STATE CLEAN ENERGY -- ENVIRONMENT TECHNICAL FORUM
Call #23: Urban Heat Islands (UHI), Clean Energy, and Air Quality
May 10, 2007, 2:00 p.m. - 3:30 p.m. EST

BACKGROUND

I. Introduction

The term "urban heat island" refers to elevated surface and air temperatures in built-up areas compared to nearby rural surroundings. On average, urban areas are generally between 2 to 5°F warmer than the natural land cover around them. These elevated temperatures lead to a number of energy, environmental and public health impacts described below. Communities across the country are adopting strategies that help mitigate urban heat island impacts. The efforts are often driven by a broader energy or environment objective and as such can have multiple benefits. Communities are also working to help their residents adapt to excessive heat events that are exacerbated by heat islands.

A. What causes urban heat islands?

Heat islands form as cities replace natural land cover with buildings, pavement, and other heat absorbing, impervious infrastructure. These changes contribute to higher urban temperatures in a number of ways:

- Removing trees and vegetation minimizes the natural cooling effects of shading and evaporation of water from soil and leaves (evapotranspiration).
- Tall buildings and narrow streets heat air trapped between them and reduce air flow.
- Waste heat from vehicles, factories, and air conditioners further warm the air, exacerbating the heat island effect.

Heat islands are also influenced by a city's geography and prevailing weather conditions. For example, strong winds and rain can flush out hot, stagnant air from city centers, while sunny, windless conditions can exacerbate heat islands.

Urban heat islands are distinct from temperature changes due to global warming. An urban heat island describes local-scale temperature differences between urban and rural areas. In contrast, global warming refers to the gradual rise of worldwide average surface temperatures.

B. Why are heat islands a concern?

Heat islands are of particular concern during the summer months. Summertime heat islands are tied to:

- Increased energy use and electricity reliability concerns. In most areas, steadily increasing downtown temperatures over the last several decades mean community-wide demand for electricity is used to compensate for the heat island effect. In U.S. cities with populations over 100,000, peak utility loads from increased cooling needs increase 1.5 to 2.0% for every 1°F increase in summertime temperature, adding stress to the electric system.[1]

- Increased emissions and stormwater temperatures. Heat islands degrade air quality in two ways: (1) the additional cooling demand increases emissions of NOx, particulates, mercury, and other pollutants from electric generators and, (2) locally, the elevated temperatures contribute to the formation of ground level ozone, which is driven by temperature in combination with sunlight and atmospheric concentrations. Increased electricity generation also increases emissions of greenhouse gases associated with global climate change. Further, hotter pavement and roof surfaces raise the temperature of stormwater runoff, which can lead to thermal shock in downstream aquatic ecosystems.

- Public health concerns. Heat islands amplify extreme hot weather events, which increase the risks of heat stroke physiological disruption, organ damage, and even death – particularly in vulnerable populations such as the elderly. There are also secondary health impacts, such as asthma, related to elevated ozone levels and increased emissions of particulate, mercury and other pollutants.

It is important to note that for cities in some colder climate zones, heat islands can be beneficial, as they help reduce heating costs and cold-related deaths. However, for most U.S. cities, the negative impacts of summertime heat islands outweigh the benefits of wintertime warming.

C. What can be done to mitigate heat islands?

Communities across the U.S. are focusing primarily on the following two heat island reduction strategies:

- Increasing tree and vegetative cover. Trees and vegetation help lower surface and air temperatures by providing shade - which reduces the amount of sunlight that reaches a surface - and by evapotranspiration - in which heat from the air is used to convert water into water vapor. Researchers have found that vegetation can reduce surface temperatures from 20 to 40°F.

[1] Cooling our Communities: A Guidebook on Tree Planting and Light Colored Surfacing. U.S. EPA, 1992. Document # 055-000-00371-8.

- Installing cool -- mainly reflective -- roofs. “Cool roofs” work in two ways: 1) they are designed to reflect away the majority of the solar energy that reaches their surfaces; and 2) they have high thermal emittance, which means they release a large percentage of the solar energy they absorb. On a hot, sunny, summer day, a conventional roof can reach temperatures as high as 190°F, contributing to surface and atmospheric heat islands. A cool roof, however, may be as cool as 120°F under the same conditions. Programs such as ENERGY STAR for cool roof products help consumers identify cool roofing technologies. (See resources, below.)

