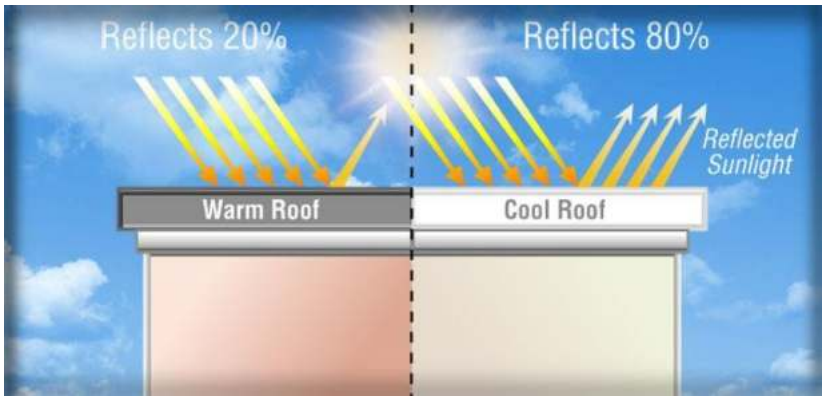
Frequently Asked Questions (FAQs)
COOL ROOFS

Cool roofs improve thermal comfort for the building occupants and save energy in air-conditioned buildings. When implemented at scale, cool roofs can counter the urban heat island effect, caused by the heat absorbing materials in the built environment. By reflecting incoming solar radiation, cool roofs can reduce temperatures inside buildings and mitigate cooling demand for an entire city.[1]

The roof is an important component of the building envelope that has a direct impact on building's energy needs and thermal comfort of the occupants. Cool roofs function primarily by absorbing less heat and reflecting more sunlight incident on the roof back to the atmosphere than a regular roof surface (Figure 1).

Figure 1: Warm roof (shown on left) absorbs more sunlight; Cool Roof (shown on right) has reflective surface and reflects more sunlight



Source: Heat Island Group, Lawrence Berkley National Lab

Cities can lead the way in cool roof implementation. In 2017 and 2018, the cities of Hyderabad and Ahmedabad initiated pilot cool roof programs. The pilot programs included citizen awareness campaigns, cooperation with businesses, and application of cool roof interventions to government buildings, schools and low-income houses. Building on the success of these pilot projects and the impact achieved in terms of improvement in the indoor temperature, these cities will be launching larger scale cool roof programs.

The city or state wide Cool Roofs Programs are a target-based programs that aim to expand the installation of cool roofs in the city or the state. Using three main strategies for different building types, the Cool Roofs Program focus on yearly targets and implementation plans to increase installation of cool roofs within cities and across the state.

The purpose of these Frequently Asked Questions (FAQs) is to explain key concepts and help to facilitate the adoption of cool roofs by building owners and occupants. The FAQs are intended for all stakeholders, including building owners, real estate developers, energy auditors, architects and occupants.

1. What is a cool roof?

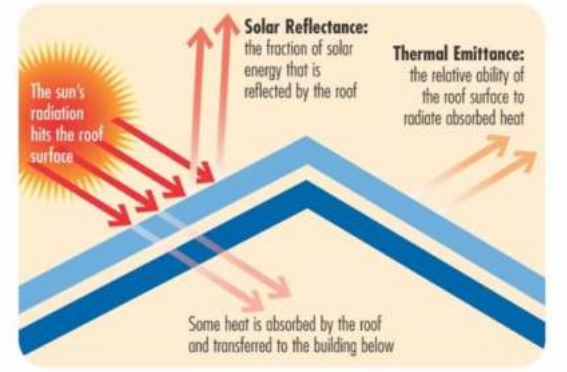
A cool roof is a roof built from materials that retain less heat and stay cooler than traditional roofs by reflecting more sunlight. These roofs are prepared, covered or coated with materials that have special characteristics (high reflectivity & high emissivity). As a result, the roof stays cooler throughout the day, keeping buildings cooler and more comfortable.

