

COOL ROOFS

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Protecting Local Communities
and Saving Energy



About this Report

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Mahila Housing SEWA Trust: Mahila Housing SEWA Trust (MHT) has been working to enable access to basic services and better habitats for the poor in urban slums in India. MHT strongly believes that access to light, ventilation, affordable, & efficient energy is critical to improving the quality of life and productivity of the poor, especially women who spend the majority of their time indoors, working on household chores, or engaged in livelihood activities. www.mahilahousingtrust.org

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Scope of Issue Brief

The focus of this issue brief is to support the development of cool roof policies and programs in leading cities in India. In particular, this issue brief examines the Ahmedabad and Hyderabad cool roof programs, including the program aims, methods, and initial implementation.

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Executive Summary

In India - home to half a billion people living in rapidly urbanizing cities, climate change is making heat waves more frequent and intense.¹ In 2015, a heat wave that spread across the country claimed over 2,300 lives, demonstrating that these extreme heat events can have deadly consequences, especially for India's most vulnerable communities.²

Currently, less than 10 percent of India's households have air conditioning.³ Yet, as living standards rise for tens of millions of Indians, the immense increase in cooling and air conditioning demand could strain the country's electric grid, increase air pollution, require increased fuel import, and magnify the impacts of global warming. Furthermore, with summer temperatures regularly exceeding 40° Celsius (°C) (104° Fahrenheit) (°F) in a majority of India's cities, and large sections of the population in low-income housing with little to no access to electricity, availability of cooler homes is a matter of survival, not just comfort.

Urbanization brings with it skyrocketing development, that converts open spaces into paved, heat-trapping surfaces like roofs and roads. More than 60 percent of the roof surface in urban India is constructed from galvanized metal, asbestos, and concrete.⁴ Collectively, these hot surfaces can exacerbate the heat island effect and worsen air pollution.⁵

More than 65 million people in India live in informal urban housing, known as slums or bastis.⁶ According to the Ministry of Power's Bureau of Energy Efficiency, low-rise buildings like these can absorb up to one-fifth of a building's heat through the roof.⁷ Roofs, therefore, offer an avenue to significantly impact internal temperatures and provide indoor thermal comfort, in both air-conditioned and non-air-conditioned buildings. Cool roofs, with their specific characteristics, are better at reflecting solar radiation and emitting absorbed heat. Depending on the setting, these cool roofs can help keep indoor temperatures lower by 2 to 5°C (3.6 - 9°F) as compared to traditional roofs, offering simple and effective protection from extreme heat especially for vulnerable communities in low-income housing.⁸ Additionally, cool roofs may help save energy, bring down cooling costs, and lead to curbing air pollution and climate change in the long run.⁹

Cities can lead the way in cool roof implementation. In 2017 and 2018, the cities of Ahmedabad and Hyderabad initiated pilot cool roof programs. These initial programs include citizen awareness campaigns, pilot initiatives targeting 3,000 roofs, cooperation with businesses, and applying cool roof techniques to government buildings and schools. These new programs build on programs and policy efforts in cities like New Delhi, Indore and Surat; research from leading subject matter experts at leading institutes like the International Institute of Information Technology, Hyderabad (IIIT-H) and Indian Institute of Public Health, Gandhinagar (IIPH G); as well as lessons learned from cool roof programs around the world.

¹ Ministry of Housing and Urban Affairs, "Urban Growth", Government of India, <http://mohua.gov.in/cms/urban-growth.php> (accessed on May 2, 2018); The World Bank, "Urban Population", data.worldbank.org/indicator/SP.URB.TOTL?locations=IN (accessed May 2, 2017)

² Hillary Whiteman, "India Heat Wave Kills 2,330 People as Millions Wait for Rain", CNN, 02 June 2015 <http://www.cnn.com/2015/06/01/asia/india-heat-wave-deaths/> (accessed on 19 May 2017)

³ Amol Phadke, Nikit Abhiyankar, Nihar Shah, "Avoiding 100 New Power Plants by Increasing Efficiency of Room Air Conditioners in India: Opportunities and Challenges", Lawrence Berkeley National Laboratory, 2013 (accessed on 19 May 2017)

⁴ Office of the Registrar General & Census Commissioner, India, "Distribution of Census Homes by Predominant Material of Roof," Census of India, censusindia.gov.in/Tables_Published/H-Series/H-Series_link/S00-004.htm (accessed on 02 May 2017)

⁵ 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 (accessed on 02 May 2017)

⁶ Office of the Registrar General & Census Commissioner, India, "Primary Census Abstract for Slum," Census of India, censusindia.gov.in/Tables_Published/H-Series/H-Series_link/S00-004.htm (accessed on 02 May 2017); Dipak Kumar Dash, "By 2017, India's Slum Population will Rise to 104 Million", Times of India, 23 August 2013 <http://timesofindia.indiatimes.com/india/By-2017-Indias-slum-population-will-rise-to-104-million/articleshow/21927474.cms> (accessed on 19 May 2017)

⁷ Bureau of Energy Efficiency, "Cool Roofs for Cool Delhi", 2011 <http://shaktifoundation.in/wp-content/uploads/2014/02/cool-roofs%20manual.pdf> (accessed on 28 April 2017)

⁸ Environmental Protection Agency, "Reducing Urban Heat Islands: Compendium of Strategies – Cool Roofs", 2008 (accessed on 02 May 2017)

⁹ Akbari et al "Using Cool Roofs to Reduce Energy Use" (see footnote 5)

Models to Develop a Cool Roofs Program

Cool roofs programs can have great benefits citywide, and should be tailored to a city's needs and resources. Three emerging models exist: 1) pilot programs; 2) municipal, voluntary, and corporate social responsibility (CSR) programs; and 3) building code programs. These models for cool roof programs enable cities to steadily make progress while building community awareness and support.

These three models allow city cool roofs program to grow from a single neighborhood to a city-wide effort. Identifying and mobilizing funding sources for each phase is critical to the program's success.



Key Features of Successful Cool Roof Programs for Cities

1. **Cool roofs keep temperatures lower during hot summers:** Cool roofs help achieve thermal comfort in homes, offices and buildings and protect human health while also contributing to reduce the urban heat island effect, air pollution, smog, and energy demand—especially during peak hours. For example, research by the International Institute of Information Technology, Hyderabad (IIIT-H) and Lawrence Berkeley National Laboratory (LBNL) found that cool roofs installations could energy savings of 10 to 19 percent in the top floor of buildings in Hyderabad, potentially reducing citywide air temperature by 2°C (3.6°F) (along with increasing vegetation), and save five billion rupees in electricity bills over 10 years across India.¹⁰
2. **Robust cool roof programs engage the community, respond to local conditions, and have strong city leadership.** For example, Ahmedabad's program engages communities by focusing on materials and standards that are locally available. This is especially useful in informal housing where the usage of tires and white tarp on metal or asbestos roofs, as an ad-hoc cool roof technique, leads to water pooling on the roof which attracts disease-carrying mosquitoes.

¹⁰ Akbari et al "Using Cool Roofs to Reduce Energy Use" (see footnote 5)

3. **Dedicated city budgets and integration with existing funding mechanisms are vital for cool roof programs in low-income communities.** Although cool roofs can be cost-competitive with regular roofing, the upfront costs of cool roof materials may pose a stumbling block for low-income communities that struggle with access to proper housing.¹¹ Incentivizing local businesses to provide cool roof materials is a key part of building a strong program to showcase benefits, as well as incorporating cool roofs as part of roof maintenance routines. Dedicated funding for financial incentives and citizen awareness programs, worker training programs and officer training programs are important. For example, Ahmedabad included initial cool roof activities as part of its Heat Action Plan and is discussing a dedicated budget.
4. **Partnering with local civil society, academic and business institutions is critical to expanding cool roofs.** Civil society and educational institutions have a wealth of knowledge that can support initiatives at the ground level and ensure a city's cool roof program responds to its local conditions. For example, both Ahmedabad and Hyderabad are working with NRDC, ASCI and PHFI-IIPH-G to develop their programs. Businesses, through Corporate Social Responsibility programs can help bring in the finance and technological support required to scale cool roof initiatives.
5. **Programs that begin as voluntary initiatives and then expand to building codes are a proven way to expand cool roofs in a city.** For instance, New Delhi, Ahmedabad, and Hyderabad are leading with initiatives to adopt cool roofs on public and government buildings. Large commercial and public buildings are addressed through the inclusion of cool roof strategies in the respective state Energy Conservation Building Codes. Ultimately, scaling up cool roof initiative as a part of compliance with city building energy codes could greatly expand the reach of cool roofs in Indian cities.

The focus of this issue brief is to support the development of cool roof policies and programs in Indian cities. In particular, this issue brief examines the Ahmedabad and Hyderabad cool roof programs, piloted in 2017, including the program aims, methods, and initial implementation.

¹¹ Vishal Garg, Kshitij Chandrasen, Surekha Tetali, Jyotirmay Mathur, "Online Energy Savings Calculator for Cool Roofs", 2010, http://web2py.iiit.ac.in/research_centres/publications/view_publication/inproceedings/677 (accessed on 19 May 2017)

Section 1: Cool Roofs and their Benefits

Introduction

India is urbanizing rapidly. Of the country's 1.2 billion population, 425 million reside in urban areas.¹² Growing urbanization and skyrocketing development has led to the increase of urban heat islands in Indian cities, a phenomenon that causes warmer temperatures in the built up urban cores of cities as compared to surrounding suburban and rural areas. Decreasing vegetation cover and increasing heat-trapping materials like tar and dark rooftops in crowded cities exacerbate the urban heat island effect.

In recent years, cities and communities across India have been grappling with record-breaking summer temperatures and heat wave conditions.¹³ Heat waves and extreme heat conditions cause direct heat related mortality and morbidity in cities, and also have longer term impacts by contributing to an increase in incidence of infectious diseases, and contributing to health impacts such as cardiovascular and respiratory issues and malnutrition from crop failures or water shortages.¹⁴ In response, the expansion of Heat Action Plans and early warning systems to around 30 cities and 11 states, with the support and guidance of the Indian Meteorological Department and National Disaster Management Authority demonstrates that the Indian Government recognizes the need to protect citizens and communities from extreme temperatures.¹⁵ Also, the hotter cities get, the more cooling demand there is overall. A majority of the buildings that will exist in India by 2030 are yet to be built – this represents a huge opportunity for energy savings and steps in the right direction.¹⁶

Estimates show that over 65 million of India's low income population lives in informal urban or peri-urban settlements known as slums or *bastis*.¹⁷ In these largely low-rise communities, up to a fifth of the building's heat gain can occur through its roof, and addressing this aspect can significantly impact internal temperatures and provide thermal comfort indoors.¹⁸ With summer temperatures exceeding 40°C (104°F) in a majority of the country's cities, and large sections of the population in low-income settlements, access to cooler dwellings is a matter of survival, not just comfort.

Research based in Ahmedabad examines and identifies specific factors that increase the vulnerability of slum residents to extreme heat:¹⁹

- Higher exposure to extreme heat: Slum residents are more likely to be exposed to heat since they work primarily outside or in unventilated conditions, they live in homes constructed of heat-trapping materials with tin or tarp roofs, and their communities lack trees and shade.
- Greater susceptibility to health effects of extreme heat: Inability to afford health care, lack of accessibility to drinking water, poor sanitation, crowding, malnutrition, and a high prevalence

¹² The World Bank, "Urban Population", data.worldbank.org/indicator/SP.URB.TOTL?locations=IN (accessed May 2, 2017)

¹³ Huizhong Wu CNN, "India Facing another Summer of Deadly Heat," ABC News 57, April 24, 2017 www.abc57.com/story/35233339/india-facing-another-summer-of-deadly-heat (accessed May 2, 2017).

