Enhancing Building Efficiency And Resilience With Solar-Reflective Walls

By Sarah Schneider and Audrey McGarrell

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CITIES ARE TYPICALLY hotter than surrounding suburban and rural areas. According to the US Environmental Protection Agency, daytime temperatures in urban areas are about 0.6°C to 3.9°C (1°F to 7°F) higher than temperatures in outlying areas, with nighttime temperatures about 1.1°C to 2.8°C (2°F to 5°F) higher.[1] Urban temperatures are higher because of the urban heat island (UHI) effect, a phenomenon where the heat from the sun is retained in areas with a high concentration of buildings, parking lots, and roads, and a lack of trees and green space (**Fig. 1**). Tall buildings that block or slow air movement, along with waste heat released by vehicles and air-conditioning units, contribute to the formation of UHIs. Smaller, more intense UHIs also exist within cities, and they can disproportionately affect low-income neighborhoods and communities of color.[2,3]

Climate change is exacerbating the UHI effect and making cities hotter. Zhao et al.[4] project that cities globally will be 4°C (7.2°F) hotter by 2100. Rising urban temperatures are a serious concern because excessive heat has a severe impact on human health.

Heat is the leading weather-related cause of human mortality, greatly outstripping hurricanes, tornadoes, lightning, and blizzards.[5] Other adverse effects of heat

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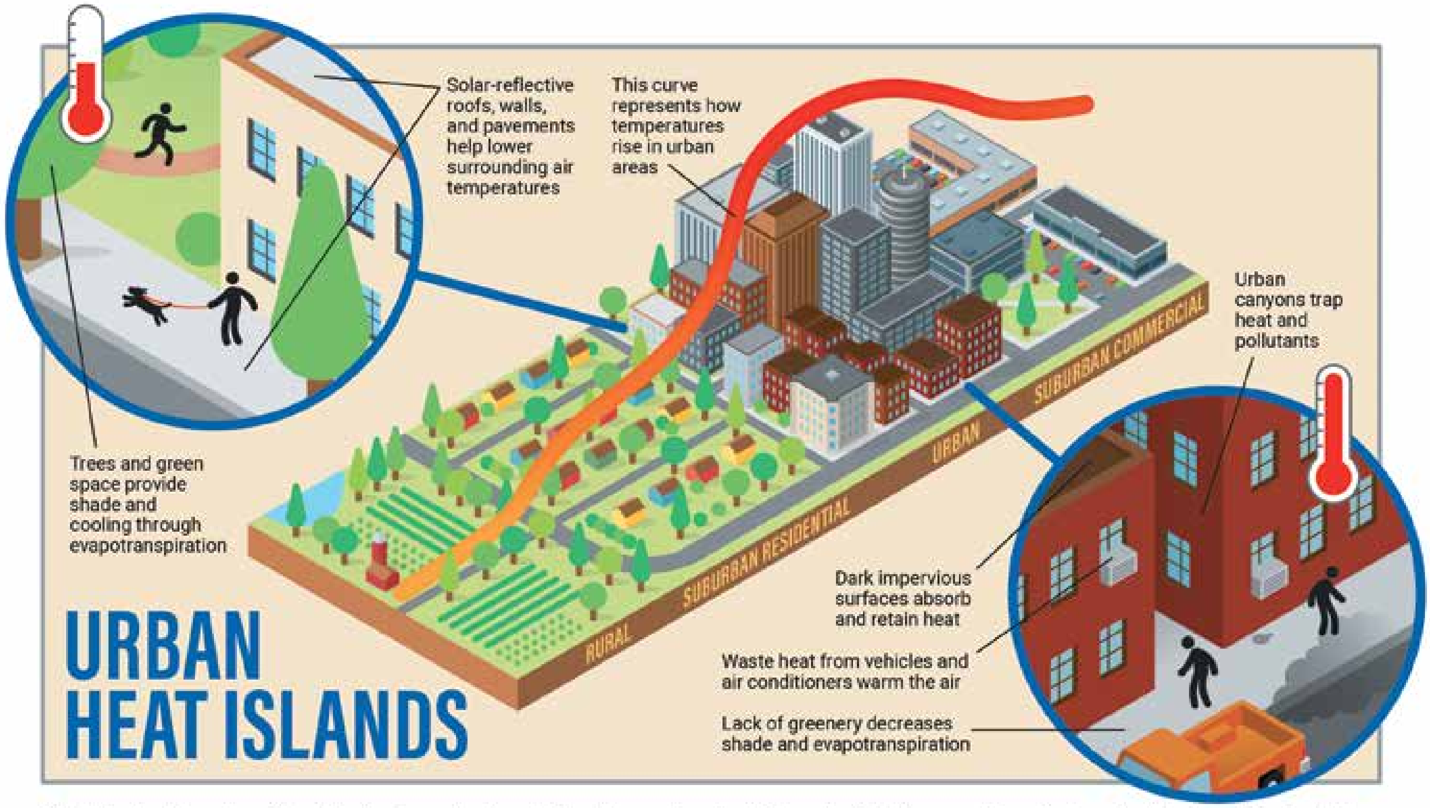