2. How does a cool roof work?

Cool roofs function primarily by reflecting sunlight incident on the roof, back to the atmosphere to a greater extent than regular roof surfaces. When solar radiation falls on a roof, the roof surface performs four functions:

- It reflects a part of the incident solar radiation back into the atmosphere.
- It conducts a part of the heat through itself into the buildings.
- It convects a part of the heat to the ambient air (external and internal).
- It emits a part of the absorbed heat to internal surfaces and back to the sky.

Figure 2: Functions of a cool roof



Source: The Cool Roofs Rating Council (CRRC)

The two most important factors that determine the effectiveness of a surface as a cool roof are its ability to reflect solar energy, termed as solar reflectance or albedo, and emit absorbed energy (thermal emittance). Most dark roofs reflect no more than 30 percent of incoming sunlight (i.e., these surfaces have a reflectance of 0.3 or less); while a new white roof reflects about 70 to 80 percent of sunlight (i.e., these surfaces have an initial reflectance of 0.7 to 0.8).[2]

Reflectance is measured over the entire solar spectrum, of which a little less than half is visible light. An equal amount is invisible infrared light. So, while most cool roofs look white, and typical white paints and whitewash have high reflectance, it is possible to have cool roofs that have a noticeable pastel color, or to have roofs that look white but are not high in solar reflectance.

3. What is Solar Reflectance Index (SRI)?

The Solar Reflectance Index (SRI) is a measure defined by the Lawrence Berkeley National Laboratory as the roof's ability to reject solar heat, as shown by a relative degree of temperature rise. The index is defined so that a standard black (reflectance 0.05, emittance 0.90) is 0 and a standard white (reflectance 0.80, emittance 0.90) is 100. Due to the way SRI is defined, particularly hot materials can even take slightly negative values, and particularly cool materials can even exceed 100.[3]

4. What are the different types of cool roofs?

Cool roofs can be installed from a wide variety of materials and coatings and can be advantageously applied to almost any building or roof type, and in most locations. To help cater to a range of contexts, cool roof techniques can be broadly divided into four categories.[4]

- *Coated cool roofs:* these roofs involve coating the roof with high reflectivity paint to increase the roof Solar Reflective Index (SRI), a measure of how well the roof reflects light and rejects heat. These coatings can be made of simple materials such as lime wash, or an acrylic polymer and may contain special pigments to increase reflectivity. Most coatings are white in color and can be applied over existing roofing materials.

- *Membrane cool roofs:* these roofs involve using pre-fabricated materials such as membranes or sheeting to cover an existing roof in order to increase the roof surface's SRI. These types of roofs can be polyvinyl chloride (PVC) or bitumen-based.
- *Tiled cool roofs:* these roofs involve the application of high albedo, white colored china mosaic tiles or shingles on top of an existing roof or to a new roof.
- *Green roofs:* green roofs make use of vegetation to help the roof absorb less solar energy and by evaporating water in their leaves, providing further cooling. They also save by providing a thermal mass layer to reduce flow of heat into a building. Vegetation is especially useful in reflecting infrared radiation.

5. What's the difference in indoor temperature after applying cool roofs?

Studies have shown that depending on the setting, cool roofs can help reduce indoor temperatures by, as much as 1.5 to 5°C (3.5 - 9°F) as compared to traditional roofs, offering simple and effective protection from extreme heat especially for vulnerable communities in low income housing.[5]

6. What are the benefits of cool roofs?

Cool roofs provide numerous benefits for households, buildings and the wider community. Cool roofs conserve energy and keep indoor temperatures lower. When installed over a large area, cool roofs can assist in mitigating the urban heat island effect and lead to lower ambient air temperatures and reduced air pollution on an urban scale.[6]