¹⁴ TARU Leading Edge, "Thermal Comfort Handbook: Volume II", 2015 (accessed 25 August 2017)

¹⁵ Natural Resources Defense Council, "Expanding Heat Resilient Cities Across India", March 2016, <https://www.nrdc.org/sites/default/files/india-heat-resilient-cities-ib.pdf> (accessed on 28 April 2017)

¹⁶ McKinsey Global Institute, "India's Urban Awakening: Building Inclusive Cities, Sustaining Economic Growth", April 2010; the study is based on building stock existing in 2010 (accessed on 02 May 2017)

¹⁷ Office of the Registrar General & Census Commissioner, India, "Primary Census Abstract for Slum," Census of India, censusindia.gov.in/Tables_Published/H-Series/H-Series_link/S00-004.htm (accessed on 02 May 2017); Dipak Kumar Dash, "By 2017, India's Slum Population will Rise to 104 Million", Times of India, 23 August 2013 <http://timesofindia.indiatimes.com/india/By-2017-Indias-slum-population-will-rise-to-104-million/articleshow/21927474.cms> (accessed on 19 May 2017)

¹⁸ Bureau of Energy Efficiency, "Cool Roofs for Cool Delhi", 2011 <http://shaktifoundation.in/wp-content/uploads/2014/02/cool-roofs%20manual.pdf> (accessed on 28 April 2017)

¹⁹ Anjali Jaiswal, Kim Knowlton, Susan Casey-Lefkowitz, "Rising Temperatures, Deadly Threat: Preparing Communities in India for Extreme Heat Events," 2017, Natural Resources Defense Council, <https://www.nrdc.org/resources/rising-temperatures-deadly-threat-preparing-communities-india-extreme-heat-events> (accessed on 02 May 2017)

of chronic medical conditions heighten slum community members' susceptibility to extreme heat effects on health.

- Fewer adaptation options available: Slum residents lack control over their home and work environments, with limited access to (and inability to afford) reliable electricity and air conditioning, insufficient access to cooling spaces, and a dearth of health information on which to act. All these factors reduce slum residents' opportunities to adapt to increasing temperatures.

Cool roofs work in the Indian context.²⁰ Leading studies have shown that cool roofs are an effective strategy against the increasingly warmer conditions facing Indian cities.²¹ Light-colored roofs have been used as traditional heat management techniques in warm climates like India, the Mediterranean, and Caribbean for centuries. However, with rapid urbanization dark rooftops have become predominant in most Indian cities.



Figure 1: Rooftops in Ahmedabad (NRDC) and Figure 2: Dark rooftops in Hyderabad as captured by an infrared camera (David B. Goldstein)

Cool roofs have immense potential to make an impact on the thermal performance of Indian cities. According to the 2011 population census of India, over 60 percent of housing in urban India is constructed of galvanized iron, metal, asbestos and concrete.²² These materials, while heat trapping if left untreated, are prime candidates to be converted into cool roofs. Studies have found that cool roof strategies have the potential to reduce roof surface temperatures in buildings in hot climates such as Hyderabad by 13.5°C (56.3°F) (as observed on a test site in Hyderabad), and indoor air temperature by 2-5°C (3.6 - 9°F).²³

What is a Cool Roof?

A cool roof is one that stays cooler than regular roofs by *reflecting* the sunlight incident on it and *emitting* thermal radiation. Cool roofs have the ability to reflect sunlight and reject heat because the roofs are prepared, covered or coated with materials that have special characteristics. Buildings and built up areas in cities are often constructed of concrete, brick or cinder blocks that absorb solar radiation, transferring this incident heat to the internal spaces of the building. This causes the interiors of a building to get heated up, and stay hot, often hotter than the external ambient temperature, and well beyond comfortable conditions. Collectively, many hot surfaces together can result in increased temperatures across an entire urban area, adding to the heat island effect in cities.

²⁰ Akbari et al "Using Cool Roofs to Reduce Energy Use" (see footnote 5)

²¹ *ibid*

²² Office of the Registrar General & Census Commissioner, India, "Distribution of Census Homes by Predominant Material of Roof," Census of India, censusindia.gov.in/Tables_Published/H-Series/H-Series_link/S00-004.htm (accessed on 02 May 2017)

²³ 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 (accessed on 02 May 2017); Akbari et al "Using Cool Roofs to Reduce Energy Use" (see footnote 5)

How Cool Roofs Work

Cool roofs function primarily by reflecting sunlight incident on the roof back to the atmosphere to a greater extent than a regular roof surface. To understand the mechanism of this process, the two primary thermal properties of a roof – solar reflectance and emittance – need to be understood. Every time solar radiation falls on a roof, the roof performs four actions:

- It *reflects* a part of the incident solar radiation back into the atmosphere.
- It *conducts* a part of the heat through itself into the ground and to other 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.

The two most important factors that determine the effectiveness of a surface as a cool roof are its ability to *reflect* solar energy and *emit* absorbed energy.

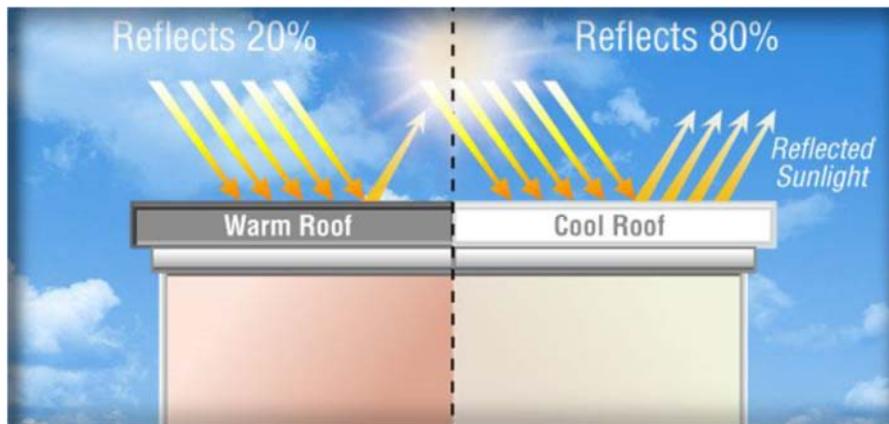


Figure 3: How a cool roof works (Heat Island Group, LBNL)

Solar reflectance: Solar reflectance is the quality in a material that enables it to reflect the solar radiation that is incident on it. It is measured as the ratio of solar energy that is reflected by a surface to the total incident solar radiation on that surface. For example, a surface with low solar reflectance will absorb a large portion of the incident solar energy. Solar reflectance is measured on a scale from 0 to 1. A reflectance value of 0 indicates that the surface absorbs all incident solar radiation, and a value of 1 denotes a surface that reflects all incident solar radiation. Solar reflectance is also referred to as “albedo”.

Thermal emittance: Thermal emittance is the ability of a material to emit absorbed energy. Emittance is measured on a scale of 0 to 1. A roofing material with higher thermal emittance will re-emit absorbed thermal energy more quickly than a material with a low emittance. The higher the emittance, the quicker the roof can emit absorbed energy, and not get as hot as a roof with low emittance.

Solar Reflectance Index (SRI): The SRI combines a material’s solar reflectance and thermal emittance into one value, to represent how the material would perform as a cool roof. The Solar Reflectance Index (SRI) is a measure of the ability of the constructed surface to reflect solar heat, as shown by a small temperature rise. It 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. Once the maximum temperature rise of a given material has been computed (for example, the standard black has a temperature rise of 50°C in full sun, and the standard white has a temperature rise of 8.1°C), the SRI can be computed by interpolating between the values for white and black. It is possible for a material (with both, a high reflectance and a high emittance) to have an SRI greater than 100.

Solar Spectrum and Reflectance²⁴

Solar energy reaches the earth as ultraviolet rays (5%), visible light (43%) and infrared energy (52%). “Cool” surfaces have a high reflectance across the entire solar spectrum.

While light colored surfaces are typically considered to be “cool”, there are some darker materials available in the market today that may also perform just as well as the lighter ones, by reflecting more of the infrared part of the spectrum. For a surface to be an effective solar reflector, it needs to have the ability to reflect solar energy across the entire spectrum.

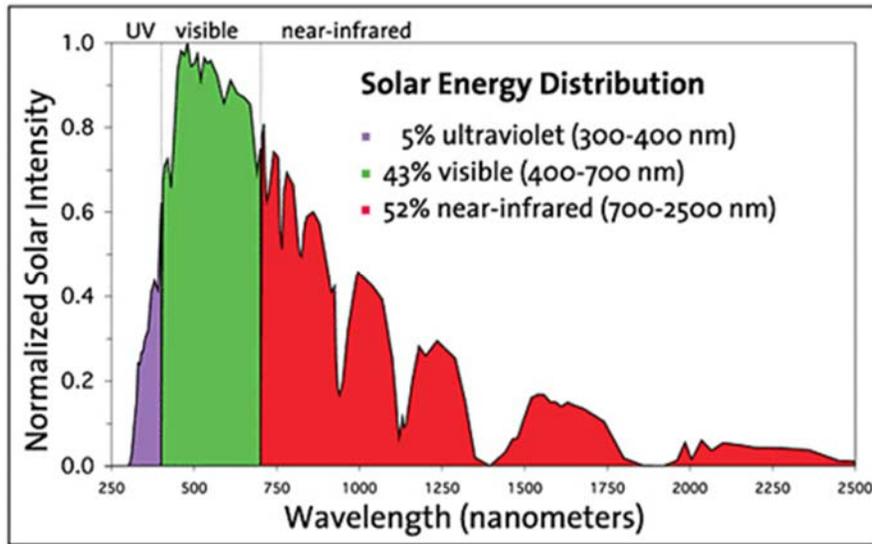


Figure 4: Graph showing solar energy distribution (Heat Island Group, LBNL)

The reflectance of building materials is usually measured across the solar spectrum, since they will be exposed to that range of wavelengths and these are the major characteristics responsible for urban heat gain/ loss.

The emissivity of building materials, on the other hand, is usually measured in the far-infrared part of the spectrum, since most building materials don’t get hot enough to radiate at the shorter near-infrared, visible, and UV wavelengths.

²⁴ Hashem Akbari, “Cool Roofs and Pavements to Cool the World: An Integrated Mitigation/Adaptation Strategy for Cities”, Concordia University, 2011, http://resilient-cities.iclel.org/fileadmin/sites/resilient-cities/files/Resilient_Cities_2011/Presentations/G/G4_Akbari.pdf (accessed on 02 May 2017)

Types of Cool Roofs

Application of cool roof coatings or paint is most cost-effective at the construction stage or when buildings need roof repair or to be re-roofed; however, they can be applied to existing buildings as well.



