Solving the Heat Threat to Urban India

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"*Climate Change needs Climate Action, as heat waves are becoming more intense and frequent across the country. Our continuous efforts are towards devising and improving strategies to mitigate the adverse impacts of heat waves, particularly upon the poor and disadvantaged sections of the society.*" – Narendra Modi, Prime Minister of India, 2019.

"*Heat and air pollution can increase premature births which are associated with multiple childhood health issues. Air pollution can also impact the cognitive development in children and generate respiratory diseases like asthma. With climate action, India can save its children's health.*" - Gaurab Basu, MD, MPH, Harvard Medical School, 2021.

India is under particular threat from climate change. As documented by McKinsey in a 2020 analysis entitled "Will India Become Too Hot to Work?," India is on track to become one of the first inhabited areas in the world to experience heat waves that cross the survivability limit even for a healthy humans resting in the shade, and this could occur as early as next decade.

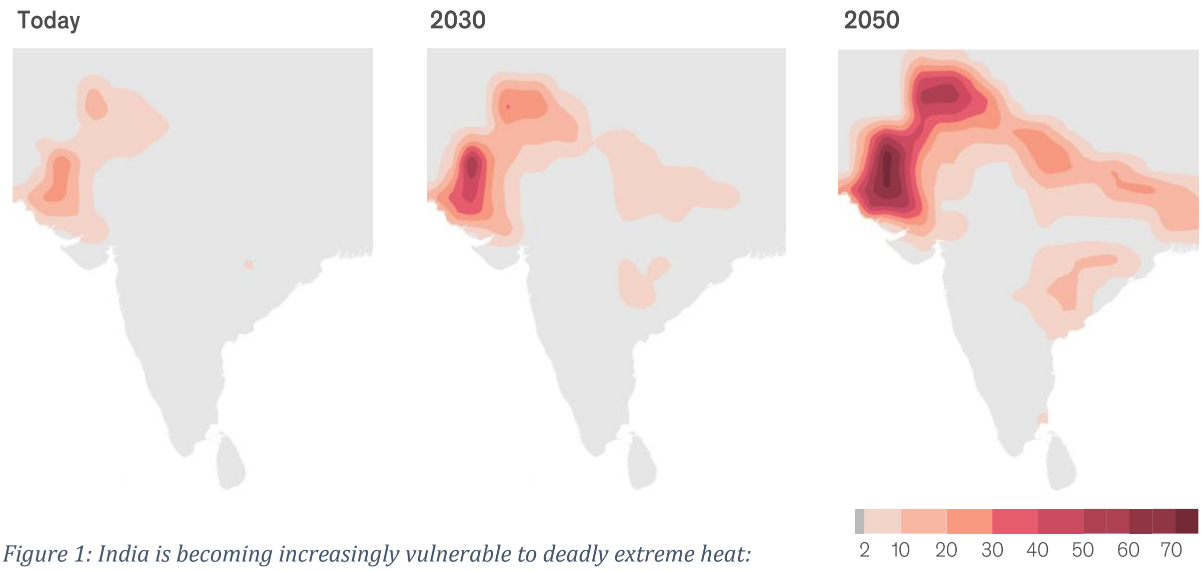

Figure 1: India is becoming increasingly vulnerable to deadly extreme heat: Lethal heat wave probability in India % annually. (Higher CO_2 concentration scenario). Source: McKinsey, 2020.

Rising heat and humidity levels will broadly hurt Indian labour productivity and economic growth in an economy that relies substantially on outdoor work. According to McKinsey, in India heat-exposed work produces about 50% of GDP and 30% of GDP growth, and employs about 75% of the labor force, some 380 million people. A NASA study [i] on temperatures, productivity, and accuracy found that high temperatures have a large negative effect on worker productivity and error rates (accuracy).

- At 23.8°C/75°F, work output drops 3%, and accuracy is unaffected.
- At 26.6°C/80°F, output drops 8% while accuracy is reduced by 5%.
- At 29.4°C/85°F, productivity drops 18%, while error rates increase by 40%.