Two additional technologies that are emerging as mitigation strategies include green roofs (also called "rooftop gardens" or "eco-roofs") and cool – mainly reflective or permeable – pavements.

- A green roof is a vegetative layer grown on a rooftop. It can be as simple as a 2 inch covering of hardy alpine-like groundcover or as complex as a fully accessible park complete with trees. Much like trees and vegetation, green roofs reduce temperatures by providing shade and evaporating water. As with cool roofs, green roof peak temperatures are generally much lower than conventional roofs. Chicago found its green roof peak temperatures ranged from 91 to 119°F compared to the conventional control roof in the adjacent building, which reached 169°F. The demand in the U.S. for these roofs is growing. A green roof trade association estimated an 81 percent increase of green roof square footage from 2004 to 2005, resulting in over 2.1 million square feet of completed green roofs.

- Cool pavements either reflect a high amount of solar energy, have thermal characteristics that can keep them cooler, or are permeable so that they evaporate water. Solar reflectance is measured on a scale of 0 to 1, with 0 meaning all the sun’s energy is absorbed and 1 indicating that all sunlight is reflected. Researchers have found that increasing the solar reflectance of a pavement by 0.1, for example by using light-colored aggregate in the pavement mix, can result in a 7°F decrease in its surface temperature. Researchers are still assessing the benefits and costs of cool pavements and, at this time, there is no official standard or labeling program to provide a consistent definition or expectation of performance.

D. How are communities adapting to heat island impacts?

In response to excessive heat events, which heat islands can exacerbate, many cities are pursuing adaptation strategies, which include developing heat-response programs. These programs generally involve cities predicting and taking steps to decrease the public's exposure to excessive summertime heat including coordinating comprehensive, city-wide responses that include direct assistance to vulnerable individuals. Some examples of "best practices" include:

- Activating telephone heat hotlines
- Alerting neighborhood volunteers, family members, and friends
- Providing public air-conditioned buildings and transportation to these facilities
- Working with local "aging agencies" to educate at-risk individuals
- Coordinating with local utility companies to ensure that service to residential electricity customers is not shut off during a heat wave

E. What benefits do heat island reduction strategies provide?

The heat island reduction strategies described above provide multiple benefits – beyond reducing surface and air temperatures. Local and state governments are investing in heat island mitigation for their contributions to many of these benefits, including improving the local environment, energy system, public health, and overall quality of life. Benefits from heat island reduction strategies are briefly summarized below:

? Trees and vegetation and green roofs reduce heating and cooling energy use and associated air pollution and greenhouse gas emissions, remove air pollutants, sequester and store carbon, help lower the number of heat-related deaths and illnesses, improve stormwater control and water quality, reduce noise levels, create habitats, improve aesthetic qualities, and increase property values.

? Cool roofs lower cooling energy use, peak electricity demand, air pollution and greenhouse gas emissions, heat-related deaths and illnesses, and solid waste generation due to less frequent re-roofing.

? Cool pavements can indirectly help reduce energy consumption, air pollution, and greenhouse gas emissions. Depending on the technology used, cool pavements can improve stormwater management and water quality, increase surface durability, enhance nighttime illumination, and reduce noise.

The USDA Forest Service calculated the benefits and costs of street and park trees in five U.S. cities and found that every dollar invested retuned annual benefits of $1.37 to $3.09.[1] Of all the benefits that cool roofs can provide, energy savings are the best documented. There are many factors that influence the exact savings a building will accrue, such as location and insulation levels, but in general, most studies show an average energy cooling load savings of 20% and a reduction in peak demand of 10–15 percent. The incremental cost of a low-sloped cool roof product, compared to its conventional equivalent, ranges from zero to approximately twenty cents per square foot.

II. Examples of Mitigation Efforts

In addition to local and state governments, utilities, universities, and NGOs are also involved with heat island mitigation activities. Some highlights of various initiatives are below:

A. Arizona

- **Phoenix –** Phoenix's night-time urban heat island has reached 12°F, which is contributing to extended periods of peak energy demand and reducing summer tourism. The city is working with Arizona State University (ASU) to test and install a variety of cool pavement applications. Through ASU's National Center of Excellence on SMART Innovations for Urban Climate and Energy, researchers and city officials are collecting

[1] McPherson, E.G., Simpson, J.R., et al. December 2005. "Municipal Forest Benefits and Costs in Five U.S. Cities." Journal of Forestry. 411-416.