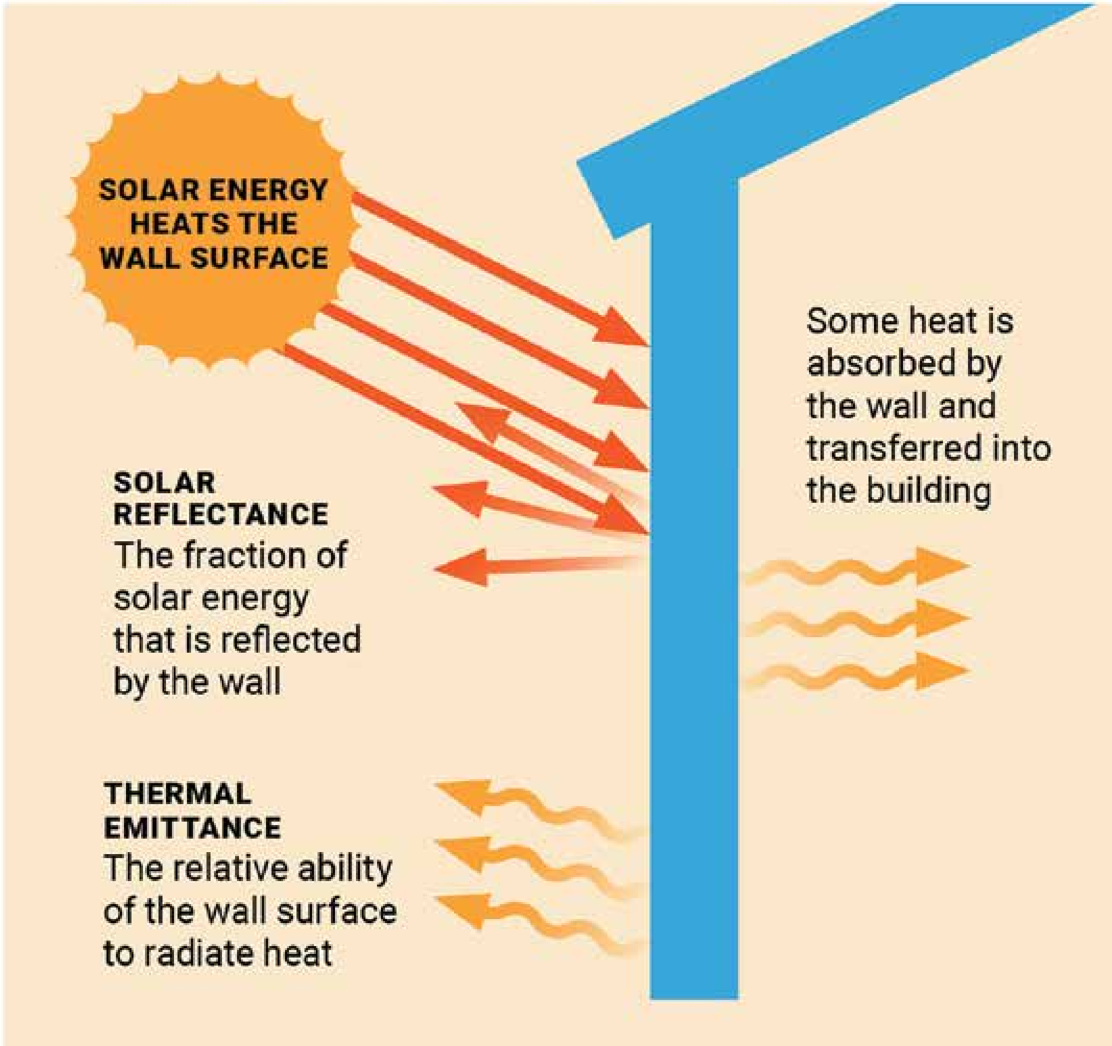
This illustration describes the factors that contribute to urban heat islands (UHI), as well as factors that help mitigate UHI. Urban heat islands occur when the temperature in urban environments is higher than surrounding areas. High surface temperatures lead to elevated air temperatures, especially at night. Heat islands increase heat-related discomfort, illness, and death. They also cause greater air conditioner use, which increases energy costs and air pollution. Urban heat has a disproportionate impact on disadvantaged communities (Hsu et al., 2021; Hoffman et al., 2020; and Wilson, 2020).