- At 32.2°C/90°F, NASA found a 29% output drop in productivity and a 300% error rate increase.[ii]

Per a study by the Tata Centre for Development, there were ~5 days/year above 35°C on average across India in 2010. In 2050, under a high emissions scenario, this will more than triple to ~16 days.[iii] By 2070, a majority of India would experience land surface temperatures as high as in the Sahara today (mean annual temperature ≥29°C), if we continue on the current emissions trajectory.[iv] Without an effective cooling strategy, 160–200 million people in India would have a 5% chance every year of being exposed to a lethal heat wave[v] by 2030. [vi]

The health and economic costs from excess heat are complicated, multiple, and cumulatively extremely damaging and costly. For example, extreme heat prevents outdoor exercise for much of the year, increasing prevalence of diabetes and obesity and hurting cognitive development. [vii] These impacts are summarized in a chart published in the Annual Review of Public Health below.[viii]

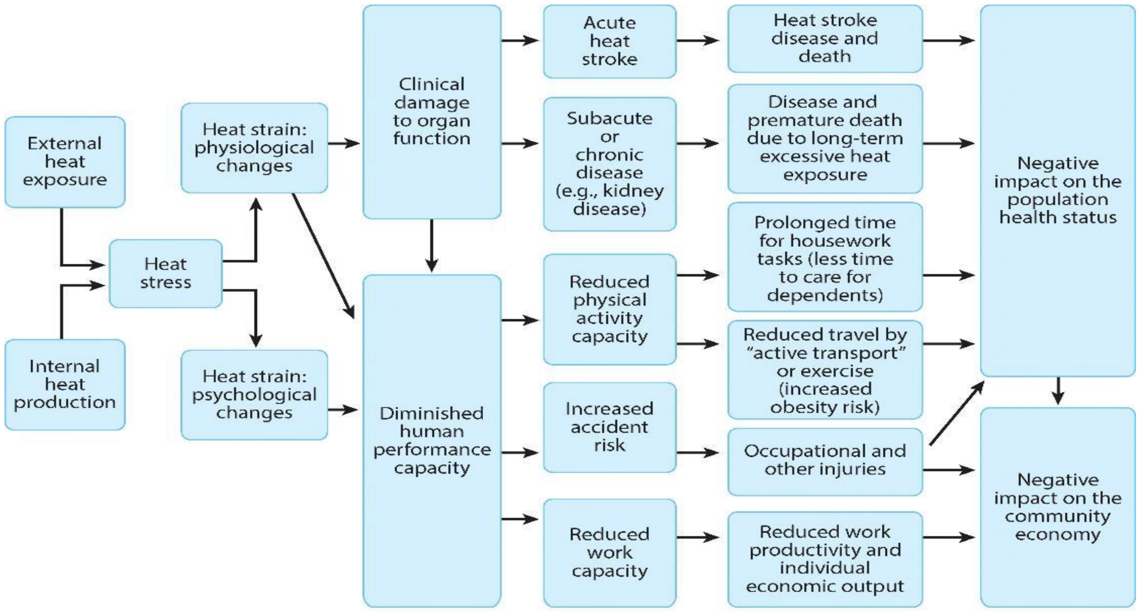

Figure 2: Impacts of excess heat on public health. Source: Kjellstrom T, et al., 2016.

The health threat to India is exacerbated by rapid urbanization, since cities are hotter due to their dark impervious surfaces – an effect called the Urban Heat Island. India accounts for 18% of the world's population, and India's percentage of urban population is projected to grow from 34% in 2018 to 70% by 2050, increasing risk for populations that move to cities that are hotter than more rural parts of India. Between 2018 and 2019, India had the largest absolute increase in heat-related mortality of any country.[ix] At greatest risk are children, elderly, and lower income populations. Due to greater body surface to lung volume ratios, children are more susceptible to heat stress and mortality.

India-wide, 26%[x] of the population are 14 or under – meaning 300 million children are at increasing risk of excess heat and heat deaths. This is the largest population of children in the world at risk from climate change. This extraordinary threat requires that Indian cities rapidly adopt city-wide cooling strategies. The only cost-effective city-wide cooling strategy is Smart Surfaces, the integrated implementation of reflective, porous, and green surfaces, trees and solar PV. Adoption of Smart Surfaces would allow Indian cities to cool by at least 3˚C cost-effectively – and deliver a substantial contribution to climate change mitigation.

