COOL ROOFS

Protecting Local Communities from Extreme Heat

INTERIM ISSUE BRIEF, JUNE 2017

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Scope of Interim Issue Brief
The focus of this interim issue brief is to support the development of cool roof policies and programs in leading cities in India. In particular, this interim issue brief examines the new Ahmedabad and Hyderabad cool roof programs, piloted in 2017, including the program aims, methods, and initial implementation. Supplemental research will examine the implementation and effectiveness of the Ahmedabad and Hyderabad pilot programs, including analysis on cool roof materials for new and existing roofs in low-income housing as well as the materials, market availability, technical specifications, among other key factors.

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Executive Summary

In India, near half a billion people live in rapidly urbanizing cities.[1] At the same time, climate change is making heat waves more frequent and intense. The tragic heat wave of 2015, that claimed more than 2,300 lives, demonstrated 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 Indian people, the enormous expansion in cooling and air conditioning 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, access to cooler homes is a matter of survival, not just comfort.

Urbanization brings with it skyrocketing development and construction, that converts open space into paved, heat-trapping surfaces like roofs and roads. In fact, 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 thermal comfort indoors, in both air-conditioned and non-air-conditioned buildings. Fortunately, cool roofs, with their specific characteristics, reflect and emit 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 the vulnerable communities in low-income housing.[8] Additionally, cool roofs may help save energy, bring down cooling costs, and lead to curbing energy demand, air pollution and climate change in the long run.[9]

Cities can lead the way in cool roof implementation. In 2017, the cities of Ahmedabad and Hyderabad initiated new cool roof programs. These initial programs include citizen awareness campaigns, pilot initiatives targeting 3000 roofs, cooperation with businesses, and applying cool roof techniques to government buildings and schools. These new programs build on programs and policy efforts in New Delhi, Indore and Surat, research from leading subject matter experts such as the International Institute of Information Technology, Hyderabad (IIIT-H) and leading institutes, as well as lessons learned from cool roof programs around the world.

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[1] 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
[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
[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
[9] 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*", 2011, Ernest Orlando Lawrence Berkeley National Laboratory

Cool Roofs Offer Multiple Benefits 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 contributing to reducing 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 could reduce peak energy demand by 10 to 19 percent in buildings in Hyderabad, potentially reducing citywide air temperature by 2°C (3.6°F) and savings 5 billion rupees over 10 years.[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 tires and white tarp on metal and asbestos roofs as an ad-hoc cool roof technique had led to water pooling on the roof which attracted disease-carrying mosquitoes.

3. **Dedicated city budgets and funding mechanisms are vital for cool roof programs in low-income communities**. Although cool roofs can be cost-competitive with regular roofing, the initial capital costs of cool roofs 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 groups and business 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 the 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.

5. **Programs that start with 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 interim issue brief is to support the development of cool roof policies and programs in leading cities in India. In particular, this interim issue brief examines the new Ahmedabad and Hyderabad cool roof programs, piloted in 2017, including the program aims, methods, and initial implementation. Supplemental research will examine the implementation and effectiveness of the Ahmedabad and Hyderabad pilot programs, including analysis on cool roof materials for new and existing roofs in low-income housing as well as the materials, market availability, technical specifications, among other key factors.

[10] 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*", 2011, Ernest Orlando Lawrence Berkeley National Laboratory

[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 at a rapid speed. Of the country's 1.2 billion population, 425 million reside in urban areas.[12] Growing urbanization has led to the increase of urban heat islands in Indian cities, a phenomenon that causes warmer temperatures in 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] In addition the expansion of Heat Action Plans and early warning systems to over 17 cities and 6 states, along with the Indian Meteorological Society and National Disaster Management Authority demonstrates that leadership in India recognizes the need for programs to combat extreme temperatures.[14] The hotter cities get, the more cooling demand there is overall. With 70 percent of the buildings that will exist in 2030 in India not having been built yet, this represents a huge opportunity for energy savings and steps in the right direction.[15]

It is estimated that India's low-income population living in informal urban or peri-urban settlements known as slums or *bastis* is over 100 million.[16] In these largely low-rise communities, up to 1/5th 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.[17] 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:[18]

- 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: A lack of accessible water, poor sanitation, crowding, malnutrition, and a high prevalence of chronic medical conditions heighten slum community members' susceptibility to extreme heat's 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.