Figure 1. Urban heat island effect.

Graphic credit: Cool Roof Rating Council.

Figure 2. The temperature difference between a dark and light wall taken on July 19, 2022, at 7 p.m. in Portland, Oregon.

Image credit: Audrey McGarrell.



This illustration describes the flow of radiant energy as heat between the sun, wall surface, building interior, and surroundings. The higher the solar reflectance, the more solar energy is reflected away from the wall surface. Some of the solar energy is absorbed by the wall as heat. The higher the thermal emittance, the more absorbed heat is radiated away from the wall surface.

Figure 3. Cool exterior wall diagram.

Graphic credit: Cool Roof Rating Council.

include heat illness, increased respiratory and cardiovascular problems, increased hospitalizations, strains on health services, and disruptions to key infrastructure such as power grids and water supplies.[6]

Air-conditioning use increases when it is hot outside, which puts a strain on electrical grids. This strain can lead to blackouts and grid failures. The increase in air-conditioning use also produces more waste heat, which adds to the heat problem. Higher outdoor temperatures also decrease air quality by increasing the production of ground-level ozone, a key ingredient in smog, and also by slowing the movement of air. Furthermore, the increase in air-conditioning use during peak times can result in the use of peaker plants.

Buildings play an integral role in UHI mitigation through the use of solar-reflective ("cool") surface materials, such as cool exterior walls. This article explores the advantages of solar-reflective wall materials, how they mitigate heat, available product options and product rating systems, relevant codes and standards, and barriers to adoption of this solution.

BUILDING SOLUTIONS TO ADDRESS HEAT AND ENERGY USE

A 2019 California Energy Commission research study led by Lawrence Berkeley National Laboratory, the University of Southern California, and the University of California at San Diego demonstrated that cool exterior walls are a viable mechanism for UHI mitigation and that the ability of cool exterior walls to mitigate the UHI effect is on par with that of cool roofs. For example, the study found that cool exterior walls in Los Angeles, California, yield about 85% of the daily average air cooling achieved with cool roofs in July.[7]

The researchers used the Weather Research and Forecasting model (mmm.ucar.edu/models/wrf) to simulate the effects of cool exterior walls and cool roofs on the near-ground (at a height of 6.56 ft [2 m]) outdoor air temperature in the Los Angeles Basin. They found that for equal increases in solar reflectance (SR), cool exterior walls were nearly as effective as cool roofs. This finding is notable because walls receive less daily

