HARNESSING THE MUTUAL BENEFITS OF COOL ROOFS + ROOFTOP PV

COOL ROOFS AND ROOFTOP PV (rooftop solar photovoltaics) are two strategies that home and building owners can use to cut energy costs, reduce greenhouse gas emissions, and enhance climate resilience. This document identifies how these strategies can be used together to enhance the benefits of both.

ABOUT COOL ROOFS

A COOL ROOF IS CONSTRUCTED of materials that efficiently reflect solar energy and radiate heat. Cool roofs come in a variety of colors and styles for commercial and residential use. The two basic characteristics that determine the "coolness" of a roof are solar reflectance (SR) and thermal emittance (TE). Both properties are measured on a scale from 0 to 1, where 1 is 100% reflective or emissive. A directory of SR and TE ratings for over 3,000 roofing products can be found at **coolroofs.org/directory/roof**.

Cool roofs help keep the surface and internal temperatures of homes and buildings cooler during warm weather and provide numerous benefits.

LEARN MORE AT
coolroofs.org/resources/what-is-a-cool-roof

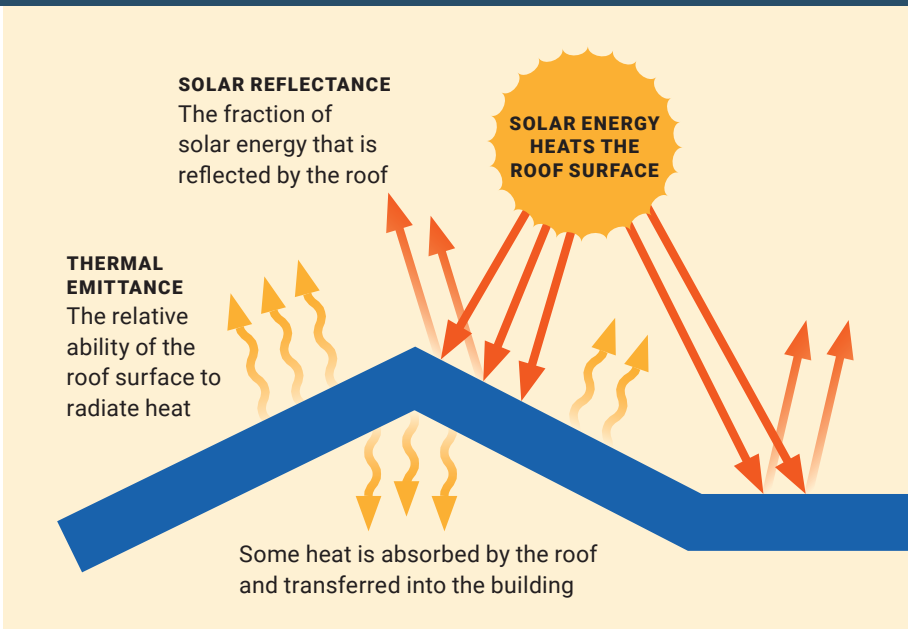


IMAGE CREDIT: COOL ROOF RATING COUNCIL

This illustration describes the flow of radiant energy as heat between the sun, roof surface, building interior, and surroundings. The higher the solar reflectance, the more solar energy is reflected away from the roof surface. Some of the solar energy is absorbed by the roof as heat. The higher the thermal emittance, the more of this absorbed heat is radiated away from the roof surface. IMAGE CREDIT: COOL ROOF RATING COUNCIL.

ABOUT ROOFTOP PV

ROOFTOP SOLAR PHOTOVOLTAIC SYSTEMS, commonly known as PV, are systems typically consisting of solar panels, an inverter, and other components to convert sunlight into electricity. **Monofacial** PV panels, which generate electricity only from the front face of the panel, are the most common and least expensive systems. They are usually installed on a southern or western-facing roof and are often flush on the roof. **Bifacial** panels have a clear backsheet and are capable of generating electricity with light coming in from both the front and the back faces of the panel, thus absorbing more light and producing more power. Bifacial PV panels are currently about 15% more expensive than monofacial, but the bifacial market share is growing rapidly as the cost premium is decreasing. Bifacial panels can be used in different configurations that maximize light on both sides, such as tilted up from the roof at a steeper tilt angle or in vertical orientations. Bifacial panels are of special consideration in a cool roof project because the back side of the PV panels can harvest sunlight reflected off the high-SR roof surface.

WORKING TOGETHER TO INCREASE EFFICIENCY AND ENERGY PRODUCTION

NUMEROUS STUDIES HAVE SHOWN that cool roofs help increase the efficiency and energy production of bifacial and, to a lesser extent, monofacial rooftop PV. The information presented here is based on a literature review by Vasilakopoulou et al. which summarizes the findings of 70 case studies for a wide range of climates and installation characteristics for both types of PV. It's important to note that the exact influence of cool roofs on rooftop PV efficiency depends on several variables, including the technology and type of PV arrays; latitude and climate (direct or diffuse sun); PV placement (spacing between rows) and positioning (tilt angle); and roof SR. See here to read the full paper.

