education for Urban Forestry*

Pros	Cons
Can target to particular areas	May result in less use than mandates
Property owners bear less cost	Government has to pay for incentives
May be more politically feasible than mandates	

Spotlighting Tree Planting

To increase awareness of the urban forest, local governments can sponsor special tree planting events or give away free trees during community celebrations,[478] perhaps in conjunction with Arbor Day.[479] Highly visible demonstration projects, such as landscaping around city buildings or on downtown streets [480] can encourage communities to plant trees, as can online activities such as tree tracking systems.[481]

Public Education and Outreach

To reach the public, local governments can offer training and consultations or disseminate information through mailings, email, websites, and videos.[482] The Los Angeles Department of Water and Power offers an online or in-person course on choosing and locating trees.[483] Governments can also train city employees, contractors, equipment operators, developers, and real estate agents to communicate the most relevant aspects of urban forestry.[484]

Community Partnerships

Potential community partners include social organizations (such as garden clubs and civic groups)[485] and businesses, especially plant nurseries.[486] The city of Washington, DC, has a close partnership with Casey Trees, a non-profit organization that plants trees, educates residents about tree maintenance and care, promotes the urban tree canopy, and works with developers to preserve trees.[487] Schools and universities can be important partners, as in Phoenix, where the city worked with Arizona State University to research sustainable urban forestry.[488] Partnerships may be formal, like the relationships among 20 forestry organizations in the Chicago Trees Initiative.[489] Regardless of the form, collaboration can increase community support for tree-planting and help local governments succeed with education programs.[490]

Local governments may also find fruitful collaborations with private companies. MillionTreesNYC (an initiative of PlaNYC) has partnered with Asplundh Tree Expert Co., STIHL Inc., Bartlett Tree Experts, and TREE Fund.[491] The program will train local young adults in tree care in order to create the workforce required to maintain the million trees the effort aims to plant.[492]

Education programs may have some up-front costs, since local governments often pay all of the costs of the project. Co-sponsoring these projects with utilities, non-profits, or other groups can reduce the costs paid by local governments. When there is little citizen activism in a city, or when there are few civic groups willing to help, education programs can help generate interest in urban forestry.[493] In addition, education programs can benefit vulnerable individuals, as long as these projects are understandable and accessible to all groups.

Conclusion

As developing urban areas remove or pave over vegetation, they eliminate plants with natural cooling properties. Trees, in particular, reduce temperatures by providing shade and evaporation. As part of an overall strategy to address urban heat, local governments can undertake an urban forestry campaign to preserve existing trees and add new trees. Local governments looking to expand their existing tree canopy or reduce stormwater problems may wish to use a landscaping ordinance, while those that wish to preserve existing trees may want to make a tree protection ordinance a high priority. Local governments with active community groups may derive greater benefit from incentive programs, which require voluntary participation. The chart below summarizes the factors that can help local governments to choose one policy tool over another.

While not every policy tool is appropriate for every city, there are several "no-regrets" tools, offering significant benefits for little cost, that all governments can consider:

- ***Demonstrate urban forestry in public projects.*** Local governments can fund landscaping in public projects and impose 2- or 3-to-1 replacement ratios for any trees removed from city property. The control that local governments have over their own properties makes this a relatively easy step.
- ***Preserve existing trees during development and construction whenever possible.*** Governments can require that trees be protected as much as possible if and when the trees conflict with street construction. They can also offer incentives for developers who agree to preserve or plant trees, such as tax credits and an expedited permitting process. These efforts may require action by the local legislature.
- ***Include tree planting in landscaping requirements attached to building permits.*** Local governments can ensure that new development will increase the tree canopy by explicitly requiring tree planting in landscaping ordinances.
- ***Partner with utilities and community groups.*** Governments can help establish utility-based incentive programs for tree planting. They can also coordinate with community groups that wish to take over the maintenance of public trees or street trees. Partnering with others can help local governments with either funding constraints or insufficient staff.

