1.2.4 URBAN HEAT ISLAND TECHNOLOGIES

Technology Description

Heat islands form as cities replace natural vegetation with pavement for roads, buildings, and other structures necessary to accommodate growing populations. These surfaces absorb – rather than reflect – the sun's heat, causing surface temperatures and overall ambient temperatures to rise. The displacement of trees and shrubs eliminates the natural cooling effects of shading and evapotranspiration. Further, urban form and anthropogenic sources of heat contribute to heat island formation. Measures to reduce urban heat islands include increasing vegetative cover, installing reflective roofs and pavements, and, potentially, using permeable pavements. Heat island mitigation measures can reduce ambient air temperatures in urban areas, thereby slowing the chemical formation of smog (ground-level ozone) and reducing cooling-season electricity demand for air conditioning. Associated with the decrease in air-conditioning use are reductions in associated air pollution and greenhouse gas emissions. In general, the larger the area implementing heat island reduction measures – and the longer, sunnier, and hotter the summer season – the more substantial the impacts on meteorology and air quality. Building level energy modeling as well as large-scale meteorological and air quality modeling can assist in understanding the effects of heat island reduction measures.

System Concepts

- Reduced temperatures reduce the need for summertime cooling energy. Reduced air-conditioning reduces power plant emissions, including greenhouse gas emissions and ozone precursors.
- Reduced temperatures decrease biogenic volatile organic compounds emissions and evaporative losses.
- Trees sequester carbon (particularly urban or suburban trees, which can sequester about 18 kg of carbon annually) and precipitate particulates and other airborne pollutants.
- Reduced ambient air temperature reduces photochemical reaction rates, which may reduce ozone production.

Representative Technologies

- Placing trees on the west-, south-, and east-facing sides of a building can significantly reduce cooling costs for a home or low-rise building during peak summertime demand. Simulations of energy savings benefits for Sacramento and Phoenix found that three mature trees around homes cut annual air-conditioning demand by 25%-40%.
- There are more than 1,000 Energy Star-labeled roof products, which include coatings and single-ply materials, tiles, shingles, and membranes. Energy savings in buildings with reflective roofs range as high as 32% during peak demand, with a summer average of 15%.
- Research regarding the impacts of cool pavements is in its infancy; and unlike roof products, many technical and institutional questions exist. To date, mechanisms for creating cool pavements include increasing solar reflectance or increasing permeability. Both asphalt and concrete products can be constructed to have higher reflectances. Higher albedos can reduce maximum pavement temperatures by about 10°F per 0.1 increase in albedo. In turn, air temperature could potentially be reduced by about 1°F if all pavement albedos were increased by 0.2. Complicating factors, though – such as the impact pavement reflectance may have on adjacent building heat gain – still need to be addressed. Permeable pavements using asphalt, concrete, or unbound materials including vegetation are becoming increasingly common. Their impacts on urban climates, though, have not been well researched.

Technology Status/Applications

- Nationally, there are numerous tree-planting programs and greening efforts aimed to meet various objectives including stormwater management, heat island reduction, and beautification. Because vegetation – particularly planting deciduous trees around buildings – can reduce air-conditioning demand, some utilities run shade-tree programs. Further, some communities have implemented shade-tree ordinances that range from planting trees along streets to requiring parking-lot developers shade 50% of paved areas 15 years after development.
- Some communities are installing alternative-pavement parking lots and alleys – mainly using porous pavement technologies. White-topping is also becoming increasingly popular, particularly in intersections.

Current Research, Development, and Demonstration

RD&D Goals

- Improved understanding and quantification of the impacts heat island reduction measures have on local meteorology, energy use and expenditures, greenhouse gas emissions, and air quality.
- Specific products include a GIS application that predicts heat island outcomes from different development scenarios (e.g., benefits from large-scale tree planting), and cool materials for roofs and pavements.

RD&D Challenges

- Better understand interaction between meteorological, land surface, and emission-specific parameters in baseline and modified modeling scenarios.
- Determine albedo and emissivity levels of city surfaces.

RD&D Activities

- The Department of Energy's Lawrence Berkeley National Lab Heat Island group has conducted research on the impact heat island reduction strategies have on local meterology, air quality, and energy demand. Currently, LBNL is working with Oak Ridge National Laboratory, the California Energy Commission, and other stakeholders to develop cool residential roofing products.
- The Environmental Protection Agency (EPA), which established the Heat Island Reduction Initiative (HIRI), works with community groups, public officials, industry representatives, researchers, and others to identify opportunities to implement heat island strategies. HIRI previously supported research. Currently, the program translates research into outreach materials, tools, and guidance that provide communities with information to develop programs, policies, codes, and ordinances to implement heat island reduction strategies.
- Oak Ridge National Laboratory and the Florida Solar Energy Center conduct research on cool-roof applications.
- Penn State and other North American universities are conducting research on green roof technologies, including their impacts on energy consumption, stormwater management, water quality, surface and air temperatures, and pollution removal.
- The USDA Forest Service develops methods and models to quantify carbon storage and sequestration, building energy-use effects, and air pollution removal by urban forests at the local to national scale.
- The Forest Service conducts analyses in numerous cities, and national assessments to quantify the effects of urban forests on carbon storage and sequestration, building energy use, and air pollution removal.
- A few cities and states (e.g., Chicago, California, and Georgia) have incorporated reflective roofs into their energy codes. Many utilities (e.g., Austin Energy, Florida Power and Light, Xcel Energy) have reflective-roof incentive programs. Reflective roofs are given credit in several environmental rating programs, including the U.S. Green Building Council's LEED (Leadership in Energy and Environmental Design) rating system. Many cool-roofing membranes and coatings are available, and these products are mainly used for commercial or flat roofs. Cool-tile and metal roofing products are also available, and these are used for residential roofs. Research is currently being conducted to develop additional cool-roof products for the residential market, for example, cool asphalt shingles.

Recent Progress

- EPA and DOE demonstrated the impact of cool roofs on building energy use; EPA developed the Energy Star Roof Products program.
- ASTM and ASHRAE standards have been developed, and prototype cool-roofing materials have been developed.
- The Cool Roof Rating Council was organized and several state and air-quality management districts have adopted heat-island-reduction measures.

Commercialization and Deployment Activities

- Reflective roofing and paving technologies may be broadly applicable to U.S. cities, but benefits will vary.
- Some cities and states require use of cool roofs, and many existing efforts support their installation (e.g., Philadelphia's Cool Homes program), thus increasing the demand and deployment of these products.

Market Context

- Heat island reduction strategies including urban reforestation, rooftop gardens, reflective roofs, and alternative pavements have been implemented in many cities including Los Angeles, Sacramento, Salt Lake City, Houston, Tucson, Chicago, Miami, and Atlanta – interest is growing.
- Nationally, reflective roofing materials probably comprise less than 10% of the roofing market; and asphalt is the most common pavement surface.