lab and field data on many pavement technologies, with the goal of providing local and state public works and transportation officials with practical information to help guide their material selection choices. See: www.asusmart.com

B. California

- Since 2005, California has included cool roofs in its Title 24: Energy Efficiency Standards for Residential and Nonresidential Buildings, with the goal of reducing overall and peak summertime air-conditioning demand. This code change has transformed the cool roof market, as these technologies are part of a portfolio of energy efficiency options building owners can select from to meet the standards. Cool roof requirements apply to low-sloped roofs of newly constructed buildings and major re-roofing projects for existing buildings in most areas of California. An analysis of the savings from installing cool roofs on these buildings found average net present value savings, which include cooling equipment cost savings and energy savings over 15 years, of $545 per 1000 square feet. The state is currently considering 2008 updates to Title 24, which might involve extending cool roof requirements to the steep-sloped market. See: http://www.energy.ca.gov/title24/index.html

- **Sacramento –** To save energy and reduce peak energy demand, the Sacramento Municipal Utility District (SMUD) has had a long running residential shade tree program and a cool roof rebate program. Since 1990, SMUD has collaborated with the Sacramento Tree Foundation to provide more than 350,000 free shade trees to residents in the Sacramento area. This program encourages residents to strategically plant vegetation around their homes to reduce energy consumption. SMUD has found that fully grown, properly placed trees can cut cooling costs by up to 40 percent. They've estimated that average cooling load savings are 153 kWh/year/mature tree and that 300,000 mature trees result in demand savings of 16 MW. The utility provides trees between 4 and 7 feet tall, as well as stakes, ties, fertilizer, tree delivery, and expert advice on tree selection and planting techniques free of charge. Homes with an eastern, western, or southern exposure that heat up during the summer are eligible. See: www.smud.org.residential/savings/trees/index.html

- **Sacramento** – The Sacramento Urban Forests for Clean Air Project is a joint effort by the Center for Urban Forest Research, the Sacramento Tree Foundation, and the Sacramento Air Quality Management District to evaluate the effectiveness of large-scale tree planting on the future air quality of the Sacramento Region. The project team has begun modeling different tree planting scenarios to quantify potential impacts. Preliminary results indicate that urban forestry can be an effective air quality control strategy for the region, and tree planting is included in the draft 8-hour state implementation plan (SIP). See: http://www.sactree.com/greenprint/urbanForests.html

C. Illinois

- **Chicago** – To help reduce summertime temperatures, save energy, and support the city's sustainability goal, Chicago amended its energy code to require cool roof, green roof, or photovoltaic installations on most new or majorly renovated air-conditioned buildings with low sloped roofs. The city has also long supported green roofs by installing them on city-owned buildings and encouraging private installations via a grant program. As of October 2006, more than 240 public and private rooftop gardens, totaling more than 1 million square feet, were installed or are being designed or constructed.
  See:
  http://egov.cityofchicago.org/city/webportal/portalEntityHomeAction.do?BV_SessionID=@@@@@1293477138.1178560255@@@@@&BV_EngineID=cccfaddkkjelmdfcefecelldffhdfgm.0&entityName=Environment&entityNameEnumValue=13

C. New York

? **New York City** - To determine the value of vegetation for reducing energy loads in New York City, the New York State Energy and Research Development Authority (NYSERDA) worked with the US Forest Service, local and state environmental agencies in New York, and various researchers to analyze New York City's urban heat island effect and various mitigation scenario impacts on temperature, energy consumption, and peak electricity demand. The 2006 study estimated that broad scale implementation of the most effective scenarios could reduce city-wide peak electric requirements by nearly 2% or 170 MW. See:
www.nyserda.org/programs/Environment/EMEP/project/6681_25/6681_25_project_update.pdf

D. Pennsylvania

? **Philadelphia** - The Energy Coordinating Agency (ECA) of Philadelphia, which provides the city's weatherization services, has applied cool roof coatings as part of its package of energy efficiency treatments. Through its Cool Homes Program, more than 550 residences in the Philadelphia area have had their roofs coated. The ECA commissioned a study that found the cool coatings and increased insulation eliminated 90 percent of the heat gain through the ceiling, reducing top-floor ceiling temperatures by an average of 5°F and chest-height temperatures by 2°F. These reduced temperatures translate into lowering air conditioning loads by about one-third in a typical row house. In homes that do not use air conditioning, these temperatures can help reduce heat-related deaths and illnesses. See www.ecasavesenergy.org/index.html.