[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] Natural Resources Defense Council, "*Expanding Heat Resilient Cities Across India*", March 2016, https://www.nrdc.org/sites/default/files/india-heat-reslient-cities-ib.pdf (accessed on 28 April 2017)
[15] 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
[16] 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)
[17] 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)
[18] 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)

Cool roofs work in the Indian context.[19] Leading studies have shown that cool roofs are an effective strategy against the increasingly warmer conditions facing Indian cities.[20] Light-colored roofs have also 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 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.[21] 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 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 air temperature by 2-5°C (3.6 - 9°F).[22]

What is a Cool Roof?

A cool roof is one that does not warm up in presence of solar radiation (or sunlight) and 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.

[19] 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*", 2011, Ernest Orlando Lawrence Berkeley National Laboratory

[20] 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*", 2011, Ernest Orlando Lawrence Berkeley National Laboratory; Scope of Cool Roof in India, http://www.coolrooftoolkit.org/wp-content/uploads/2015/04/Scope-of-Cool-Roofs-in-India.pdf (Assessed November 10, 2015)

[21] 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)

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

How Cool Roofs Work

Cool roofs function primarily by reflecting heat incident on a building 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 heat 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 extent to which the surface can perform these actions determines its effectiveness as a cool roof, with the two most important factors being its ability to *reflect* solar energy and *emit* absorbed energy.

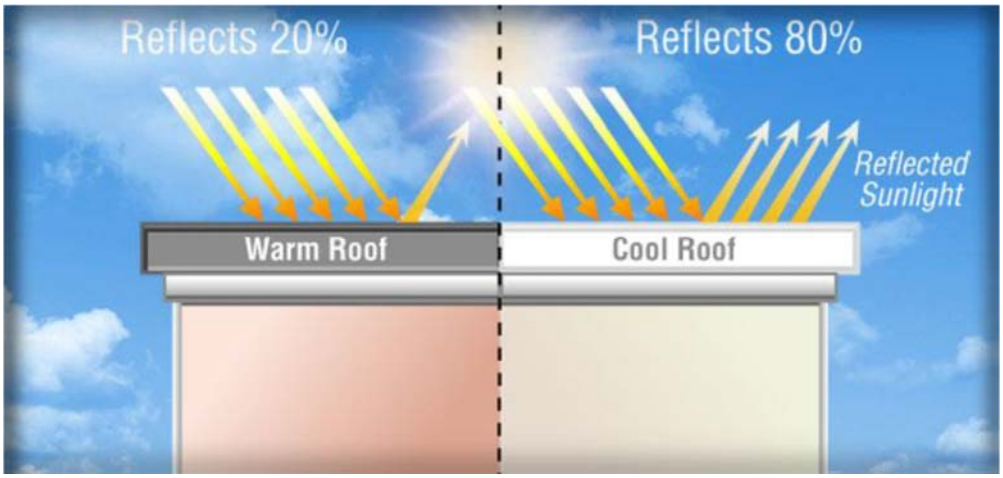

Figure 1: How a cool roof works

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 materials 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 Reflectance[23]
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.