Status Quo
The National Disaster Management Authority of India developed heat-wave guidelines and National Disaster Management Plans, reflecting a growing Indian commitment to reducing rising urban heat risk. The western Indian city of Ahmedabad in Gujarat became the first south Asian city to prepare a heat wave action plan in 2013 following the 2010 heat wave that claimed 1,344 lives. Since its rollout, the plan has prevented about 1,100 deaths each year in Ahmedabad. This has since expanded to 23 states and 100 cities and districts.[xi] Measures include cooling centres and increased access to air-conditioned spaces, but do not yet include city-wide cooling strategies.

Today, the selection of dark, impervious surfaces is standard in cities in India and globally because agencies that make infrastructure decisions for most roads, parking lots, sidewalks, and many roofs – such as Public Works Departments – look at initial cost as the basis for surface design selection. As a result, cities are overwhelmingly covered in dark and impervious surfaces.

The dark, impervious surfaces that characterize Indian cities today absorb over 80% of incoming sunlight, heating up cities (especially low-income neighborhoods) driving up air conditioning (AC) demand, energy costs, CO2 emissions, and global warming. AC penetration in Indian cities today is commonly 15% or less. Under business-as-usual, air conditioners globally are projected to triple by 2050, adding an estimated 0.5˚C of global warming from electricity use alone. In addition, expansion of air conditioners (that eject hot air outside) can directly heat cities by 1˚C or more.[xii] Even with much needed improvements in AC efficiency, AC units leak greenhouse gas refrigerants, accelerating global warming and urban heating. More urban heating will drive even greater growth in air conditioning demand and further accelerate urban and global heating. Additionally, this rapid growth in AC would substantially rely on increased coal use as the source of needed additional electricity, in turn accelerating climate change and increasing air pollution.

This accelerating urban heating loop is illustrated below, and this is the deadly path Indian cities are on – unless they adopt city-wide cooling.

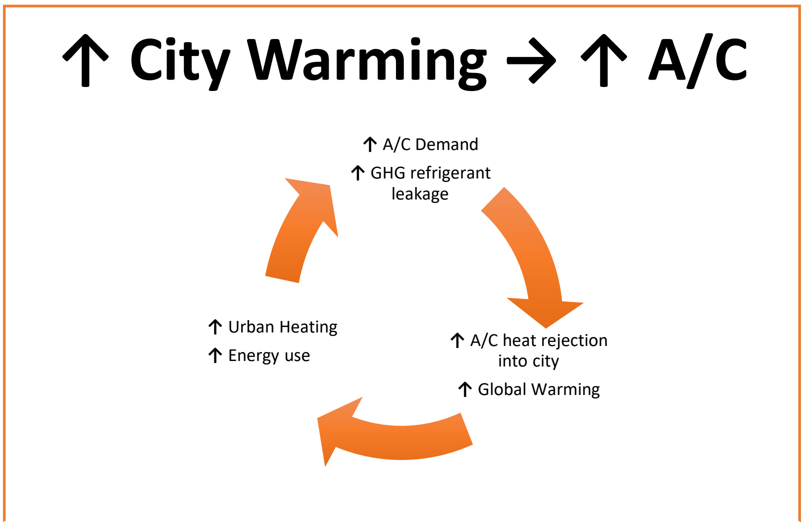

Figure 3: The Urban Heat Loop. Source: Smart Surfaces Coalition.

The Options
To cope with extreme heat events, air conditioning is the preferred choice for those who can afford it. However, up to 630 million slum dwellers in India may lack the income to purchase or run even a fan.[xiii] Most Indian city dwellers cannot afford air conditioners and the electricity costs of operating them. And power grids fail regularly, especially in summer months when air

conditioning loads put greatest pressure on grids. So, except for the few who can afford backup power generators, rapid expansion of private air conditioning is a poor and counterproductive strategy to mitigate rising urban heat. Far more effective and affordable is city-wide cooling which would greatly reduce cost burdens on the poor, avoid urban heating feedback loops, protect outdoor workers and economic productivity, and reduce urban temperatures as the world warms.

City-wide adoption of Smart Surfaces would decrease city-wide heat and air pollution, cut global warming and deliver enormous financial, economic and health co-benefits. Modelling these multiple Smart Surfaces adoption scenarios to identify the most effective and cost-effective strategies at an individual city level would enable an integrated city-wide surfaces deployment to reduce risks, costs, inequity and climate warming contribution. Financial benefits would include lower energy bills, avoided expense of purchasing air conditioners, increased economic productivity, reduced health costs and protection of city access to low-cost capital. Financial institutions such as credit rating agencies have already begun factoring climate change related risks into their portfolios.[xiv] A 3-part series in *Risk & Insurance* documents how urban Smart Surfaces adoption protects and strengthens the credit rating of cities.