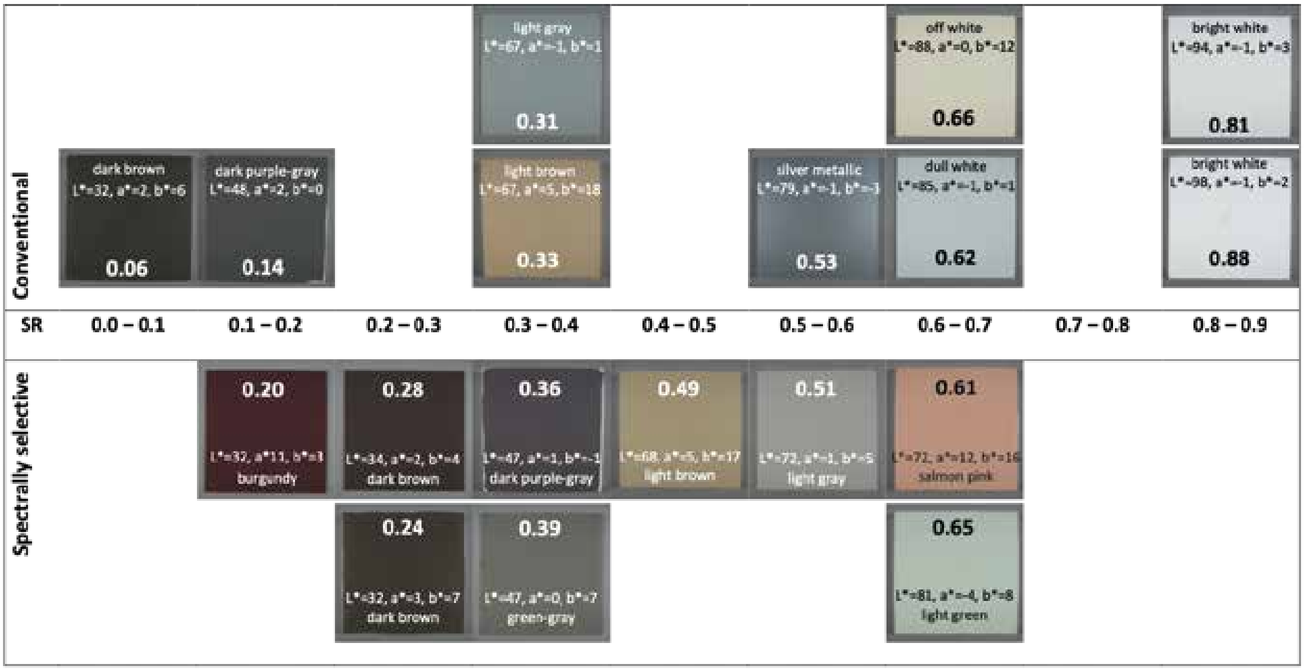


Figure 4. Range of solar reflectance among exterior wall products colored with conventional and infrared-reflective "cool" pigments.

Image credit: Heat Island Group, Lawrence Berkeley National Laboratory, Berkeley, CA.

solar irradiance than roofs since there is about 50% more net wall area (walls minus windows) than roof area in Los Angeles. Walls are also closer to ground air than the roofs (the average wall height is half the average roof height).[7]

The researchers also found that cool exterior walls produce annual heating, ventilating, and air-conditioning (HVAC) energy savings in US Climate Zones 1 through 4 (which includes the southern half of the US) and across all 16 of California's climate zones for both residential and nonresidential buildings.[7] As long as there are no rules that limit color choice, such as requirements dictated by a homeowners' association or a historic building preservation commission, designing or painting a building in a lighter color is low-hanging fruit and a viable option for reducing cooling bills during hot times of the year.

COOL EXTERIOR WALL IMPACTS

When an exterior wall surface highly reflects solar radiation, it lowers the surface temperature of the wall material (**Fig. 2**) and reduces the building's solar heat gain. This causes a chain reaction of impacts on individual building, community, and global scales.

Reduced heat gain lowers the building's indoor temperature. For non-air-conditioned buildings, this improves occupant comfort and safety.[8] For air-conditioned buildings, reduced heat gain helps lower the building's cooling demand and, by extension, reduces the amount of waste heat released by air-conditioning units.[9] Less waste heat leads to lower outdoor temperatures, which improves air quality by slowing the formation of ground-level ozone that can trigger severe health problems and contribute to smog formation.[10,11]

Reduced cooling demand also helps decrease peak power demand,[12] which can alleviate strain on the electrical grid, lowering the risk of blackouts and brownouts, and lessen the use of "peaker" plants. Peaker plants are additional, as-needed power plants, which are large emitters of air pollution. Reductions in peak and conventional power generation decrease the emission of greenhouse gases, which helps address the greenhouse effect and the impacts of climate change.[10,12]

