WRITTEN BY KURT SHICKMAN

Cool Roofs in Northern Climates

There Is Evidence Cool Roofs Provide Benefits to Buildings in Climate Zones 4 through 8

Reflective roofs are a tried and true way to improve building energy efficiency and comfort, generate net energy savings and help mitigate summer urban heat islands. Reflective roofs work by reflecting solar energy off the roof surface, rather than absorbing the energy as heat that can be transmitted into the building and surrounding community.

The simple act of switching from a dark to a light-colored roof surface has a number of benefits. Buildings protected by these types of roofs require less energy to cool and help building owners and residents save money. Cool roofs on buildings without air conditioning can save lives during heat waves by lowering indoor temperatures. Cooler city air is safer to breathe and less polluted, which makes cities more livable and less vulnerable during heat waves. Increasing the reflectivity of urban surfaces can also offset the warming effect of greenhouse gases already in the atmosphere and help us address the challenges of climate change. Taken together, these benefits are worth billions of dollars to the growing number of people that live and work in U.S. cities.

The energy-savings case for cool roofs in warm climates is clear. Widely adopted model building-code systems, ASHRAE and the IECC, address roof reflectivity. ASHRAE 90.1-1999 added a credit for highly reflective roofs with IECC allowing compliance via ASHRAE in 2003. ASHRAE 90.1-2010 added reflectivity requirements for new and replacement commercial roofs in Climate Zones 1 through 3. IECC added the same requirements in its 2012 version. (Figure 1, page 77, shows the ASHRAE climate zone map for the U.S.)

There is, however, an ongoing debate about whether cool roofs deliver net energy benefits in northern climates that experience cold winters and warm to hot summers (Climate Zones 4 through 8). Do reflective roofs remain beneficial as the cold weather season kicks in? The same properties that allow reflective roofs to keep buildings cooler in the summer may also cause them to make buildings colder in the winter. Theoretically, buildings with cool roofs could require more energy to reach a comfortable temperature in winter—a consequence known as the "winter heating penalty." Furthermore, building codes tend to require more roof insulation in colder climates than warmer climates, potentially reducing the energy-efficiency benefits of roof surface reflectivity.

The "winter heating penalty" and the impact of insulation are considerations when installing reflective roofs in some cold climates, but their negative effects are often greatly exaggerated. The sun is generally at a lower angle and days are shorter in winter months

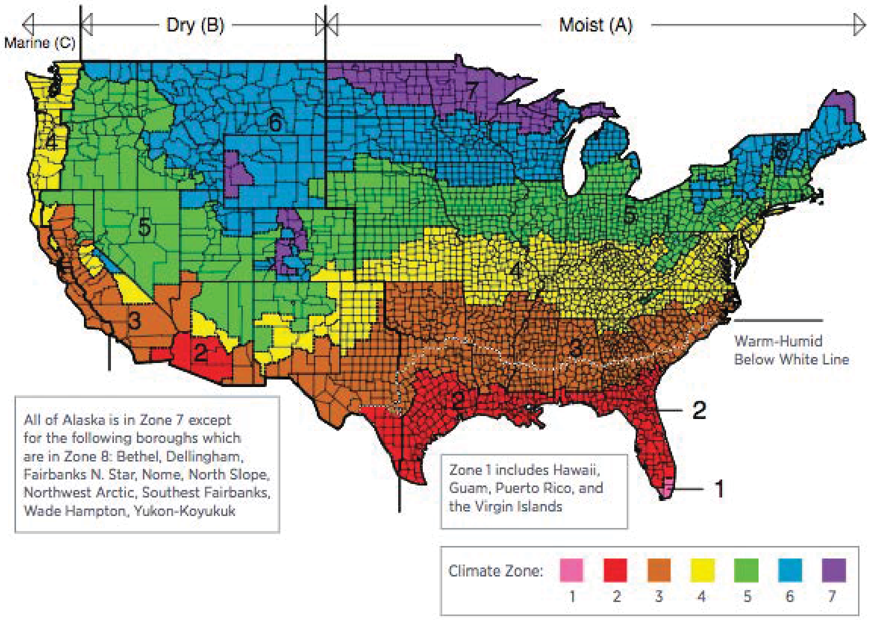

FIGURE 1: Reflective roof requirements in ASHRAE 90.1 and IECC only apply in Climate Zones 1 through 3, shown here on the ASHRAE Climate Zone Map.