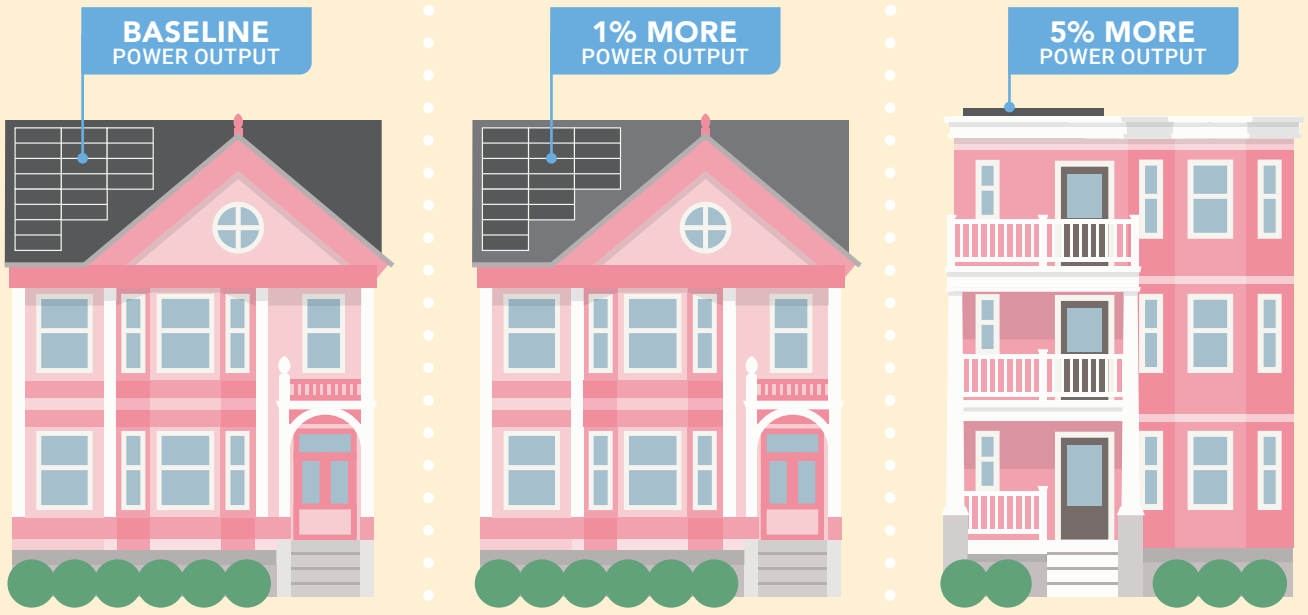
LOWER TEMPERATURES = GREATER EFFICIENCY

Rooftop PV systems function better at lower temperatures. Because cool roofs substantially reduce roof surface temperatures and the ambient air temperature around roofs, they help improve the efficiency of both mono- and bifacial rooftop PV.

IMPACT OF COOL ROOFS ON MONOFACIAL POWER OUTPUT

MONOFACIAL ROOFTOP PV are often used on residential roofs, both low- and steep-sloped. Because they only capture sunlight from one side, they are less affected by increased roof SR than bifacial PV. However, according to Vasilakopoulou et al., there is a modest linear relationship between roof SR and monofacial PV energy production, with every 0.1 increase in roof SR yielding an average increase in annual energy production of 0.7%. This means that raising a roof's SR from 0.15 to 0.25 would increase monofacial PV power output by approximately 1%, and raising it to 0.8 would increase power output by approximately 5%.

Estimated Increase in Monofacial PV Power Output with Cool Roofs



Examples of possible increases in monofacial PV power output as a result of raising a roof's SR. The SR values included in these examples are representative of steep- and low-slope roofing material options that were rated by the CRRC at the time of publication.

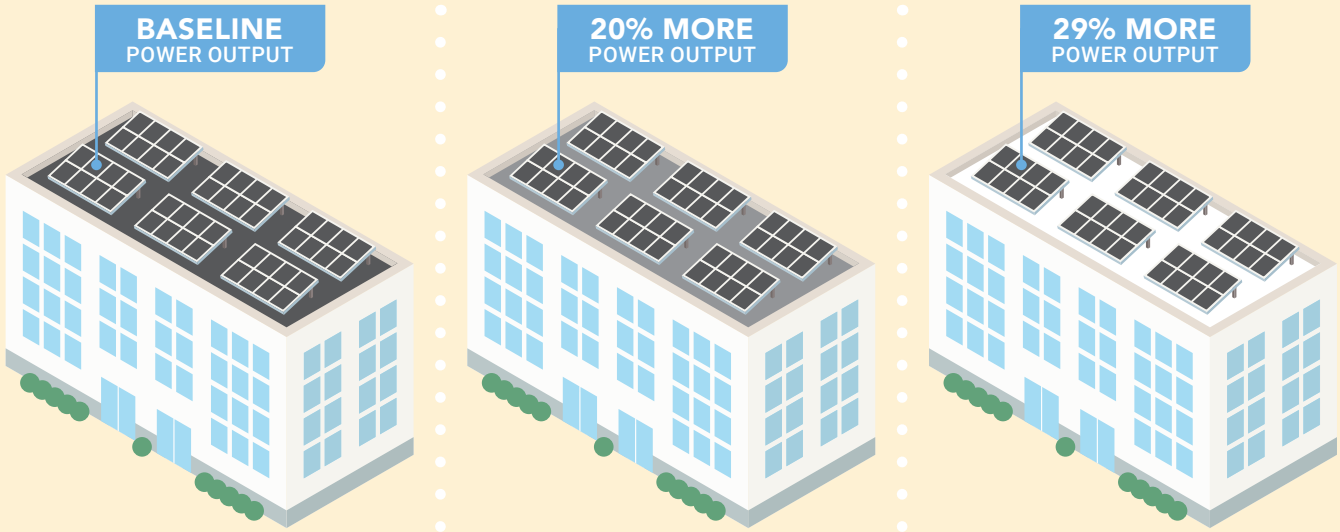
IMPACT OF COOL ROOFS ON BIFACIAL POWER OUTPUT