The Solution – Smart Surfaces with the Smart Surfaces Coalition

The extraordinary heat risk to India requires that Indian cities adopt a city-wide Smart Surfaces cooling strategy. Adoption of Smart Surfaces would allow Indian cities to cool by at least 3˚C – and deliver a significant contribution to climate change mitigation.

The Smart Surfaces Coalition is a rapidly growing coalition of 40+ organizations committed to enabling and supporting cities in adopting Smart Surfaces. The Coalition Steering Committee ranges from the Executive Director of the World Cement Association to the CEO of the American Public Health Association and includes former COOs of both the International Finance Corporation and the InterAmerican Development Bank. (Rashad Kaldany, former COO of the IFC, is a co-author of this paper.)

Detailed city-wide analyses of multiple cities demonstrate that switching to a Smart Surfaces strategy delivers very large net benefits. For example, a 2021 study of Baltimore, Maryland, a city of 610,000 people in a warm mixed-humid climatic zone in the United States, demonstrates that city-wide adoption of 12 Smart Surfaces strategies would cut peak summer temperatures downtown by 4.3°F, reduce pollution and flood risk, protect health and tourism, enhance city credit rating, deliver an NPV of $13 billion, and have a benefit-cost ratio of more than 5:1. These measures include increasing albedo (reflectivity) of parking lots and flat dark roofs, increasing use of porous surfaces and increasing tree coverage – particularly in lower income neighborhoods that are generally less reflective and have fewer trees. Five months after this report was issued, the Baltimore City Council has already developed legislation to adopt most of the Smart Surfaces measures identified in the report. This and similar analyses were built around a powerful cost-benefit analytic engine customizable to each city that allows dozens of scenarios to be modelled and optimized to identify the most effective and cost-effective Smart Surfaces strategy at the city-level.

Indian State-specific concerns

Punjab, Haryana, and Rajasthan are the three hottest Indian states in summer, with Delhi being equally hot. The average summer temperature of Delhi is about 40°C, imposing worse environmental stress and health impacts than cities like Srinagar or Pune, which are less hot in the summer (although these cities may have the same Urban Heat Island effect).[xv]

City Selection
Mumbai and Delhi have the largest share of contribution to India's GDP followed by Kolkata, Bengaluru, and Chennai[xvi]. Both the cities also account for the largest share of population in the country followed by Bengaluru, Kolkata, and Chennai [xvii]. As per a study by Oxford Economics, Delhi and Mumbai are the only Indian cities making to their list of top 50 cities in the world to witness the biggest increase in population and GDP by 2030[xviii]. Mumbai and Kolkata have the largest share of children (population below age15) followed by Delhi [xix]. Note that chart below extends to 5 stars – this is cut off to allow higher resolution for the indicated elements.