Figure 5: Photo of Hyderabad with an infrared camera showing dark rooftops, light walls and grey or white vegetation (David B. Goldstein)

The choice of an appropriate cool roof material in a particular context would be dependent on a range of factors, from existing roof material, life and maintenance, availability, cost, time needed for installation and availability of skilled labor. To help cater to a range of contexts, cool roofs techniques can be broadly divided into four categories:²⁵

- **Coated cool roofs:** these roofs involve the coating of a material or paint with high reflectivity on top of a conventional roof material to increase the roof surface's SRI. These are liquid-applied coatings made of simple materials such as lime wash, or an acrylic polymer or plastic technology and are usually white in color.
- **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, china mosaic tiles or shingles on top of an existing roof or to a new roof.
- **Special cool roof materials such as ModRoof:** these roofs, made of coconut husk and paper waste, have been installed in households around Gujarat and Delhi and can serve as an alternative to RCC roofs.
- **Green roofs:** green roofs make use of vegetation to help the roof absorb less solar energy by providing a thermal mass layer to reduce flow of heat into a building. Vegetation is especially useful in reflecting infrared radiation. Green roofs are also considered cool roofs, but due to higher costs and need for water, they are likely not a cost-effective solution for heat reduction in low-income communities in India. They are therefore not included in this report.

²⁵ Anil Bakshi, "Scope of Cool Roof in India," 2015, <http://www.coolrooftoolkit.org/wp-content/uploads/2015/04/Scope-of-Cool-Roofs-in-India.pdf> (Assessed November 10, 2015)

Cool Roof Materials

Choosing an appropriate cool roof material is a key step in the process of implementing a cool roof. A wide variety of cool roof materials are available in the market with differences in the values of their emittance, reflectance, life and initial cost. The performance of each of these materials would also vary based on external factors such as climatic conditions, roof type, and HVAC system type.

Cool Roof Rating Systems

To help navigate the layers of technical information that affects the performance of a cool roof material, ratings are being developed to help consumers understand the “coolness” of a surface in simple terms. Internationally, organizations such as the Cool Roof Rating Council help to develop accurate and credible methods for evaluating and labeling the solar reflectance and thermal emittance of roofing products. Their rated product directory has over 1,000 materials, focused on the U.S. market.²⁶ The EU Cool Roofs Council performs a similar function in Europe by rating the SRI of different roof materials to help users make an informed decision.²⁷ While India does not have a cool roof rating council at present, efforts are underway to work towards its establishment. Leading institutes such as IIIT-H have materials testing centers to determine the SRI of different materials in the Indian landscape.

Most cool roofs are created using reflective coatings, membranes, or tiles. These different materials have different advantages and drawbacks in terms of cost, effectiveness, accessibility, ease of installation, and durability. However, most types of cool roofs are comparable in terms of effectiveness, and so the decisive factors are likely to be cost and local conditions. The best materials for cool roofs for an area are materials that are easy to find locally, require no special training for installation, and are relatively durable. In India, several types of materials are used for cool roofs – NRDC’s Ahmedabad pilot program used a special coating for a few buildings and simple white lime paint for the other roofs, and the Hyderabad pilot program used HDPE Tyvek membranes donated by Dupont.

Cost of Materials

Little comprehensive data exists for the cost of materials for cool roofs in India, but anecdotal prices can be taken as examples of the likely range of prices. The Ahmedabad pilot program used simple white lime paint for the most part, at a cost of approximately ₹0.5 (~\$0.07) per square foot. More specialized materials, such as high reflective coatings or membranes, are significantly more expensive, and the price per square foot from Indian companies commonly ranges in the hundreds of rupees.²⁸

A 2014 study by TARU Leading Edge experimented with 13 cool roof construction types on roofs in Surat and Indore in central India to test for ease of application, cost and availability. While the least expensive technique tested in this study was a cool roof paint that cost ₹25 per square foot (including labor and transport), the other techniques focused on strong, durable construction that would serve to not only cool the building, but also improve its construction. For low income communities particularly susceptible to heat waves, donations of materials from governments, NGOs, or companies can have a significant impact on the ability of residents to implement cool roofs. The Hyderabad pilot program, for example, was made possible by a donation of membranes from Dupont.

²⁶ United States Department of Energy, “Cool Roofs are Ready to Save Energy, Cool Urban Heat Islands, and Help Slow Global Warming”, Energy Efficiency and Renewable Energy (accessed on 02 May 2017)

²⁷ European Cool Roofs Council, “Product Rating Database”, <http://coolroofcouncil.eu/rpd.php> (accessed on 02 May 2017)

²⁸ Bureau of Energy Efficiency, “Cool Roofs for Cool Delhi”, 2011, <http://shaktifoundation.in/wp-content/uploads/2014/02/cool-roofs%20manual.pdf> (accessed on 02 May 2017)

Effectiveness

The effectiveness of a cool roof in reducing heat absorption is determined largely by two factors: its solar reflectance and its thermal emittance.

The chart below shows the solar reflectance (x-axis) and thermal emittance (y-axis) of various common types of roofing materials.²⁹ Materials with high reflectance and high emittance, such as white plaster and white paint, make good candidates for cool roofs. Unfortunately, most roofs in India have either low reflectance (asphalt, asbestos) or low emittance (metal sheets).

Figure 6 shows the average SRI for various roofing materials, along with their reflectance, emittance, and temperature increase in direct sunlight.³⁰ Color is the most significant property – white cement tiles have an SRI that is 65 units above that of unpainted cement tiles. Interestingly, painted coatings on metal roofs dramatically increase their thermal emittance.

Example SRI Values for Generic Roof Materials	Solar Reflectance	Infrared Emittance	Temp Rise (C Deg)	SRI
Gray EPDM	0.23	0.87	38	21
Gray Asphalt Shingle	0.22	0.91	37	22
Unpainted Cement Tile	0.25	0.90	36	25
White Granular Surface Bitumen	0.26	0.92	35	28
Red Clay Tile	0.33	0.90	32	36
Light Gravel on Built-up Roof	0.34	0.90	32	37
Aluminum	0.61	0.25	27	56
White Coated Gravel on Built-up Roofing	0.65	0.90	16	79
White Coating on Metal Roof	0.67	0.85	16	82
White EPDM	0.69	0.87	14	84
White Cement Tile	0.73	0.90	12	90
White Coating – 1 coat- 8 mils	0.80	0.91	8	100
PVC White	0.83	0.92	6	104*
White Coating – 1 coat- 20 mils	0.85	0.91	5	107*

*Materials that have reflectance and emittance values greater than those of Standard White, will have a SRI value greater than 100.

Figure 6: Solar Reflectance Index (SRI) for Typical Roofing Materials (Shakti Foundation)

Different 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.

Accessibility

Local availability: Simple white paint is likely the most easily accessible material for cool roofs in India, and it was the predominant material used in the Ahmedabad pilot. Various other companies sell specialized coatings, tiles, and membranes, but these are likely to have higher costs without significant difference in effectiveness. Where possible, donations or subsidies for materials, as with the Hyderabad pilot, can make a significant impact.

Durability

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. 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.³¹

White Asphalt Shingles

- Solar Reflectance: 0.25-0.31 (initial), 0.25-0.29 (3-year)
- Thermal Emittance: 0.89-0.94 (initial), 0.87-0.98 (3-year)

²⁹ United States Agency for International Development, ECO-III Project Office, “An Introduction to Cool Roof”, Bureau of Energy Efficiency, 2007. <http://www.coolrooftoolkit.org/wp-content/uploads/2012/05/Cool-Roof-Technology-Guide-India.pdf> (accessed on 02 May 2017)

³⁰ Bureau of Energy Efficiency, “Cool Roofs for Cool Delhi”, 2011, <http://shaktifoundation.in/wp-content/uploads/2014/02/cool-roofs%20manual.pdf> (accessed on 02 May 2017)

³¹ Cool Roof Rating Council, “Rated Products Directory”, <http://coolroofs.org/products/results> (accessed on 02 July 2017)

Membranes above Built-Up or Modified Bitumen Sheet Roofing

- Solar Reflectance: 0.27-0.87 (initial), 0.24-0.80 (3-year)
- Thermal Emittance: 0.73-0.94 (initial), 0.73-0.93 (3-year)

White Tiles/Slates

- Solar Reflectance: 0.34-0.79 (initial), 0.33-0.74 (3-year)
- Thermal Emittance: 0.82-0.91 (initial), 0.82-0.97 (3-year)
- Field Applied Paint Coats (Acrylic or Silicone-based)
- Solar Reflectance: 0.71-0.94 (initial), 0.46-0.87 (3-year)
- Thermal Emittance: 0.79-0.95 (initial), 0.82-0.97 (3-year)

Cool Roof Calculator for Indian Conditions

While cool roof calculators have been built in the past, for example by the US Department of Energy, the International Institute for Information Technology, Hyderabad (IIIT-H), has developed a cool roof calculator customized for Indian conditions.³²

The easy-to-use tool builds on existing tools such as the Department of Energy’s cool roof calculator, and performs online simulations for different types of cool roofs. The tool has the ability to model conditioned and un-conditioned space and shows temperature levels inside a space based on roof type and external temperature conditions. The online tool also enables the user to calculate the payback period of each specific cool roof technique for different types of buildings.

Energy, and Environmental Benefits of Cool Roofs

Cool roofs provide a number of quantifiable benefits. By reducing temperatures in homes, especially at peak hours of heat, they mitigate heat-related mortality and illnesses. By decreasing the use of air cooling systems, cool roofs save residents money on electric bills. Thanks both to this reduction in energy usage, which means lower demand for power generation, and to the reduction in HFCs emitted directly by air conditioners during operation, cool roofs also significantly lower greenhouse gas emissions.

Economic Benefits of Cool Roofs: Energy Savings

Most Indians do not have air conditioning; room AC penetration was only about 5% in urban India in 2011.³³ However, cool roofs can result in significant energy savings for those who do. Figure 7 shows that 45% of all Indian residential energy is used for cooling homes.³⁴ The percentage of Indian homes with air conditioners, and consequently the energy used by air conditioners, is expected to

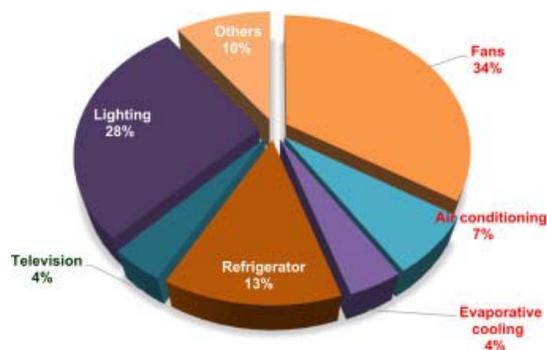


Figure 7: Indian Residential Energy Use (Tengfang Xu et al, 2012)

³² Oakridge National Laboratory, “Cool Roof Calculator”, US Department of Energy <http://web.ornl.gov/sci/buildings/tools/cool-roof/> (accessed on 02 May 2017); Vishal Garg, “Cool Roof Calculator”, International Institute of Information Technology, Hyderabad (IIIT-H), coolroof.cbs.iiit.ac.in (accessed on 02 May 2017)

³³ Nikit Abhyankar et al., *Accelerating Energy Efficiency Improvements in Room Air Conditioners in India: Potential, Costs-Benefits, and Policies*, Ernest Orlando Lawrence Berkeley National Laboratory, Energy Analysis and Environmental Impacts Division, April 2017. https://eta.lbl.gov/sites/default/files/publications/india_ac_national_impact_of_accelerated_ee_lbnl_1005798_0.pdf (accessed on 02 May 2017)

³⁴ Tengfang Xu et al., “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 2012): 1-6. <https://doi.org/10.1016/j.rser.2017.05.030> (accessed on 07 July 2017)

materially increase as India develops and standards of living rise in the future. For comparison, room AC penetration in urban China rose from around 5% in 1995 to more than 130% by 2012 as the country developed. India is by far the world’s biggest potential AC market, and AC use is expected to add around 140 GW to peak demand by 2030.³⁵ The graph below illustrates the potential cooling demand of major Indian cities compared to other major world cities; Mumbai’s potential air conditioning use (measured in cooling degree days) is 24% of the entire US’s.³⁶



Figure 8: Potential of Cooling Demand in Key Cities (Sivak, 2009)

By reducing the work that air conditioning systems have to do, cool roofs can save residents energy and money. A Hyderabad study found that cool roofs reduced cooling energy usage by 14-26% for previously black roofs, and 10-19% for previously uncoated concrete roofs.³⁷ Annually, cool roofs resulted in energy savings of 20-22 kWh per square meter of roof area for previously black roofs, and 13-14 kWh per square meter of roof area for previously uncoated concrete roofs. Considering the 2014 electricity prices of ₹3 per kWh in India,³⁸ a 20 square meter cool roof could save as much as ₹1,320 a year in utility bills for a house with an air conditioning system.