- *Cool roofs conserve energy and save costs by reducing cooling load requirements in a building:* By lowering the temperature inside the top floor of a building, cool roofs reduce the need for cooling. They also reduce energy use in air-conditioned buildings. Experiments have shown that a change from black to white (cool) roofs can achieve 14-26% cooling energy savings on the top floor of the building.[7]
- *Cool roofs help mitigate the urban heat island effect, improve air quality and combat climate change:* By reducing the amount of heat gain in an urban area, cool roofs can mitigate the urban heat island effect. Modelled studies have shown that city-wide installations of highly reflective roofs and pavements, along with planting shade trees will, on average, reduce a city's ambient air temperature by 2 to 4 degrees Celsius in summer months.[8] By reducing local outdoor air temperatures, cool roofs also improve air quality by curtailing ground-level ozone smog formation, which increases in higher temperatures.[9] By reducing cooling energy demand, cool roofs help in reducing carbon pollution emitted from burning fossil fuels to generate electricity, thus reducing PM2.5 generation and also combating climate change.
- *Cool roofs enhance durability and appearance of roofs*: By keeping roof structures from heating up through applying cool roofing techniques, cool roofs can prevent excessive expansion and contraction of the materials and reduce cracking, prolonging the life of the roof.
- *Cool roofs increase energy access by reducing peak load on the grid*: By saving energy through reduced cooling needs in air-conditioned buildings, cool roofs can cut peak load on the grid, enabling lesser load shedding during the peak summer months.[10]
- *Cool roofs help build community resilience to extreme heat by reducing heat stress*: Cool roof installations enhance community resilience to extreme heat and can reduce heat-related illnesses and casualties.

7. What factors can reduce the reflectivity and long-term durability of cool roofs such as coated roofs?

- Before application: poor drainage, poor surface preparation, or improper mixing.
- During application: under-applying, over-applying, or misapplying.
- Post application: excessive metal abrasion.

Given the above listed factors, it is therefore important for the process of cool roof installation to undertake proper surface preparation and the material should have properties of low dirt pick up, antialgae & antifungal properties. The system should be protected from the UV radiations of the solar radiations.

8. Why are cool roofs important?

In India, nearly half a billion people live in rapidly urbanizing cities with skyrocketing development that converts open spaces into paved, heat-trapping roofs and roads. These hot surfaces worsen the heat island effect, drive temperatures higher, and, due to increased power demand for cooling, worsen air quality. Cool roofs offer a simple and cost-effective solution to these urbanization challenges and are therefore important for a country like India.

9. Can all buildings have cool roofs?

Yes, all buildings can have cool roofs. Cool roofs are also a viable option for both new and existing building applications. For new buildings, the incremental cost of adding cool roofs is minimal, or, at times, none. For existing buildings too, the additional expenses may be insignificant if the retrofit is properly integrated with the re-roofing schedule.

10. Do cool roofs cost more than conventional roofs?

Initial material costs are comparable with traditional roofing materials. Some cool roof products cost less than traditional materials, while some may cost higher than others. For example, cool tiles typically cost higher than cool coatings. Cool protective coatings can be reapplied approximately every 4-5 years and increase the longevity of the roof structure under it.[11] Combining the maintenance savings with an average 20 percent savings on air conditioning costs make cool roofing a great bargain over the long term.[12]

11. How much do cool roofs cost?

Comprehensive data for the cost of materials for cool roofs is local and subject to variation with time. Informal market information gives a likely range of prices. The Ahmedabad Cool Roofs Pilot Program used simple white lime paint for the most part, at a cost of approximately ₹0.5 per square foot.[13] More specialized materials, such as high reflectivity coatings or membranes, are significantly more expensive, and the price per square foot from Indian companies commonly ranges in the hundreds of rupees. Table below, indicates approximate costs of various cool roof materials but the actual costs may vary depending on the local vendors.

Table 1: Indicative costs of cool roofs material types[14]

	Material	Cost per sq. ft (in rupees)	Payback period (approx.)
1	Coatings	20-40	1.5 - 2 years
2	Cool roof tiles	50-100	2 years
3	Membranes	20-55	2 to 3 years

12. Are cool roofs effective and durable?

Several cool roof techniques appear to have similar levels of effectiveness in terms of their ability to reflect solar radiation – tiles, membranes (PVC), and coatings have SRIs that are relatively close to each other. This makes it unlikely that any particular type of cool roof results in much greater temperature reductions than another, so cost, accessibility, ease of installation, and durability

are more important variables to consider when choosing a material for a cool roof.

