Recent research highlights: Quantifying the energy and environmental consequences of cool pavements

18 May 2017

Alongside other strategies such as urban forestry, solar PV, and cool roofs, the use of high-albedo (high solar reflectance) "cool" pavements can be considered in programs intended to help cities, regions, and states meet greenhouse gas (GHG) emission reduction and sustainable community goals. Cool pavements can mitigate urban heat islands, improve urban air quality, and in some cases reduce GHG emissions from building energy use. However, it is important to consider also the energy and environmental consequences of pavement materials and construction.

What we did

With support from the California Air Resources Board and the California Department of Transportation, the Heat Island Group at Lawrence Berkeley National Laboratory teamed with the University of Southern California, the University of California Pavement Research Center, and thinkstep, Inc. to develop a pavement life-cycle assessment tool for California cities (Levinson et al. 2017). Local officials can use it to compare the life-cycle energy and environmental impacts of conventional (lower albedo) and cool (higher albedo) pavements. The analysis spans a 50-year pavement life cycle, including extraction and manufacturing, building energy use, and removal/disposal/recycling. The tool reports how pavement choice affects life-cycle energy consumption; life-cycle emission of greenhouse gases, particulate matter, and smog precursors; urban air temperature; and urban ozone concentration. Local governments can use the tool to evaluate pavement-related strategies for reducing carbon footprint and helping California meet its climate goals. It may also provide insight into public health impacts of pavement choice.

What we found

Gilbert et al. 2017 used the tool to explore several case studies in which a cool surface treatment was selected instead of a more typical treatment. Impacts assessed over a 50-year period included the changes in primary energy demand (PED, excluding feedstock energy), feedstock energy (primary energy used for purposes other than fuel), and global warming potential (GWP, meaning carbon dioxide equivalent) in Los Angeles and Fresno, California. The analysis considered two stages of the pavement life cycle: materials and construction (MAC), comprising material production, transport, and construction; and use, scoped as the influence of pavement albedo on cooling, heating, and lighting energy consumption in buildings.

In Los Angeles, substituting a styrene acrylate reflective coating or a chip seal for a slurry seal in routine maintenance, or a bonded concrete overlay on asphalt (BCOA) without supplementary cementitious materials (SCM) for mill-and-fill asphalt concrete in conventional or long-life rehabilitation, induced MAC-stage PED and GWP penalties that substantially exceeded use-stage savings, primarily due to material production. Modified rehabilitation cases in which SCM comprised 21% to 50% of the BCOA's total cementitious content by mass (portland cement + SCM) yielded smaller total (MAC + use) PED and GWP penalties, or even total PED and GWP savings. Trends in Fresno were similar, with some differences in GWP outcomes that result from Fresno's longer heating season.

The modified rehabilitation cases using BCOA with high SCM content yielded total GWP savings in each city; all other cases yielded total GWP penalties. The magnitude of the one-time GWP offset offered by global cooling from the increased albedo itself always, and sometimes greatly, exceeded the 50-year total GWP penalty or savings. In Los Angeles, the annual building conditioning (cooling + heating) PED and energy cost savings intensities yielded by cool pavements were each about an order of magnitude smaller than those from cool roofs.

Energy savings projected by the tool are compatible with the results of other studies published by the Heat Island Group. Pomerantz et al. (2015) and Pomerantz 2017 predicted the maximum possible energy savings, the resulting monetary savings, and other environmental benefits from the air cooling effect that might be achieved by increasing the albedo of surfaces in a large city. They derived a direct relationship between the increase of albedo and the maximum saving of air-conditioning energy in an entire city due to cooler outside air. They applied this novel method with data obtained from the electric utility companies of seven warm cities in California, such as Sacramento and Riverside. They found that raising the albedo of a square meter of pavement by 0.20 (on a scale of 0 to 1) would reduce cooling-energy use by less than 1 kWh/year, saving less than US$0.60/year, and would decrease carbon dioxide emissions by less than 1 kg/year, valued at less than US$0.01/year.

Key takeaways from cases studied

- Cool pavement materials usually require more energy and carbon to manufacture than conventional pavement materials. One exception is concrete with substantially reduced levels of energy- and carbon-intensive ordinary portland cement.
- Raising by 0.20 the albedo of all paved surfaces is projected to reduce summertime outdoor air temperatures in California cities by about 0.1 to 0.5 °C (about 0.2 to 0.9 °F), depending on city geography and climate.
- In cities with a lot of air conditioning, the savings of air conditioning energy due to lowered air temperature is less than 1 kWh (saving less than US$0.60) a year per m^2 of pavement modified. The avoided CO_2 is valued at less than a penny a year per m^2.
- The energy and carbon saved in buildings is typically much less than the extra energy and carbon needed to make the cooler pavements.

- For comparison, building energy savings from cool pavements are about an order of magnitude smaller than those from cool roofs.
- Reflective pavements offer a one-time carbon offset (benefit) that exceeds the 50-year life-cycle carbon penalty (or 50-year life-cycle carbon savings).
- An important challenge is to create cool pavement materials that reduce life-cycle energy, carbon, and cost.

To obtain the pavement life cycle assessment tool

Please see instructions in Section 2.8.3 of Levinson et al. 2017.

References

1. Levinson RM, Gilbert HE, Jin L, Mandel BH, Millstein D, Rosado PJ, Harvey JT, Kendall A, Li H, Saboori A, Lea J, Ban-Weiss G, Mohegh A, Santero N. 2017. Life Cycle Assessment and Co-Benefits of Cool Pavements. Final report for Contract #12-314, California Air Resources Board, Sacramento, CA. https://www.arb.ca.gov/research/single-project.php?row_id=65149
2. Gilbert HE, Rosado PJ, Ban-Weiss G, Harvey JT, Li H, Mandel BH, Millstein D, Mohegh A, Saboori A, Levinson RM. 2017. Energy and environmental consequences of a cool pavement campaign. *Energy and Buildings*, in press. http://doi.org/10.1016/j.enbuild.2017.03.051. A free pre-print of this article is online at https://eetd.lbl.gov/publications/energy-and-environmental-consequences .
3. Pomerantz M, Rosado PJ, Levinson RM. 2015. A simple tool for estimating city-wide annual electrical energy savings from cooler surfaces. *Urban Climate* 14(2), 315-325. http://doi.org/10.1016/j.uclim.2015.05.007
4. Pomerantz M. 2017. Are cooler surfaces a cost-effect mitigation of urban heat islands? *Urban Climate*, in press. http://doi.org/10.1016/j.uclim.2017.04.009
5. Mohegh A, Rosado P, Jin L, Millstein D, Levinson R, Ban-Weiss G. 2017. Modeling the climate impacts of deploying solar reflective cool pavements in California cities. *Journal of Geophysical Research*, in press. http://doi.org/10.1002/2017JD026845
6. Rosado PJ, Ban-Weiss G, Mohegh A, Levinson RM. 2017. Influence of street setbacks on solar reflection and air cooling by reflective streets in urban canyons. *Solar Energy* 144, 144-157. http://dx.doi.org/10.1016/j.solener.2016.12.026