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Cool Roof initiatives in India: An evaluation of the existing conditions and lessons to be learnt from global best practices.

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ABSTRACT

Cool roof is a simple yet powerful technology used for temperature control of buildings and urban areas. To understand the effectiveness of cool roof application in Indian cities and to understand the existing policies, codes and practices being carried out in India, a review of the existing conditions is done. This paper also studies various best practices from around the world and suggests the lessons India can learn from these global examples. There have been several studies done to prove the applicability and effectiveness of cool roofs in Indian conditions. In line with the country's National Cooling Policy, there are a few state and city level initiatives for the wider application of cool roof technology. Several green rating systems in India highlight cool roof as an energy saving strategy. There is a code specific to energy conservation in buildings with cool roofs requirement. However, at this point this code is not mandatory for majority of the Indian states. As learnt from the global examples, mandatory codes, policies, incentives, tax credits, and other such similar measures have a higher outreach for this technology adoption. India would benefit greatly from updating the existing policy framework to include cool roof related interventions, supporting focused research in the area and maximizing ground implementation through short and long term strategies. A consortium of scientific partners, industry partners, policy makers, along with the NGOs and volunteers working towards a common goal will make wider adoption and visible reduction in Urban Heat Island a reality.

Keywords: Cool roof, High reflective surfaces, UHI mitigation, India, Global learning

Introduction

Human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C. Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate (IPCC, 2018). The effects of global warming include severe weather conditions such as high temperatures, change in the amount and pattern of precipitation and related extreme events such as flooding, droughts, glacier retreat, landslides, sea level rise which we are already experiencing.

Added to the effect of global warming, cities, due to high built-up areas and high concentrations of anthropogenic activities, have led to the development of higher temperatures in urban microclimates. This phenomenon, which is widely known as the Urban Heat Island (UHI), is regarded as the best documented proof of climate modification in times of intensifying

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urbanization. The causes for higher temperatures in urbanized environments are anthropogenic heat, excess of heat stored by buildings, roads, and other constructions materials that absorb heat during the day and re-emit after sunset, decreased long-wave radiation losses from urban areas, lack of vegetation and reduced evaporate-transpiration processes, reduction of wind speed and consequent reduction of convective heat removal from urban surfaces to the atmosphere. In some cases, it causes an average urban daytime air temperatures of typically 5.6°C higher than the surrounding rural areas in summer (Akbari, Menon & Rosenfeld 2009).

As major cities globally are experiencing increasing urban heat island effect and more extreme heat events due to global warming and changing weather patterns, addressing these hazards through cooling techniques and strategies is a key way to undertake urban climate change adaptation while reducing greenhouse gas emissions and offsetting global temperature increase.

Role of Cool Roofs in Urban Heat Island Mitigation

Sustainable solutions to improve resiliency against UHI effects, both short and long-term, have received attention in recent years in the context of creating and maintaining livable cities. In light of this, cool roofing is one of the main strategies used to mitigate the effects of heat island effects. Cool roof is a simple yet powerful technology used for temperature control of buildings and urban areas. A cool roof made of a highly reflective type of paint, a sheet covering, or highly reflective tiles or shingles prevents heat absorption by reflecting the sun's heat and then emitting its radiation back into the atmosphere. By doing this, cool roofs allow for a more comfortable and controlled indoor environment.

Quoting Dr.Steven Chu, US Energy Secretary "Cool roofs are one of the quickest and lowest cost ways we can reduce our global carbon emissions and begin the hard work of slowing climate change." There are several direct and indirect benefits of cool roofs, out of which as few key benefits are: (i) mitigation of global warming by reflecting the component of short wave radiation coming from the Sun, out of the atmosphere, (ii) energy saving by reducing cooling requirements of buildings and increasing comfort, (iii) mitigating the urban heat island phenomenon. There are several studies that prove these benefits.