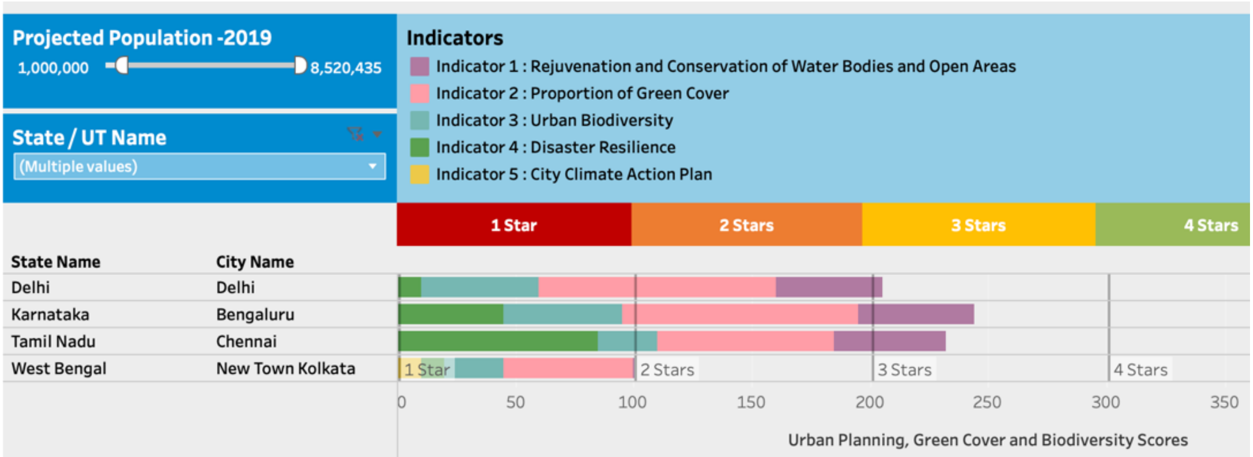

Figure 4: Climate Data Observatory city ranking for indicator Urban Planning, Green Cover & Biodiversity

The CSCAF 2.0 city assessment framework was developed to assess 126 Indian cities on climate relevant parameters by C-cube, National Institute of Urban Affairs (NIUA). Mumbai, Delhi, Kolkata, Chennai, and Bengaluru were selected to review and assess their scores for indicators under the theme Urban Planning, Green Cover & Biodiversity.

The major urban and economic centres of the country ranked fairly low in comparison to other cities. The two largest cities of India, Delhi and Mumbai could each set a powerful example to mitigate urban extreme heat for other cities to follow. Mumbai is a coastal city with more warm and humid type while inland Delhi is less humid and is classified as composite as per the Climatic Zone map of India [xx].

Delhi
Delhi, India's capital and second largest city by population, has been widely studied in terms of its spatial distribution of heat. In Delhi, with a population of 23 million, 27% – more than 6 million – are 14 years old or younger.[xxi] A 2021 study found that in Delhi the most vulnerable demographic and economic groups are young children, outdoor agricultural workers, and households lacking assets and electricity.[xxii] Outdoor laborers and construction workers are also at great risk of excess heat.

The albedo (reflectivity) of surfaces is very low (0.08 to 0.13) for most of Delhi. Smart Surfaces can, over the next 10-20 years, double Delhi's albedo. Areas around Delhi have an albedo that ranges from 0.15 to 0.2. The Enhanced Vegetation Index (EVI) over Delhi varies from 0.06 to 0.29 and these two factors largely explain why the day and night-time land surface temperatures over Delhi are 6°C–10°C hotter than the surrounding more rural regions.[xxiii]

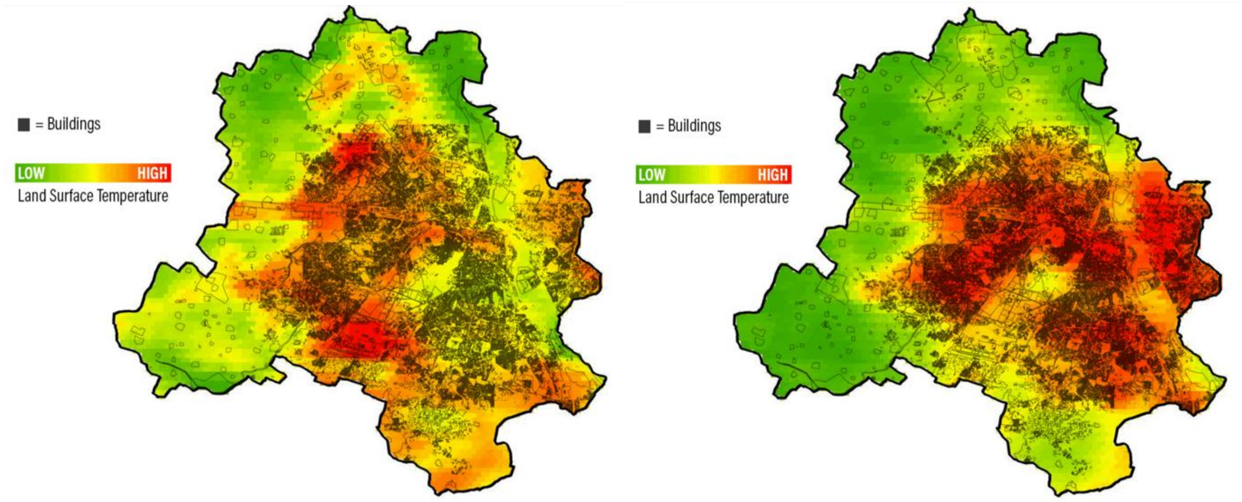

Figure 4: Land Surface temperatures day (left) and night (right) time in Delhi. Source: WRI India, October 2019.