E. Texas

- **Austin** – Since 2002, Austin Energy has given 10-cent-per-square-foot rebates for cool roof installations. The utility has been promoting cool roof products as a cost-effective and low-risk approach to reducing cooling loads and peak demand. Customers must use cool roof products that have a minimum reflectivity of 75 percent, and the project must pass a cost-benefit analysis. As of 2005, Austin Energy had awarded more than $164,000 as rebates, representing more than 1.6 million square feet of roof area and saving an estimated 1.26 million kWh of energy. See www.austinenergy.com/Energy%20Efficiency/Programs/Rebates/index.htm

- **Houston** – In 2004, Houston developed the first, comprehensive, urban heat island reduction action plan – titled "The Cool Houston Plan." This plan sets targets for each heat island mitigation strategy – cool trees, cool roofs, and cool pavements -- and provides baseline measurements of these three components and information on mitigation technologies. To develop the plan, the Houston Advanced Research Center (HARC) facilitated over 100 meetings with numerous city staff, city officials, and other interest groups over several years to collect data, address information gaps, and to bring stakeholders to consensus regarding goals and ideas for taking action.

  Since completing the plan, HARC has been working with local and state policymakers on implementation. In 2005, the 75th Texas legislature passed two bills – one that required the Texas Council on Environmental Quality to develop methods for determining emission reduction credit for energy efficiency and urban heat island mitigation in connection with the area's state implementation plan (SIP), and a second that allowed utilities to provide new energy efficiency options, such as tree planting, as part of their Standard Offer Programs. Plan implementation is ongoing, and Houston is helping other cities, such as Dallas, embark on similar efforts – modeled on Houston's successes. See: http://files.harc.edu/Projects/CoolHouston/CoolHoustonPlan.pdf

III. Resources

A. General Resources

? U.S. EPA Heat Island Website. This website provides basic information on urban heat island causes and impacts, heat island reduction strategies, local and state heat island reduction activities, and announces information about EPA's Heat Island Reduction Initiative (HIRI), such as the dates and times of the program's national, quarterly heat island conference calls. The HIRI program offers outreach materials, tools, and guidance to provide communities with information to help them develop heat island reduction projects. http://www.epa.gov/heatisland/

? Clean Energy-Environment Municipal Network. The Clean Energy-Environment Municipal Network is an informational resource network designed to (1) assist local governments in their efforts to invest in and promote clean energy strategies and to advance their priorities and (2) provide opportunities to showcase leadership by local governments. http://epa.gov/cleanenergy/stateandlocal/network.htm

? DOE's Lawrence Berkeley National Laboratory (LBNL) Urban Heat Island Group. This web site contains an overview of urban heat islands and mitigation strategies as well as results of LBNL's urban heat island and cool roof research, links to other sites, and a database comparing various roofing materials. http://eetd.lbl.gov/heatisland/

? ICLEI's Hot Cities Website. The International Council for Local Environmental Initiatives (ICLEI) provides information on cool policies and heat island workshops that the organization has hosted in partnership with cities throughout the country. See: www.hotcities.org.

? International Association for Urban Climate. The International Association for Urban Climate (IAUC) is an organization of members with scientific, scholarly, and technical interests and responsibilities in: urban climatology, urban meteorology, urban air quality, and other aspects of the atmospheres above cities, and the interactions between those atmospheres and the built-up surface beneath, including social, economic, and biological impacts. www.urban-climate.org

- NASA's Global Hydrology and Climate Center (GHCC). The National Aeronautic and Space Administration web site provides information on the center's work to reduce heat islands. GHCC uses aerial photography and infrared remote sensing technology to tell cities "what's hot" within their jurisdictions. http://wwwghcc.msfc.nasa.gov/uhipp/urban_uhipp.html

B. Trees and Vegetation

- USDA Forest Service's National Urban and Community Forest Program. The Forest Service's National Urban and Community Forest Program helps state forestry agencies, local and tribal governments, and the private sector manage trees and forests in urban communities. The program's goals are to build awareness of the need for urban forestry; reach out to underserved communities; create partnerships between business, government, and nonprofit organizations; and manage urban forests in a sustainable manner. http://www.fs.fed.us/ucf/