A cool roof on an air-conditioned building can save energy and reduce power-plant emissions of CO_2, SO_2, and NO_x (Akbari et al., 1999; Levinson and Akbari, 2010), while a cool roof on an unconditioned building can lower indoor air temperature and improve indoor comfort (Synnefa et al., 2007). Widespread adoption of cool roofs is thought to be an effective strategy for mitigating UHI. A study by Oleson et al (2010) estimate that adopting cool roofs in cities around the globe could decrease the difference between urban and rural air temperature by 0.4 K on an average. Taha et al (1998) and Taha (2008a, 2008b) show that large-scale increase in urban albedo can reduce summertime 2 pm air temperatures in various cities in the United States, and also decrease building energy use and mitigate photochemical air pollution.

One of the studies based in Hyderabad, India in year 2011 mentions that, with the projected annual increase of 100,000 square meters of new roof construction for the next 10 years, the annual cooling energy savings due to whitening of concrete roof would be 13 -14 GWh of electricity and cumulative cooling energy savings of 73 – 79 GWh for the region

(Akbari et al., 2011). The reduced energy demands leads to reduced energy generation which further leads to less use of fossil fuels and hence reduces harmful air pollutants like NO_x, CO_2, etc. One of the studies in Houston and Baton Rouge estimated that there is a possibility of CO_2 reduction by 6-7% from reduced energy use in the buildings (Konopacki and Akbari, 2002). There are also studies that suggest that implementing cool roofs in cities around the globe would lead to global cooling (Akbari et al 2009, 2012).

Though it is clear from these studies that cool roofs have many direct and indirect benefits almost everywhere, the exact benefits and costs of cool surfaces will depend on a variety of locally specific conditions. To understand the effectiveness of cool roof application in Indian cities and to understand the policies, codes and practices being carried out in India at present with respect to cool roofs, a review is done. This study tries to understand the aspects that lead to success of the existing cool roof programs in the country and to identify the areas for improvement. This paper further studies various best practices from around the world and suggests the lessons India can learn from these global examples.

Cool Roof Initiatives in India

India's increasing cooling energy demand has an increased environmental and social impact such as requirement for significant additional power generation, peak load impacts, and an enormous greenhouse gas (GHG) footprint. Managing India's cooling energy needs is one of the key contributors to meeting India's sustainable development goals and its international climate change commitments under the Paris Agreement (2015) and the Kigali Amendment (2016) to the Montreal Protocol. The following are the list of initiatives taken by Indian Government and various state and city governments for reducing their cooling needs and their contribution to UHI.

National Cooling Action Plan, India

The Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India, is in the process of developing a National Cooling Action Plan (NCAP, 2019) that provides a 20-year outlook on how cooling demand in India evolves and grows, and outline strategies and actions that promote sustainable and smart cooling practices across the nation while mitigating adverse impacts. MoEFCC's approach to formulate a powerful narrative that will resonate with multiple stakeholders in the government, private sector, and non-profit and research organizations in India, and help position India as a leader in using sustainable and smart cooling strategies, linking Montreal Protocol to both mitigate climate change and support India's sustainable development goals. The India Cooling Action seeks to

(i) reduce cooling demand across sectors by 20% to 25% by 2037-38,
(ii) reduce refrigerant demand by 25% to 30% by 2037-38,
(iii) reduce cooling energy requirements by 25% to 40% by 2037-38,
(iv) recognize "cooling and related areas" as a thrust area of research under national Science and Technology programme,
(v) training and certification of 100,000 servicing sector technicians by 2022-23, synergizing with Skill India Mission.

These actions will have significant benefits to society and the environment such as provision for cooling for Economically Weaker Section (EWS) and Low Income Group (LIG) housing, sustainable way of cooling - lowering GHG emissions related to cooling, Robust R&D on alternative cooling technologies – to provide push to innovation in cooling sector etc. This national level policy is hoped to influence many city and state level policies and initiatives to promote cool roofs as a measure to reduce the cooling needs of Indian cities.

