Local government and urban heat island mitigation

Rachel Anderson
Environmental Sciences, UC Berkeley

Abstract

A heat island is an area where the air temperature is significantly higher than its surrounding areas. In cities, heat islands are caused by a combination of reduced vegetation and the high use of impermeable surfaces. Higher temperatures lead to human discomfort, costly energy bills, and an increase in smog. Local government action is essential for mitigating urban heat island (UHI) effects. However, many local governments are unaware of the problem and the steps they can take to combat it. This project evaluated a model ordinance prepared by research consultant Barnie Popkin that may be used as a guideline for local governments in their attempt to reduce city temperatures. This project also analyzed the strategies for UHI mitigation undertaken in creating the Highland Town Center to see how those strategies compared with Popkin's ordinance. The model ordinance could be a useful reference for local governments starting UHI mitigation programs. However, it would serve local governments most ideally if some minor changes were made and if it were a work in progress, promoting the newest and most successful ones as cities facing UHI problems experiment with them.

Introduction

An urban heat island refers to a city that is hotter than its surrounding rural areas. On a clear summer day, an average city is 5°F hotter than its surrounding rural areas (Rosenfeld *et al.* 1995*).* American Forests (1996) reports summer temperatures in Atlanta have been as high as 12°F above surrounding countryside temperatures. Significantly increased city temperatures produce damaging local and global environmental impacts such as increased energy use, resource consumption, and air pollution.

Higher temperatures not only make it miserable to walk on city streets, but they also cause businesses and families to waste billions of dollars on air conditioning. The resources used to provide the extra energy to cool buildings and homes further taps the earth's limited resources. Using these resources causes an increase in urban air pollution and contributes to the global greenhouse effect. In a preliminary study using computer simulations, Rosenfeld *et al.* (1995) note that increasing the albedo, or reflectivity, of the city of Los Angeles's surfaces by a small amount (an average of 0.07) would reduce smog by 10%, equal to removing ten million cars from the road.

A study by Haider Taha (1997) found that the primary contributors to urban heat islands are reduced vegetation and darker surfaces. Replacing vegetation with paved surfaces leads to higher air temperatures because the sun's energy that was previously used for evapotranspiration is now used to heat these surfaces. These surfaces usually have a lower albedo, and thus reflect less of the sun's rays. Pavement, especially dark pavement, sitting in the hot sun during the day will readily absorb the sun's heat, and then it will release that heat into the air to warm the environment around it.

Using a combination of tree planting strategies and lighter paving and roofing materials, cities will be able to save money and energy for years to come. Rosenfeld *et al.* (1995) estimate that widespread use of cooler surfaces and increased vegetation on a national level could reduce cooling energy by a peak of 20% after 20 years of integrating these methods. At this maximum value, $10 billion dollars could be saved nationally.

Tree planting is an inexpensive way to reduce the UHI effect. Vegetation cools buildings, roads, and parking lots by providing shade. Trees improve air quality and serve to reduce the negative effects of stormwater runoff such as flooding and storm sewer problems. Planting trees is relatively inexpensive, and the economic benefits are great. According to

the US Department of Energy (1999), properly positioned trees can save an average of 20-25% of residential energy costs annually.

Using lighter colored pavements and rooftops reduces UHI effects by raising surface albedo. However, these methods are less popular than tree planting for combating UHI effects because they can be initially quite costly. For example, most roads and parking lots are made of asphalt rather than lighter colored concrete mostly for short-term economical reasons. Asphalt is initially cheaper to lay than concrete, but concrete has a lower life cycle cost. Because cities are either unaware or unconcerned about this long-term economic benefit, asphalt continues to be the more popular paving material.

Local government awareness and involvement are key for the mitigation of urban heat island effects, but there are obstacles preventing the implementation of UHI mitigation strategies. According to Lisa Gartland, education about UHI issues is one of the biggest problems facing local government in dealing with its mitigation. And even if the local government understands the issue and wants to work towards UHI mitigation, they then have to convince the public that a properly designed roof, parking lot, or street can really have a positive impact on local micro-climate, energy use, and environment (Gartland 2000, pers. comm.).

Last year, Barnie Popkin, a resources management consultant, drafted a model ordinance for UHI mitigation to help local governments adopt their own ordinances to curb heat island effects (Popkin 1999). This model ordinance will soon be given to the EPA for review, and in the future it may serve as an official recommendation for communities addressing UHI issues across the United States.