- Treelink is a comprehensive site on urban forestry issues including information on current legislation, technical reports, and links to state and local planting guides. www.treelink.org

- USDA Forest Service Research Stations are located throughout the country. The Northeastern Station in Syracuse and the Pacific Southwestern Station conduct heat island and climate change related research. See: http://www.fs.fed.us/ne/syracuse/ and http://www.fs.fed.us/psw/programs/cufr/

- Urban Forestry Webcasts - The Urban Natural Resource Institute - is sponsored through the USDA Forest Service Northern Research Station. They host a series of monthly webcasts, which are highly informative on topics ranging from the latest tree disease to hand-held devices used to develop forest inventories. There are other resources at their website, like a web-based bulletin board See: http://www.unri.org/webcast/

- i-tree is the newest tool available to assess and manage communtiy forests. This tool has been developed by researchers from the Forest Service, two NGOs, and the Davey Resource Group. See: http://www.itreetools.org

- Trees Clean Air is a website dedicated to building the case for urban tree canopy cover inclusion in state air quality plans – or SIPs. This site provides information on the link between trees and air quality and on navigating the state air quality improvement planning process. Website sponsors include the USDA Forest Service, the National Tree Trust, the Davey Resource Group, and the Center for Chesapeake Communities. See: www.treescleanair.org

C. Cool Roofs

? EPA ENERGY STAR®. ENERGY STAR is a voluntary labeling program jointly sponsored by EPA and the Department of Energy. This site identifies and promotes a wide range of energy-efficient products, including cool roofs. http://www.energystar.gov/index.cfm?fuseaction=find_a_product

? Cool Roof Rating Council. The core of the CRRC is its Product Rating Program through which roofing product manufacturers can label their products with solar reflectance and thermal emittance values. http://www.coolroofs.org/

? DOE's Lawrence Berkeley National Laboratory Cool Roofing Database. This database displays research results on the solar reflectance and thermal emittances of various roofing products. The site provides a useful comparison of cool roofing materials to traditional options. http://eetd.lbl.gov/CoolRoofs/

- DOE's Oak Ridge National Laboratory Building Technology Center is a research facility devoted to developing technologies that improve the energy efficiency and environmental compatibility of residential and commercial buildings. This web site contains research information on both the building envelope and its constituent materials. Fact sheets and various publications also are available. http://www.ornl.gov/sci/btc/

- Cool Colors Project In 2002, the California Energy Commission asked Lawrence Berkeley National Laboratories and Oak Ridge National Laboratories to collaborate with a consortium of 16 manufacturing partners and develop "cool" non-white roofing products that could revolutionize the residential roofing industry. The project team has since been working on developing dark shingles with solar reflectances of at least 0.25 and other nonwhite roofing products—including tile and painted metal—with solar reflectances not less than 0.45. http://coolcolors.lbl.gov/

D. Green Roofs

- Green Roof Technology Alert DOE's Energy Efficiency and Renewable Energy program publishes technology alerts and developed a July 2004 report of green roofs that provides a primer on the technology. www.nrel.gov/docs/fy04osti/36060.pdf

? Green Roofs for Healthy Cities is a coalition of private sector firms founded in 1999. Its web site contains recent research, information on green roof demonstration projects, and additional resources. http://www.greenroofs.org/

? Greenroofs.com is a web site that provides basic information on green roofs case studies, a green roof project database, and a list of product suppliers. http://www.greenroofs.com/

- The Green Roof Research Center at Penn State gathers data on the efficacy and potential of green roofs to mitigate storm water runoff, capture energy savings, and buffer acid rain. The site highlights current research projects at Penn State and provides links to green roof-related organizations and businesses. http://hortweb.cas.psu.edu/research/greenroofcenter/about_ctr.html

E. Cool Pavements

- Cool Pavements to "Sustainable Pavements" The Arizona Experience. This presentation by Arizona State University researchers describes their multidisciplinary program to explore sustainable pavements within the context of urban sustainability. http://www.epa.gov/heatisland/resources/pdf/presentations/Golden_ASU.pdf

F. Urban Heat and Health

- Excessive Heat Events Guidebook. Designed to help community officials, emergency managers, meteorologists, and others plan for and respond to excessive heat events, the guidebook highlights best practices that have been employed to save lives during excessive heat events in different urban areas and provides a menu of options that officials can use to respond to these events in their communities. http://www.epa.gov/heatisland/about/heatguidebook.html