The Telangana Cool Roofs Program

The Telangana Cool Roofs Program (Telangana Cool Roof Policy, 2019) aims to meet the following specific objectives:

1. Drive rapid state-wide adoption of cool roofs to save energy, strengthen heat resilience and increase thermal comfort.
2. Support inter-agency coordination to implement the city-wide cool roof program.
3. Identify financing frameworks, outreach and awareness building tools for implementing cool roofs
4. Support workforce development and training programs for cool roof application

Three main program areas that will help achieve these objectives:

1. Mandatory Program (government and commercial): Mandatory cool roofing for all municipal, government-owned, and commercial buildings covered under the state building efficiency codes, for new and major upgrades.
2. Voluntary Program (residential): Voluntary cool roofing for residential and smaller buildings for new and major upgrades.
3. Vulnerable Communities Program: Cool roofing for all low-income housing related to the city’s Heat Action Plan.

This program has recently been launched and yet to see to the results.

City-level cool roof initiatives by Indore and Surat

The city governments of Indore and Surat, with the support of TARU Leading Edge and the Rockefeller Foundation, in 2011 initiated a project to address the potential of cool roofs in the two cities (NRDC Report, 2019). 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. Cost benefit analysis 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 these cities and ways to incorporate cool roofs into future building projects. 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.

Ahmedabad cool roofs initiative: Addressing cool roofs as a response to extreme heat, 2017 and 2018

A devastating heat wave hit Ahmedabad city in 2010, that heat contributed to more than 1,300 deaths. City leadership in Ahmedabad in order to protect local communities from rising temperatures and the deadly threat of extreme heat, unveiled a cool roofs initiative as a part of the updated Heat Action Plan (Ahmedabad Heat Action Plan, 2017). 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.

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. 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, as compared to conventional concrete roofs. Building on the findings of the pilot, the Ahmedabad Cool City Program, if implemented city-wide, will go a long way in making the city cooler and protecting the most vulnerable from deadly impacts of heatwaves (NRDC Report, 2019).

Cool roofs initiatives in Delhi

In January 2011, the Chief Minister of the City of Delhi announced a pilot project to install cool roofs on the government buildings in the city. It was done with the intention that the visibility of these demonstration projects to the public will help raise awareness of the energy saving and thermal comfort benefits of cool roofs. In the same year Bureau of Energy Efficiency commissioned Environmental Design Solutions to develop a design manual (Cool Roofs for Cool Delhi, 2011) design manual that describes different elements of a cool roof initiative, from materials to case studies of energy savings in buildings. 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.

Research on Cool Roofs in India

There have been several studies using both field measurements and computer simulations that document the energy savings from increasing the solar reflectance properties of buildings in India. One such study is the Cool Roof Pilot on Affordable Houses in Ahmedabad by CEPT University, where of the thermal comfort benefits of applying cool coatings to a metal roofs on a traditional affordable houses were recognized. A cool roof monitoring experiment was done at Satyam Learning Centre in Hyderabad (Akbari, 2011), in which installing a white roof coating reduced the average summertime daily maximum roof-surface temperature of a two-storey office building in Hyderabad, India from 52°C to 32°C. The total airconditioning energy use was reduced by 30 kWh/day (5% on hot days and 8% on average days). At Rs.5 per kWh, the coating on this 700 m^2 building is estimated to save about Rs 450,000 over the 10 year life of the roof.

To assess this impact of cool roofs on buildings in rural and peri-urban areas of India, a study (Garg, 2016) was performed on two un-conditioned school buildings in Hyderabad (ZPH School) and Nagpur (VNHM School). Two classrooms of same size, function, and occupancy from both the school buildings were monitored for a period of ten weeks starting from March 2014 till May 2014. The average reduction and peak reduction in indoor air, roof underdeck and roof overdeck surface temperatures are 2.1˚C, 5.0˚C and 12.3˚C and 4.3˚C, 10.0˚C and 26.3˚C respectively for the room with white roof as opposed to grey roof in ZPH School and 1.5˚C, 4.0˚C and 9.5˚C, and 3.3˚C, 4.2˚C, and 25.2˚C respectively in VNHM School.