The model ordinance begins with a background section, where the local government acknowledges the UHI phenomenon's causes and effects. It also discusses the purpose of the ordinance and a time scale for its adoption. The second section, policy, has many different subsections, including a call for the local government to hold a mini-summit. In this mini-summit, the government and community will discuss UHI effects, mitigation strategies, and build coalitions for ongoing efforts. This section also includes procurement, implementation and monitoring, staffing and resources, financial impact and environmental impact. The third section deals with ordinance issues such as education and outreach, an incentives program, measurement of radiation emissions and solar reflectance, and issuing variances

and exceptions to the ordinance. The final section discusses the standards of physical performance of UHI mitigation.

In this project, I evaluated how a town center being developed in Highland, Utah integrates UHI mitigation strategies and how these strategies follow or stray from Popkin's guidelines. By using the Highland Town Center (HTC) as a real-life example, I was able to better understand the highlights and shortcomings of the HTC strategies as well as Popkin's guidelines in dealing with UHI mitigation.

Methods

Popkin's model ordinance serves as a base against which to compare the UHI mitigation strategies of the Highland Town Center. Popkin's ordinance was written to help local governments deal with their entire jurisdictions (as opposed to just specific areas, such as a town center). Therefore, some of the information in it was superfluous in the scope of this paper. However, I did identify the specific criteria that are directly applicable to the town center.

The Highland Town Center Design Guidelines (Cooper/Roberts Architects, 1999) were completed in October of 1999. I reviewed the Town Center Design Guidelines to see what UHI mitigation strategies were important to the planners. Written in the plans were guidelines for paving roads, landscaping, and building reflective rooftops. However, there was no information on the specific steps taken to integrate UHI strategies into the design guidelines or how these steps were to be carried out.

I then conducted an interview with Soren Simonsen, an architect with Cooper/Roberts Architects, the firm that prepared the guidelines. I asked him many questions about the Highland Town Center and about the town of Highland itself. I wanted to know how and why the idea of creating a town center arose and how important UHI mitigation was when drafting the design plans. We discussed what sources he used to help him integrate UHI strategies, what the actual strategies were, and how the town intends to monitor them. I asked him about the progress of the town center construction and the challenges he has come across in construction.

After conducting the interview, I first looked at the most basic and quantifiable information to compare to Popkin's ordinance: reflectivity and shading requirements for

rooftops, parking lots, and roadways. I compared Popkin's physical standards of performance to the standards stated in the design guidelines.

Apart from Popkin's physical standards of performance, I also selected other less quantifiable sections in his guidelines that would apply to the town center. It was important to keep in mind that UHI mitigation was not the main priority in building the town center, so some parts of the model ordinance would be irrelevant to the town center. Also, integrating UHI strategies is a relatively new idea in this area, so some parts of the model ordinance are unfeasible at this stage because of lack of research and resources (financial and human) to implement them. I concluded that the background, staffing and resources, and variances and exceptions sections were most applicable to the HTC.

In order to understand more about local government involvement in the creation and implementation of UHI mitigation strategies, I analyzed the steps involved in making UHI mitigation as an important point in the design guidelines and the parties involved in achieving this.

Results

Model Ordinance Popkin's model ordinance is written "in terms of meeting standards of performance rather than in prescribing specific building materials or specific trees" (Popkin 1999). It recognizes that the extent of local government jurisdiction and local UHI conditions varies, and it serves to assist cities in developing policies and ordinances appropriate for their areas.

The information most applicable to the Highland Town Center is included in the section of the ordinance relating to the standards of physical performance. The first standard that is directly relevant to the town center discusses lightening and greening of rooftops. All public low-sloped and flat roofs must follow the EPA Energy Star standard for roof reflectivity, which is 65% when new and 50% within 3 years. The suggested measures to achieve this standard are:

- lightening rooftops with light-colored, non-metallic surface coatings
- harvesting heat from roofs with photovoltaic cells (solar energy)
- planting a roof garden to cover 65% of the roof area with vegetation

The next standard in the ordinance involves the lightening and greening of roads and pavements. A surface reflectivity of 25% or more can be (but does not necessarily have to be) achieved by a combination of the following methods:

- pervious pavements and parking lots
- lightening paved surfaces with products such as reformulated cement or asphalt using light-colored aggregates and without dark pigments
- narrower and/or tree shaded streets
- placing suitable shade trees and other vegetation to shade at least 50% of surfaces after 15 years

The final standard involves using shade trees and vegetation to reduce UHI effects. Each community should compile a list of suitable shade trees for their ordinances.

