Emphasizing the Co-Benefits of Heat Island Mitigation: Lessons from U.S. Local Governments Engaged in Climate Protection

Nikolaas Dietsch, U.S. Environmental Protection Agency
Ryan Bell, International Council for Local Environmental Initiatives
Bill Drumheller, International Council for Local Environmental Initiatives

ABSTRACT

Urban areas are facing increased daily temperatures caused, in part, by the heat island effect. This is of concern to city officials and the public because heat islands result in additional demand for summertime air conditioning and a range of impacts to the environment and public health. However, research and on-the-ground experience indicate that by planting shade trees, installing "cool roof" products (i.e., high reflectivity and emissivity), using reflective paving materials, and planting green roofs, local governments can mitigate the heat island effect.

Despite the existence of readily available mitigation strategies, local officials face barriers to policies and projects intended to reduce or adapt to oppressive summertime temperatures. Fortunately, concerned stakeholders are demonstrating that these strategies help communities achieve their economic, environmental, and public health objectives. This gives extra weight to the argument that heat island mitigation is a sound investment.

The experience of cities participating in the International Council for Local Environmental Initiatives' (ICLEI) Urban Heat Island Policy Adoption and Peer Exchange Initiative illustrates how focusing on "co-benefits" can help communities integrate heat island mitigation measures into their building and land use plans, increasing the quantity of successful projects. The Initiative also demonstrates how leading local governments can foster the adoption of heat island reduction strategies in other communities.

This paper surveys recent heat island mitigation efforts in cities affiliated with ICLEI's international climate protection program. Lessons learned from these jurisdictions are identified, with an emphasis on how co-benefits are motivating action.

Background

Research shows that replacing natural landscapes with heat-absorbing surfaces – including roads, buildings, and other man-made structures – causes increased temperatures in urbanized areas. This phenomenon, known as the urban heat island effect (UHI), leads to temperatures 2–8°C degrees hotter than surrounding rural areas, and results in negative impacts at the community-level. Hotter summertime temperatures increase cooling requirements in air-conditioned buildings, which in turn raises overall energy costs (Konopacki 1997). High temperatures also result in increased emissions of ozone precursor compounds and greenhouse gases from power plants, accelerating the temperature-dependent formation of photochemical smog.

Heat island mitigation measures lower ambient temperatures by reducing the amount of solar radiation absorbed and subsequently re-released as heat by urban infrastructure. Mitigation strategies include increasing the use of cool roof technology (including green roofs), using reflective paving materials, and planting trees and vegetation to shade buildings and paved surfaces (Rosenfeld 1997).

Despite the negative impacts of urban heat islands and the existence of mitigation measures, local governments face many barriers to action. Foremost among them is the fact that reducing ambient air temperature requires a widespread, well-coordinated, and resource-intensive investment.

Other barriers include: a) Lack of understanding of how heat islands impact urban areas, as well as the availability of mitigation options; b) Lack of real world results about the benefits of heat island reduction strategies, combined with a reluctance to be the first to take action; c) Uncertainty about the transferability of results between different geographic regions and climatic zones; d) The high level of coordination required between stakeholders (i.e. government agencies, industry, non-government organizations, and the public); e) Absence of regulatory incentives – such as recognition of heat island mitigation benefits in air quality plans – to encourage large-scale efforts; f) Resistance to incurring up-front expenditures that return paybacks to third parties (i.e. building owners install reflective roofs but the businesses or tenants receive the energy savings).

The ICLEI – CCP Urban Heat Island Initiative

The Urban Heat Island Policy Adoption and Peer Exchange Initiative is a project of the International Council for Local Environmental Initiatives' (ICLEI) Cities for Climate Protection (CCP) campaign. ICLEI is a membership association of local governments dedicated to preventing and solving environmental problems through cumulative local action. The CCP campaign is an ICLEI program that brings together more than 500 local governments, including over 130 U.S. cities and counties, to reduce emissions of greenhouse gases and improve air quality within their communities.