TABLE 26 *Decision-Making and Urban Forestry: How the Criteria Affect Tool Choices*

	Outcome Criteria				Governance Criteria	
	Heat	Economic	Public Health	Environmental	Administrative	Legal
Government Operations						
Publicly-Owned Land	+	~	~	+	~	+
Mandates						
Tree Protection Ordinances	+	+	+	+	~	~
Landscaping Ordinances	+	+	+	+	~	~
Other Mandates	+	+	~	+	+	~
Incentives						
Tree Planting Programs	+	+	+	+	~	+
Financial Incentives	+	~	+	+	~	~
Development Incentives	+	+	~	+	~	~
Public Education						
Spotlighting Tree Planting	~	+	+	+	+	+
Public Education	~	+	+	+	+	+
Community Partnerships	~					

Advantageous (+) The choice maximizes benefits and is feasible.
Neutral (~) The choice may present may present mixed advantages and disadvantages.

Conclusion

America's cities are hot and getting hotter.[494] Urban areas today are already two to five degrees F warmer than surrounding rural areas because of the urban heat island effect,[495] and scientists predict that climate change will raise average world temperatures between two and 11.5 °F by the year 2100.[496] As over 80 percent of the U.S. population lives in urban areas, the heat island effect is a threat to public health.[497] Extreme heat can lead to heat cramps, heat rash, heat exhaustion, heat stroke, and death. Higher temperatures increase smog formation and pollution, which cause or exacerbate respiratory problems.[498]

Many local governments have emergency preparedness plans to respond to heat waves.[499] Although incredibly important to save lives, emergency responses only help after residents are hot and in danger. This Tool Kit examines four methods to reduce urban heat before it can endanger lives: cool roofs, green roofs, cool pavements, and urban forestry. Each of these can help communities adapt; taken together, they can drastically reduce the heat island effect, while providing many co-benefits.[500] The Tool Kit provides criteria for deciding which method of reducing heat works best and provides guidance for choosing policy tools.

In addition to providing tools for implementation, the Tool Kit also identifies "no-regrets" policies: the policy options local governments can strongly consider adopting because, regardless of climate change, the policyies' benefits outweigh the costs. Some no-regrets options are summarized below.

Cool Roofs

Government Operations

- Require cool roofs on all new city-owned buildings to demonstrate the benefits of cool roofs.

Mandates

- Revise building codes to mandate cool roofs on all new buildings with flat or low-slope roofs to ensure cool roof adoption.

Incentives

- Establish utility rebate programs for cool roofs, which lower peak energy demand and reduce the likelihood of brownouts and blackouts.

Green Roofs

Incentives

- Create tax credits for building owners who install green roofs and agree to maintain them for a minimum time period to encourage green roof adoption with no up-front cost to the city.

- Give floor-area-ratio bonuses in zoning codes to buildings that install green roofs to provide an incentive to building owners and developers with no cost to the city.
- Create expedited permitting for projects that incorporate green roofs to provide an incentive to building owners and developers with no cost to the city.

Cool Pavements

Mandates

- Minimize paved surfaces by imposing a maximum amount of parking for projects or maximum size for parking spaces.
- Examine the environmental impact of public paving projects.

Incentives

- Encourage porous pavements for stormwater management by removing prohibitions in zoning codes.
- Include porous pavement in best management practices.
- Institute a rebate program to support the use of cool pavements.

Urban Forestry

Government Operations

- Demonstrate urban forestry practices in public projects.

Mandates

- Preserve existing trees during development and construction.

Incentives

- Encourage tree preservation and planting through tax credits and expedited permitting.

Education Programs

- Establish partnerships with utilities and community groups to provide and plant additional trees.

High temperatures in cities already place many in our communities at risk. This Tool Kit strives to inform decision-making in determining how to protect public health from rising heat through change in the built environment. Implementing these policies allows local governments to begin to adapt to urban heat while often providing for even greater economic, environmental, and societal benefits even under current conditions.

TABLE 27 *Urban Heat Methods: How the Criteria Affect Tool Choices*

	Outcome Criteria				Governance Criteria	
	Heat	Economic	Public Health	Environmental	Administrative	Legal
Green Roofs	+	~	~	+	~	~
Cool Roofs	~	+	+	~	~	~
Cool Pavements	+	~	~	+	~	~
Urban Forestry	+	+	+	+	~	+

Advantageous (+) The choice maximizes benefits and is feasible.
Neutral (~) The choice may present may present mixed advantages and disadvantages.