BIFACIAL ROOFTOP PV can be used on low-sloped roofs. Since they absorb solar energy on both sides, they greatly benefit from highly solar-reflective roofs. Vasilakopoulou et al. found a strong linear relationship between the two, with every 0.1 increase in roof SR yielding an average increase in annual energy production of 4.5%. This means that raising a roof's SR from 0.15 to 0.60 would increase bifacial PV power output by approximately 20%, and raising it to 0.80 would increase power output by approximately 29%.

These estimates are based on data from numerous simulation and experimental studies for a wide variety of locations and characteristics. Importantly, the tilt angle and the elevation of the bifacial PV above the roof has a large impact on the influence of roof SR on performance, with the optimal positioning depending on the latitude of the location (e.g., the sun is higher in the sky at low latitudes).

See Vasilakopoulou et al. for more information.

Estimated Increase in Bifacial PV Power Output with Cool Roofs



Examples of possible increases in bifacial PV power output as a result of raising a roof's SR. The SR values included in these examples are representative of low-slope roofing material options that were rated by the CRRC at the time of publication.

ADDITIONAL RESOURCES

LEARN MORE ABOUT COOL ROOFS

LEARN MORE ABOUT SOLAR ENERGY

Visit the CRRC Rated Roof Products Directory

Browse CRRC Fact Sheets and Brochures

Join the CRRC Email List

READ ON FOR FAQS ABOUT COOL ROOFS AND ROOFTOP PV

FAQs

DO ROOFTOP PV HAVE AN IMPACT ON THE URBAN HEAT ISLAND EFFECT?

PV panels convert about 20% of the incident solar energy that they absorb into electricity which is exported from the roof by wires into the building electrical system. This reduces the amount of absorbed solar energy that is dissipated as heat and helps curb urban heating. Studies have shown that PV can both warm and cool urban environments, depending on many factors. Below are several examples:

- **SCHERBA ET AL. (2011):** A simulation study that included six U.S. climate zones and was validated by an experiment in Portland, OR quantified the impact of adding PV to low- and high-SR roofs on the total sensible heat flux (net flux over a 24-hour period) from the roof to the urban environment during the summer. The study found that adding PV to a low-SR roof reduced the total heat flux by about 11%. Replacing the low-SR roof with a high-SR roof reduced the total flux by about 80%; however, adding PV to the high-SR roof lowered the decrease in total flux to 55%.
- **TAHA (2013):** A simulation study found that rooftop PV had no impact on air temperature in the LA area because the effective SR of rooftop PV is comparable to that of the surrounding urban environment.
- **SALAMANCA ET AL. (2016):** An experimental study found that rooftop PV can reduce citywide cooling energy demand in Phoenix and Tucson (excluding additional savings from energy production).
- **BARRON-GAFFORD ET AL. (2016):** An experimental study found that the air over a large PV plant in southern Arizona was regularly 3–4°C (5.4–7.2°F) warmer than the neighboring natural desert at night and 1.5°C (2.7°F) warmer during the day. The temperature probes were 2.5 meters (8.2 ft) above the soil surface at each site.

In any case, increasing the SR of the roof beneath PV arrays reduces the ambient air temperature and the surface temperature of the roof and PV, which improves PV efficiency and helps counteract potential urban heating.

DO COOL ROOFS INCREASE THE LIFESPAN OF ROOFTOP PV?

Experts believe that cool roofs may extend the life of rooftop PV due to reduced temperatures and increased efficiency. For one example, see Rahmani et al. (2021). Because rooftop PV can last about 25-30 years, there is limited data available at this time about the lifespan of PV arrays installed on cool roofs compared to conventional roofs.

DO PV PANELS INCREASE THE LIFESPAN OF COOL ROOFS?

Rooftop PV panels shade the roof surface underneath, which reduces heat gain into the building and the amount of ultraviolet solar light reaching the roof. The shadow of the PV panels is greatest under the panels but moves around on the roof as the sun moves across the sky. As a result, it is likely that PV modules can help prolong the life of the roof by reducing surface degradation caused by solar heat and UV radiation and protecting the roof from the elements.

FOR MORE INFORMATION AND RESOURCES ABOUT COOL ROOFS

VISIT coolroofs.org

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