The goals of the CCP Initiative are to help local governments overcome the barriers noted above, increase the penetration of heat island reduction measures, and create a model for the implementation of urban heat island policy that can be used by other communities. This Initiative is a collaboration between CCP staff, scientific experts, and five local governments selected on the basis of a demonstrated commitment to developing, adopting, and implementing heat island mitigation policies and projects. Participants in the Initiative include San Jose (Calif.), Atlanta (Ga.), Louisville / Jefferson County (Ky.), Philadelphia (Pa.), and Tucson (Ariz.)[1]. Since December 2001, CCP staff has been working with these locales to provide technical and policy assistance, coordinate workshops and peer exchange events, and facilitate outreach campaigns. For their part, the communities have committed to: a) providing staff time and resources to the project; b) participating in two workshops; and c) taking steps to mitigate heat island effects in their communities. EPA's Heat Island Reduction Initiative (HIRI) provides funding and assistance to the CCP Initiative.

Experience thus far suggests that while many jurisdictions perceive the negative consequences of rising urban temperatures, there are seldom resources available or coordination present within the community to motivate the policy action necessary to affect community-wide change on the heat island issue. The direct benefits of heat island

[1] Other CCP participants – Santa Monica, Chicago, Davis, Sacramento and Los Angeles – are taking steps to reduce their urban heat islands but are not formal participants in this Initiative.

mitigation strategies, even when quantifiable (e.g., measured reductions in ambient temperatures), are rarely sufficient to motivate policy.

On the other hand, the indirect co-benefits of heat island mitigation, such as energy conservation and the corresponding financial savings, can be major incentives for a jurisdiction to take action. Decision-makers generally attribute a higher degree of credibility to projects where discrete energy savings can be measured, as is the case with many heat island reduction strategies. Therefore, increasing the prevalence of projects and policies to mitigate heat islands requires an emphasis on the quantifiable co-benefits of actions.

The Co-Benefits of Heat Island Mitigation Measures

The major co-benefits of heat island reduction measures include energy savings, improved public health, and better management of stormwater runoff. These factors have convinced many jurisdictions, including those participating in the CCP initiative, that heat island mitigation strategies are sound investments.

Energy savings. Estimates suggest that urban areas experience a 3-4% rise in peak utility load for every 1° C increase in summertime temperature. In light of steadily increasing downtown temperatures of 0.1° C to 1.1° C per decade, 3-8% of citywide demand for electricity can be attributed to cooling purpose (Akbari 1990). Installing cool roofs and planting shade trees adjacent to homes and buildings reduces heat transfer into the building and decreases its energy use while minimizing the urban heat island effect.

Public health. The heat island effect can raise summertime temperatures to a level that poses a direct threat to certain individuals. Temperature is also a key ingredient in the formation of dangerous ground-level ozone. Similarly, increased cooling demand requires additional electrical generation for air conditioning, which increases the amount of sulfur, nitrogen, and particulate matter in the atmosphere. This, in turn, has a negative impact on people with asthma and other reparatory illnesses.

Reduced stormwater runoff. Whereas farmland and open spaces assimilate rainwater, conversion to urban infrastructure increases the amount of impervious surfaces and associated storm water runoff. This overwhelms sewer systems and induces pollutant dispersal and flooding. In contrast, surface lots with reflective pervious paving material and green roofs assimilate stormwater, filter pollution, and could even minimize the need for expensive drainage infrastructure. Similarly, trees intercept rainfall and loosen soil, which increases infiltration and prevents surface runoff.

Heat Island Mitigation Measures

Despite numerous obstacles, many local governments are implementing measures that help reduce the heat island effect in their communities. The following sections describe programs currently in place, highlighting successes from each.

Cool Roofs as an Energy Efficiency Strategy

Installing highly reflective and emissive[2] roofs can reduce cooling costs and decrease ambient temperature. Monitoring done on 10 buildings in California and Florida showed a 20–70% savings in annual cooling energy use (Gartland 1999). In general, energy savings, peak power avoided, and emission reductions are correlated with the size of the area implementing the heat island measures, and the length and average temperature of the summer season (Konopacki 2001). The magnitude of the winter penalty (any observed increase in energy costs from reflecting valuable wintertime sunlight) is usually small in comparison to summertime savings, making cool roofs a good investment for almost any region (Gartland 2000).