Appendix I: Methodology

Framework for Decision-Making

We analyze each method in terms of four outcome criteria: heat, economic, public health, and environmental; these criteria will correspond to decision makers' priorities and the physical realities of their urban areas. Additionally, we assess the impact of two governance criteria: administrative and legal. With this governance analysis, local governments can determine whether a particular tool is within their current legal authority or administrative capacity.

Outcome Criteria

Our decision-making framework enables local governments to tailor the best heat adaptation strategies for their unique situations. This section describes both sets of decision criteria—outcomes and governance—and then outlines the sets of policy tools that we use in the following chapters. Following the lead set by our Sea-Level Rise Adaptation Tool Kit[501], we organize the outcome criteria into four categories:

Heat: First and foremost, the built-environment method or policy tool must actually reduce heat. Considerations of geography and climate, land cover, and the type of development that generates each heat island will guide policy makers' choices of which method or tool will most effectively reduce heat.

- *Geography and climate:* Urban areas with long, hot summers and mild winters have different considerations than those with warm summers and long, cold winters. In cold climates, cool roofs keep building interiors cooler in winter as well as in summer, potentially leading to greater expenditures on heating costs that could outweigh summer savings.[502] Levels of rainfall can affect the evaporative cooling from vegetation and permeable pavements, and areas with fine or clay soils may not be able to use permeable pavements at all.

- *City land cover:* Local governments can determine what percentage of their land is covered by pavement, roofs, and vegetation in order to directly address their most common surface type. For instance, in an urban area experiencing rapid development like Phoenix, pavements may comprise a greater proportion of the land surface than roofs and vegetation, making cool pavements a logical priority.[503] On the other hand, a city like Salt Lake City (where surprisingly vegetation covers 46 percent of the surface) may focus first on preserving the existing tree canopy.[504] Certain trends may influence the choice of adaptation method. For example, urban areas with many large parking lots may use cool pavements that are appropriate for low-traffic areas (e.g., porous pavements).[505]

- *New vs. existing development:* Urban areas with a high level of new development have more opportunities to mandate or incentivize adaptation measures than those with less ongoing construction. For example, local governments can offer zoning incentives to new buildings that install green roofs[506] or require that developers use cool pavements for new roads.[507] Applying mandatory conditions on pre-existing structures is legally problematic; to reduce heat in older neighborhoods, local governments will likely need a combination of incentive-based programs. Additionally, applying some adaptation measures to existing buildings can be difficult, costly, or impractical. For instance, not all existing buildings can be retrofitted to have green roofs because green roofs require a certain level of structural support to bear the increased weight.

Public Health: Local governments' public health interest in reducing urban heat focuses primarily on equity and the needs of vulnerable populations. For a variety of reasons, low-income individuals and the elderly are more susceptible to heat-related illnesses,[508] and they may also suffer more from the effects of the urban heat island, such as poor air quality.[509] These residents may also have less access to air conditioning[510] or spend a higher percentage of their income on energy costs.[511] Therefore, local governments may choose to focus on identifying areas where heat islands are likely to affect vulnerable populations and then apply the heat-reducing methods to these high-need areas. For instance, Philadelphia sponsored a "cool block" program, giving away cool roofing materials in neighborhoods with elderly residents who committed to energy-saving measures.[512] Local governments may want also to ensure that adaptation measures are implemented equitably, such as by offering financial assistance with tree planting and maintenance in low-income communities where maintaining trees might be a burden.[513]

Environmental: All of the methods for reducing urban heat islands play a role in mitigating climate change as well as adapting, and several offer environmental co-benefits outside of their climate benefits. Three of the major co-benefits are lowering energy use, reducing air and water pollution, and improving stormwater management. The first two co-benefits will improve environmental conditions and public health.[514] Because of demand for air conditioning, energy use rises by about 1.5 to 2 percent for every 1 °F temperature increase in large cities.[515] The built-environment methods, especially cool and green roofs, can significantly reduce energy demand in buildings while keeping people cooler. For instance, the green roof installed on Chicago's City Hall is expected to reduce energy costs by $3,600 per year.[516] Heat adaptation strategies can also help local governments address air pollution such as ground-level ozone and water quality from stormwater runoff.

