State Clean Energy-Environment Technical Forum
Urban Heat Islands (UHI), Clean Energy, and Air Quality
May 10, 2007
Call Summary

Participants: 51 participants from 19 states and several national and international organizations (see the participants list at http://keystone.org/html/documents.html#heat)

Key Issues Discussed

- Co-benefits of heat island mitigation – air quality, energy savings, public health
- Methods for measuring the UHI (air and surface temperature differences)
- Mitigation measures – cool roofs, green roofs, porous paving, urban forestry
- Measuring mitigation impacts on UHI

Summary of Presentations

Note: All of the presentations from this call are available for download at http://www.keystone.org/html/documents.html#heat . Please refer to these documents for additional detail on the presentations.

A. Welcome and Introduction – Julie Rosenberg, Chief, State and Local Branch, U.S. Environmental Protection Agency (EPA)

- As summer approaches, EPA gets many inquiries about what can be done to address the UHI effect.
- There are several reasons for the growing interest in UHIs: 1) temperatures building up in urban areas, 2) energy impacts, and 3) public health concerns.
- Some communities have done a good job of linking energy savings, air quality mitigation, and public health in addressing UHIs.
- There are multiple direct benefits of mitigating UHIs, although the co-benefits tend to be the easiest to quantify.
- EPA is working with local and state governments to share information and advance strategies for addressing UHIs. The agency is also serving as a clearinghouse of information on heat islands and is working to connect experts with communities looking for assistance.
- EPA sponsors quarterly heat island conference calls to foster discussion on this issue. Eva Wong can add interested individuals to the participant list for those calls (contact Eva directly for more information at wong.eva@epa.gov).
- EPA also translates research into guidance for communities, which helps turn very technical information into understandable action items. The agency provides funding for the new National Center of Excellence on SMART Innovations for Urban Climate and Energy. The center, located at Arizona State University (ASU), seeks to develop a new generation of sustainable materials and renewable technology innovations (SMART Innovations).

B. The Urban Heat Island (UHI) – Causes, Impacts and Mitigation Strategies – David Sailor, Associate Professor, Department of Mechanical and Materials Engineering, Portland State University

- **Definition of an urban heat island:** An urban heat island is an area of higher temperatures in an urban setting compared to the temperatures of the suburban and rural surroundings. It appears as an island in the pattern of clustered surface temperatures on a map. (See figure in presentation of a typical summer afternoon heat island.)
- **Complexities of UHIs**
  - They are largest in the early morning and in winter.
  - They depend on large-scale weather.
  - Distinguishing between surface temperatures and air temperatures is important. Increased air temperatures alone do not necessarily indicate the presence of a UHI.
  - The difference between urban and rural temperatures tends to be the focus of UHI analysis, but relative humidity is also important.
- **Effects on ozone concentrations**
  - Ozone concentrations are affected by emissions and chemical reactions, both of which are functions of UHIs.
  - Emissions from both plants and humans tend to increase by 5-10% per 1 degree of ambient air temperature.
  - UHIs create their own inversion, which affects pollutant mixing and dispersion.
  - Atmospheric chemistry is important, as key ozone reactions are temperature-dependent.
  - These connections have been well documented by actual monitoring data.
- **Energy impacts from UHIs**
  - It is not uncommon for the summer electricity load to increase 3-5% with each degree of urban temperatures.
  - This affects how much additional capacity needs to be built.
- **Public health concerns from UHIs**
  - Heat kills more people than hurricanes, tornados, and other natural phenomena do.
  - UHIs also affect morbidity, mortality, and worker productivity.
- **Causes of UHIs**
  - Mitigation measures tend to focus on short-wave (solar) radiation and latent heat, but sensible heat, heat caused by humans, and long-wave radiation also play a role in the formation of UHIs.
  - Urban surfaces typically do not reflect solar radiation (low albedo) and are the primary cause of UHI, as shown in aerial infrared images in the presentation.
  - Lack of vegetation also reduces water retention and evaporative cooling. As seen in aerial infrared photo of Atlanta, higher temperatures in the heart of the city, which has less vegetation and soil
- **Measurements of UHIs**
  - Satellite pictures show a high degree of variability of surface temperatures.
  - Air temperature heat islands are measured with weather stations or monitoring equipment mounted on vehicles driving traverses. This data is linked to geographic information systems (GIS) data.