Cities in action. The City of San Jose recently instituted a cool roof incentive program. This effort, funded by a grant from Pacific Gas & Electric, arose out of a "cool communities" workshop attended by people from the public, private, and non-government sectors. San Jose's program is designed to reduce peak energy loads by providing rebates to encourage commercial and multi-family building owners to install energy efficient roofs. In addition, the city conducted a series of outreach meetings to over 200 community stakeholder such as contractors, building owners and managers, architects, and others (Hamilton 2002).

This citywide effort complements the existing statewide Cool Savings Program to provide rebates for the installation of cool roofs on qualifying commercial buildings. The California Energy Commission (CEC) established their program to ease the energy crisis in the State of California at that time. Under the Program, the state provides rebates for the installation of highly reflective and emissive roofs: refrigerated buildings receive $0.25 ft^2 rebates, while other non-residential buildings are eligible for $0.20 ft^2. These incentives were in effect until September 30, 2001, after which each decreased by $0.05 (California Energy Commission 2001).

In another part of the country, the City of Tucson installed a cool roof on their municipal service center as a model project. They resurfaced the black metal roof with a white elastomeric coating and are investigating a larger project to pave the building's parking lot with reflective paving materials and plant shade trees (Hunt 2002).

In June 2001, the City of Chicago amended its energy code to include a cool roof requirement. The new language was drafted, "To minimize the undesirable urban heat islands effect," by implementing reflectivity and emissivity requirements on all low and medium sloped roofs (City of Chicago 2001a). The code acknowledges the role that cool roofs can play in achieving peak energy savings, which LBNL estimates at $11 million per year in Chicago (Konopacki 2002)[3].

Lessons learned & results. Tucson's experience illustrates the effectiveness of promoting the co-benefits of heat island mitigation. The reflective roof coating not only reduced energy costs by almost 50% (400 million BTU annually), but also fixed numerous leaks in the original roof, which helped to generate additional support for the project among the city's maintenance staff (Gartland 2002). Because the city is able to promote these benefits,

[2] Emissivity is a measure of the rate of heat transfer from the roof to the surroundings. A highly emissive radiates heat quickly, while a roof with low emissivity retains heat and contributes to the heat island effect.

[3] Based on an estimate of 162 kWh per 1,000 square feet for the city.

interest in cool roof projects is increasing. As a result two other city facilities are being targeted for roof resurfacing and the city architect wants to upgrade the city's municipal standards to promote reflective roofing for all city facilities. On the other hand, the paving section of the program is on hold because of a lack of agreement as to which department is responsible for parking lots (Hunt 2001).

The key to the success of San Jose's program was public involvement. By starting with a group of stakeholders who came together to discuss a common problem (i.e. spiraling energy costs) the city laid the foundation for public acceptance of the program. The city also helped raise community interest in cool roofing options through a public education campaign. The public meetings reached over 200 people and resulted in 50 roofing contractors being certified to install cool roofs for the program. Overall, Tucson's participation in the ICLEI Initiative resulted in assistance to 18 different projects, which currently reduce peak electrical demand in the city by 185 kilowatts. Additionally, in the 3-months following program termination, another 40 people have been referred to the CEC's rebate program, illustrating how a program can be influential long after its active life.

In contrast, the City of Chicago discovered that having a "champion" in a position of local authority was instrumental to modifying their energy code to incorporate a cool roof standard. In this case the current mayor, Richard Daley, served as that champion. The stated goal of Mayor Daley's administration is to have the, "greenest city in the country" (Daley 2001). To ensure successful implementation of a cool roof standard, the city's energy code was modified to set explicit standards for the type of building it applies to and designated a minimum required rooftop albedo[4] (>0.65) and emissivity (>0.9) standard (City of Chicago 2001a). The code also identifies a city agency responsible for carrying out, interpreting, and enforcing the ordinance's provisions.

