Life-Cycle Assessment and Co-benefits of Cool Pavements

Statement of Significance

The construction, use, and maintenance of California’s roadways and parking lots are responsible for substantial energy and resource consumption and emissions of greenhouse gases (GHGs) and other air pollutants. In addition, pavements—which cover about one-third of a typical U.S. city (Akbari et al. 2009)—can have a strong influence on local temperatures and air quality.

Research has identified opportunities to reduce the environmental impacts of pavements. For instance, “cool” pavements with high solar reflectance can reduce ambient temperatures, slow the temperature-dependent formation of smog, decrease air conditioning and peak electricity demand, and induce negative radiative forcing that cools the atmosphere (Rosenfeld et al. 1998; Akbari et al. 2009). Moreover, cooler asphalt pavements may be less prone to rutting and cracking, and under certain conditions may also have lower rolling resistance due to viscoelastic energy dissipation under heavy truck loading (Lenke and Graul 1986; Pouget et al. 2012).

Recognizing the potential for cool pavements to reduce greenhouse gas emissions and improve heat islands and air quality, California cities are beginning to adopt cool pavement strategies in their Climate Action Plans. Chula Vista, Vallejo, and Santa Rosa are a few of the cities that have already identified cool pavements as an important strategy to both mitigating and adapting to climate change. Despite this interest, the greenhouse gas, local climate, and air quality impacts of cool pavements remains largely un-quantified.

As California re-engineers its cities to reduce greenhouse gas (GHG) emissions and air pollution and to adapt to climate change, decision-making requires a strong understanding of the life-cycle environmental impacts of conventional and cool pavements.

To address this need, investigators from Lawrence Berkeley National Laboratory (LBNL); University of California Pavement Research Center; University of Southern California; and PE-International will build on existing pavement life-cycle assessment (LCA) work to evaluate various conventional and cool pavement types (including new cool pavement technologies) along several environmental dimensions, including greenhouse gas emissions, and local climate and air quality impacts. This analysis will yield a modeling tool that will allow the investigators to run scenarios that quantify the potential impacts of various pavement strategies in different settings. The results of these scenarios will then be synthesized into a pavement strategy guidance tool that will help local and regional decision-makers as they consider adopting more sustainable pavement design practices.

Evaluating the environmental impacts of pavement in California and estimating the potential impact of GHG reduction strategies present an opportunity to reduce greenhouse gas emissions, reduce ambient temperatures, improve air quality, and protect public health. This will help ARB meet its short and long-term greenhouse gas emission
reduction targets; help regions and the state meet air pollution standards; and help cities adapt to increasing temperatures.

**Research methods**

To assess urban climate and air quality impacts, we can use simulations from high-resolution regional climate models. The Weather Research and Forecasting (WRF) model is a mesoscale numerical weather prediction model based on fully compressible and nonhydrostatic fluid dynamics. WRF-CHEM is a configuration of the model that allows for detailed simulation of atmospheric chemistry and physics of air pollutants (Grell et al. 2005). The model is coupled to a land surface model such as “Noah” (Ek et al. 2003) or “Community Land Model” (CLM) (Oleson et al. 2010) to represent interactions between the land surface and atmosphere. By altering land surface characteristics in the land surface model, we can develop scenarios for the deployment of reflective urban surfaces. The resulting changes in climate and air quality are then simulated by WRF-CHEM and compared to control simulations. Regional temperatures and ozone and particulate matter concentrations are typically simulated. Emissions of volatile organic compounds (VOC) are temperature dependent.

An alternate approach to assessing climate and air quality is the urban heat island “mitigation impact screening tool” (MIST) (Sailor and Dietsch 2007). MIST was developed as a simple screening tool to help air quality management districts and urban planners understand the potential for reflective surfaces and vegetation to mitigate urban heat islands, ozone pollution, and energy consumption in various cities in the U.S. The tool provides a user-friendly web-based interface in which the city and mitigation strategy of interest can be chosen. Detailed simulations using a meteorological model (MM5 version 3.4) for 20 U.S. cities form the basis of MIST. The effects of increases in urban albedo on climate and air quality are simulated by increasing albedo by 0.1 and 0.2 above the control simulation. Results for approximately 240 cities in the U.S. are derived by extrapolating results from the 20 simulated cities using a Tree Structured Regression (TSR) classification method.