A field monitoring experiments (Rallapalli, 2016) for MSEDCL Building in Nagpur demonstrate the impact of cool roofs in reducing energy use and improving thermal comfort. The results were observed that daily cooling energy savings per unit roof area is maximum in April with average saving of 0.15 kWh/m^2/day (40% cooling energy savings) and minimum in December with average saving of 0.07 kWh/m^2/day (15% cooling energy savings). An online cool roof calculator was developed by IIIT Hyderabad which works on EnergyPlus engine, to estimate the energy saving potential of cool roofs in various Indian cities. In another study, a controlled field experiment (Arumugam, 2014) was done to demonstrate the energy saving potential of high albedo roofs using an apparatus consisting of two nearly identical test chambers has been built in four Indian climates: Chennai (hot & humid), Bangalore (temperate), Jhagadia (hot & dry) and Delhi (composite). The results shows that savings from high albedo roof ranges from 0.04 kWh/m^2/day in temperate climates, to 0.08 kWh/m^2/day in hot & dry climate. In another simulation based study (Arumugam, 2015), to identify suitable roof insulation thickness for a roof with high albedo and radiant barrier combination, it was found that incremental benefits decline after 25mm thickness of insulation (1.02 m^{2}K/W).

There is some very important ongoing research such as the natural exposure of cool roofing products in India to study the weathering and aging process. This research would lead to the development a protocol for accelerated weathering and aging in laboratory that would aid the development and testing of new cool roof products. Another controlled experiment is being carried out for estimating the energy saving potential and indoor thermal comfort improvement by the use of high-albedo surfaces on a pitched concrete roofs funded by Indo-French Centre for the Promotion of Advanced Research (IFCPAR). All these studies are a proof that cool roofs are an effective energy saving and UHI mitigation strategy for Indian conditions. Research and development are crucial in understanding potential of a technology and to constantly be upgrading with the changing conditions. It provides empirical data on how cool roof can help in UHI mitigation for various city contexts that would act as a driver for policy change. Therefore, government should make it a priority to fund R&D in this field for evaluating, testing and aiding the development of new products.

Codes and Rating Systems

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. These rating systems require mandatory Energy Conservation Building Code (ECBC) norms compliance as a prerequisite for buildings applying for rating.

The Energy Conservation Building Code (ECBC, 2017) requires commercial building roofs with a minimum solar reflectance of 0.6, either through the prescriptive method or whole building simulation method 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 in accordance with ASTM E408-71 (RA1996).

Apart from these codes, City governments are in a position 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 coordination among various groups is critical.

Global Best Practices & Policies Related to Cool Roofs – Lessons to be Learnt

Cool roof initiatives have been implemented in the past two decades in leading cities around the world as an effective strategy to counter the urban heat island effect and reduce cooling loads in buildings. 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.

The EU Cool Roofs Council (EU-CRC) was founded on February 2009, within the framework of the Cool Roofs Project, aiming to merge all the driving forces for the promotion and adoption of Cool Roofs in Europe (Synnefa, 2011). The EU-CRC's aim is to accelerate the transfer of knowledge, to remove market barriers, to help manufacturers to develop Cool Roofs products, to educate the public and policy makers and to develop incentive programs. Four countries (Greece, UK, Germany, and Italy) in Europe have adopted initiatives to promote cool materials and Greece particularly has adopted cool roof standards. Apart from this, under a program called "Building the future" European government offered incentives for the application of 20,000 cool roofs on residential buildings as a means to improve their energy performance.

Italy is developing a national declaration that promote cool materials as a part of EPBD that focuses on regulating the cooling issues of buildings: residential, public and industrial. In the UK, BREEAM Communities is a voluntary certification standard that includes cool materials as a heat island mitigation strategy. The German Sustainable Building Certificate [2009], which is effectively a standard of the German Sustainable Building Council, on the topic of ecological quality includes the Criterion 9: Microclimate, that specifies that the choice of appropriate materials can contribute to the heat island mitigation and requires the documentation of the albedo values of roofs and facades.