Source: U.S. Department of Energy

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than summer months. In fact, in northern locations winter solar irradiance is only 20 to 35 percent of what is experienced in summer months, which means the sun has a reduced impact on roof surface temperature during the winter. Heating loads and expenditures are typically more pronounced in evenings, whereas the benefit of a darker roof in winter is mostly realized during daylight hours. Many commercial buildings require space cooling all year because of human activity or equipment usage, thereby negating the little—if any—heating benefit achieved by a dark roof.

Two new studies, along with decades of real-world examples from the marketplace, indicate that reflective roofs are an effective net energy (and money) saver even in our coldest cities.

SNOW'S IMPACT

In a study recently published in *Energy and Buildings*, researchers from Concordia University in Montreal evaluated the energy-consumption impact of adding cool roofs to a number of retail and commercial buildings in Anchorage, Alaska; Milwaukee; Montreal; and

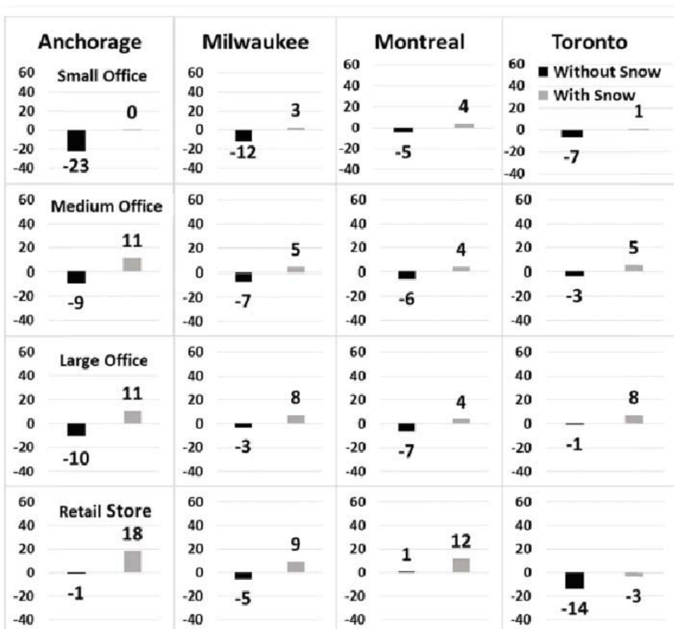

FIGURE 2A: Annual energy-cost savings ($1 per 100 square meters) from cool roofs on newly constructed, code-compliant buildings with all-electric HVAC.

Source: Energy and Buildings

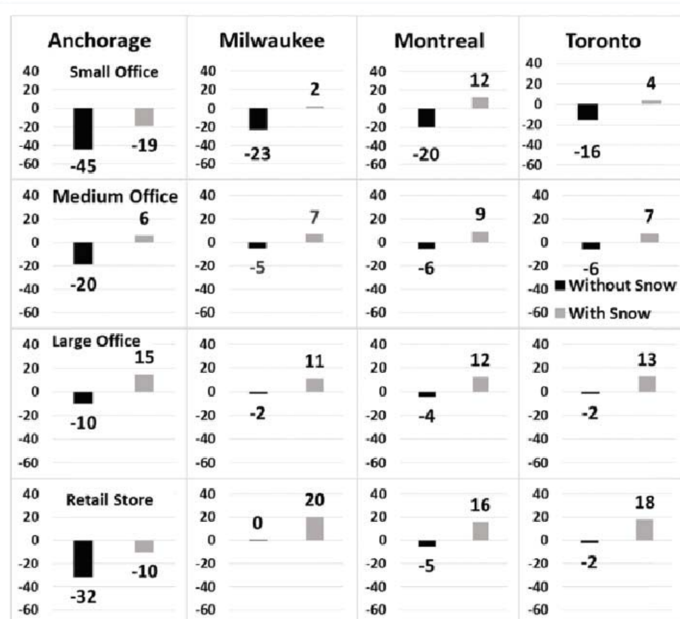

FIGURE 2B: Annual energy-cost savings ($1 per 100 square meters) from cool roofs installed on older buildings with all-electric HVAC.

Source: Energy and Buildings

Toronto. The researchers looked at older, less insulated building prototypes, as well as newer buildings built with code-compliant levels of insulation. Unlike earlier work evaluating the impact of roof reflectivity on building energy consumption in cold climates, this new analysis also accounted for the impact of snow on the roof during winter months.