Cool Roofs as Public Health Strategy

Extremely hot weather can result in illness and even death. A 1995 heat spike in Chicago resulted in the deaths of over 500 people (Chagnon 1996), illustrating why extreme temperature should concern city officials. Because extreme heat kills more people in their homes than out of doors, cooling strategies such as reflective roofs and shade trees can save lives.

Cities in action. The City of Philadelphia is in a region particularly vulnerable to heat stress[5] (Kalkstein 2001). Therefore the city instituted a passive-cooling program for residential homes that features cool roofs. One hundred homes were initially targeted for white roof coatings in the portion of the city suffering from the highest incidence of heat-related mortality. The city also sponsored a "cool block" competition in which the winning neighborhood committed to taking temperature-reducing measures to lower energy bills and extend rooftop lifetime (Robinson 2001). Additionally, the city instituted a "buddy system" in which participating seniors are contacted during heat waves to ensure debilitating heat-induced health effects do not go unnoticed. The success of the Program convinced decision-makers to expand it to cover 400 additional homes. This will accomplish several goals: a)

---

[4] Albedo is a measure of the portion of incoming light that is reflected by a surface. High albedo equals high reflectivity.

[5] Dr. Kalkstein estimates that 8.3 heat-related deaths occur in an "average summer," but that this figure could increase in a particularly hot summer.

reduce indoor temperatures to a comfortable level; b) minimize health risks; c) stabilize energy consumption; and d) provide social interaction and outreach to seniors.

Lessons learned & results. Philadelphia's experience illustrates why collaboration between different departments and agencies is an important component of heat island reduction programs. By including cool roof measures as part of a total redevelopment policy package involving many city departments focused on different policy areas – such as public health and reducing energy costs for low-income residents – the city was able to justify activity under its cool roof program in multiple ways and accelerate its progress. It worked because urban redevelopment is a major issue in the Philadelphia community.

Philadelphia's experience also shows that retrofitting dark-colored, heat-absorbing rooftops with cool roofing material is a cost-effective way to improve the public's health and safety in circumstances where air conditioning is unavailable. The roof coatings lower indoor temperatures an average of 3°F. The city has also received approval to use federal weatherization funds in similar programs (Miller 2002).

Shade Trees

Besides beautifying a city, trees and vegetation (such as a vine-covered trellis) prevent runoff and block the sun's rays, preventing heat transfer to a home or building. The shading effect of vegetation can reduce residential cooling energy consumption by up to 40% annually (Parker 1983). In addition, vegetation cools the air directly through evapotranspiration[6], effectively reducing temperature-dependent evaporative emissions from vehicles and providing "indirect" air conditioning energy savings (Scott 1999).

Cities in action. The Sacramento Municipal Utility District, in collaboration with the Sacramento Tree Foundation, provides free trees for residents to plant for summertime air conditioning demand-reduction. Since 1990, the Shade Tree Program has planted over a quarter million shade trees adjacent to homes, commercial buildings, in parks, playgrounds, and around schools. The program includes an educational component to inform participants about how trees should be cared for and planted for maximum savings (Sacramento Municipal Utility District 2000).

Also in California, Santa Monica includes shade tree planting in their Green Building Program. The city's Design and Construction Guidelines instruct builders to, "locate landscaping and landscape structures to shade buildings" (Munves 2001). Similarly, Los Angeles's "Cool Schools" project helped 40 schools across the city improve their energy efficiency. During the first phase of the program, over 4,200 trees were planted at in the Los Angeles Unified School District with help from local nonprofit partners (Longcore 2001).

Additionally, many jurisdictions in warmer climates, including Davis, Los Angeles, and Sacramento, have adopted legislation requiring shade tree coverage of at least 50% of the surface area of parking lots. On average parking lots cover 10% of a city's total area and 20%-30% of the urban core (McPherson 2000), making them ideal candidates for heat island

[6] The process through which plants secrete or "transpire" water through leaf-pores. As the water evaporates, it draws heat and cools the air.

mitigation measures. These ordinances are aimed at cooling the parking lots, increasing human comfort, and reducing air pollution from car start-ups.