Economic: When contemplating the financial impact of adaptation strategies, governments must take stock of the short- and long-term costs of each method, as well as the potential cost-savings of each over time, and choose who will pay the costs. Some heat adaptation methods require large upfront investments; green roofs, for example, have initial costs ranging from $10 to $25 per square foot. However, building owners commonly offset this cost over time in energy savings and other co-benefits.[517] Incentive programs that encourage citizens to adapt may require more government funding than mandates, which would place the cost on private actors. Green roofs and some types of cool pavements may have greater maintenance costs over time as well.

Local governments may draw from a variety of funds to pay for adaptation measures, including general funds as well as targeted taxes, fees, or charges.[518] Some localities have used pre-existing federal, state, or local funding streams to pay for adaptation, such as incorporating urban forestry measures into federal grants for air quality improvement.[519] By simply using existing funding streams in smarter ways, governments with tight budgets may be able to begin their adaptation efforts.

Governance Criteria

Governance criteria are grouped into two categories:

Administrative: Program administration and the city's current practices may influence which strategies are most likely to work.

- *Program Administration:* Government organization, coordination with outside groups, and the level of participation of citizens and interest groups can strongly affect the success of various strategies. Authority for the various strategies may be divided among a number of government agencies, such as planning, public works, health, and environmental departments; coordination among these agencies will lead to better outcomes. Local governments may also need to coordinate and/or partner with other levels of government, community groups, local utilities, and others with expertise in the field. Strategies that involve public engagement or support, such as maintaining urban forests, will naturally be more successful in areas with a high level of community interest and activism. Finally, governments might evaluate whether opposition from interest groups, such as developers, contractors and suppliers, or utilities, could delay or prevent implementation of certain adaptation measures, particularly those that are mandatory.[520]
- *Current Practices:* Because most local governments are not starting from nothing, they must consider how current policies fit with their adaptation goals. In order to capitalize on current programs and policies that may work well, local governments may choose to build upon an existing urban forestry program, for example, rather than beginning an entirely new program from scratch.

Legal: Local governments will need to consider which tools fall within the authority that agencies already possess and which may require further granting of authority from either the local legislative body or the state legislature. In addition, certain methods or tools could conflict with current state or local law. For instance, existing building or paving standards may conflict with heat adaptation priorities.[521] To improve current laws, governments can consider consolidating the laws on a particular topic[522] or revising existing ordinances to better address heat adaptation needs. We have attempted here to identify potential legal obstacles for each local government to consider.

Appendix II: Additional Resources

Background on the Urban Heat Island

Source (and Author)	Link
Cool Surfaces and Shade Trees to Reduce Energy Use and Improve Air Quality in Urban Areas (Akbari et al.)	http://www.fs.fed.us/ccrc/topics/urban-forests/docs/cool%20surfaces%20and%20shade%20trees%20to%20improve%20air%20quality.pdf
Heat Island Group, Lawrence Berkeley National Laboratory	https://http://heatisland.lbl.gov/
Mitigating New York City's Heat Island with Urban Forestry, Living Roofs, and Light Surfaces (Rosenzweig et al.)	http://www.giss.nasa.gov/research/news/20060130/103341.pdf
Reducing Urban Heat Islands: Compendium of Strategies (U.S. EPA)	http://www.epa.gov/heatisld/resources/compendium.htm
Science Corner: Heat Island Effect (U.S. EPA)	http://www.epa.gov/heatisld/resources/reports.htm#mitigation
Sustainable South Bronx, Urban Heat Island Mitigation Can Improve New York City's Environment: Research on the Impacts of Mitigation Strategies on the Urban Environment (Rosenthal et al.)	http://csud.ei.columbia.edu/sitefiles/file/SSBx_UHI_Mit_Can_Improve_NYC_Enviro%5B1%5D.pdf
The Urban Heat Island, Photochemical Smog, and Chicago: Local Features of the Problem and Solution (Gray & Finster)	http://www.epa.gov/heatislands/resources/pdf/the_urban_heat_island.pdf