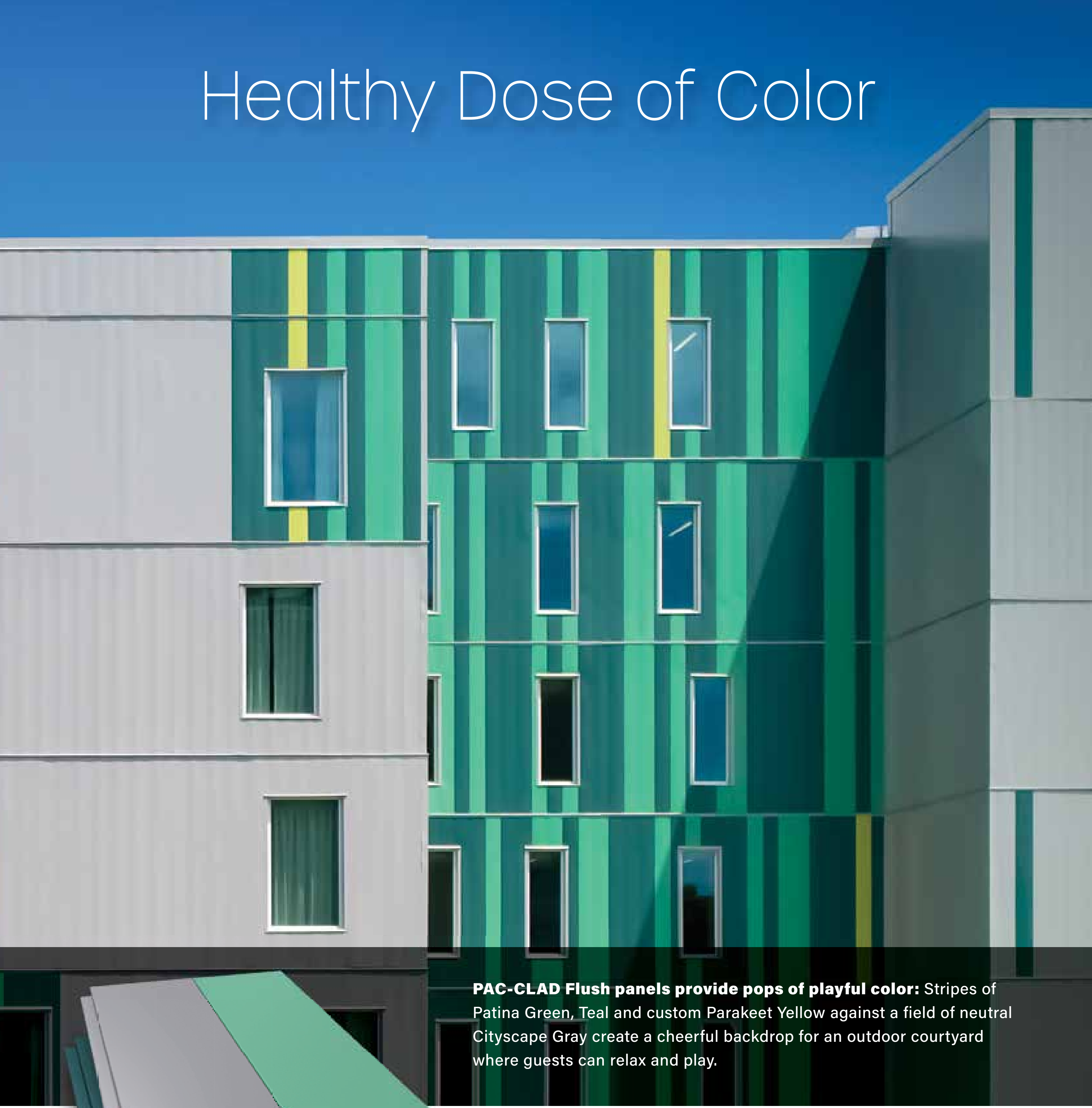
The outcomes associated with cool exterior walls for an individual structure can depend on a variety of factors, including, but not limited to, wall SR, wall insulation and construction, climate zone, building orientation, and building occupant use. Though cool exterior walls have been shown to reduce a building's cooling demand in US Climate Zones 1 through 4 and across California, they can also cause heating bills to increase during the winter because they do not absorb as much sunlight as darker or less solar-reflective walls. The magnitudes of energy savings and penalties from cool exterior walls depend on several key factors, including climate, wall construction, wall orientation, building orientation, and HVAC efficiency. Rosado and Levinson[12] found that installing cool exterior wall technology on the south-facing wall of a building in California led to the largest penalties in terms of heating costs. However, the same arrangement led to large savings during the cooling season. Across California and the southern half of the US, the study also found that all buildings of any vintage would benefit from cool exterior walls, especially on the east, south, and west faces.