Cool roofs are subject to wear and tear, and depending on the materials used in their construction, they have varying lifetimes. Wind, rain, dust, and dirt all play their part in gradually reducing the effectiveness of cool roofs. The life of any cool roofing product also depends on the application techniques and the process followed. The cool roof coating system is more successful when it is applied with proper surface preparation with proper base primer coats and protecting the cool roof surface from dirt pickup, algae fungus and UV radiations. The coating applied with proper process can have a life of more than 4-5 years. However, based on data from the Cool Roofs Rating Council, tiles and shingles are more durable over a three-year period than paint, coatings, or membranes.[15]

13. Are cool roofs recommended for buildings with rooftop solar?

Yes, any surface not covered by the solar panels would still be absorbing heat and can benefit from cool roof application. Research suggests that solar cells work more efficiently in optimum temperature, when the roof is coated, the roof temperature is reduced and the heat intensity on the coated roof area is less, that leads to increased efficiency of solar panels. Solar panels may operate more efficiently when cooled by the wind which has just blown over the cool roof.[16] Besides this, the other reason for increase in the efficiency of the solar cells is the absorption of more incident rays that is reflected by cool roof, thus leading to increased efficiency. Reducing the cooling loads indirectly also contributes to lesser energy requirement thus could be sufficing the energy generated by solar cells.

14. Are green roofs better than cool roofs?

Both green roofs and cool roofs are excellent choices to improve our homes and buildings. Green roofs provide cooling effect mainly due to evaporation. While green roofs also provide some of the cool roof benefits, they can be more expensive.[17] Green roofs require careful plant selection (to maintain the green roof with less water - plant selection that requires less water is very important) and green roof may need higher maintenance and prevention from water leakage. But they can offer recreational value or other amenity value that may justify the additional costs.

15. Are cool roofs material available locally?

Simple white paint is considered as the most easily accessible material for cool roofs in India, most widely available. However the selection of the right material is very important for the sustainability and performance of the cool roof systems. Various other companies sell specialized cool roof coatings specially formulated to have sustainable performance. Also tiles and membranes are available. Some of these materials (for example, tiles) may facilitate the use of exterior insulation under them, which will further reduce energy consumption for cooled buildings.

16. Are there other "cool" options besides white roof coatings?

Yes. Cool roof coatings are available in wide variety of colors – including "cool" black in some cases.[18]

17. Does the Energy Conservation Building Code include adoption of cool roofs?

The Telangana State Energy Conservation Building Code (TS ECBC) for example has incorporated cool roof and its testing standard. The code states that if a project follows the prescriptive compliance method, then it is necessary to have a cool roof. The code allows using high reflectivity in energy simulations when the project assesses whole building performance method. As per the code, for qualifying as a cool roof, roofs with slopes less than 20° should have an initial solar reflectance of no less than 0.70 and an initial emittance no less than 0.75. Solar reflectance shall be determined in accordance with ASTM E903-96 and emittance shall be determined in accordance with ASTM E408-71

(RA 1996). For qualifying as a vegetated roof, roof areas shall be covered by living vegetation of 50 millimetres or greater height. More recently, Telangana has incorporated cool roofs as part of the Telangana Municipalities Act 2019.[19]

18. Other resources to learn more about cool roofs

Cool Roof Calculator
http://coolroof.cbs.iiit.ac.in
http://rsc.ornl.gov/

Cool Roof Material Database
https://heatisland.lbl.gov/resources/cool-roofing-materials-database

Other Cool Roof Resources
http://www.coolroofs.org
www.epa.gov/heatislands
www.urban-climate.org
http://www.coolrooftoolkit.org/

For more information, please contact:

Ms. Prima Madan
Lead- Energy Efficiency and Cooling
Natural Resources Defense Council (NRDC)
Email: pmadan@nrdc.org

Mr. Rajkiran Bilolikar
Associate Professor, Energy Area
Administrative Staff College of India
Email: rajkiran@asci.org.in

ENDNOTES

[1] May 2018, Cool Roofs: Protecting Communities and Saving Energy, Issue Brief, NRDC.