- **Mitigation measures**
    - One tool for mitigating UHIs is to increase evaporative cooling by installing green roofs, shade trees, and porous pavement.
    - Increasing urban albedo by building more structures with highly reflective surfaces is also effective, although it has met with some resistance in the residential sector. The Lawrence Berkeley National Laboratories have addressed this by engineering coatings that reflects near-infrared wavelengths, which allows dark colored roofing products to maintain high reflectivity.
- **Potential impact of mitigation strategies**
    - To determine how much impact can be achieved from a particular level of mitigation, one needs to create a model of the urban area as it is and then create a different model reflecting the proposed changes. This can be linked to other models for air quality and energy consumption.
    - There is an existing model that is an excellent starting point for calculating the impact of mitigation measures. It is available at www.Heatislandmitigationtool.com

C. Cool Roofs in California – Ronnen Levinson, Lawrence Berkeley National Laboratories (LBNL)

- **Background**
    - Roofs make up approximately 20% of the surface in urban areas.
    - Cool roofs reflect sunlight and stay cool due to high reflectivity and thermal emittance.
    - Communities can promote the use of cool roofs by requiring that new developments meet certain building standards, such as those prepared by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (AHSRAE) and some states.
    - Utility rebates also provide a strong incentive for installation of cool roofs.
- **Direct benefits of cool roofs**
    - Lower energy use due to cool interior
    - Reduced peak demand for electricity due to lower energy use for cooling during the highest temperatures of the day
    - Reduced need to run peak power plants, which are inefficient and expensive
    - Extended life for membrane or asphalt roof materials designed to meet UHI impacts (these materials reduce the day and night temperature differentials and thereby endure less environmental stress and last longer)
- **Indirect benefits of cool roofs**
    - Reduced outside air temperature
    - Reduced smog
    - Reduced wear and tear on air conditioners, because they are not required to work as hard
    - Increased equipment life
- **Penalties from cool roofs**
    - Could cause increased heating demand in winter

    - Because most homes are heated with local fuel such as natural gas or fuel oil, increased heating demand may cause more local pollution
- **Categories of roofing materials**
    - The most common cool roofing materials are white membranes or coatings for flat roofs that are not visible from the street. They are very efficient and reflect 70-80% of sunlight.
    - White roofs on pitched roofs also exist, but they are at an aesthetic disadvantage, because they are visible from the street and are not perceived as attractive.
    - There is now a full pallet of cool roof colors available for sloped or pitched roofs, for example cool clay tiles and metal roofs.
- **Lawrence Berkeley National Laboratories' Cool Roofs Simulation**
    - LBNL has simulated building energy savings from cool roofs and has helped bring cool roofing materials to market. Cool roof technologies have been available for a long time. In the last 5 years, colored cool roof products for flat roofs have emerged.
    - LBNL simulated urban and surrounding areas and found that, for example, in 1997 Phoenix could have enjoyed $37 million in savings from cool roofs (gray to soiled white). The extent of potential savings for other cities depends on city size and climate. However, LBNL estimates that the U.S. as a whole could see $1 billion in savings from cool roofs.
    - Calculators to help determine the potential benefits of cool roofs are available from both the U.S. Department of Energy (DOE) and EPA.
- **California's Title 24 Building Energy Code**
    - $0.10-$0.20 rebates by utilities have made a difference in promoting cool roofs.
    - Title 24 allows for a prescriptive approach, which requires that certain building elements, including cool roofs, be checked off a pre-determined list. (The California Energy Commission is still considering a number of additional elements for this list.)
    - California also allows for a performance based approach.
    - The incremental cost for a cool roof is generally less than 20 cents per square foot. Energy savings typically offset the additional cost.
    - LBNL, with other groups including the EPA, started the Cool Roof Rating Council (CRRC), which is an independent organization that has established a rating system for displaying accurate reflectance and thermal emittance data on cool roof products. More information is available at www.coolroofs.org.