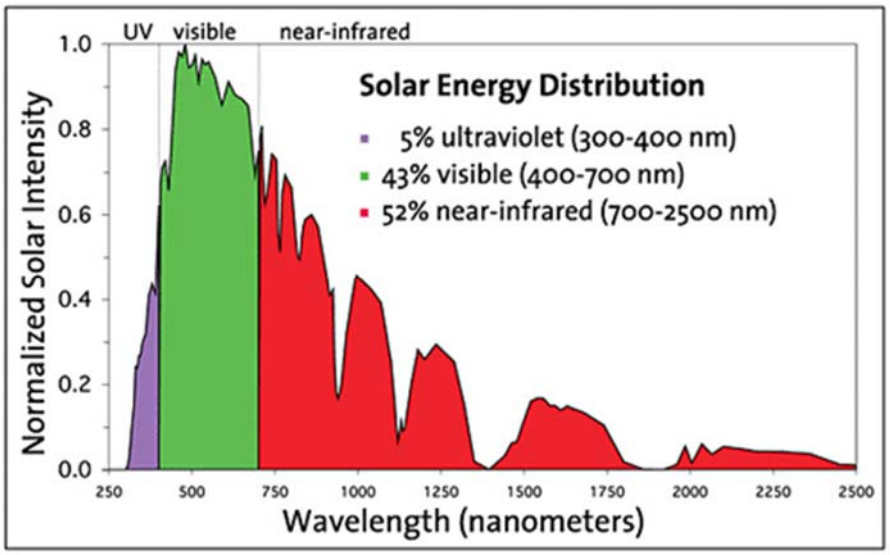

Figure: Graph showing solar energy distribution (Berkeley Lab Heat Island Group)

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.

[23] Hashem Akbari, "*Cool Roofs and Pavements to Cool the World: An Integrated Mitigation/Adaptation Strategy for Cities*", Concordia University, 2011, http://resilient-cities.iclei.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 4: 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 technologies can be broadly divided into four categories:[24]

- **Coated cool roofs**: these roofs involve the coating of a material or paint on top of an existing roof material in order to increase the roof surface's SRI. These are liquid-applied coatings made of an acrylic polymer technology and are usually white in color.

- **Membrane cool roofs**: these roofs involve the application of a pre-fabricated membrane such as tiles, shingles, or sheeting over 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 tiles on top of an existing roof or to a new roof.

- **Green roofs**: green roofs make use of vegetation to help the roof absorb less solar energy by providing a thermal mass layer to reduce flow of heat into a building. Vegetation is especially useful in reflecting infrared radiation. The picture below shows how trees that look dark in normal light, are shown to be lighter under an infrared camera.

[24] 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. Performance of each of these materials would also vary with 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.[25] The EU Cool Roofs Council performs a similar function in Europe by rating the SRI of different roof materials to help users made an informed decision.[26]

The common types of cool roofing products are - materials for low-slope roofs, found on commercial and industrial buildings fall into two categories: single-ply materials and coatings. Single-ply materials are large sheets of pre-made roofing that are mechanically fastened over the existing roof and sealed at the seams. Coatings are applied using rollers, sprays, or brushes, over an existing clean, leak-free roof surface. Products for sloped roofs are currently available in clay, or concrete tiles. These products stay cooler by the use of special pigments that reflect the sun's infrared heat. In India, lime coats, white tiles grouted with white cement, special paints, etc. are used as cool roofing materials.[27]

Supplemental research will examine the implementation and effectiveness of the Ahmedabad and Hyderabad pilot programs, including analysis on cool roof materials for new and existing roofs in low-income housing as well as the materials, market availability, technical specifications, among other key factors.

Cool Roof Calculator

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.[28]

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 technology for different types of buildings.

[25] 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

[26] European Cool Roofs Council, "*Product Rating Database*", http://coolroofcouncil.eu/rpd.php (accessed on 02 May 2017)

[27] Thermo Physical Optical Property, Database of Cool Roof Construction Material http://cberd.org/wp-content/uploads/2014/03/CBERD_BR_005_MAR2014.pdf (Accessed on November 15, 2015)

[28] 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)

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.[29]

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.[30] 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 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, cool roofs can mitigate the urban heat island effect and provide opportunities to reduce air pollution and emissions.[31]

- **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, thereby prolonging the life of the roof.[32]

- **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 during the heat season, enabling lesser load shedding during the peak summer months.

- **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.[33]

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[29] 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

[30] Akbari, Hashem, Tengfang Xu, Haider Taha, Craig Wray, Jayant Sathaye, Vishal Garg, Surekha Tetali, M. Hari Babu, and K. Niranjan Reddy, 2011, "*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; Scope of Cool Roof in India, http://www.coolrooftoolkit.org/wp-content/uploads/2015/04/Scope-of-Cool-Roofs-in-India.pdf (Assessed November 10, 2015); 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

[31] Akbari, Hashem, Tengfang Xu, Haider Taha, Craig Wray, Jayant Sathaye, Vishal Garg, Surekha Tetali, M. Hari Babu, and K. Niranjan Reddy, 2011, "*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

[32] ibid.