Greenhouse Gas Emissions Reductions from Cool Roofs

Cool roofs not only keep indoor temperatures lower, they also help to combat climate change. Thanks to the reduction in energy usage for air conditioning that cool roofs enable, the same study of Hyderabad cool roofs estimated that the annual CO₂ emissions reduction from energy savings was 11-12 kg of CO₂ per m² of roof area.³⁹ A 20 sq. meter roof would save a quarter-ton of CO₂ every year.

Additionally, most air conditioners use hydrofluorocarbons (HFCs) as refrigerants, some of which have a global warming potential (GWP) of thousands of times that of CO₂. In other words, one

³⁵Nikit Abhyankar et al., *Accelerating Energy Efficiency Improvements in Room Air Conditioners in India: Potential, Costs-Benefits, and Policies*, Ernest Orlando Lawrence Berkeley National Laboratory, Energy Analysis and Environmental Impacts Division, April 2017. https://eta.lbl.gov/sites/default/files/publications/india_ac_national_impact_of_accelerated_ee_lbnl_1005798_0.pdf (accessed on 07 July 2017)

³⁶ Sivak, “Potential Energy Demand for 50 cities”, 2009, Energy Policy (accessed on 07 July 2017)

³⁷ Tengfang Xu et al., “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 2012): 1-6. <https://doi.org/10.1016/j.buildenv.2011.08.011> (accessed on 07 July 2017)

³⁸ Tim Buckley, *Briefing Note: Indian Power Prices*, Institute for Energy, Economics, and Financial Analysis, May 6, 2014. http://www.ieefa.org/wp-content/uploads/2014/05/IEEFA-Briefing-Note_IndianElectricityCoalPricing_4-May-2014.pdf (accessed on 07 July 2017)

³⁹Tengfang Xu et al., “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 2012): 1-6. <https://doi.org/10.1016/j.buildenv.2011.08.011> (accessed on 07 July 2017)

kilogram of a typical HFC released into the Earth’s atmosphere contributes to the planet’s warming as much as a ton or more of CO₂. Less use of air conditioners through techniques such as cool roofs, can help limit refrigerant emissions as well.

Economic Benefits of Cool Roofs: Worker Productivity

By lowering temperatures in factories and workplaces and reducing worker productivity loss due to heat stress and heat exhaustion, cool roofs can result in significant increases in economic output for companies. Summers in India are hot, and the interiors of factories often reach temperatures that jeopardize workers’ ability to function. Below are selected health effects from a WHO study on workers in ironworks and ceramics factories in western India, and the percentage of workers in each type of factory who experienced a specific health condition from excessive heat during the summer:⁴⁰

Health Effect	Iron Workers	Ceramic Workers
Heavy Sweating	68.7%	79.6%
Extreme Weakness/Fatigue	36.9%	50.4%
Dizziness/Nausea	14.9%	18.2%
Muscle Cramps	15.9%	29.9%
Blurred Vision	20.0%	16.1%
Mental Disorientation	18.5%	22.6%
Seizures	1.5%	0.7%
Muscle pain/arms spasms	20.5%	19.7%
Muscle pain/legs spasms	27.2%	22.6%
Fainting/collapse	10.8%	19.0%
Loss of consciousness	6.2%	10.9%
Loss of work capacity	25.1%	31.4%

Table 1: Health Effects on Ironworks and Ceramics Workers in Factories in Western India (WHO, 2009)

If one in ten employees in a factory lose consciousness, one in four are unable to work, and many of the rest have some combination of the above effects, the productivity of the factory and its economic output are drastically reduced. However, cool roofs can mitigate these effects. Another study of manufacturers in India showed a manufacturing output decline of an average of 2.8% output per °C.⁴¹ When temperatures climb above 30 °C, this output decline per degree increases to above 5%. Since cool roofs can keep temperatures in buildings lower by at least 2 to 5°C, installing cool roofs in factories has great potential to increase worker productivity and output.

⁴⁰P.K. Nag et al, *Vulnerability to Heat Stress: Scenario in Western India*, WHO APW No. SO 08 AMS 6156206, National Institute of Occupational Health, 2009. http://www.searo.who.int/india/topics/occupational_health/Occupational_Health_Vulnerability_to_heat_stress_scenario_of_western_India.pdf (accessed on 07 July 2017)

⁴¹ Anant Sudarshan and Meenu Tewari, “*Working Paper 278: The Economic Impacts of Temperature on Industrial Productivity: Evidence from Indian Manufacturing*”, Indian Council for Research on International Economics, July 2014. http://icrier.org/pdf/working_paper_278.pdf (accessed on 07 July 2017)

Value Proposition for Cool Roofs

Cool roofs provide direct benefits by providing thermal comfort within buildings and helping to protect human health and reduce cooling costs. Cool roof techniques can also help to enhance the durability of roofs and reduce peak power load on the grid. They provide indirect benefits through contributing to reduction of the urban heat island effect, which over time impacts ambient air temperatures in an urban area, reduces air pollution and combats climate change.⁴²

Six key benefits of cool roofs are:

- **Cool roofs save energy and costs by reducing cooling load requirements in a building:** Cool roofs enhance comfort by reflecting sunlight away from the building. This minimizes heat absorption by the roof. Cool roofs also emit more thermal radiation and keep the building cooler. By keeping the temperatures inside a building lower, cool roofs reduce the need for air conditioning, providing more affordable cooling. They also reduce the energy loads in buildings that do have air conditioning. The magnitude of energy savings depends upon building type, level of roof insulation, ventilation rate between roof and ceiling, a/c size and efficiency, and of course, roof solar reflectance.
- **Cool roofs keep homes and buildings from gaining heat and thereby improve occupant comfort:** Key studies have shown that cool roof techniques and treatments can keep indoor temperatures lower as compared to traditional roofs.⁴³ By keeping building temperatures low, cool roofs offer multiple benefits for a city. They serve to protect vulnerable groups such as children and elderly from excessive indoor heat and increase comfort levels for everyone during hot summer days.
- **Cool roofs can help reduce the urban heat island effect, improve air quality and combat climate change:** by reducing the amount of heat gain and storage in an urban area at a large scale, cool roofs can mitigate the urban heat island effect and provide opportunities to reduce smog, air pollution and emissions.⁴⁴ By reduction in the city temperature, the cool roofs also help in reducing air conditioning energy consumption in the buildings.
- **Cool roofs enhance durability and appearance of roofs:** by keeping roof structures from heating up through the application of cool roofing techniques, cool roofs can prevent excessive expansion and contraction of the materials and reduce incidences of cracking and rusting, thereby prolonging the life of the roof.⁴⁵
- **Cool roof increase energy access by reducing peak load on the grid:** through the reduction of cooling needs in air-conditioned buildings, cool roofs can reduce peak load on the grid, enabling lesser load shedding during the peak summer months and the heat season.
- **Cool roofs help build community resilience to extreme heat:** as shown in the Ahmedabad Heat Action Plan, increasing community resilience to cope with heat waves can lead to fewer heat-related illnesses and casualties.⁴⁶

⁴² Vishal Garg, Rajshree Kotharkar, Jayant Sathaye, Hema Rallapalli, Nilesh Kulkarni, Niranjana 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 (accessed on 07 July 2017)

⁴³ Akbari et al "Using Cool Roofs to Reduce Energy Use" (see footnote 5); Vishal Garg, Rajshree Kotharkar, Jayant Sathaye, Hema Rallapalli, Nilesh Kulkarni, Niranjana 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 (accessed on 07 July 2017)

⁴⁴ Akbari et al "Using Cool Roofs to Reduce Energy Use" (see footnote 5)

⁴⁵ *ibid.*

⁴⁶ Ahmedabad Municipal Corporation, "Ahmedabad Heat Action Plan 2017", 2017, <https://www.nrdc.org/sites/default/files/ahmedabad-heat-action-plan-2017.pdf> (accessed on 02 May 2017)

Section 2: Cool Roof Programs in India

Cool roof programs have been gaining momentum in Indian cities in the past decade. Green building rating systems such as Leadership in Energy and Environmental Design (LEED), Green Rating for Integrated Habitat Assessment (GRIHA) and the Indian Green Buildings Council (IGBC) rating systems highlight cool roofs as a key strategy in reducing the energy consumption in buildings. As awareness of cool roof concepts has grown, their usefulness in addressing thermal comfort in low-income households and for vulnerable populations has come to the forefront.

Cool roof initiatives in Indian cities thus far have been tackled from a variety of angles:

- a design-led approach to drive momentum for policy change, such as in Delhi;
- a pilot project-led approach to make the case for the benefits of cool roofs as in Indore and Surat, or
- policy-led programs to drive action as in Ahmedabad.

Other cities such as Hyderabad are also making progress towards instituting their own cool roof policies. While each approach has its advantages, a clear, comprehensive strategy is needed for sustained action and results in the city environments. While the subject of cool roofs is addressed in the national level National Building Code (NBC) and the Energy Conservation Building Code (ECBC), it has most strongly been addressed by city governments, often with support from local NGOs and institutional partners. City governments are well placed to effect change on cool roof strategies, since they often exercise control over local development control regulations and building codes. However, different sections of Indian cities are controlled and managed by different city, state and regional agencies. Therefore, for collective impact to reduce the urban heat island effect, interagency coordination is critical.

“Cool Roofs for Cool Delhi”: A Design Manual to Promote Cool Roofs - 2011

The greater metropolis area of Delhi is one of the largest in India, with a population of 18.6 million.⁴⁷ Once a city with a multitude of green spaces, Delhi’s vegetation has been increasingly under threat with pressure on building for this immense population. With rapidly depleting green cover, and an air quality deterioration that led to Delhi being ranked one of the world’s worst cities for air pollution by the World Health Organization, the city and state authorities have been working to identify areas of intervention that could make significant impacts on the city’s energy consumption, air quality and thermal comfort.⁴⁸

Approach: As a large metropolis and the national capital, Delhi is the site of attention and action by decision makers. In 2011, the Bureau of Energy Efficiency commissioned Environmental Design Solutions to develop a “Cool Roofs for Cool Delhi” design manual, with the support of the Delhi national capital territory government, and the Shakti Sustainable Energy Foundation.⁴⁹

Details: The manual is structured to be a source of information for key stakeholders – decision makers, citizens and industry – on the benefits of adopting cool roofs in buildings in Delhi. The manual describes different elements of a cool roof initiative, from materials to case studies of energy savings in buildings that have utilized cool roof techniques. The manual has a special focus on low tech, low cost solutions that can be applied to vulnerable communities.