D. Urban Forestry and Air Quality Impacts – David Nowak, Research Forester, U.S. Forest Service

- Negative impacts from urban heat islands include reduced visibility, environmental problems, and public health concerns.
- Researchers took an interest in the role of vegetation in air quality in the mid-190s and began to study the effect of trees on urban air quality. They found that:

- Urban forestry could reduce temperatures, increase energy conservation, and reduce emissions
- Increased canopy cover 20-40% of an area typically reduced ozone by 1 part per million (ppm) in the daytime
- Tree species was not important, but wind speed and boundary layer height were.

- Early studies were repeated in New York City. Results indicated that:
  - A 10% increase in tree coverage can reduce 1-hour ozone levels by 4 ppm and 8-hour ozone by 1 ppm.
  - There is no discernible advantage to planting trees in more than 10% of the area. Areas planted with 30% tree coverage exhibited the same results as areas with 10% coverage.
- Maryland recently submitted their state implementation plan (SIP) to EPA. It includes urban forestry as a mitigation element and proposes changing canopy from 20 to 40% with 1.3 ppm ozone reduction as the anticipated benefit. However, they are not asking for credit for this reduction in the SIP.
- EPA's 2004 document on emerging and voluntary measures in SIPs opened the door for trees to be considered as a mitigation tool. Both the emerging and voluntary categories treat trees as providing uncertain air quality benefits and therefore only allow a 6% credit of the estimated total benefits toward meeting air quality targets.
- Voluntary measures are not enforceable at the source.
- More information about the role of urban forestry in mitigating heat islands is available at www.treescleanair.org.

Questions and Answers

How do you get air quality credit for trees?

You must understand the baseline canopy cover, model the increase in canopy cover, and demonstrate your plans for implementation and verification.

How do you verify increasing canopy cover in a changing landscape? Sprawl and urban development may reduce cover in opposition to planting.

It is difficult to demonstrate that tree planting is keeping pace with tree loss. You need to decide whether to count the number of trees or the overall canopy cover. The net effect of planting and development can be documented by satellite and/or aerial photographs. Forest land lost over the next 50 years is predicted to be an area the size of the state of Pennsylvania, so preservation of existing tree cover can be an important strategy. The greatest benefits tend to come when the canopy of trees is mature, so maintenance of newly planted and existing trees is very important.

Participant comment: In Washington, D.C., they included trees in a voluntary program for no credit. The weight of evidence was taken from the Maryland program. In D.C., they are losing more trees than they are gaining. They experienced some resistance to the use of the phrase "canopy preservation" as a measure to reduce ozone, so they focused their terminology on "tree planting."

In modeling reflectivity, did you model evapo-transpiration?

We used the standard EPA model and then looked at changes in albedo. I am not sure if that model looks at evapo-transpiration directly.

Is anyone looking at the impacts of green roofs in terms of temperature or air quality?
Boston has been looking at the impacts on temperature from green roofs.

Are you looking at vegetation other than trees when modeling impacts from green roofs?
We are also looking at grasses, shrubs, and trees in modeling green roofs.

Is anyone looking at putting control measures in the baseline of a state implementation plan?
In the Houston and Sacramento SIPs, urban forestry is not included in baseline, but perhaps it is in Alabama, Maryland, or Washington, D.C. Control measures will be taken off the top.

E. State and Local Strategies, David Hitchcock, Director, Sustainable Transportation Programs, Houston Advanced Research Center

- UHI factors are multifaceted, and each can be dealt with in a variety of ways. Consequently, there is a wide range of local policies that can be implemented to address the problem.
    - There are at least 35 different mitigation measures under four different categories: vegetation, roof, paving, and "mixed."
    - Some are not designed directly for UHI mitigation; in fact, comprehensive UHI policies are the exception, not the standard.
- Cool Houston Plan
    - This is an example of a more comprehensive program. It includes educational efforts and sets forth specific actions intended to address multiple audiences (paving and roofing professionals and various decision makers).
    - Working within the SIP timeframe has been very challenging, but making changes in local policies is important above and beyond SIPs.
    - The Cool Houston Plan did not emerge from a single event. It receives funding from several sources, including EPA, DOE, NASA, private foundations, and a range of stakeholders.
    - The Plan's implementers are trying to impact decision processes on paving and roofing surfaces to result in a change in albedo over a given period of time.