Mumbai

Over the past few years, rising temperatures and oppressive humidity have made Mumbai dangerously hot. A 2020 World Resources Institute study found that in October, Dharavi (with Asia's largest slum) is typically 5 ˚C hotter than Matunga, its immediate neighbour. (See Figure 5, below.) The study looked at Mumbai's average land surface temperatures in October over three years (2017-19) and found greater heat exposure in poorer communities. This reflects a lack of Smart Surfaces, building materials, limited green cover, and limited access to open spaces within these poorer neighbourhoods.[xxiv]

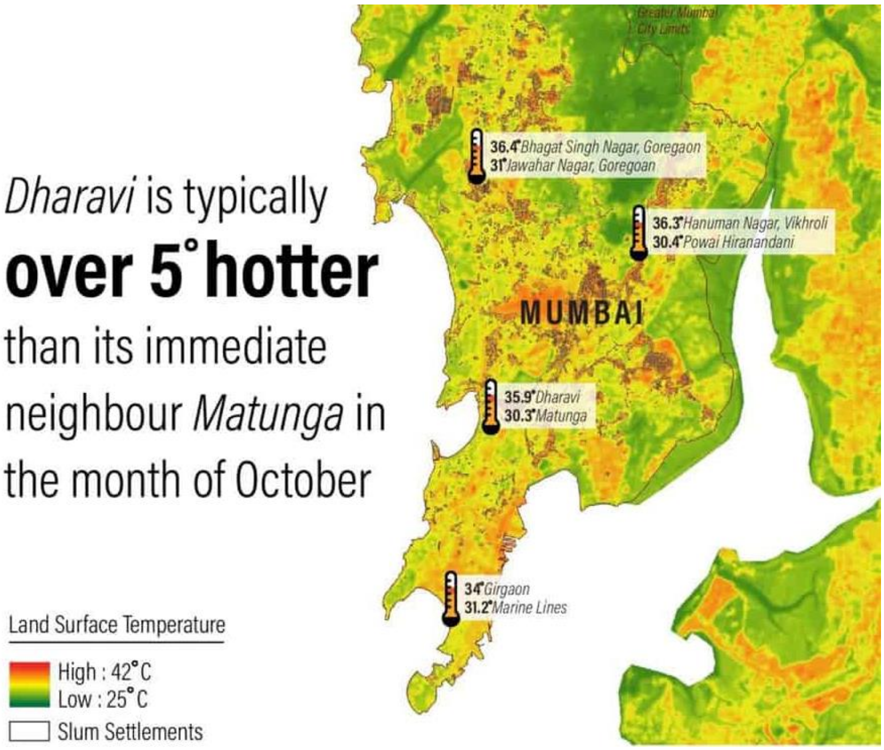

Figure 5: Difference in Surface Temperature. Poorer communities of Mumbai are much hotter than adjoining wealthy neighbourhoods. Source: WRI-India, 2020.

Conclusion
Global warming cannot be limited to 1.5˚C without global city-wide cooling – and the only viable way to achieve this is through city-wide adoption of Smart Surfaces. Smart Surfaces – reflective, green and porous surfaces, trees and solar PV – manage sun and rain much more effectively than conventional dark, impervious surfaces such as asphalt.

Due its large and urbanizing population, low city albedo, high summer temperatures, and projected climate change-driven warming, India has the largest population at risk from extreme summer heat. Current policies of relying on private purchase and operation of air conditioners would increase costs for hundreds of millions of people, reduce productivity of outdoor workers, and increase urban heat, smog and global warming. Even with a rapid increase in purchasing air conditioners, many will not have adequate cooling capacity or ability to pay for the required electricity. And recurring grid failures will put the lives of millions at risk from heat deaths. The only viable cooling strategy for India's cities is adoption of city-wide cooling through broad adoption of Smart Surfaces. City reflectivity can be doubled through Smart Surfaces adoption, reflecting much more sunlight, with much of this heat exiting the atmosphere. This process, by which energy is lost to space, is called negative radiative forcing and has a cooling effect that counters anthropogenic global warming.