THE BASICS OF WALL RADIATIVE PERFORMANCE

Cool exterior wall materials are either light in color or include special pigments that efficiently reflect infrared radiation and radiate heat that was absorbed. As a result, the exterior wall surface and inside of the building are cooler than they would have been if other exterior wall materials were used. **Figure 3** is a simple illustration of the physics of cool exterior walls. The two basic characteristics that determine the "coolness" of the wall surface are SR and thermal emittance (TE). Both properties are measured on a scale from 0 to 1, where 1 is 100% reflective or emissive. The same properties are used to evaluate the radiative performance of roofing materials.

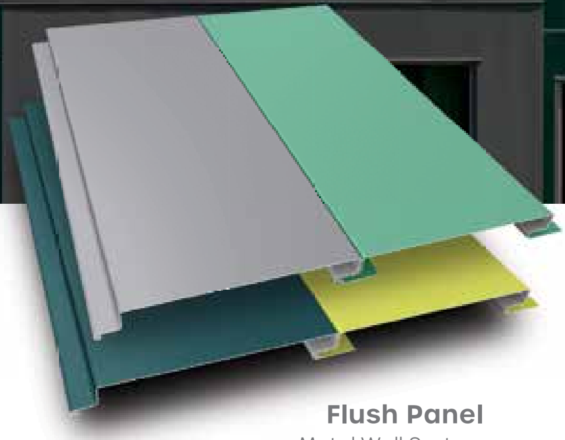
When exterior walls are compared with roofs, the amount of sunlight that hits the walls of a building has greater diurnal and annual variation, with less solar energy hitting the walls overall. However, walls also generally have less insulation than roofs, with about half the amount of resistance to heat flow achieved by a roof.

Healthy Dose of Color



PAC-CLAD Flush panels provide pops of playful color: Stripes of Patina Green, Teal and custom Parakeet Yellow against a field of neutral Cityscape Gray create a cheerful backdrop for an outdoor courtyard where guests can relax and play.

Ronald McDonald House, Cincinnati Installing contr. (walls): Neiheisel Steel Architect: GBBN Architects
General contractor: Messer Construction Photo: hortonphotoinc.com



Flush Panel
Metal Wall System

Patina Green, Teal, Cityscape and custom Parakeet Yellow

View the case study and video

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The combination of these two factors results in cool exterior walls and cool roofs having similar impacts.[7]

There are important differences in how SR and TE are evaluated for wall surfaces as compared with roofs. First, SR measurements for a wall surface must be taken using an irradiance model specific to a sun-facing, 90 degree (vertical) surface to account for how a wall surface interacts with solar radiation. Wall materials must also be exposed for natural weathering at a 90 degree angle facing south. Natural weathering is an important factor in evaluating wall materials because it helps users understand the product's radiative performance over time. Lastly, while the Solar Reflectance Index (SRI) is a common calculated metric for comparing the overall ability of roofing materials to stay cool, it is not used for wall products because the formula to calculate SRI does not account for a vertical surface.[13]

The radiative properties of wall materials are measured in accordance with several ASTM International standards and other industry-vetted test methods. The most common SR test method is ASTM Standard C1549.[14] ASTM Standard C1371[15] and the Slide Method, published in the Devices and Services Company's Technical Note 11-2,[16] are the most common for measuring TE.

AVAILABLE PRODUCTS

Exterior paints, claddings, and other wall products sold today have SRs ranging from about 5% (black) to 90% (bright white). A standard dark- to medium-colored wall might reflect 25% of sunlight, whereas a typical off-white or dull-white wall might reflect 60%. A clean bright-white wall could reflect 80% of sunlight.

Some products are colored with conventional pigments, and others use special infrared-reflective pigments that boost the SR of darker surfaces (**Fig. 4**). The coated-metal industry has been using these special pigments for years.

ADOPTION OF COOL EXTERIOR WALLS

In recognition of their ability to reduce building energy use and mitigate the UHI effect, provisions for cool exterior walls are found in several model codes and standards, including ASHRAE Standard 90.1;[17] the *International Green Construction Code* (IgCC),[18] which is based on ASHRAE 189.1;[19] and ANSI/RESNET/ICC Standard 301.[20]

Although the prescriptive requirements for wall SR and TE in ASHRAE 90.1-2022 only pertain to Climate Zone 0 (which does not apply to any parts of the US or Canada), Appendix G, the Performance Rating Method, sets the wall SR and TE as 0.25 and 0.90, respectively, in the baseline building performance. This means that US building enclosure consultants may be able to help their clients obtain a small compliance credit in Climate Zones 1 and above for proposed buildings that use exterior wall materials with a measured SR greater than 0.25 (the wall surface must be modeled using a baseline SR of 0.25 and a baseline TE of 0.90). Hawaii also offers a compliance credit for the installation of a highly reflective exterior wall material on residential and commercial buildings in its statewide building code.