New York City's (NYC) cool roofs program has done an exemplary job of securing the participation of volunteers to help speed the City's transition to cool roofs. The NYC CoolRoofs program is run as a joint effort between NYC Department of Buildings and NYC Service, the agency responsible for coordinating city-wide volunteer efforts. In 2010, NYC CoolRoofs coated 1,168,369 square feet (108,545 m^2) of rooftops across 135 buildings. Sixteen-hundred volunteers participated in these coating efforts. So far the city has coated over 5.7 million ft^2 (around 530,000 m^2) of rooftop (626 buildings) with a white, reflective coating, offsetting the urban heat island effect and thereby cooling the city (Practical guide to cool roofs and cool pavements, 2012). The programme provides benefits and savings directly to the building owner by reducing cooling costs by 10-30% and has proved to be an effective way to help tackle the urban heat island effect and reduce GHG emissions. This type of solution works well when a city does not have a budget earmarked for cooling but has other resources to contribute – such as a volunteer force or training programmes that can be mobilized and matched with building owners etc.

Some cities have undertaken comprehensive evaluation of the urban heat island effect impact on their communities through satellite imagery to identify the hotspots in the cities that need urgent attention (Eg. Dallas, Houston). In 2005, California prescribed white surfaces for low-sloped commercial roofs as part of its Title 24 energy efficiency codes. In 2008, the state prescribed cool colored surfaces on steep roofed residential buildings in its five hottest climate zones. It was one of the first US states to enact a robust cool roof standard. Japan Ministry of Environment announced "Cool Roof Project" in 2006 that provided subsidies for buildings that covered at least 50 square meters of their rooftops with a green roof or highly reflective paint.

The City of Toronto launched the Eco-Roof Incentive Programme in 2009 to encourage the uptake of eco-roofs by building owners, make buildings more sustainable and promote the creation of green jobs. The Programme provided grant funding for building owners to install new roofing materials – green roofs with living plants and cool roofs that reflect solar heat – that provide environmental benefits and build resilience. Since its introduction, the programme has avoided 106 tonnes of GHG emissions and established 233,000 m^2 of eco-roof space (cool + green). The "One Degree Less" movement pioneered in Brazil, has adopted cool roofs and heat island mitigation as its first practical program to combat global warming (ODL 2009).

Market penetration of cool materials across the US, Singapore and Canada were driven to a large extent by the creation of supportive policies backed by long term financial support (example: utility rebates, federal tax deductions and incentives) based on voluntary systems. In US, the federal government set up and heavily promoted the Energy Star for Cool Roofs. (Kolokotsa, 2015). Sharing information and knowledge among cities across the globe concerning their achievements and the evaluation of their experiences is important. 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.

Conclusion

Cool roofs are an affordable and smart solution that helps manage cooling demand and mitigate the impact of urban heat island effect. Solutions, such as the heat action plan and new cool roofs initiative, are critical to saving lives and addressing skyrocketing cooling demand in cities across India, as climate change continues to drive towards extreme temperatures. Interdisciplinary applied research can help policy makers to gather intelligence and to monitor and evaluate the efficacy of their approaches.

Policy makers at all levels should be able to draft policies, incentives and regulations matching economic, social and environmental factors. A market study for understanding the current status of cool roofs among market key players in India is necessary. The more the demand, the more would be chances to get the materials at a cheaper cost in the local market. Quality certification in-line with the technical standards will increase the credibility of these products among the stakeholders. The database thus developed can be made public through a web portal for the benefit of architects, engineers, policy makers, building owners and other stakeholders.

Building relationships with local and international experts will prove to be extremely valuable to develop national and state level cool roof programs. These experts, researchers, academicians, manufacturers, consultants, and more—have a wealth of knowledge and experience. One needs to identify the potential for cool roofs in their region and connect with these experts to get their guidance to adopt cool roofs, identify suitable materials and means of increasing the life of cool roofs. Consistent partnership between different stakeholders such as the policy makers, academicians, industry partners, and environmental monitoring agencies is crucial for the implementation of cool roofs on a wider scale.

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