Lessons learned & results. Sacramento's experience teaches them that the effectiveness with which trees reduce energy-transfer largely depends on their placement. In Sacramento's climate, trees provide maximum benefit when shading the east, west and to a lesser extent south facing walls (Sarkovich 2001a). In addition, Sacramento learned that having a follow-up mechanism to verify proper planting and tree care is essential to minimize mortality and maximize benefits (Sarkovich 2001b).

The City of Davis learned that increasing the shade in parking lots, from 8% coverage to 50% coverage, not only reduce ambient temperatures 1-2° C but also increases human comfort by lowering the temperature inside the car by 26.2° C. These temperature reductions also help prevent air pollution by decreasing the quantity of reactive organic gasses (ozone precursors) that evaporate from parked vehicles by 2% and the NO_x emitted during start-up by 1% (Scott, Simpson, McPherson 1999). If the shade standard is met in all parking lots across the city, the air quality benefit would equal the projected emissions reductions from the Air Quality Management District's hydrocarbon and NOx control programs[7] (Scott, Simpson, McPherson 1999).

Despite these benefits, California communities implementing parking lot shade ordinances have found that, over time, most lots do not meet the 50% standard. This is due to a combination of factors including the planting of inappropriate tree species, poor soil conditions, and an insufficient program for maintenance and replacement. In order to obtain this goal the city of Davis and others are considering amending their landscaping ordinances to specify guidelines for planting and irrigation, minimize conflicts with signs and lights, and instituting a system for maintaining the trees and monitoring the sites over time (McPherson & Simpson 2000).

Local governments can also promote tree planting as a program to decrease storm water runoff. The City of Garland, Texas has determined that increasing the amount of tree cover on a 3.86 acre residential site from 8% to 35% would lead to a four-fold decrease in stormwater runoff (Keating 2002). Similarly, the City of Olympia determined that tree cover in residential neighborhoods prevents the runoff of 3.4 million ft^3 of rainfall per two-year 24-hour storm event (Bell 2001).

Green Roofs

Green roofs are an innovative variation on the cool roofs concept. Covering a rooftop with natural materials increases its albedo and, depending on the type of vegetation planted, shades the building. This practice both cools the buildings and takes advantage of the hydrologic properties of vegetation to decrease the amount of runoff.

Cities in action. Atlanta has invested in a green roof construction project on a prominent government building. The plan is a response to the unprecedented rate of green space loss in the region and the associated increase in impervious land-cover, which degrades water quality and stresses the stormwater system. This program hopes to: a) Generate technical

---

[7] Which apply to the graphic arts industry, ethylene oxide sterilizers, alternative fuel stations waste burning and includes their light-duty vehicle scrappage program

data on energy efficiency, stormwater retention, roof membrane life span, and vegetation survival; b) Assess the effect on energy demand, greenhouse gas emissions, and smog reduction so that the costs and benefits of city investments in green roofs can be measured; c) Increase awareness of green roof technology by giving professionals the opportunity to visit a working pilot site (Taube 2002).

The City of Chicago has installed a green roof on its City Hall. This 20,300 square foot roof has reduced air conditioning demand, serves as a roofing demonstration project, and reduces local temperature. It is an "intensive" roof[8] with 20,000 plants (mostly native) from more than 150 species including vines, shrubs, and trees. As the roof matures, the city will measure temperature and stormwater run off and compare it to the adjoining county building's conventional black tar roof.

Lessons learned & results. Initial data from Chicago's roof top garden indicate that it is having a significant effect on ambient temperatures. On a typical afternoon there is a 50^{o}F difference between the surface temperatures of the green roof and the adjoining asphalt roof. The new roof is reducing energy use by an estimated 9,272 kWh (7,372 therms) per year, which translates into a $3,600 energy savings annually (City of Chicago 2001b; Holt 2001).