In this model ordinance, compliance with all of these standards would be necessary to obtain a building permit unless it can be proved to the mitigation commission that compliance is impractical. Measuring radiation emissions and solar reflectance should be done according to American Society for Testing Materials (ASTM) Standards or the equivalent. ASTM Standard E1918 uses a pyrometer to measure incoming and outgoing radiation; ASTM Standard E1980 uses temperatures measured during peak sunlight hours as a Solar Reflectance Index.

The ordinance also calls for staff to perform various tasks relating to UHI regulation. The local government adopting the ordinance will appoint members to a UHI Mitigation Commission that will, among other duties, have the authority to implement exceptions and variances to the ordinance on a case-by-case basis. It will monitor, document, and conduct outreach in UHI issues. A staff member will provide research and education for UHI mitigation. Also, a reference library will be created to document information such as research and implementation of UHI mitigation strategies.

Highland Town Center Highland is a small town located approximately 30 miles south of Salt Lake City. Its current population is 8,000 residents, and it has experienced an annual growth rate of 10-15% over the past five years. It currently remains a small town, with the residential density about 1 household (five to six persons) per acre. However, given its growth rate, it has the potential to become a highly populated suburb in years to come. Daily average summer and winter temperatures are about 90 to 95°F and 30 to 35°F, respectively (Simonsen 2000, pers. comm.)

Since the city was incorporated in 1977, it has been entirely zoned for single family residences. About five years ago, Highland residents took an interest in having a local shopping center, bank, and offices to provide basic services for their growing community. Previously, they had to drive to the main highways of surrounding cities to perform basic tasks such as shopping. They were also concerned with the growing population and feared unmonitored growth. They shared their concerns with the local government's planning commission, which formed a task force with community members to discuss what exactly they wanted out of the center. The task force concluded that they wanted to create a commercial and civic center to serve as a gathering place for community members and to provide infrastructure so that residents could take advantage of basic services locally.

The planning commission created rough plans based on the guidelines the task force provided them. The commission held a community design workshop, or charette, with broad participation by residents, design professionals, elected officials, and city staff. It then hired Cooper/Roberts Architects to finish the plans and to create design standards that would help guide future commercial development patterns for the community. The design team at Cooper/Roberts focused on creating a town center that was pedestrian friendly. In order to achieve this, the team knew that part of the design strategy would involve taking measures to keep temperatures low so that residents would be comfortable and encouraged to walk.

The design team leader, Soren Simonsen, an architect and urban designer, collaborated with Camille Russell, an environmentalist in Salt Lake City working with urban heat island mitigation strategies. Russell discussed incorporating minimum reflectance requirements for paved surfaces and rooftops to lower ambient air temperatures and keep the center pedestrian friendly. The two identified positive ways to incorporate generous landscaping in and around parking lots and buildings. Highland had already established the Highland Shade Tree Ordinance, so any trees and foliage selected for landscaping were to be in compliance with that ordinance. The design team also incorporated strategies for reducing the overall parking demand for larger retailers by adding requirements for shared parking facilities and for creating incentives that encourage employee use of public transportation.

Simonsen took the ideas back to the planning commission, and they agreed to adopt the following strategies in the design standards. First, residential development is encouraged to use gabled roofs and earth tones (Cooper/Roberts Architects 1999). Commercial and retail

buildings should use landscaped yard areas as buffers between the building, street, and parking lot. Low-sloped roofs on commercial and civic buildings should have a minimum solar reflectance of 0.75 and the use of rooftop gardens is encouraged when applicable. Second, the guidelines state that paved roads and parking lots should be constructed with concrete or similar light colored paving to reduce surface heat, ambient air temperature, and life-cycle costs. Next, parking strips and medians should be landscaped with low maintenance ground cover, and drought tolerant trees and vegetation should be planted to provide maximum shade in compliance with the Highland Shade Tree Ordinance. Finally, parking lots paved with asphalt must reserve 20% of the interior area for landscaping islands while concrete lots must reserve 10%.

A Design Review Board was selected to work with developers and ensure that they meet these guidelines. Currently, 40 to 50 acres of the reserved 80 acres for the town center district are in the design process. The development is market driven, and Simonsen estimates construction will be completed over 10 to 20 years. There is still a lot of speculation as to the outcome of incorporating UHI mitigation strategies into the town center with regard to buy-in by developers and continued support by city officials responsible for approval of future development plans. The design team and elected officials, however, are optimistic that the results will be very positive for the Highland community, and will serve as a model for other communities in the region.

Discussion

The Highland Town Center Design Guidelines incorporate many of Popkin's strategies for UHI reduction. The degree to which the guideline strategies and Popkin's ordinance coincide or differ varies with each strategy.