Urban Heat Island Plans and Proposals

Source (and Author)	Link
Adding Green to Urban Design: A City for Us and Future Generations (City of Chicago)	http://www.cityofchicago.org/dam/city/depts/zlup/Sustainable_Development/Publications/Green_Urban_Design/GUD_booklet.pdf
Cool Houston! A Plan for Cooling the Region (Houston Advanced Research Center)	http://files.harc.edu/Projects/CoolHouston/CoolHoustonPlan.pdf
Dallas Urban Heat Island (Houston Advanced Research Center)	http://files.harc.edu/Projects/DallasUHI/FinalReport.pdf
Green Codes Task Force Recommendations to New York Building Code (Urban Green Council, U.S. Green Building Council)	http://www.nyc.gov/html/gbee/downloads/pdf/gctf_all_proposals.pdf
Urban Planning Tools for Quality Growth, 2002 Supplement (Envision Utah)	http://www.envisionutah.org/Urban%20Planning%20Tools%20for%20Quality%20Growth_First%20Ed.pdf

Cool Roofs

Source (and Author)	Link
The Economics of Cool Roofing: A Local and Regional Approach (Hoff)	http://www.roofingcenter.org/syncshow/uploaded_media/Economics%20of%20Cool%20Roofing(1).pdf
Guidelines for Selecting Cool Roofs (Urban & Roth)	http://www1.eere.energy.gov/femp/pdfs/coolroofguide.pdf

Green Roofs

Source (and Author)	Link
International Green Roof Association	http://www.igra-world.com/
Beating the Heat in the World's Big Cities (Scott)	http://earthobservatory.nasa.gov/Features/GreenRoof_greenroof.php
Ecoroof Handbook (Environmental Services, City of Portland)	http://www.portlandonline.com/bes/index.cfm?c=50818&a=259381
Design Guidelines for Green Roofs (Peck & Kuhn)	http://www.cmhc-schl.gc.ca/en/inpr/bude/himu/coedar/loader.cfm?url=/commonspot/security/getfile.cfm&PageID=70146
Green Roof Policies: Tools for Encouraging Sustainable Design (Ngan)	http://www.gnla.ca/assets/Policy%20report.pdf

Cool Pavements

Source (and Author)	Link
Cool Pavement Report (Cambridge Systematics, Inc.)	http://www.epa.gov/heatisld/resources/pdf/CoolPavementReport_Former%20Guide_complete.pdf
Preliminary Evaluation of the Lifecycle Costs and Market Barriers of Reflective Pavements (Ting et al.)	http://www.osti.gov/energycitations/servlets/purl/791839-bU8he2/native/791839.pdf
Managing Wet Weather with Green Infrastructure (U.S. EPA)	http://water.epa.gov/infrastructure/greeninfrastructure/upload/gi_action_strategy.pdf

Urban Forestry

Source (and Author)	Link
City of Phoenix Tree & Shade Master Plan	http://phoenix.gov/webcms/groups/internet/@inter/@dept/@parks/documents/web_content/071957.pdf
Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project (McPherson et al.)	http://www.nrs.fs.fed.us/pubs/gtr/gtr_ne186.pdf
Guidelines for Developing and Evaluating Tree Ordinances (Swiecki & Bernhardt)	http://phytosphere.com/treeord/
Portland Urban Forestry Management Plan (Portland Parks and Recreation)	http://www.portlandonline.com/parks/index.cfm?a=184641&c=38306
Protecting and Developing the Urban Tree Canopy: A 135-City Survey (City Policy Associates for The U.S. Conference of Mayors)	http://www.usmayors.org/trees/treefinalreport2008.pdf
Urban Forestry Management Plan (City of Seattle)	http://www.seattle.gov/environment/documents/Final_UFMP.pdf

Endnotes

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11 *See, e.g.,* EPA, Heat Island Effect: Basic Information; C.J.G. Morris, Urban Heat Islands and Climate Change—Melbourne, Australia, http://www.earthsci.unimelb.edu.au/~jon/WWW/uhi-melb.html (last visited Jan. 9, 2012).