Atlanta's project also demonstrates how improving regional air and water quality protection can be a motivating factor for local governments to promote green roofs. This is especially relevant for cities, like Atlanta, that are in non-compliance with criteria air pollutants (Quattrochi 1998). Atlanta officials suggest that communities interested in improving local water quality could use green roofs as a mitigation option. Similarly the EPA is currently investigating the possibility of incorporating credit for heat island mitigation programs into a community's State Implementation Plan for compliance with the Clean Air Act (Wong 2002).

The Cities of Atlanta and Chicago demonstrate that "project icons" are an effective way to generate local interest in green roofs. Approaching heat island mitigation on a project-by-project basis – and tracking the accrued benefits – can increase demand for additional mitigation activities. However, this bottom-up strategy depends on several conditions to be successful. Demonstration projects must be chosen wisely so that desired results are achieved. Resources should be made available for project monitoring and analysis. And finally, results should be publicized to ensure that support is garnered from decision-makers and the community (Zalph 2001).

The projects in Atlanta and Chicago also show that while green roofs benefit the environment they come with a high price tag. In the US, the costs of material and labor required for installation of a green roof ($15-20 / ft^2) are twice as high as a traditional gravel-ballast roof ($7-8 / ft^2) (Schloz-Barth 2001a). Additionally, compared to many European countries, green roof contractors in the US are in short supply.

However, if demand for green roofs increases, and additional contractors enter the market, up-front costs will likely decrease. And as the Chicago model illustrates, up-front costs are not the only consideration: viewed over a longer time frame, future energy savings offset the initial cost of materials and labor. To encourage the installation of green roofs, existing incentive programs to reduce stormwater runoff could be easily adapted to

[8] Intensive roofs have at least one foot of soil to support trees, large shrubs, and other vegetation. Drainage and irrigation is complex and multi-layered, resulting in a relatively heavy.

incorporate rooftop vegetation. Similarly, electric utilities or sewer authorities could initiate incentive programs to help offset construction costs (Schloz-Barth 2001b).

Cool Paving

It is also possible to reduce urban temperatures by utilizing reflective paving materials. Examples include utilizing light colored aggregates in asphalt, switching from asphalt to cement, and applying a thin overlay to traditional materials. Highly reflective surfaces can increase the durability and life of an area, and may be designed to allow water to flow through – rather than over – pavements, which results in financial savings. For example, if Los Angeles increased the reflectivity of all its paved surfaces, ambient temperatures would decrease by 1^oF, leading to \$15 million / year in energy savings and saving \$75 million / year in smog related health costs. Over a typical 5-year life span, these saving far outweigh the \$0.35 / m^2 cost of the white surface (Lawrence Berkeley National Laboratory 1999).

Cities in action. In order to take advantage of the increased durability and life expectancy of cooler paving materials, the City of Louisville is applying thin concrete overlays to frequently traveled bus routes. They expect this treatment to microclimate temperatures and reduce maintenance cost and increase the streets' life span (Zalph 2001). In Sacramento, the local Cool Community Program recently partnered with the local utility to construct a parking lot from pervious cement at a neighborhood park. This material is not only lighter in color – and therefore cooler – than traditional asphalt, but also allows water to pass through, decreasing stormwater runoff and filtering pollution (Youngs 2001).

Similarly, Chicago has installed a porous paving system in a neighborhood alley. The new paving system – consisting of fine-grain, light-colored gravel in interlocking cups over a stone and sand base – replaced an asphalt topped road that regularly flooded neighboring property. With the installation of the porous paving system, city officials eliminated the expensive flooding problem, while significantly increasing the reflectivity of the paving material (Holt 2001).

Lessons learned & results. These demonstration projects indicate that the stormwater absorptive capacity of pervious concrete and porous paving systems is significant. Sacramento's pervious parking lot allows 3-5 gallons of water / ft^2 / minute to filter through the surface (Youngs 2001). This high flow-rate minimizes clogging from leaves and other debris. Similarly, the material from which the Chicago alley is constructed absorbs up to three-inches of rainfall in one hour (Holt 2001).