[33] 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 roofs has grown, its 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 mentioned 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, as the first line of defense against increasing energy needs and growing heat stress in their cities, are well placed to effect change on cool roof strategies, since they often exercise control over local development control regulations and building codes. However, large parts of a city's built up area are controlled and managed by different city, state and regional agencies, and 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.[34] 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.[35]

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.[36]

Details: The manual is structured to be a source of information for different 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 savings in energy from buildings that have utilized cool roof technologies. The manual has a special focus on low tech, low cost solutions that can be applied to vulnerable communities.

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

[34] World Population Review, "*Delhi Population 2017*", http://worldpopulationreview.com/world-cities/delhi-population/ (accessed on 02 May 2017)
[35] World Health Organization, "*Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease*", September 2016
[36] Bureau of Energy Efficiency, "*Cool Roofs for Cool Delhi*", http://shaktifoundation.in/wp-content/uploads/2014/02/cool-roofs%20manual.pdf (accessed on 02 May 2017)

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.[37] 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 the 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 technologies were promoted to broader audiences, including local businesses. The Cool Roof Project used simple products such as thermatile, China mosaic, and broken earthen pots, to increase insulation and ventilation, 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, 2007 requires commercial building roofs with a minimum solar reflectance of 0.7, either through the prescriptive path or whole building simulation path to prove a minimum expected reflectance of 0.7. 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 0.7 and an initial emittance no less than 0.75. Where solar reflectance shall be determined in accordance with ASTM E903-96 and emittance shall be determined in accordance with ASTM E408-71 (RA1996)."[38]

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 1: Testing Standards

[37] 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)
[38] USAID ECO III Project, "*Energy Conservation Building Code Tip Sheet: Building Envelope*", https://www.coolrooftoolkit.org/wp-content/uploads/2012/05/ECBC-Envelope-Tip-Sheet-V-3.0-March-2011.pdf (accessed on 02 May 2017)

Section 3: Cool Roofs for Low Income Communities

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

For the fifth 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 2017.[39] As temperatures around the globe inch up degree by degree because of climate change, this western Indian city is working to protect local communities from rising temperatures and the deadly threat of extreme heat. It's a model other cities might follow to safeguard their citizens from this increasing health danger. After a devastating heat wave hit the city in 2010, experts estimated the heat contributed to more than 1,000 deaths.[40]

In 2017, the Ahmedabad Municipal Corporation unveiled a cool roofs initiative as a part of the updated Ahmedabad Heat Action Plan 2017.[41] With a clear goal to deploy cool roof technologies 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 projects 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 is being carried out in collaboration with the private sector and their corporate social responsibility activities in the city, coupled with a volunteer program.

- **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 paint is being used for 10-15 pilot households, remaining households are being painted with three layers of lime, through contractors hired by the AMC.

Ahmedabad has shown leadership by proactively including cool roofs within the city's heat action plan. The city's next steps would include 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.

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

[40] 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)

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

Figure 6: Billboard in Ahmedabad promoting the positive effects of cool roofs in the city (NRDC)

Figure 5: Gautam Shah, Mayor of Ahmedabad, paints the first cool roof coating in the city, May 2017 (NRDC)

The 2017 pilot in Ahmedabad builds on earlier efforts by leading groups in the city. For example, the **Mahila SEWA Housing Trust (MHT)**, a non-profit organization, has installed over 250 cool roofs in low income communities in Ahmedabad, using a technology called ModRoof – roofs made of coconut husk and paper waste – as an alternative to concrete roofs.[42] According to MHT, these modular roofs provide greater cool roof benefits than regular roof materials and data collected from installed sites showed a reduction in indoor air temperature of 7-8°C (12.6 – 16.4°F), as compared to conventional concrete roofs.

