Energy saving and emission reduction 14 kWh

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Development of the integrated modeling approach.

The specific research objectives include: (1) developing the integrated modeling approach for detailed building energy simulation; (2) identifying the impacts of local ambient climate on the energy-saving performance of green roofs and cool roofs; (3) identifying the impacts of urban built environment on the performance of two roof types; and (4) predicting the energy-saving performance of two roof types under different Shared Socioeconomic Pathways (SSPs). This research has the potential to inform policy decisions on building design and energy consumption reduction strategies. The findings may also provide insights into the most effective roof-level strategies for reducing building energy consumption in different regions worldwide in the future.

The K?ppen-Geiger climate classification maps were obtained from ref. 27 The climatological data for each city is based on monthly averages from the 30-year period of 1981-2010. The data was sourced from the World Meteorological Organization (WMO).

The proposed integrated modeling framework was used to simulate the energy use of buildings in six cities with varying local climates over a 1-year period. We compared the energy consumption of buildings installing cool roofs and green roofs to a reference building using concrete roofs without any energy-saving strategies. The comparison results are shown in Fig. 3, which displays the annual reduction of both cooling and heating energy by cool roofs and green roofs in each city.

Annual building energy reduction by cool and green roofs in different climates among cities: (a) annual cooling energy reduction by two roofs in each of six selected cities; and (b) annual heating energy reduction by two roofs in each of six selected cities.

It is found that the energy-saving performance of cool roofs and green roofs varied across different climates. Observed from Fig. 3a, the mean cooling energy reduction of cool roofs ranged from 67.18% to 86.70% among the six cities, while the mean reduction of green roofs ranged from 63.38% to 83.21%. In most study regions, the cooling energy reduction effect of cool roofs was slightly better than that of green roofs. The best cooling energy reduction effects for cool roofs and green roofs were observed in London and Sao Paulo, respectively, with mean reduction rates of 86.7% and 87.9% across different built environments.

In this study, the effect of the urban built environment, characterized by local climate zones (LCZs), on building energy savings by cool roofs and green roofs was analyzed. A LCZ is defined as a region of uniform surface cover, structure, material, and human activity30. These zones, which are localized, climatically-driven, and representative of specific areas, are designed to describe landscapes with distinct thermal climates based on their surface properties31. LCZs are being used in numerous studies focusing on temperature, ecological, and other environmental variables32,33,34,35.

The simulation was conducted for each LCZ among all the cities. The annual energy reduction ranges for both cooling and heating energy by two roof types in different built environments were identified. Figure 4 shows the comparison results of the annual energy reduction effects by cool roofs and green roofs in each LCZ.

A sensitivity analysis was performed to investigate the effect of both ambient climate and urban built environment on building energy savings of the two roof systems. The sensitivity analysis of the influence of the local climate simulated the energy-saving performance of cool roofs and green roofs under local climatic conditions characterized by different ambient temperatures and relative humidity, while for the analysis of the influences of the urban built environment, building density and height are two key parameters that affect building energy use.

In each city, a total of ten scenarios were simulated for the sensitivity analysis of each selected parameter: two baseline conditions (typical summer and winter conditions), -50%, -25%, 25%, and 50% from each baseline condition. The baseline condition for the urban layout was fixed among different cities, with building density of 50% and a building height of 40 m. The baseline summer and winter conditions in each city were derived from TMY files, with the days with the maximum and minimum daily ambient temperatures selected as the summer and winter conditions for each city, respectively. The results of simulations are shown in Fig. 5.