⁴⁷ World Population Review, “Delhi Population 2017”, <http://worldpopulationreview.com/world-cities/delhi-population/> (accessed on 02 May 2017)

⁴⁸ World Health Organization, “Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease”, September 2016 (accessed on 07 July 2017)

⁴⁹ Bureau of Energy Efficiency, “Cool Roofs for Cool Delhi”, 2011, <http://shaktifoundation.in/wp-content/uploads/2014/02/cool-roofs%20manual.pdf> (accessed on 02 May 2017)

Goal: Through the manual, Delhi hoped to provide solutions to cities for mitigating greenhouse gas emissions through converted white cool roofs.

Indore and Surat “Cool Roof Project”: Pilot Projects to Showcase Benefits of Cool Roofs at an Urban Level - 2011

The Indian cities of Indore and Surat are among the fastest growing cities in India.⁵⁰ With populations of 1.9 million and 4.4 million in 2011 respectively, the two cities are expected to be impacted by growing heat stress and power demand.

Approach: The city governments of Indore and Surat, with the support of TARU Leading Edge and the Rockefeller Foundation, in 2011 embarked upon a project to address the potential of cool roofs in the two cities. With buy in from the city decision makers and stakeholders, the program focused on displaying successes through pilot case studies on residential buildings in the two cities. The program worked to leverage these local success stories into a compelling case for a cool roof policy development process in the cities of Surat and Indore.

Details: Cost benefit analyses of the implemented locations showed the city government, real estate developers, and technology providers the impact of cool roofs on thermal comfort for vulnerable populations in each city and ways to incorporate cool roofs into future building projects. Through a series of workshops and seminars, cool roof techniques were promoted to broader audiences, including local businesses. Covering over 100 households and 40,000 square feet in Indore and Surat, the Cool Roof Project used simple products such as lime concrete, China mosaic tiles, and broken earthen pots, helping to reduce temperatures and the associated costs of electricity and water.

Cool Roof Standards in India

Energy Conservation Building Code: The Energy Conservation Building Code, 2017 requires commercial building roofs with a minimum solar reflectance of 0.6, either through the prescriptive path or whole building simulation path to prove a minimum expected reflectance of 0.6. While the ECBC does not specify cool roof requirements for different climate regions, it does state: “Roofs with slopes less than 20 degrees shall have an initial solar reflectance of no less than 0.6 and an initial emittance no less than 0.9. Where solar reflectance shall be determined in accordance with ASTM E903-96 and emittance shall be determined in accordance with ASTM E408-71 (RA1996).”⁵¹

Rating systems in India, including the Indian Green Building Council (IGBC), Leadership in Energy and Environmental Design (LEED) and the Green Rating for Integrated Habitat Assessment (GRIHA) require mandatory ECBC norms compliance as a prerequisite for buildings applying for rating.

	Standards
ECBC	ASTM E 903-96, ASTM E408-71 (RA 1996)
LEED India	ASTM Standard E1980-01, ASTM E 408-71 (1996) e1, ASTM E 903-96, ASTM E1918-97, ASTM C1371-04, ASTM C1549-04
GRIHA	The GRIHA rating system takes into account the provisions of the National Building Code 2005; the Energy Conservation Building Code 2007 announced by BEE (Bureau of Energy Efficiency) and other IS codes

Table 2: Testing Standards

⁵⁰ City Mayors Foundation, “The World’s Fastest Growing Cities and Urban Areas from 2006 to 2020,” www.citymayors.com/statistics/urban_growth1.html (accessed on 02 May 2017)

⁵¹Bureau of Energy Efficiency, “Energy Conservation Building Code 2017”, 2017, Ministry of Power, Government of India, https://beeindia.gov.in/sites/default/files/BEE_ECBC%202017.pdf (accessed on 07 May 2018)

Financial Mechanisms for Cool Roof Programs

While cool roofs can provide savings in energy and energy bills, the initial capital required for their installation needs to be addressed. In commercial, office and high end residential buildings in India, it can be expected that cool roofs will reduce air-conditioning costs, peak power demand and improve the performance of the HVAC system. However, in low-income communities, where heat stress is high, power supply is limited, and usage low (typically for ceiling fans), a substantial reduction in energy usage is unlikely to be observed, as cooling loads will not be reduced. However, cool roofs can result in more comfortable conditions indoors. In these cases, the payback period of a cool roof is not a motivation for households, and therefore other collective means of financing these cool roofs may be needed.

Some of the types of financial mechanisms that can be leveraged in both cases are:

- Utilizing public funds (national and state) under smart city or energy efficiency schemes
- Utilizing Corporate Social Responsibility (CSR) funds for cool roof installations in low-income and vulnerable housing
- Property tax rebates for cool roof installation: many cities around the world began their programs by offering credits or incentives for cool roof installations

Section 3: Cool Roofs for Low Income Communities

As stated earlier in this report, an estimated 65 million of India's population live in urban, low income communities with little or no access to adequate housing, electricity and other urban services. These communities currently live under non-ideal conditions, and city governments are putting in place initiatives to improve these communities and life for their residents. Within these communities, as income levels rise, an increase in energy demand is also expected. A World Bank study reported by TARU Leading Edge estimates that the use of ceiling fans can be expected to increase from 130 million in 2011 to 735 million 2031, and air-conditioning stock is likely to increase from 4.7 million in 2011 to 48 million in 2031. Cool roof initiatives addressing the urban heat island and cooling demand are key first steps to addressing many of the issues faced by these growing urban regions. Two recent cool roof initiatives, undertaken in Ahmedabad and Hyderabad, are described here.

Ahmedabad Cool Roofs Initiative: Addressing Cool Roofs as a Response to Extreme Heat – 2017 and 2018

One of India's fastest growing cities, Ahmedabad is the economic center of the state of Gujarat. Ahmedabad district, including the surrounding suburban and rural areas, is home to 7.2 million people. Located in the arid western region of India, Ahmedabad's warm, dry conditions are conducive to heat waves. After a devastating heat wave hit the city in 2010, experts estimated the heat contributed to more than 1,000 deaths.⁵² In response, city leadership in Ahmedabad is working to protect local communities from rising temperatures and the deadly threat of extreme heat. For the sixth consecutive year, and as temperatures soar to 42°C (108°F), the city of Ahmedabad and partners released the ground-breaking Ahmedabad Heat Action Plan for 2018.⁵³ It is a model other cities might follow to safeguard their citizens from this increasing health danger.

In 2017, the Ahmedabad Municipal Corporation unveiled a cool roofs initiative as a part of the updated Ahmedabad Heat Action Plan 2017.⁵⁴ With a clear goal to deploy cool roof techniques in 3,000 low income households across 6 city zones, the initiative was inaugurated by the mayor of the city symbolically painting the first roof himself.

Highlights of Ahmedabad's cool roof initiative:

- **Engaging citizens:** The Ahmedabad Municipal Corporation has designed dedicated information, education and communication (IEC) materials on cool roofs to increase community awareness on what cool roofs are, on how they can help reduce indoor temperatures and what materials can be used to convert to a cool roof. A group of 50 volunteer students from local colleges in Ahmedabad have joined the drive to support the AMC in painting many rooftops.
- **Pilot project to showcase benefits:** The Ahmedabad Municipal Corporation initiated a cool roofs pilot for the city of Ahmedabad with a target to convert 3000 homes to cool roofs. This pilot was carried out in collaboration with the private sector and their corporate social responsibility activities in the city, coupled with a volunteer program.

⁵² Gulrez Shah Azhar, Dileep Mavalankar, Amruta Nori-Sarma, Ajit Rajiva, Priya Dutta, Anjali Jaiswal, Perry Sheffield, Kim Knowlton, Jeremy J. Hess, "Heat-Related Mortality in India: Excess All-Cause Mortality Associated with the 2010 Ahmedabad Heat Wave", PLOS One, 2014 (accessed on 02 May 2017)

⁵³ Nehmat Kaur, "Ahmedabad: Cool Roofs Initiative with 5th Heat Action Plan," 2016, www.nrdc.org/experts/nehmat-kaur/ahmedabad-cool-roofs-initiative-5th-heat-action-plan (accessed on 02 May 2017)

⁵⁴ Ahmedabad Municipal Corporation, "Ahmedabad Heat Action Plan 2017", 2017, <https://www.nrdc.org/sites/default/files/ahmedabad-heat-action-plan-2017.pdf> (accessed on 02 May 2017)

- **Showcase municipal leadership:** The Ahmedabad Municipal Corporation will spearhead the cool roofs initiative by converting municipal buildings and other publicly owned buildings to reflective cool roofs and including cool roofs in their procurement criteria.
- **Partnering with local businesses for implementation:** the AMC partnered with a company that manufactures heat reflective paint for cool roofs. The paint used for the inaugural was provided free of cost by the manufacturer and has an SRI of 122. While this donated paint was used for 10-15 pilot households, the remaining households were painted with three layers of lime, through contractors hired by the AMC.

By May 2017, the city completed its pilot and applied coatings of lime wash on 3000 low-income homes in the city, with 500 in each city zone, covering almost 2% of the city’s low-income households.⁵⁵ The total cost of the project was ₹700,000 (\$10,924), at an average cost of ₹225 per household (\$3.51).⁵⁶ With a low unit cost per square foot of ₹0.5 (~\$0.07), lime wash is an extremely cost competitive material. A study by TARU Leading Edge in the city of Indore experimented with a composite roofing material consisting of locally available Mangalore tiles, cement mortar bedding and lime concrete. The technique was found to reduce indoor temperatures by 2-3 degrees C and cost ₹120 (\$1.85) per square foot. While significantly higher in cost than lime wash alone, this construction could be a long-term alternative for low income homes in India which often do not have proper roof structures.⁵⁷ In 2018, the pilot incorporated reflective paint coatings, and 20-25 local real estate developers came forward to expand cool roofs to private buildings in Ahmedabad on a voluntary basis.

Ahmedabad has shown leadership by proactively including cool roofs within the city’s heat action plan. The city’s next steps would include implementing cool roofs on municipal buildings, incentive mechanisms for cool roofs in private buildings, incorporation of cool roofs initiatives into the city’s building codes as a voluntary or mandatory requirement along with budget and financing considerations. The urban heat island is not a localized effect, but a regional one, and cool roof initiatives need to make a collective effort for the impact to be felt in the city environment.