Snow has two impacts on the roof that are relevant to understanding the true impact of roof surface reflectivity on energy consumption. First, snow helps insulate the roof. As a porous medium with high air content, snow conducts less heat than soil. This effect generally increases with snow density and thickness. Second, snow is white and, therefore, reflective. At a thickness of about 4 inches, snow will turn even a dark roof into a highly reflective surface (approximately 0.6 to 0.9 solar reflectance).

When snow is factored in, the benefits of cool roofs in cold climates become much clearer. Figure 2a, page 77, shows the net energy savings and peak electricity reduction with and without snow for cool roofs installed on newly constructed, code-compliant buildings, assuming all-electric HVAC. Figure 2b, page 77, shows savings from cool roofs installed on existing, older vintage buildings. The paper, available from the journal *Energy and Buildings*, bit.ly/2aXSMfF, also includes results with gas HVAC systems.

INSULATION'S EFFECTS

Another argument often heard against reflective roofing in cold climates is that buildings in northern climates tend to have higher levels of roof insulation that reduce or negate the energy-savings impact of roof surface color. A new field study and model analysis of black and white roof membranes over various levels of insulation by the City University of New York and Princeton University and Princeton Plasma Physics Lab, the latter two of Princeton, N.J., clearly rebuts the "insulation versus reflectivity" tradeoff.