As these paving alternatives perform well during storm events, neither project required the installation of expensive drainage infrastructure, bringing the price close to that of an asphalt project. For example, the Sacramento lot cost \$108,000, while a traditional asphalt surface was estimated at \$101,000 (Youngs 2001). The competitive price tag of pervious materials and their stormwater runoff mitigation properties have prompted both cities to invest in new cool paving construction. Although these paving alternatives are typically used in relatively low-traffic areas, these surfaces significantly minimize water pollution and rural-urban temperature differentials.

Conclusions and Recommendations

Despite early successes at heat island mitigation in select cities, significant barriers to widespread implementation still exist. For most local governments, the prospect of reducing urban temperatures is at best a secondary motivation. More important for driving community policy are the indirect benefits: achieving energy and financial savings, increasing public health and reducing stormwater runoff. The ICLEI – CCP Urban Heat Island Peer Exchange and Policy Adoption Initiative is helping local governments promote mitigation actions by working together to identify the benefits of action and develop strategies to overcome the barriers that hinder widespread adoption.

The Initiative highlights several strategies available to urban areas interested in increasing the penetration of heat island mitigation measures. First, it is important to have both public and political support for mitigation actions and involve multiple agencies in the process. Public input helps to design an effective program that will be accepted and political leadership helps ensure staff support, funding availability, and increases the likelihood that programs are translated into long-term policy. Involving multiple agencies within a locality opens up opportunities for resource-sharing and support that might otherwise be overlooked.

It is often useful to start with small projects that can demonstrate results and help "sell" larger actions. These initiatives demonstrate specific impacts on a community, and if publicized, can be used to educate the public and earn its support. To be sure, public education is an important component of any program because it can increase the use of mitigation techniques in the private sector and ensure a long-lasting and successful initiative.

Additionally, it is important that heat island-related programs and legislation be designed with larger issues in mind. Parties familiar with local environmental, social, and economic challenges should be designated to oversee the program and take appropriate follow-up action. It is also helpful to consider the life-cycle costs of each measure, and not just the up-front costs. Finally, and perhaps most importantly, it is useful for jurisdictions to consider how their programs fit into other community goals, such as air quality and storm water improvement, energy conservation, and sustainability.

Although heat island mitigation policies and programs are not yet commonplace, the experiences of leading communities in this area will be invaluable to the design and implementation of future initiatives.

References

Akbari, H. et al. 1990. "Recent Developments in Heat Island Studies: Technical and Policy." In *Controlling Heat Islands*, K. Garbesi et al. Berkeley, Calif.: Lawrence Berkeley National Laboratory.

Bell, R. 2001. "Olympia's Residential Tree Cover and Site Development." *Investing in Natural Capital: 2001 National Urban Forestry Conference Proceedings. September 5–8, 2001, Washington D.C.* Cheryl Kollin, ed. American Forests.

California Energy Commission. 2001. *Cool Savings with Cool Roofs.* Accessed May 8, 2002, from the Consumer Energy Center web site.

Changnon, S. A., K. E. Kunkel, and B. C. Reinke. 1996. "Impacts and Responses to the 1995 Heat Wave: A Call to Action." *Bulletin of the American Meteorological Society* 77 (7): 1497-1506.

City of Chicago 2001a. *Chicago Energy Conservation Code: 18-13-303.1.* Accessed May 8, 2002, from the City of Chicago Department of Buildings web site.

City of Chicago 2001b. *City Hall Roof Top Garden: Monitoring*. Accessed April 25, 2002, from the Department of the Environment web site.

Daley, Brendan (City of Chicago). 2001 Personal communication. September 25.

Gartland, L. 2002. *Cool Roof Energy Savings Evaluation for City of Tucson Thomas O. Price Service Center Administration Building One.* PositivEnergy, Oakland, Calif.

Gartland, Lisa (PosivEnergy, Inc.). 2002 Personal communication. May 2.

Gartland, L. 1999. "Cool Coatings Heat Up Savings." *Maintenance Solutions.* January.