Figure 9: Billboard in Ahmedabad promoting the positive effects of cool roofs in the city (IIPH-G)

⁵⁵ Ahmedabad’s Slum Free City Plan lists 691 notified slum settlements in the Ahmedabad Municipal Corporation area, containing 162,749 houses and a population of 727,934. Ahmedabad Municipal Corporation, “Ahmedabad Slum Free City Action Plan”, 2014 <http://pas.org.in/Portal/document/PIP%20Application/Ahmedabad%20Slum%20Free%20City%20Action%20Plan%20RAY.pdf> (accessed on 25 August 2017)

⁵⁶ These calculations apply to an average roof size of 450 square feet

⁵⁷ TARU Leading Edge, “Handbook on Achieving Thermal Comfort within Built Environment – Volume IP” 2015 (accessed on 07 July 2017)



Figure 10: Gautam Shah, Mayor of Ahmedabad, paints the first cool roof coating in the city, May 2017 (IIPH-G)

The pilot in Ahmedabad builds on ongoing efforts by leading groups in the city. For example, the **Mahila Housing SEWA Trust (MHT)**, a non-profit organization, has installed over 250 cool roofs in low income communities in Ahmedabad, using a material called ModRoof – roofs made of coconut husk and paper waste – as an alternative to concrete roofs.⁵⁸ According to MHT, these modular roofs provide greater cool roof benefits than regular roof materials and data collected from installed sites showed indoor air temperature being lower by 7-8°C (12.6 – 16.4°F), as compared to conventional concrete roofs. A 2017 study by MHT, NRDC and IIPH-G found that at 1:00 pm the ambient temperature of homes with mod roof were approximately 4.5°C lesser than other control roofs. The study compared the indoor ambient temperature of the households that implemented cool roof techniques with the support of Mahila Housing SEWA Trust (MHT) against the controls. Modular roofing system, solar reflective white paint on tin roof, air lite ventilation on tin roof and thermocol sheet insulation beneath asbestos have been compared against roofing of control households: tin, asbestos/cement sheet and concrete in the slums across Ahmedabad. The study was conducted in 16 households during September 2017.⁵⁹



Figure 11: ModRoof installation in Ahmedabad by Mahila Housing SEWA Trust (Mahila Housing SEWA Trust, 2016)

⁵⁸ Mahila Housing SEWA Trust, “Building Climate Resilience Capacities of Urban Poor in South Asia - Compendium of Solutions”, Global Resilience Partnership (accessed on 07 July 2017)

⁵⁹ Mahila Housing SEWA Trust, “Research Report: Combating Climate Change Induced Heat Stress: Assessing Cool Roofs and its Impact on the Indoor Ambient Temperature of the Households Across Slums of Ahmedabad”, 2018 (accessed on 02 May 2018)

Hyderabad Cool Roofs Program: Addressing Thermal Comfort for Vulnerable Communities - 2017 and 2018

The city of Hyderabad in Telangana, popularly known as one of India's IT capitals, is home to over 7 million residents, and spans one of the largest urban municipal areas in the country. Located in the hot and arid Deccan Plateau region of south central India, the city and state leadership have begun the process to develop a cool roofs policy, with a focus on low income communities in the city. Already a leader in energy efficiency in commercial and large buildings through the implementation of the Energy Conservation Building Code, the state of Telangana is now developing a cool roofs policy to address the wellbeing of its most vulnerable residents.⁶⁰ In March 2017, the Greater Hyderabad Municipal Corporation (GHMC), along with the Municipal Administration and Urban Development department of the Telangana State government, with the support of the Administrative Staff College of India (ASCI) and NRDC, held a workshop on cool roofs in Hyderabad. During this workshop, the state government announced its intention to develop a cool roofs policy for the State of Telangana.

Highlights of Telangana's proposed cool roofs policy development process:

- **Identification of key stakeholders:** The Telangana cool roofs policy program identifies key government stakeholders for successful policy adoption and implementation, including the state government departments and urban local bodies. The inclusion of the Chief Commissioner for the Revenue Department from the state Municipal Administration and Urban Development department is a key indicator that the state intends to ensure a strong implementation plan through allocation of funds and financing mechanisms.
- **Engagement of technical partners:** with strong leadership and buy in by the GHMC, NRDC, ASCI and IIIT-H have been engaged to implement a trial pilot, assist with the policy development process and provide implementation support.
- **Implementation of city wide cool roofs initiative:** working along with technical partners, the city leadership will work to implement cool roof solutions and monitor performance, comfort, as well as impact on health outcomes, beginning with a trial pilot and then expanding out to a larger citywide program.
- **Development of financing solutions for cool roofs initiative:** to enable an effective and sustainable city level cool roofs program, the city government along with partners will focus on the development of financing solutions, including exploring city budget allocations and other sources of income, such as corporate social responsibility funds. While many simple cool roof materials are extremely cost competitive with conventional roofing materials, they require some initial investment, along with costs for regular maintenance and upkeep.

⁶⁰ Natural Resources Defense Council, "Building a Better Future: Implementing the Energy Saving Building Code in Hyderabad", 2016 <https://www.nrdc.org/sites/default/files/better-future-energy-saving-building-code-hyderabad.pdf> (accessed on 02 May 2017)

Pilot for cool roof implementation in a low-income neighbourhood in Hyderabad

In 2017, ASCI and NRDC, with technical support from IIIT-H, implemented a cool roofs pilot in a low-income neighborhood of Hyderabad to showcase and document the benefits and impact cool roofs can have.

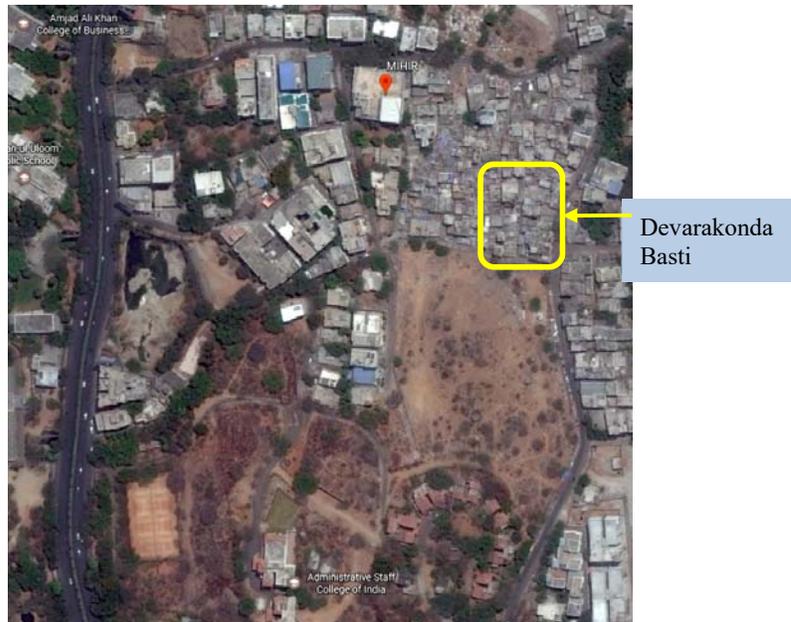


Figure 12: Location of the Hyderabad cool roof trial pilot in Hyderabad surrounded by mid-rise residential construction

Objectives and methods

The objective of this program was to implement a cool roofs pilot to:

- Identify cost-effective cool roof solutions for low-income housing
- Identify a scalable financial mechanism to support the cool roofs program in the city

The pilot was undertaken by ASCI and IIIT-H in May and June 2017, towards the end of the heat season in Hyderabad and prior to the monsoon. This period is characterized a combination of high heat and humidity, often making indoor conditions extremely uncomfortable. The cool roof pilot project focused on a set of 25 low-income households in the city of Hyderabad. Dupont India supplied an High-density Polyethylene (HDPE) cool roof coating membrane, Tyvek, for the pilot implementation free of cost as a part of their CSR efforts. The membrane retails in Hyderabad for ₹13/square foot (\$0.2/square foot).

Property	MD/XD	Nominal value	Test method
Basis weight	-	50 - 100 g/m ² (Tyvek® only)	ASTM D3776
		200 – 400 g/m ² (with insulation or backing)	
Tensile Strength of Tyvek® only	MD	100 N ± 10 N	ASTM D882
	XD	80 N ± 10 N	
Tensile Elongation of Tyvek® only	MD	10 % ± 2 %	ASTM D882
	XD	20 % ± 5 %	
Tear Strength (Elmendorf) of Tyvek® only	MD	55 N ± 8 N	ASTM D1424
	XD	47 N ± 7 N	
Emissivity (USEM)* Tyvek® side	-	60 % ± 5 %	ASTM C1371
Emissivity (USEM)* Metal side	-	16 % ± 6 %	ASTM C1371
Light reflection (SCI)* (350-3000 nm)	-	91.3% ± 3%	ASTM E1164
Moisture Vapor Transmission*	-	1000 ± 600 g/m ² for 24h	DIN EN ISO 12572
Water pressure (Hydrostatic Head)*	-	195 cm H ₂ O ± 35 cm H ₂ O	DIN EN 20811 (92)
Air permeability (Standard Gurley)*	-	150 Gs ± 50 Gs	TAPPI T460
Water Tightness (WTI)*	-	PASS	EN 1928-A (00)
Thermal conductivity (at 0 °C)**	-	0.0288 W/m.K	ASTM C518
	-	0.3035 m ² K/W	
Thermal resistance (at 0 °C)**	-	1.72 ft ² °F. hr /BTU	
	-	4.37 ft ² °F. hr /BTU.in	

Figure 13: Specifications of the Tyvek cool roof membrane in the Hyderabad trial (Dupont, 2017)

The main steps in the trial pilot process were:

1. **Trial site identification:** The site for the trial pilot in Hyderabad was Devarakonda basti in west Hyderabad. The neighborhood is an informal settlement, or basti, surrounded by mid-rise residential development, and comprises primarily single-floor, dense residential homes. The homes are predominantly constructed of reinforced cement concrete and brick, with roofs made of corrugated asbestos sheets or concrete slabs. Almost 50% of the households have asbestos sheet roofs, making this community a typical representative of the 1,468 low income communities in Hyderabad, as described in the 2014 Slum Free City Plan for Hyderabad by the GHMC.⁶¹
2. **Pilot design:** ASCI and IIIT-H designed the pilot to cover 25 test households with an additional 15 households serving as a control group to test the results of the experiment.
3. **Stakeholder consultation:** Prior to beginning installation and monitoring, ASCI and IIIT-H conducted a stakeholder consultation with the residents and building owners.
4. **Membrane installation process:** the ASCI and IIIT-H teams undertook the installation process for the pilot households, installing both the cool roof membranes and the testing equipment. The cool roof membrane was secured to the roofs of the 25 houses through use of ropes or bricks to weigh the membrane down. As no permanent installation took place, the process had many added advantages: first, the membrane could be removed and stored at the end of each heat season, considerably increasing the life of the membrane; second, the membrane provided a waterproofing layer to the buildings that were often improperly constructed and had leaks or cracks in the roof structure; third, the process allowed for quick and easy installation that did not require specialized labor and served as an example to residents about measures they could take themselves to replicate the process.
5. **Resident surveys:** All 25 households, along with an additional 15 households that served as the control group, were surveyed both before and after the pilot to capture responses of the residents. The pilot covered a total area of 10,000 square feet for over 100 residents.

⁶¹ The 2014 Slum Free City Plan for Hyderabad, by the GHMC states that 47% of the city's low-income households have asbestos roofing. Greater Hyderabad Municipal Corporation, "Slum Free City Plan of Action for Greater Hyderabad Municipal Corporation", 2013 (accessed on 25 August 2017)

Sample survey questions

The survey spanned aspects of basic characteristics of the households (number of residents, construction of the house), and thermal comfort (level of comfort experienced by the residents before and after the installation of the membranes).

- On the basis of temperature, how do you feel right now?
 - o Cold
 - o Cool
 - o Slightly cool
 - o Neutral
 - o Slightly warm
 - o Warm
 - o Hot
- If you could choose to change it, how would you prefer the temperature to be right now?
 - o Much cooler
 - o A bit cooler
 - o No change
 - o A bit warmer
 - o Much warmer
- Whenever you want to change the temperature, what would you normally do?
 - o Open window
 - o Switch on fan
 - o Open door
 - o Switch on air cooler

- 6. **Monitoring:** Monitoring tests were carried out on four houses, two with cool roof membranes and two from the control group without the membrane. The tests monitored outdoor and indoor ambient air temperature, relative humidity, air speeds and carbon dioxide levels using indoor air quality measurement meters, anemometers and testo globes.



Figure 14: Pictures showing cool roof pilot installation and testing underway in Hyderabad, May 2017 (ASCI-IIIT)

Results of pilot

Two key indicators of a successful cool roof intervention are a lowering of the roof surface temperature, and a lowering of the indoor air temperature.