First, the HTC guideline for minimum reflectance standard of public low-sloped roofs is 0.75, exceeding the standard in Popkin's ordinance by 0.10. Like the model ordinance, the guidelines also mention the use of rooftop gardens when applicable to the specific project. The guidelines do not mention using photovoltaic cells, most likely because of the high initial cost of incorporating them.

The HTC Guidelines also encourage the use of earth tones for residential development, a factor that Popkin's ordinance did not mention. Although the local government may not

have sufficient jurisdiction to regulate residential buildings, encouraging UHI mitigation strategies in residential construction sends the positive message that everybody is responsible for UHI mitigation.

Second, Popkin calls for a surface reflectivity of 25% for roads and pavements. The HTC guidelines do not have this specific reflectivity requirement. Rather, they merely state that when paving roads and parking lots, concrete and other light-colored pavements should be used. Concrete and other light-colored pavements alone may not meet this standard a few years after construction because of darkening by dust and dirt accumulation. It may be beneficial for the design team to have a stricter guideline for surface reflectivity. This would establish a strong base by which to negotiate UHI strategies when discussing design and construction with the contractors.

Simonsen reports that the design team has met some opposition regarding the pavement materials guideline with respect to the construction of large parking lots because concrete is initially more expensive than asphalt. Furthmore, developers amortize their costs over a period of 10 to 20 years. Properly mixed concrete will typically last 40 to 50 years while asphalt paving typically lasts about 10 to 15 years, and requires top coating about every five years. Concrete is cheaper in the long run, but for developers, charging clients more money for material that will be amortized over 40 to 50 years does not make economic sense. The design team has made provisions for using asphalt paving in such instances, but they have offset negative UHI effects by requiring twice as much interior landscaping, including shade trees (Simonsen 2000, pers. comm.). Perhaps the design team and city should require lifecycle cost analysis when hiring a contractor to pave the roads and lots. This is a case where Simonsen and his team could use the strict 25% reflectivity guideline to encourage the use of concrete and other light surfaces.

The guidelines also call for parking strips and medians to be landscaped to provide maximum shading in accordance with the Highland Shade Tree Ordinance. In parking lots, the guidelines reserve a certain percentage of the interior of the lot for shade trees (10% for concrete lots and 20% for asphalt). In contrast, Popkin's ordinance monitors the shade coverage (50%) rather than the interior coverage. Because different types of trees give different coverage, it may be more effective to incorporate shading requirements rather than interior coverage.

The third step requires compiling a list of shade trees and vegetation to reduce UHI effects. Highland already has a Shade Tree Ordinance in effect, and trees and foliage will be selected according to this ordinance.

Finally, Popkin's ordinance calls for a UHI Mitigation Commission to monitor and document UHI strategies. It seems that the Design Review Board, among many other duties, serves as this mitigation commission. The Board works with the architects and contractors to ensure that their guidelines are being followed as closely as possible. Perhaps Design Review Board staff should be assigned to research the UHI mitigation policies and technologies. The staff could continually monitor the UHI mitigation progress of other cities and towns in order to learn about and possibly incorporate new strategies into the Highland Town Center. Establishing a reference library would also be a good step to monitoring this research and ensuring that those in charge over the next ten to twenty years have all the resources possible to keep UHI mitigation a priority in the construction of the town center. The staff could also document the steps involved in incorporating UHI mitigation in the HTC Design Guidelines and its implementation to serve as a model for other cities and towns with the same UHI problems.

Conclusion

Using light-colored surfaces, planting trees, and using reflective roofing materials can lower a city's temperature between 1 and 5°F. It could save millions of dollars nationally on energy costs and reduce air pollution.

Cities and towns must take their own initiative to implement these programs. Popkin's model ordinance is beneficial to local governments because it provides a reference by which they can design and implement their own UHI mitigation strategies. The Highland Town Center is a good example of an area that has good UHI mitigation strategies but could be served further by Popkin's model ordinance. His ordinance could give the Design Review Board new ideas on how to make their guidelines stronger and progress the UHI mitigation process even further.

At the same time, Popkin's model ordinance can be a work in progress of sorts. Over time, it may be helpful to piece together information from various local governments (such as successful mitigation measures or examples of how to deal with certain kinds of opposition)

so that local governments can turn to his ordinance for guidance in their own dealings with UHI mitigation.

By referring to this model ordinance and looking to towns such as Highland as examples, other cities will have the proof that UHI reduction initiatives really work. These models will also provide them with strategies that the cities can draw ideas from to implement their own UHI reduction policies and tactics.

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