[42] Mahila Housing SEWA Trust, "*Building Climate Resilience Capacities of Urban Poor in South Asia - Compendium of Solutions*", Global Resilience Partnership;

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

The city of Hyderabad in Telangana, popularly known as India's IT capital, has 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 well being of its most vulnerable residents.[43] In March 2017, the Greater Hyderabad Municipal Corporation, along with the Municipal Administration and Urban Development department of the Telangana State government, with the support of the Administrative Staff College of India 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:

- Key stakeholders identified: The Telangana cool roofs policy 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.
- Technical partners engaged to help with policy development and provide implementation support
- Policy outline developed

NRDC and ASCI are implementing a cool roofs pilot in a low-income neighborhood of Hyderabad to showcase the benefits and impact of cool roofs on the city fabric. The objective of this program is 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

Key activities for the program include:

- Select cool roof coatings and materials through a feasibility analysis (cost-effectiveness-availability) based on secondary research
- Stakeholder engagement with city and state officials for a pilot
- Implement cool roof solutions and monitor performance, comfort, as well as impact on health outcomes
- Develop financing solutions in partnership with city officials and other key stakeholders

The cool roof pilot project focuses on a set of 20-25 low-income households in the city of Hyderabad. Over the 2017 summer period, pilot implementation is being carried out to monitor the temperatures with an identified cool roof membrane technology applied. A leading Indian company has come forward to provide cool roof coating material for the pilot implementation free of cost as a part of their CSR efforts. Pictures below show progress on the cool roof pilot in Hyderabad.

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

Figure 7: Pictures showing cool roof pilot installation and testing underway in Hyderabad, May 2017 (NRDC)

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

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.[44] 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.[45]

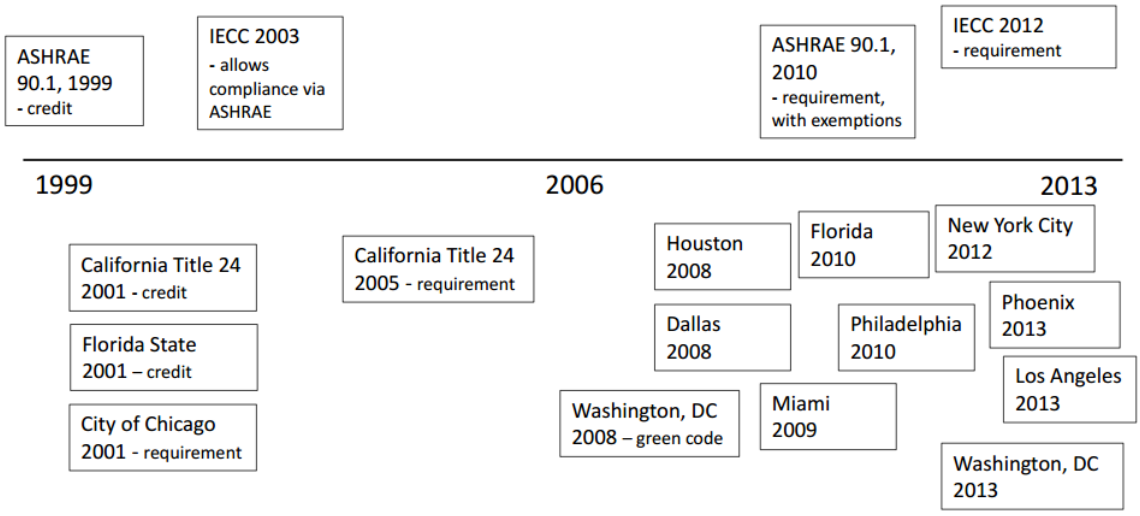

Figure 8: Evolution of cool roof inclusion in US building codes (Akbari et al)

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.[46]	
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. The eventual goal was determined to be one million square feet of rooftops coated each year since.

[44] Hashem Akbari, "*Evolution of Cool Roof Standards in the United States*", LBNL, 2008
[45] 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)
[46] NYC Cool Roofs, "*NYC Cool Roofs: Annual Review 2013*", 2013

Awareness programs/citizen engagement	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.
Policy inclusion	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.[47]
Impact	Since its launch, the program has successfully coated over six million square feet of New York City rooftops and resulted in a reduction of over 830 tonnes of carbon dioxide.