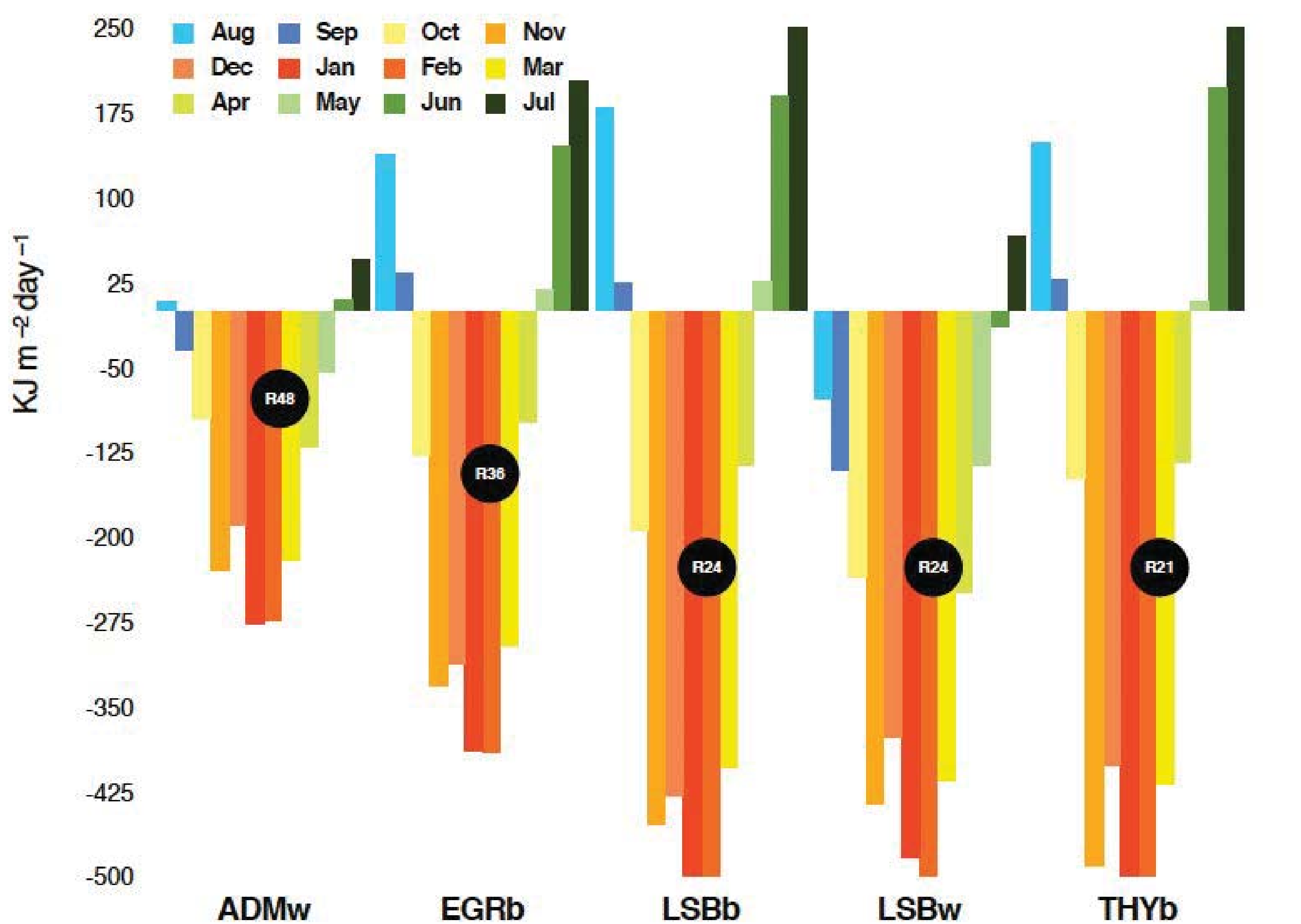

FIGURE 3: Heat transfer into and out of buildings in the City University of New York, Princeton University and Princeton Plasma Physics Lab, the latter two of Princeton, N.J., field tests.
Source: "The joint influence of albedo and insulation on roof performance: An observational study"

The papers highlight the interconnected role of reflectivity and insulation in roofing systems. Their studies, published in *Energy and Buildings*, found that reflectivity is the variable that minimizes heat flux during the summer and that insulation levels are the driving variable during winter. (See "The joint influence of albedo and insulation on roof performance: An observational study", 2015, *Energy and Buildings*, Volume 93, pages 249-258, or bit.ly/2aSfeFO, and "The joint influence of albedo and insulation on roof performance: A modeling study", 2015, *Energy and Buildings*, Volume 102, pages 317-327, or bit.ly/2aYVdeR.) In other words, to be a high-performance roofing system that minimizes heat gain in the summer and heat loss in the winter, you need both insulation and a highly reflective roof surface.

The researchers deployed high-resolution heat flux sensors over and through various roofs on buildings inside the Princeton University campus. The buildings were very similar in design and usage with the exception of different roof membranes (black or white) and thicknesses of polymer-based insulation (R-21 up to R-48).

This study, which gathered measurements for one year, is one of the first to directly observe heat flux entering and leaving the building. It is the first study that paired a field test with an evaluation of the same buildings using a highly accurate and finely resolved model to validate and more deeply understand the interaction between insulation levels and surface reflectivity.

Figure 3, page 78, shows the net heat entering (positive values) or leaving the building (negative values) by month for each roof. The findings are easiest to observe on the two buildings with R-24 insulation levels but different membrane colors. (See buildings LSBb and LSBw in Figure 4, page 80, which shows all the buildings included in the study.) These two roofs were installed at the same time on adjacent areas of the same building. During the cold months of November through April, both the white and black roofs let the same amount of heat escape from the building (thus requiring heating). In the summer months, however, the heat gained by the white roof is minimal and much less than the heat gained by the black roof. As can be seen in Figure 3, even in the building with R-48 insulation, a level far above code requirements in even the coldest U.S. climates, there is a net reduction in heat flux in the roof with the highly reflective surface.

MOISTURE'S INFLUENCE

Another common argument against highly reflective roofs in cold climates is the alleged increased risk of moisture damage from condensation. Although condensation is not a focus of the new research described in this article, it is worth reviewing the issue briefly here.

During the course of a year in seasonal climates, moisture can build up in roof systems during cool periods and dry out during warm periods. This process occurs regardless of roof color. Research indicates that although

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cool roofs may take a little longer to dry out than dark roofs, they also fully dry out, resulting in no net moisture buildup over yearly weather cycles. As the Washington, D.C.-based U.S. Department of Energy has noted in reference to the potential for condensation in cold climates (bit.ly/2bolj9s), "while this issue has been observed in both cool and dark roofs in cold climates, the authors are not aware of any data that clearly demonstrates a higher occurrence in cool roofs."

COOL ROOFS ARE HERE TO STAY

The roofing market, particularly the market for low-slope commercial roofs, demonstrates the effectiveness of reflective roofing in northern climates. Sales of white membrane roofs now significantly outpace dark membranes across the country, including in cold climates. Currently, about half of the nation's 30 largest metropolitan areas have some kind of cool roof requirement or policy in place. Many of those cities are located north of the climate zones where ASHRAE and IECC require reflective roofs. These cities have had cool-roof requirements for quite a long time—Chicago since 2001; Washington, D.C., since 2005; and New York and Philadelphia since 2012.

There are online tools available to evaluate the energy- and cost-savings potential of cool roofs on buildings across all climate zones. For example, GAF Corp., Parsippany, N.J., recently introduced the CREST calculator (Cool.GAF.com). Lawrence Berkeley National Laboratory, Berkeley, Calif.; Oak Ridge National Laboratory, Oak Ridge, Tenn.; and others are working on a new version of the Roof Savings Calculator that, although live, is not recommended for current use while under development and validation.