Hamilton, Carey (City of San Jose). 2002 Personal communication. February 28.

Holt, Alex (City of Chicago). 2001 Personal communication. December 6.

Hunt, Vinnie (City of Tucson). 2002 Personal communication. March 4.

Kalkstein, Larry. (Univ. of Delaware). 2001 Personal communication. December 10.

Keating, Janis. 2002. "Trees: The Oldest New Thing in Stormwater Treatment?" *Stormwater: A Journal for Surface Water Quality Professionals*. 3(2).

Konopacki, S. and Akbari, H. 2002. *Energy Savings for Heat Island Reduction Strategies in Chicago and Houston*, LBNL-49638, Berkeley, Calif.: Lawrence Berkeley National Laboratory.

Konopacki, S. and Akbari, H. 2001. *Energy Savings Calculations for Heat Island Reduction Strategies in Baton Rouge, Sacramento, and Salt Lake City*, LBNL-42890, Berkeley, Calif.: Lawrence Berkeley National Laboratory.

Konopacki, S. and Akbari, H. 1997. *Measured Energy Savings and Demand Reduction from Reflective Light-Colored Roofs for Residential and Commercial Buildings in 11 U.S. Metropolitan Areas*. LBNL-39433. Berkeley, Calif.: Lawrence Berkeley. National Laboratory.

Lawrence Berkeley National Laboratory. 1999. *The Cost of Hot Pavements*. Accessed February 4, 2002, from the Heat Island Group web site.

Longcore, T. et al. 2001. “Assessment of Los Angeles Department of Water and Power Cool Schools Tree Planting Program.” Paper prepared by the Sustainable Cities Program, University of Southern California.

McPherson, E.G., Simpson, J.R. 2000. *Actualizing Microclimate and Air Quality Benefits With Parking Lot Tree Shade Ordinances.* Accessed April 25, 2002, from the USDA Forest Service, Center for Urban Forestry web site.

Miller, K. (Municipal Energy Efficiency Office). 2002. Personal Communication. May 5.

Munves, Susan (City of Santa Monica). 2001 Personal communication. October 17.

Parker, J.H. 1983. “Landscaping to Reduce the Energy Used in Cooling Buildings.” *Journal of Forestry* 81(2):82-83.

Quattrochi, D., Luvall, J. and Estes, M. 1998. "Project ATLANTA (Atlanta Land use Analysis: Temperature and Air quality): A Study of How the Urban Landscape Affects Meteorology and Air Quality Through Time." Paper presented at 2nd Urban Environments Meeting, Albuquerque, New Mexico. Nov. 2-6.

Robinson, Liz (City of Philadelphia). 2001 Personal communication. December 11.

Rosenfeld, A.H. et al. 1997. "Painting the Town White - and Green," *Technology Review*, February/March.

Sacramento Municipal Utility District. 2000. *Shade Tree Program Plan.*

Sarkovich, M. 2001a. “Creating an Energy Efficient Urban Forest.” *Investing in Natural Capital: 2001 National Urban Forestry Conference Proceedings. September 5–8, 2001, Washington D.C.* Cheryl Kollin, ed. American Forests.

Sarkovich, M. (SMUD) 2001b. Personal communication. September 7.

Schloz-Barth, Katrin. 2001a. “Green Roofs: Stormwater Management From the Top Down.” *Environmental Design & Construction*. January 15.

Schloz-Barth, K. (HOK Planning Group). 2001b. Personal communication. October 14.

Scott, K.I., J.R. Simpson, and E.G. McPherson. 1999. “Effects of Trees on Parking Lot Microclimate and Vehicle Emissions.” *Journal of Arboriculture* 25(3): 129-142.

Taube, Benjamin (City of Atlanta). 2002 Personal communication. February 20.

Wong, E (US EPA). 2002. Personal communication. May 3.

Youngs, A. (Cement Promotion Council). 2001 Personal communication. January 30.

Zalph, Barry (City of Louisville). 2001 Personal communication. December 6.