[2] Li, Dan, Elie Bou-Zeid, and Michael Oppenheimer. 2014. "The Effectiveness of Cool and Green Roofs as Urban Heat Island Mitigation Strategies." Environmental Research Letters 9 (5): 055002. (https://doi.org/10.1088/1748-9326/9/5/055002

[3] Ronnen Levinson, Cool Roof Q & A (draft), Lawrence Berkeley National Laboratory, July 29, 2009 (https://heatisland.lbl.gov/sites/all/files/Cool-roof-Q+A.pdf) and https://coolroofs.org/resources/faq).

[4] May 2018, Cool Roofs: Protecting Communities and Saving Energy, Issue Brief, NRDC.

[5] U.S. Environmental Protection Agency, "Reducing Urban Heat Islands: Compendium of Strategies – Cool Roofs", 2008; Vishal Garg, Rajshree Kotharkar, Jayant Sathaye, Hema Rallapalli, Nilesh Kulkarni, Niranjan Reddy, Prabhakara Rao, Ashok Sarkar, 2015, "Assessment of the Impact of Cool Roofs in Rural Buildings in India", Energy and Buildings 114 (2016) 156-163; Hashem Akbari, Tengfang Xu, Haider Taha, Craig Wray, Jayant Sathaye, Vishal Garg, Surekha Tetali, M. Hari Babu, and K. Niranjan Reddy, "Using Cool Roofs to Reduce Energy Use, Greenhouse Gas Emissions, and Urban Heat Island Effects: Findings from an India Experiment", Ernest Orlando Lawrence Berkeley National Laboratory, 2011.

[6] Urban Heat Island: Heat islands form as vegetation is replaced by asphalt and concrete for roads, buildings, and other structures necessary to accommodate growing populations. These surfaces absorb and later re-radiate—rather than reflect—the sun's heat, causing surface temperatures and overall ambient temperatures to rise. An urban heat island (UHI) is a metropolitan area which is significantly warmer than its surroundings. (https://scied.ucar.edu/longcontent/urban-heat-islands). The properties of urban roofs and pavements, as well as human activity, contribute to the formation of summer urban heat islands (source: https://heatisland.lbl.gov/coolscience/urban-heat-islands).

[7] May 2011, Akbari H., Xu T., Taha H., Wray C., and Sathaye J., Garg V., Tetali S., Babu M., and Reddy K.N, 'Using Cool Roofs to Reduce Energy Use, Greenhouse Gas Emissions, and Urban Heat island Effects: Findings from an India Experiment', Environmental Energy Technologies Division Lawrence Berkeley National Laboratory (LBNL) and International Institute for Information Technology (IIIT) Hyderabad, India.

[8] Global Cool Cities Alliance and R20 Regions of Climate Action, 'A Practical Guide to Cool Roofs and Cool Pavements'. January 2012.

[9] Zhang, Jiachen, Yun Li, Wei Tao, Junfeng Liu, Ronnen Levinson, Arash Mohegh, and George Ban-Weiss. 2019. "Investigating the Urban Air Quality Effects of Cool Walls and Cool Roofs in Southern California." Environmental Science & Technology 53 (13): 7532–42. (https://doi.org/10.1021/acs.est.9b00626).

[10] Xu, Tengfang, Jayant Sathaye, Hashem Akbari, Vishal Garg, and Surekha Tetali. 2012. "Quantifying the Direct Benefits of Cool Roofs in an Urban Setting: Reduced Cooling Energy Use and Lowered Greenhouse Gas Emissions." Building and Environment 48 (February): 1–6. (https://doi.org/10.1016/j.buildenv.2011.08.011).

[11] This may vary product to product. Based on discussions with different cool coating manufacturers.

[12] Government of India, 'Cool Roofs for Cool Delhi", Bureau of Energy Efficiency, 2012.

[13] May 2018, Cool Roofs: Protecting Communities and Saving Energy, Issue Brief, NRDC.

[14] International Institute for Information Technology- Hyderabad (IIIT-H) market research, based on interactions with select cool roofs material manufacturers, 2019.