By adopting Smart Surfaces city-wide, Delhi, Mumbai and other Indian cities can cool themselves by at least 3˚C, greatly reducing projected need for and use of air conditioning. India is recognized as a global leader for its national cooling strategies, while some cities like Delhi are already leaders in recently increasing tree coverage. Through city-wide adoption of Smart Surfaces, Delhi, Mumbai and other Indian cities can build on this leadership to protect and cool their citizens, cut energy costs and health risks, enhance economic competitiveness, and slow global warming.

Some useful links
National Guidelines for Preparation of Action Plans- Prevention & Management of Heat Waves, National Disaster Management Authority, Ministry of Home Affairs, Government of India. October, 2019.
National Disaster Management Plan, National Disaster Management Authority, Ministry of Home Affairs, Government of India. November, 2019.
Smart Cities Assessment Framework 2.0, Climate Centre for Cities (C^3), NIUA, Ministry of Housing & Urban Affairs, Government of India. 2020.
CDoT- Climate Data Observatory, Climate Centre for Cities (C^3), NIUA, Ministry of Housing & Urban Affairs, Government of India. 2020.
Smart Surfaces Coalition, Multiple Smart Surfaces cost benefits analysis reports, industry resources and studies and articles on Smart Surfaces.
Risk&Insurance, Here's How Cities Can Reduce Climate Change Risk. 2019.

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[i] Productivity and Work Area Temperatures in Industrial Facilities, AZEVAP, 2022.
[ii] How Heat Saps Warehouse Productivity, Causes Errors and Reduces Retention: Keep employees working, happy, safe and productive. CISCO, 2019.
[iii] Climate Change and Heat-Induced Mortality in India, 2019. Climate Impact Lab. University of Chicago.
[iv] Future of the human climate niche, May 2020. PNAS.
[v] A lethal heat wave is defined as a three-day period with maximum daily wet-bulb temperatures exceeding 34°C wet-bulb, where wet-bulb temperature is defined as the lowest temperature to which a parcel of air can be cooled by evaporation at constant pressure. This threshold was chosen because the commonly defined heat threshold for human survivability is 35°C wet-bulb, and large cities with significant urban heat island effects could push 34°C wet-bulb heat waves over the 35°C threshold. Under these conditions, a healthy, well-hydrated human being resting in the shade would see core body temperatures rise to lethal levels after

roughly 4–5 hours of exposure. These projections are subject to uncertainty related to the future behavior of atmospheric aerosols and urban heat island or cooling island effects, and do not factor in air conditioner penetration. Source: McKinsey Global Institute, 2020.

[vi] Climate risk and response: Physical hazards and socioeconomic impacts. Will India get too hot to work? November 2020. McKinsey Global Institute.

[vii] Prioritizing the needs of children in a changing climate. PMC. July 2018.

[viii] Kjellstrom T, et al. 2016. Annual Review of Public Health.37:97-112

[ix] The 2021 report of the Lancet Countdown on health and climate change: code red for a healthy future.

[x] Population ages 0-14 (% of total population) – India. World Bank, 2020.

[xi] Expanding Heat Resilience across India: Heat Action Plan Highlights. NRDC, 2020.

[xii] How India is solving its cooling challenge. World Economic Forum, 2019.

[xiii] Sustainable Energy for All (SEforALL), Chilling Prospects: Providing Sustainable Cooling For All, 2018.

[xiv] Ibid, 81.

[xv] Anthropogenic forcing exacerbating the urban heat islands in India. March 2020.

[xvi] India Brand Equity Foundation, Ministry of Commerce and Industry, Government of India.

[xvii] World Population Review, 2022.

[xviii] Future trends and market opportunities in the world's largest 750 cities: How the global landscape will look in 2030. Oxford Economics.

[xix] Urban world: Mapping the economic power of cities. Mckinsey Global Institute.2011

[xx] National Building Code of India, 2005

[xxi] Government of NCT of Delhi. Economic Survey of Delhi, 2014–2015. Chapter 2. Planning Department. 2019.

[xxii] Social Inequities in Urban Heat and Greenspace: Analyzing Climate Justice in Delhi, India. Bruce C. Mitchell, Jayajit Chakraborty, and Pratyusha Basu. International Journal of Environmental Research and Public Health. 2021.

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[xxiv] Application of split- window algorithm to study Urban Heat Island effect in Mumbai through land surface temperature approach. Aparna Dwivedi, M.V.Khire. Sustainable Cities and Society. 2018.