<u>Questions and Answers</u>
Please expand on the opportunities to use paving to reduce UHI effects.
There are new materials that have improved emissivity and reflectivity. For roadways and parking, the typical materials are concrete, cement, and/or asphalt. Porous paving is an alternative that comes in a variety of forms, allowing it to be used in a variety of circumstances (including grass for occasional uses). The transition to alternative paving products is difficult, largely because technology transformation is a problem. The products do exist already and are affordable.

What are the cost differentials on paving?
Projects vary so much that it is difficult to make generalizations. However, porous paving will cost a little more, so you need to consider how much runoff the pavement will need to handle to determine the appropriate material. For roadways, you will need to pay for the cost of removal of existing materials first.

What is the typical longevity of porous pavement?
Different porous paving applications can be designed for different uses. Relatively new materials will last about 25 years.

What are the relative merits of green roofs compared to light-colored, highly reflective roofs?
White roofs are going to be cheaper with more energy savings. With any roofing technology, it is not cost-effective to replace a roof just for energy benefits. Building owners should wait until they need to replace the roof for other reasons. Green roofs are more complicated systems and are more expensive. Evaporative cooling is an added benefit, but solar reflectiveness is lower than with white roofs. If the green roof is designed to also serve as a recreation area, the additional social benefits may make it worthwhile economically.

<u>Comments/Responses via Email Exchange after the Call</u>

Comment on Comparative Benefits of Green and White Roofs
Here in Philadelphia we are in the process to study and construct a green roof for energy efficiency, and air quality purposes. We looked through some literature for our study. I found that a green roof has a lot of advantages over a white roof for the following reasons:

- Green roofs can be used in many applications, including industrial facilities, residences, offices, and other commercial property.
- Green roofs are an attractive roofing option that can reduce urban heat islands by providing shade and through evapo-transpiration, the release of water from plants to the surrounding air.

Green roofs also:

- Reduce sewage system loads by assimilating large amounts of rainwater
- Absorb air pollution, collect airborne particulates, and store carbon
- Protect underlying roof material by eliminating exposure to the sun's ultraviolet (UV) radiation and extreme daily temperature fluctuations
- Serve as living environments that provide habitats for birds and other small animals
- Offer an attractive alternative to traditional roofs, addressing growing concerns about urban quality of life
- Reduce noise transfer from the outdoors
- Insulate a building from extreme temperatures, mainly by keeping the building interior cool in the summer

By contrast, white roofs have only few advantages and are mostly used for reflecting solar heat from the sun. We should also not forget the disadvantage for the white roof, which are a) people do not like it (also mentioned by the presenter), and b) it has easily become dirty and within a few weeks it reduces its solar reflectance value.

Remember there are two types of green roofs, intensive and extensive. Intensive green roofs are very advantageous once the structural system of the roof is fitted for extra loads.

Presenter Response (Dave Sailor)
We actually have done quite a bit of work at Portland State University on modeling and measurements of green roof systems. The Department of Energy recently released my green roof module as part of their release of EnergyPlus v. 2.0 (April 2007). This module allows the energy modeler to investigate the energy implications of green roof design options. We've found some interesting benefits in terms of both summer and winter energy savings. As the attendee notes, however, there are many other benefits. In Portland, the key focus is on the stormwater runoff reduction (money saved in treatment and in EPA fines for Combined Sewer Overflows).

Additional Response (Eva Wong, EPA)
I think one of the big differences between green and cool roofs is the incremental cost. One question is, "What's the payback period of a green roof?" (Of course, it will vary depending on type.) Green roofs do provide multiple benefits, and fortunately people are gathering data on them, but are they the most cost-effective way to achieve these benefits? By comparison, I think there are a lot of data on the energy cost savings from cool roofs.

NEXT TECHNICAL FORUM CALL: June 14th, from 2:00 p.m. to 3:30 p.m. ET
TOPIC: Using Co-Benefits to Advance Clean Energy Programs