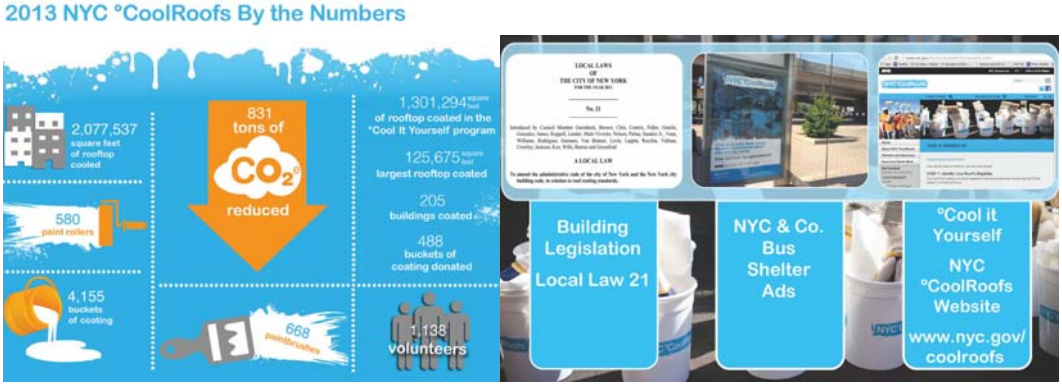

Figure 9: NYC °Cool Roofs impact and phased citizen awareness plans (NYC °Cool Roofs)

Houston Cool Roofs and Urban Heat Island Program

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.[48]

Awareness programs/citizen engagement	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.
Policy inclusion	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.

[47] LOCAL LAWS OF THE CITY OF NEW YORK FOR THE YEAR 2011 No. 21, http://www.nyc.gov/html/coolroofs/downloads/pdf/ll21of2011.pdf
[48] Houston Advanced Research Center, "*Cool Houston! A Plan for Cooling the Region*", 2006

Cool Roofs in Tokyo, Japan

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.[49]

Cool Roofs in Europe

Cool roof development in Europe is being spearheaded by the European Union Cool Roofs Council (ECRC). [50] The ECRC is a non-profit organization that aims to:

- 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

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).[51] 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 technology installation
- Conduct demonstrations of cool paint on low-income houses to improve thermal comfort for residents as well as reduce energy consumption

[49] 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)

[50] 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

[51] 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)

Global Networks for City-City Knowledge Exchange on Cool Roofs

Cities are 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.[52]

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.[53]

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:

- UHI 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

[52] Global Cool Cities Alliance, "*About Us*", https://www.globalcoolcities.org/about-us/ (accessed on 02 May 2017)
[53] C40 Cities, "*Network Overview*", http://www.c40.org/networks/cool_cities (accessed on 02 May 2017)

Conclusion

Cities and city governments are critical to ensure the right decisions are made, and that citizens have the information and the financial and legal incentives to make those decisions. Cool roofs can improve not only an individual's life, but also an entire city's.

Cool Roofs Offer Multiple Benefits for Cities

1. **Cool roofs keep temperatures lower during hot summers:** Cool roofs help achieve thermal comfort in homes, offices and buildings while contributing to reducing the urban heat island effect, air pollution, smog, and energy demand—especially during peak hours. For example, research by the Lawrence Berkeley National Laboratory (LBNL) and IIIT-H found that cool roofs could reduce peak energy demand by 10 to 19 percent in buildings in Hyderabad, potentially reducing citywide air temperature by 2 °C (3.6 °F) and savings 5 billion rupees over 10 years.[54]

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 settlements where tires and white tarp on metal and asbestos roofs as an ad-hoc cool roof technique had led to water pooling on the roof which attracted disease-carrying mosquitoes.

3. **Dedicated city budgets and funding mechanisms are vital for cool roof programs in low-income communities**. Although cool roofs can be cost-competitive with regular roofing,[55] the initial capital costs of cool roofs may pose a stumbling block for low-income communities that struggle with access to proper housing. 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 groups and business 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 the 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.

5. **Programs that start with 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. Leading US cities are an example of the success of this phased approach.

[54] Akbari, Hashem, Tengfang Xu, Haider Taha, Craig Wray, Jayant Sathaye, Vishal Garg, Surekha Tetali, M. Hari Babu, and K. Niranjan Reddy, 2011, "*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

[55] 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)