Monitoring results

- In the Hyderabad trial, indoor air temperatures that were lower by an average of 2 degrees C were observed in the homes with cool roofs as compared to similar homes without cool roofs.
- Peak over deck roof temperatures in the cool roof homes were observed to be 15 degrees C lower than temperatures in homes with just asbestos roofs and 10 degrees C lower than temperatures in homes with just cement roofs.

Survey results

- A majority of the trial group residents, 76 percent, expressed satisfaction with the cool roofs, while residents in the control group and other parts of the neighborhood began to apply makeshift cool roof membranes on their own roofs in response to the positive feedback by the trial.

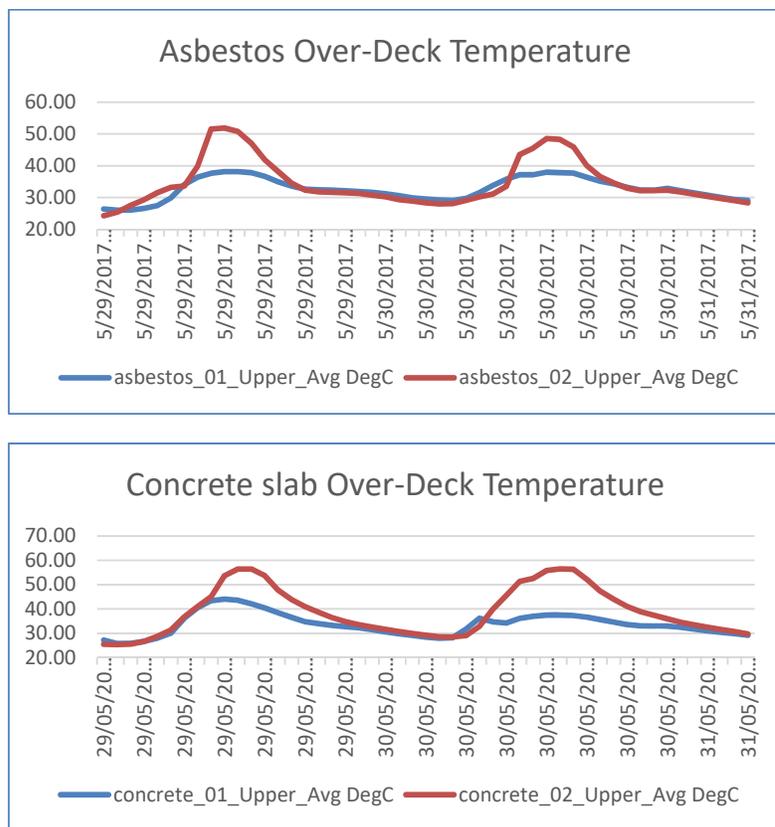


Figure 15: Monitoring results from the 2017 Hyderabad trial on cool roofs (IIIT-H, 2017)

Hyderabad’s 1,468 notified low-income communities house a population of over 1.9 million people. A majority of the houses within the city’s low-income neighborhoods are constructed with concrete slab or asbestos roofs.⁶² As the city works to improve living and housing conditions in these neighborhoods, the use of cool roofs provide great opportunity to impact human health and comfort in Hyderabad.

Use of asbestos in construction in India
 While the adverse health impacts of asbestos are known around the world, it is not banned in India. India is a major importer of asbestos where it is used mainly for making asbestos cement and pipes.⁶³ A majority of slum improvement and housing schemes, however, aim to provide reinforced concrete housing to lower income populations, and awareness of concrete as a more durable construction material is also increasing.⁶⁴ Traditional and vernacular construction in different parts of India has included more locally available materials such as lime concrete or mud brick, and some efforts are underway to bring back these construction methods as well.

⁶² The 2014 Slum Free City Plan for Hyderabad, by the GHMC states that 47% of the city’s low-income households have asbestos roofing. Greater Hyderabad Municipal Corporation, “*Slum Free City Plan of Action for Greater Hyderabad Municipal Corporation*”, 2013 (accessed on 25 August 2017)

⁶³ Frank AL, Joshi T K, “*The Global Spread of Asbestos*”, *Annals of Global Health*, Vol 80, Issue 4, Pages 257-262, 2014, <https://www.sciencedirect.com/science/article/pii/S2214999614003191> (accessed on 9 May 2018)

⁶⁴ Greater Hyderabad Municipal Corporation, “*Slum Free City Plan of Action for Greater Hyderabad Municipal Corporation*”, 2013 (accessed on 25 August 2017); Ahmedabad Municipal Corporation, “*Ahmedabad Slum Free City Action Plan*”, 2014 <http://pas.org.in/Portal/document/PIP%20Application/Ahmedabad%20Slum%20Free%20City%20Action%20Plan%20RAY.pdf> (accessed on 25 August 2017)

Section 4: International Cool Roof Programs and Practices

Cool roof initiatives have been implemented in the past two decades in leading cities as an effective strategy to counter the urban heat island effect and reduce cooling loads in buildings.⁶⁵ While the cool roof movement began to take shape in the late 1990s as a policy program, the nature of its inclusion in policies has evolved over time. While initially building owners were provided credits and rebates to incentivize the inclusion of a cool roof strategy in their building, it has gradually evolved into a requirement as part of the building code in many cities around the world.⁶⁶

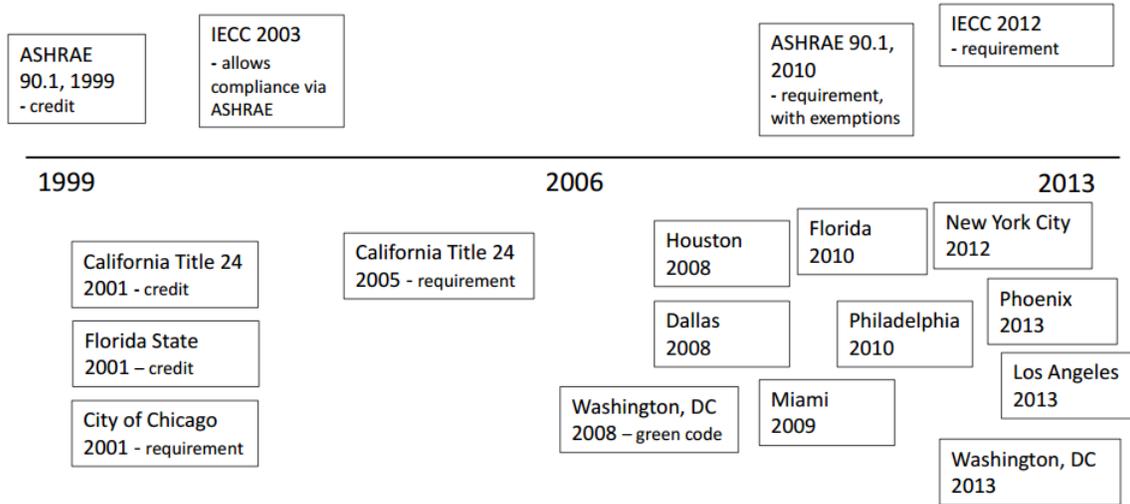


Figure 16: Evolution of cool roof inclusion in US building codes (Akbari et al)

NYC °Cool Roofs: Cool roofs Coating Program in New York City	
NYC °Cool Roofs is a city government-led initiative in New York City. First launched in 2009, the program works to coat rooftops in New York with a white reflective coating to reduce energy consumption in the buildings. ⁶⁷	
Worker training	NYC °Cool Roofs works with volunteer groups that undergo a 2-3 month training program in order to qualify as roof coaters. The training program aims to be a citywide workforce training as the participants not only learn the techniques of physically installing cool roofs, but also learn skills of leadership, project evaluations, working with diverse sets of stakeholders, including building owners, tenants, community volunteers, and program partners. All participants are supported by the NYC Department of Small Business Services' Workforce1 system throughout the training and post training in connecting them to fulltime work in sectors ranging from industrial to construction to building maintenance, among others.
Target	NYC °Cool Roofs was first launched in 2009 with a pilot project to showcase the benefits of installing cool roofs in the city. A goal of coating one million square feet of rooftops each year was adopted.

⁶⁵ Hashem Akbari, "Evolution of Cool Roof Standards in the United States", LBNL, 2008 (accessed on 07 July 2017)

⁶⁶ Kurt Shickman, "Cool Policy Review – Cool Roof Rating Council Membership Meeting," Global Cool Cities Alliance coolroofs.org/documents/Exhibit_4_-_Global_Cool_Roof_Policy_and_Code_Update_Shickman.pdf (accessed on 02 May 2017)

⁶⁷ NYC Cool Roofs, "NYC Cool Roofs: Annual Review 2013", 2013 (accessed on 07 July 2017)

<p>Awareness programs/citizen engagement</p>	<p>Throughout the process, the initiative engages local property owners, community partners, workforce training organizations, and volunteers. The awareness campaign followed a phased approach after the inclusion of cool roofs in the Local Laws of New York consisting of public advertisements on bus shelters promoting the initiative and directing citizens to the website containing information on implementing cool roofs.</p>
<p>Policy inclusion</p>	<p>Cool roofs have been included in the Local Laws of the City of New York, which were amended in 2011 to include roof coating standards.⁶⁸</p>
<p>Impact</p>	<p>Since its launch, the program has successfully coated over six million square feet of New York City rooftops and resulted in offsetting of over 830 tons of carbon dioxide.</p>

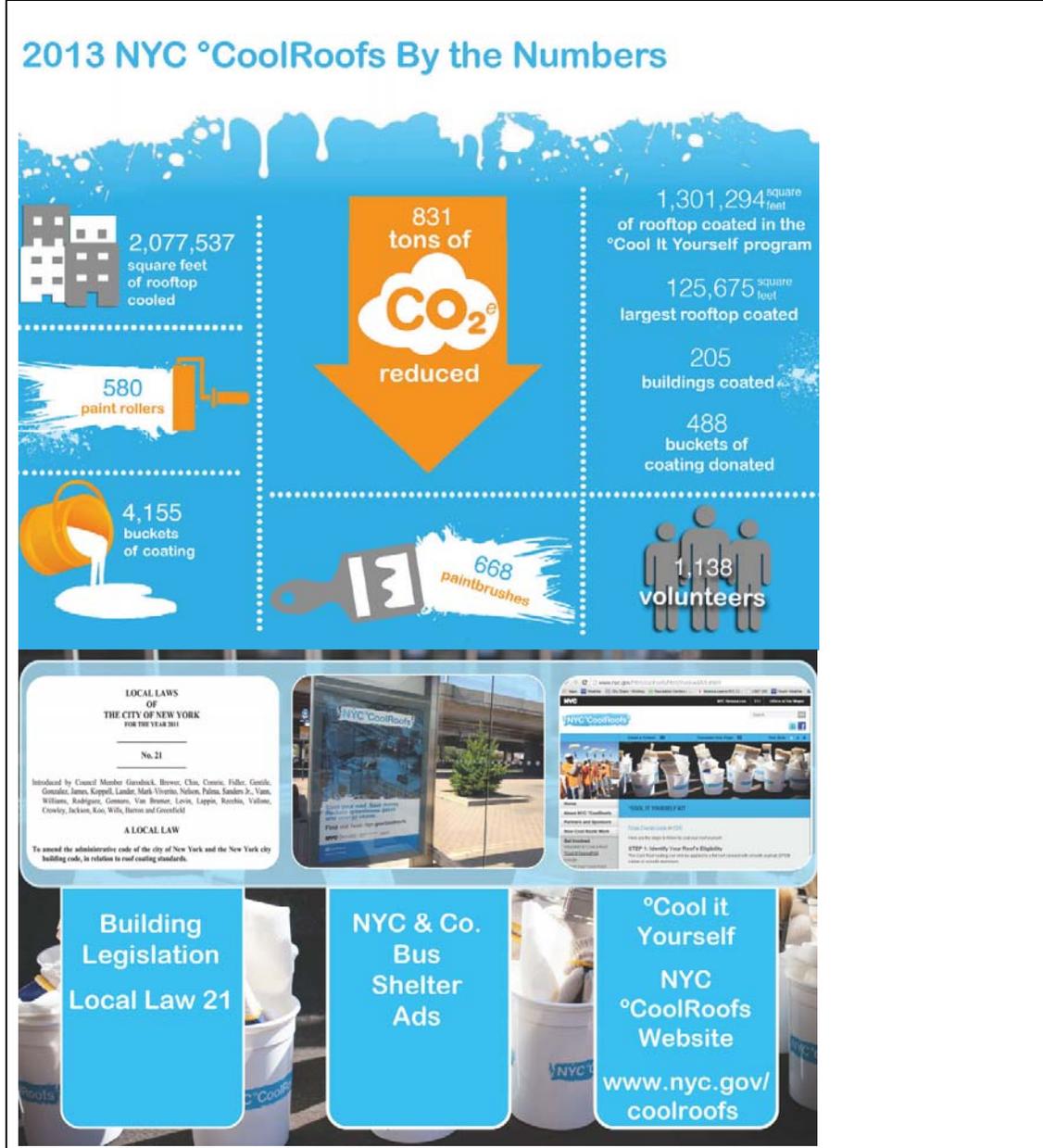


Figure 17: NYC °Cool Roofs impact and phased citizen awareness plans (NYC °Cool Roofs)