While it may seem counterintuitive at first glance, cool roofs can be a net benefit to buildings and cities in cool climates. Research in the field and lab, as well as decades of market experience, are demonstrating that highly reflective roofs can be a net energy saver for buildings even in very cold climates. R

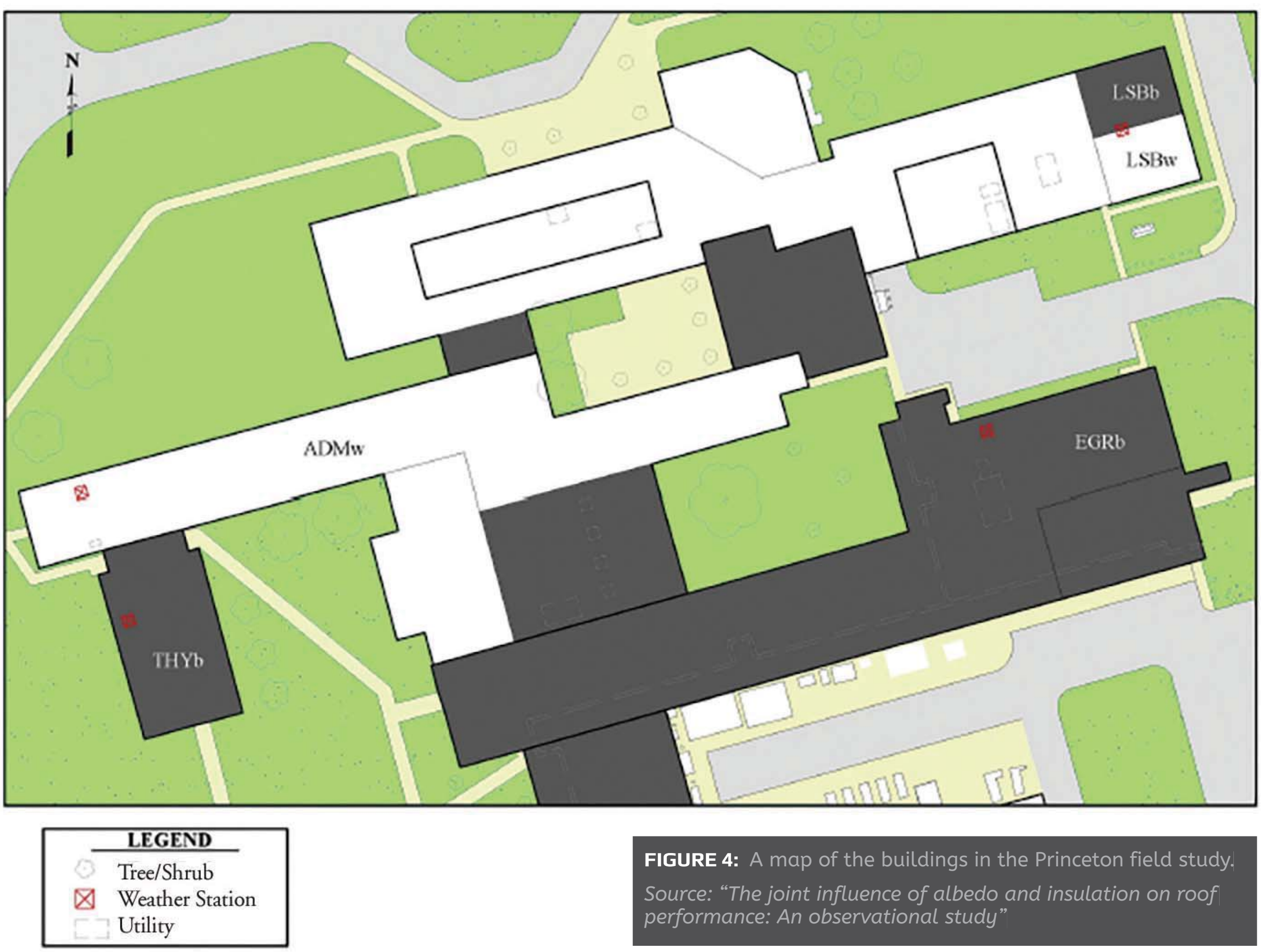

FIGURE 4: A map of the buildings in the Princeton field study.

Source: "The joint influence of albedo and insulation on roof performance: An observational study"