[15] The Cool Roof Rating Council was created in 1998 to develop accurate and credible methods for evaluating and labeling the solar reflectance and thermal emittance (radiative properties) of roofing products and to disseminate the information to all interested parties.

[16] Global Cool Cities Alliance and R20 Regions of Climate Action, 'A Practical Guide to Cool Roofs and Cool Pavements'. January 2012.

[17] Global Cool Cities Alliance and R20 Regions of Climate Action, 'A Practical Guide to Cool Roofs and Cool Pavements'. January 2012.

[18] For more details, refer to https://coolroofs.org/directory.

[19] Telangana Municipalities Act 2019, (https://cdma.telangana.gov.in/pdfs/Municipaliteis%20Act-English.pdf).

OTHER RESOURCES

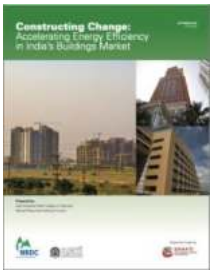
Retrofitting Mahindra Towers: How an Innovative ESCO Model Lowers Energy Bills With No Upfront Cost
https://www.nrdc.org/sites/default/files/esco-energy-retrofit-mahindra- CS.pdf

Adoption, Compliance, Enforcement for Energy Efficiency in Buildings http://ace-e2.eu/

Taking Energy Efficiency to New Heights: Analysis and Recommendations for the Buildings Sector from the Hyderabad Experience
https://www.nrdc.org/sites/default/files/efficiencynewheights.pdf

Building Smart from the Start: Spotlight on Energy- Saving Commercial Office Building in Noida, India
https://www.nrdc.org/sites/ default/files/energy-saving- construction-legacy-spectral- CS.pdf

Online Compliance System For Energy Conservation Building Code (ECBC) For Hyderabad
https://www.nrdc.org/sites/default/files/online-compliance-ecbc-hyderabad-faq.pdf



Constructing Change: Accelerating Energy Efficiency in India's Buildings Market
https://www.nrdc.org/sites/default/files/india-constructing-change-report.pdf

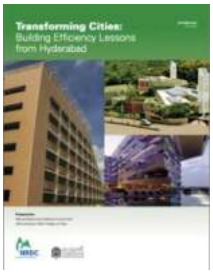
Saving Money and Energy: Case Study of the Energy-Efficiency Retrofit of the Godrej Bhavan Building in Mumbai
https://www.nrdc.org/sites/default/files/energy-retrofit-godrej-bhavan-CS.pdf

Greener Construction Saves Money: Incentives for Energy Efficient Buildings Across India
https://www.nrdc.org/sites/default/files/energy- efficient-construction-incentives-IB.pdf

Capturing Energy Savings Opportunities Through Increased Building Efficiency
https://www.nrdc.org/sites/default/files/energyefficiency-fs.pdf

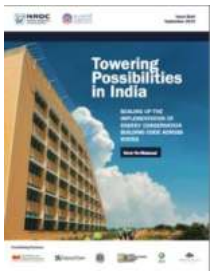
Building a Better Future: Implementing the Energy-Saving Building Code in Hyderabad.
https://www.nrdc.org/sites/default/files/better- future-energy-saving-building-code-hyderabad.pdf

Building Efficient Cities: Strengthening the Indian Real Estate Market Through Codes and Incentives
https://www.nrdc.org/sites/default/files/real-estate-efficiency-codes-IB. pdf



Transforming Cities: Building Efficiency Lessons from Hyderabad
https://www.nrdc.org/sites/default/files/ india-transforming- cities-2014-report.pdf

Bureau of Energy Efficiency, Government of India
https://beeindia.gov.in/content/buildings



Towering Possibilities in India: Scaling Up the Implementation of Energy Conservation Building Code Across States
https://www.nrdc.org/sites/default/files/towering-possibilities-in-india-20190910.pdf

NRDC
NATURAL RESOURCES DEFENSE COUNCIL

Headquarters: 40 West 20th Street
11th floor
New York, NY 10011
www.nrdc.org