⁶⁸ City of New York, “Local Laws of the City of New York for the Year 2011 No. 21”, <http://www.nyc.gov/html/coolroofs/downloads/pdf/1121of2011.pdf> (accessed on 07 July 2017)

Houston Cool Roofs and Urban Heat Island Program	
<p>After a study by the Houston Advanced Research Center in 2006 yielded findings about the adverse impacts of Houston’s built environment on the city’s heat island and the potential to improve thermal comfort in the city, the Houston city government in 2007 undertook an independent impact study for cool roofs. Houston found that in addition to providing energy savings, cool roofs reduce thermal expansion and contraction and extend the life span of the roof itself, thus reducing construction material waste in landfills. These potential environmental and economic benefits inspired the adoption of a cool-roof requirement in the Houston Commercial Energy Conservation Code of 2008.⁶⁹</p>	
Awareness programs/citizen engagement	<p>To further encourage cool-roof deployment on private buildings, the Mayor’s Office of Sustainability ran the one-off Houston Green Office Challenge, an energy-efficiency incentive program that helped finance energy-saving retrofits. Any project that saved 15% or more of the building’s energy was eligible for \$20,000 to \$500,000 incentives. These projects included cool or green roofs.</p>
Policy inclusion	<p>The Energy Conservation Code, enforced by the Code Enforcement Division of the Department of Public Works and Engineering, requires that air-conditioned government, commercial, and multifamily residential buildings that install or replace low-slope roofs have a minimum initial solar reflectance of 0.70 and a minimum thermal emittance of 0.75.</p>
Cool Roofs in Tokyo, Japan	
<p>In Asia, Japan is a regional leader in cool roof and urban heat island mitigation programs at the national and local level, with over a decade of action to mitigate urban heat islands. The heat island effect was first defined as a category of heat pollution in a landmark move by Japan’s Environment Ministry in 2001. An interagency policy council for heat islands was established in 2003. In 2006, the Tokyo Metropolitan Government’s Committee to Promote Cool Roofs announced a three-year project on cool roofs to provide subsidies for buildings that covered at least 50 square meters of their rooftops with a green roof or highly reflective paint.⁷⁰</p>	
Cool Roofs in Europe	
<p>Cool roof development in Europe is being spearheaded by the European Union Cool Roofs Council (ECRC).⁷¹ The ECRC is a non-profit organization that aims to:</p> <ul style="list-style-type: none"> • Implement five cool roofs pilot studies around Europe to serve as examples of successful cool roofs implementation • Develop a database of cool roofing materials and a rating for materials for the thermal properties • Promote cool roofs to stakeholders and building owners in Europe through workshops and seminars • Provide knowledge resources and strategy to overcome policy barriers and engage with key stakeholders and decision makers 	

⁶⁹ Houston Advanced Research Center, “Cool Houston! A Plan for Cooling the Region”, 2006 (accessed on 07 July 2017)

⁷⁰ Bureau of Environment, “Green Building Program”, Tokyo Metropolitan Government <http://www.kankyo.metro.tokyo.jp/en/climate/build.html> (accessed on 19 May 2017); C40 Cities, Tokyo Metropolitan Government, “Urban Efficiency: A Global Survey of Building Efficiency Policies in Cities”, 2014, http://www.c40.org/researches/urbanefficiency_i (accessed on 19 May 2017); Japan for Sustainability, “Tokyo Government Announces 2006 Cool-Roof Projects”, 02 August 2006, http://www.japanfs.org/en/news/archives/news_id026405.html (accessed on 02 May 2017)

⁷¹ Cool Roofs, “Cool Roofs in Europe: Initiatives and Examples”, http://www.buildup.eu/sites/default/files/content/Cool%20Roofs_EN_1.pdf (accessed on 19 May 2017); Kostas Gobakis, Heinz Meier, Denia Koloktsa, Afroditi Synnefa, Russel Evans, Mettheos Santmouris, “Cool Roofs in the European Context”, 2016 (accessed on 07 July 2017)

Cool Roofs Initiatives in South Africa

In 2014, South Africa launched a multi-agency effort to address the benefits of cool roofs in the country. The South African National Energy Development Institute (SANEDI) and the Association of Architectural Aluminum Manufacturers of South Africa (AAAMSA), together with the South African Department of Energy and the U.S. Department of Energy's Global Superior Energy Performance Partnership (GSEP) initiative, formed the South African Cool Surfaces Association (SACSA).⁷² Through interagency cooperation efforts, the South African cool surfaces program aims to:

- Develop testing systems for product compliance
- Establish a worker training initiative in cool roof technique installation
- Conduct demonstrations of cool paint on low-income houses to improve thermal comfort for residents as well as reduce energy consumption

Global Networks for City-City Knowledge Exchange on Cool Roofs

Cities and urban areas are increasingly considering the potential impacts of addressing cool roofs on their urban environment, and the urban local governments that govern them have often spearheaded the initiatives. Recognizing that cities can learn from each other, global networks working to promote cool cities have been formed, such as the Global Cool Cities Alliance and the Cool Cities Network.

The Global Cool Cities Alliance (GCCA) was launched in 2010 to accelerate a world-wide transition to cooler, healthier cities. Its mission is to advance urban heat island mitigation policies and programs to promote more efficient and comfortable buildings, healthier and more resilient cities, and to cancel some of the warming effects of climate change through global cooling.⁷³

The Cool Cities Network supports city efforts to reduce the impact of the urban heat island effect, working in partnership with the Global Cool Cities Alliance.⁷⁴

Cities participating in the network have prioritized three focus areas around which they are actively sharing policies and strategies with one another. The focus areas are:

- Urban Heat Island data monitoring and measurement – collecting and using UHI data to target future action
- Heat health vulnerability – considering the populations most vulnerable to health impacts from UHI and identifying strategies to reduce heat health vulnerability
- Integrating heat into long-term planning - integrating urban heat assessments and strategies to address it into long-term planning
- Green and cool solutions - evaluating green and cool solutions and their implementation

⁷² South African National Energy Development Institute, “*The Cool Surface Project*”, <http://www.sanedi.org.za/Cool%20Surface.html> (accessed on 19 May 2017); Clean Energy Ministerial, “*South African Cool Surfaces Association Launched*”, <http://www.cleanenergyministerial.org/News/south-african-cool-surfaces-association-sacsa-launched-1530> (accessed on 02 May 2017)

⁷³ Global Cool Cities Alliance, “*About Us*”, <https://www.globalcoolcities.org/about-us/> (accessed on 02 May 2017)

⁷⁴ C40 Cities, “*Network Overview*”, http://www.c40.org/networks/cool_cities (accessed on 02 May 2017)

Conclusion

City governments must take decisions to develop and finance cool roof programs – it is a critical tool to protect their citizens from extreme heat. Citizens must have the information and the financial and legal incentives to adopt cool roofs. Cool roofs can improve not only an individual’s life, but also an entire city’s environment.

Key Features of Successful Cool Roof Programs for Cities

1. **Cool roofs keep temperatures lower during hot summers:** Cool roofs help achieve thermal comfort in homes, offices and buildings and protect human health while also contributing to reduce the urban heat island effect, air pollution, smog, and energy demand—especially during peak hours. For example, research by the International Institute of Information Technology, Hyderabad (IIIT-H) and Lawrence Berkeley National Laboratory (LBNL) found that cool roofs installations could energy savings of 10 to 19 percent in the top floor of buildings in Hyderabad, potentially reducing citywide air temperature by 2°C (3.6°F) (along with increasing vegetation), and save five billion rupees in electricity bills over 10 years across India.⁷⁵
2. **Robust cool roof programs engage the community, respond to local conditions, and have strong city leadership.** For example, Ahmedabad’s program engages communities by focusing on materials and standards that are locally available. This is especially useful in informal housing where the usage of tires and white tarp on metal or asbestos roofs, as an ad-hoc cool roof technique, leads to water pooling on the roof which attracts disease-carrying mosquitoes.
3. **Dedicated city budgets and integration with existing funding mechanisms are vital for cool roof programs in low-income communities.** Although cool roofs can be cost-competitive with regular roofing, the upfront costs of cool roof materials may pose a stumbling block for low-income communities that struggle with access to proper housing.⁷⁶ Incentivizing local businesses to provide cool roof materials is a key part of building a strong program to showcase benefits, as well as incorporating cool roofs as part of roof maintenance routines. Dedicated funding for financial incentives and citizen awareness programs, worker training programs and officer training programs are important. For example, Ahmedabad included initial cool roof activities as part of its Heat Action Plan and is discussing a dedicated budget.
4. **Partnering with local civil society, academic and business institutions is critical to expanding cool roofs.** Civil society and educational institutions have a wealth of knowledge that can support initiatives at the ground level and ensure a city’s cool roof program responds to its local conditions. For example, both Ahmedabad and Hyderabad are working with NRDC, ASCI and PHFI-IIPH-G to develop their programs. Businesses, through Corporate Social Responsibility programs can help bring in the finance and technological support required to scale cool roof initiatives.
5. **Programs that begin as voluntary initiatives and then expand to building codes are a proven way to expand cool roofs in a city.** For instance, New Delhi, Ahmedabad, and Hyderabad are leading with initiatives to adopt cool roofs on public and government buildings. Large commercial and public buildings are addressed through the inclusion of cool roof strategies in the respective state Energy Conservation Building Codes. Ultimately, scaling up cool roof initiative as a part of compliance with city building energy codes could greatly expand the reach of cool roofs in Indian cities.

⁷⁵ Akbari et al “Using Cool Roofs to Reduce Energy Use” (see footnote 5)

⁷⁶ Vishal Garg, Kshitij Chandrasen, Surekha Tetali, Jyotirmay Mathur, “Online Energy Savings Calculator for Cool Roofs”, 2010, http://web2py.iiit.ac.in/research_centres/publications/view_publication/inproceedings/677 (accessed on 19 May 2017)

