Quantifying the impact of pavement reflectivity on radiative forcing and building energy demand in neighborhoods

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PROBLEM

Albedo is the measure of the fraction of solar energy reflected by the Earth's surface. High-albedo surfaces, which are lighter in color, absorb less sunlight energy and reflect more shortwave radiation. The change in radiative energy balance, which is called radiative forcing (RF), reduces nearby air temperatures and impacts the surrounding building energy demand (BED) including heating and cooling energy loads. The impact of reflective surfaces on RF and BED has been investigated by researchers through modeling and observational studies, however previous studies have not assessed RF and BED impacts under the same context and therefore cannot be directly compared. Here, we take a more comprehensive approach in assessing the net impacts of pavement albedo modification strategies in urban areas.

APPROACH

We apply an adapted analytical model for RF and, for BED, a hybrid model framework combining information from DIVA and Urban Weather Generator to estimate the impacts of increasing pavement albedo from 0.1 (typical for asphalt) to 0.3 (typical for concrete) for different urban neighborhoods in Phoenix. The 0.2 increase is also associated with changes of thermal properties. A universal and climate-based classification of urban neighborhoods is used to categorize different types of urban morphology into local climate zones (LCZs). For the purpose of illustration, we select two hypothetical LCZs (open high-rise and open low-rise, out of 10 LCZs) in Phoenix, representing a dense downtown area and a sparsely built residential neighborhood, respectively. See Figure 1, page 2.

FINDINGS

The impacts of RF and BED are translated into global warming potential (GWP) savings and normalized to kg CO_2 equivalent per square meter of pavement modified (see Fig. 1). Increasing pavement albedo results in temperature reductions and CO_2 savings from negative RF in both neighborhoods in Phoenix, but the impacts of changing pavement albedo on BED vary by urban morphology. The change often causes cooling energy to go up while leading to savings in heating load, but the magnitudes of burdens and savings depend on location of the urban neighborhood. In the densely-built high-rise neighborhood, reflective pavements can create net GWP burdens—this occurs because the tall buildings trap multiple reflections of radiation between them, thereby increasing BED—however, because high-rise and densely-built districts make up a small fraction of urban areas, the expected total savings from increasing pavement albedo at the urban scale is expected to be positive.

WHY DOES THIS RESEARCH MATTER?

This brief creates a foundation for future research taking into account various neighborhood characteristics. Making use of GIS data is necessary in order to demonstrate the impacts of reflective pavements accurately at urban scale. Results show:

- Evaluating the effectiveness of albedo modification strategies (changing surface reflectivity) involves quantifying the net impacts from both radiative forcing (RF) and building energy demand (BED).
- The relative magnitude of RF and BED depends on context, but usually RF is more significant.

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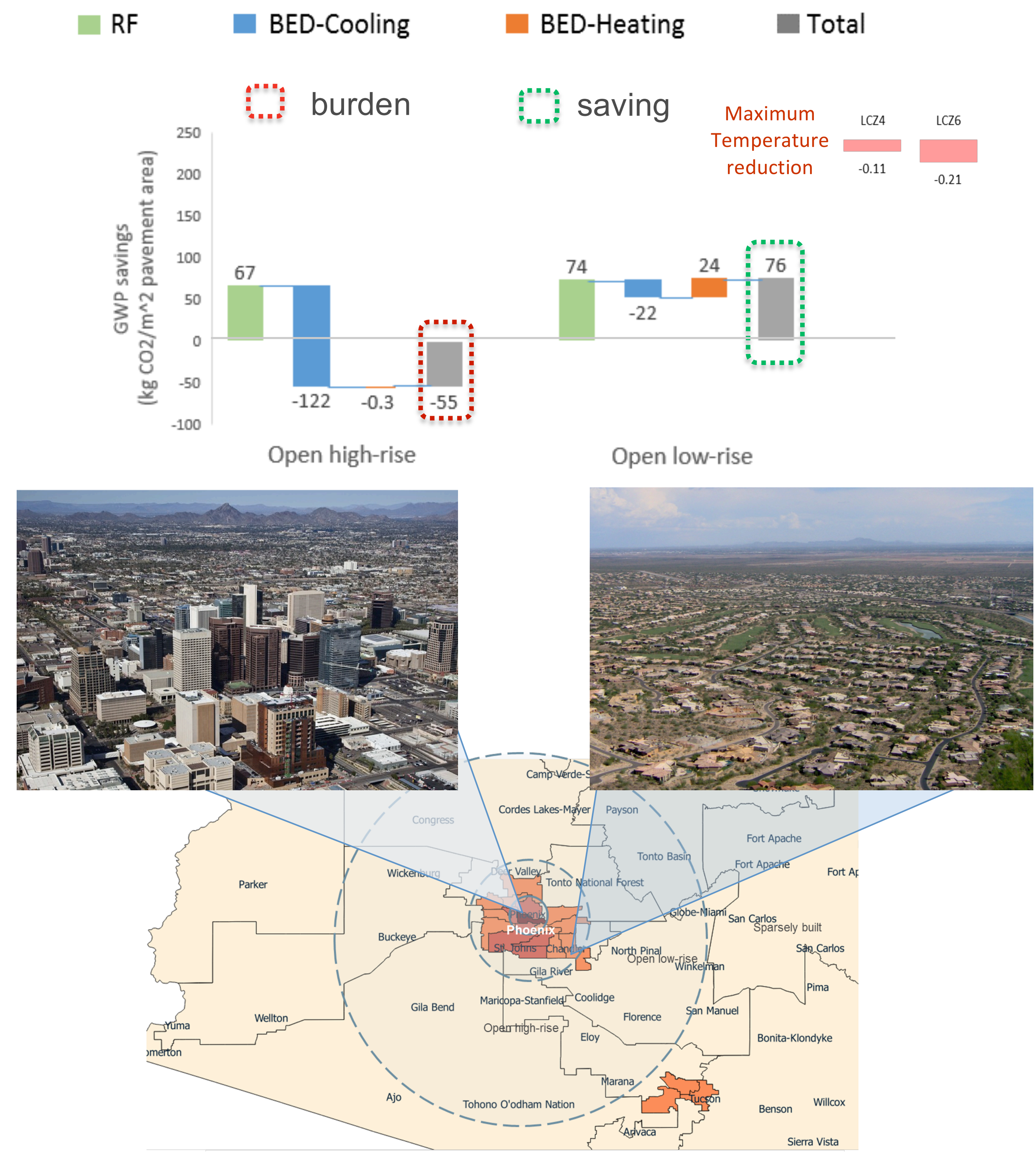

Figure 1. GWP savings from RF and BED due to 0.2 increase in 1 m^2 pavement albedo for two neighborhoods in two different LCZs over 50 years (positive indicates savings). Pictures in the middle show two example neighborhoods in Phoenix, representative of the two LCZs, and their locations in the map.

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