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13 Ctrs. for Disease Control & Prevention (CDC), *Heat Waves*, http://www.cdc.gov/climatechange/effects/heat.htm (last visited Jan. 9, 2012).

14 *Id*. *See* also Cal. Natural Resources Agency, 2009 California Climate Adaptation Strategy 31 (2009), *available at* http://www.energy.ca.gov/2009publications/CNRA-1000-2009-027/CNRA-1000-2009-027-F.PDF.

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16 Office of Climate, Water, and Weather Services, National Weather Service, National Oceanic and Atmospheric Administration (NOAA), *Heat Wave: A Major Summer Killer*, http://www.nws.noaa.gov/om/brochures/heat_wave.shtml (last visited Jan. 9, 2012).

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18 CDC, *Extreme Heat*.

19 *See* U.S. EPA, *Excessive Heat Events Guidebook* (2006) at 5-6, *available at* http://www.epa.gov/heatisld/about/pdf/EHEguide_final.pdf (last visited Jan. 24, 2012).

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448 *See, e.g.,* Chi., Ill., Municipal Code § 17-11-0203 (American Legal Publishing through Sept. 8, 2010); Sacramento, Cal., City Code § 17.68.040 (Quality Code Publishing through Nov. 2010 supp.).

449 E. Gregory McPherson, *Sacramento's Parking Lot Shading Ordinance: Environmental and Economic Costs of Compliance*, 57 Landscape and Urban Planning 105, 106 (2001), *available at* http://www.sciencedirect.com/science?_ob=MImg&_imagekey=B6V91-449V2S4-1-T&_cdi=5885&_user=655954&_pii=S0169204601001967&_origin=search&_coverDate=11%2F20%2F2001&_sk=999429997&view=c&wchp=dGLzVtz-zSkzk&md5=1e73cad0337b2bd77a65cce35c5da0af&ie=/sdarticle.pdf.

450 Swiecki & Bernhardt. Conversely, some local governments have considered taking over the care and management of all street trees because of the presumed positive effect on tree health. City of Seattle at 79.

451 Venner Consulting & Parsons Brinckerhoff, Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance 3-121 (2004), *available at* http://onlinepubs.trb.org/onlinepubs/archive/NotesDocs/25-25(4)_FR.pdf.

452 Portland Parks & Recreation, Portland Urban Forestry Management Plan at 76-77.

453 City of Seattle Dep't of Planning & Dev. at 7, 15. Additionally, it may be difficult for industrial areas to meet tree requirements because storage, manufacturing, and transportation require large, continuous areas.

454 *Cf.* HARC, Dallas Urban Heat Island at 20.

455 Swiecki & Bernhardt.

456 HARC, Dallas Urban Heat Island at 56; Water Env't Research Found.

457 U.S. Green Building Council at 6, 20-21.

458 Swiecki & Bernhardt.

459 *Id.*

460 *See, e.g.,* Santa Clarita, Cal., Municipal Code § 23.30.040(J) (Code Publishing Company through Aug. 24, 2010 ordinances).

461 Planning & Dev. Dep't, City of Houston, Houston Landscape Regulations for Development 4-5 (2009), *available at* http://www.houstontx.gov/planning/DevelopRegs/docs_pdfs/tree_shrub.pdf.

462 Swiecki & Bernhardt.

463 *E.g.,* U.S. Conference of Mayors at 24, 26.

464 *Id.* at 29-30.

465 *See* HARC, Dallas Urban Heat Island at 30-31.

466 McPherson et al. at 136. Utilities may be statutorily required to encourage energy efficiency. *See, e.g.,* Misha Sarkovich, Sacramento Municipal Utility District's (SMUD) Urban Heat Island Mitigation Efforts 39 (2009), http://heatisland2009.lbl.gov/docs/221120-sarkovich-ppt.pdf.

467 McPherson et al. at 136. Some utilities have taken a hands-off role by providing tree coupons or rebates, U.S. Conference of Mayors at 19, while others are more directly involved in the provision of trees and help plant trees in hard-to-reach neighborhoods. HARC, Dallas Urban Heat Island at 36.

468 HARC, Dallas Urban Heat Island at 36.

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