Another state that promotes the use of cool exterior walls is California. Any California city can adopt the SR prescriptions in the *California Green Building Standards Code*[21] (also known as CALGreen) as part of its reach code. Jurisdictions outside of California may choose to adopt the reflective wall provisions in the IgCC (2018 edition or newer) or the *National Green Building Standard* (ICC 700-2020).[22]

For a list of codes and standards that contain provisions for cool exterior walls, visit https://coolroofs.org/resources/codes-programs-standards.

BARRIERS TO WIDE-SCALE DEPLOYMENT

Although there are "cool" products on the market today, there are also barriers to the wide-scale deployment of cool exterior walls. First, education and marketing are insufficient to make consumers aware of available products and the various benefits these products provide. For example, there is a perception that cool wall products limit color choices for consumers. However, as previously described, there are darker-color products on the market that use infrared reflective pigments to achieve higher SR. Consumer education about such products is critical.

Second, the codes and standards that require the use of cool exterior walls have multiple limitations. The codes and standards discussed in the previous section have voluntary compliance only. Furthermore, there are uncertainties about how a prescriptive or mandatory requirement for the use of highly reflective exterior wall materials might be enforced if there is no mechanism, such as a permitting process, in place to ensure that highly reflective materials are used when a building's exterior is repainted or replaced.

Additionally, some existing code provisions use an incompatible metric that makes it virtually impossible to comply. For example, SRI is a calculated metric that is only applicable to roofs, but it is also included in some code requirements for walls. To address this issue, several codes have been revised to include SR and TE instead of SRI. More work needs to be done regarding existing and new building code requirements.

THIRD-PARTY PRODUCT RATINGS BOOST COMPLIANCE

Third-party product ratings can help policymakers and consumers identify and understand the benefits of cool exterior walls. In the context of wall products, a third-party rating informs consumers about the material's ability to reduce solar heat gain (the amount of heat that enters the building through the exterior wall surface). The rating is based on radiative property data measured by an accredited independent testing laboratory, which is then verified and published by a third-party entity. A third party may be a government agency, nonprofit organization, or a company that is not affiliated with the manufacturing or distribution of exterior wall products.

Third-party product ratings can also assure consumers that the data are credible and accurate, obtained through consensus standards and industry-vetted test methods, and validated through quality assurance mechanisms. This is why third-party product ratings are widely used by government agencies and energy utilities in the development, compliance, and enforcement of policies and programs that require or promote the use of certain building materials.

The Cool Roof Rating Council (CRRC) maintains a publicly available database of exterior wall products with radiative property ratings.[23] The database is a free online resource designed to help end users, such as building enclosure consultants, search for and identify products that can be used to comply with codes and standards, as well as green building certification programs. Products are searchable by keyword, product type, manufacturer, brand or model, color, product market, and SR and TE values. Published ratings are obtained in accordance with the CRRC Wall Rating Program requirements,[24] which were developed with input from a wide array of stakeholders and subject matter experts.

CONCLUSION

Like cool roofs, solar-reflective exterior walls offer promising technology to reduce solar heat gain in buildings, which can improve occupants' comfort in hot weather, reduce air-conditioning needs and associated energy costs, and help mitigate the adverse effects of UHIs and

Cool Roof Rating Council

The Cool Roof Rating Council (CRRC) is a 501(c)(3) nonprofit that was established in 1998 through a collaboration between industry, government, national laboratories, utilities, and nonprofit organizations with the goal of developing a rating system for roofing products based on accurate and credible methods for evaluating a product's radiative performance. The organization expanded its scope to include exterior walls in 2019. For more information about CRRC, **visit coolroofs.org.**

climate change. Consumer education about the benefits of solar-reflective wall materials and available products, as well as effective codes and standards for the testing and use of such products, will be critical to the successful wide-scale adoption of cool exterior walls.

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