# Ensuring that India's Cities Remain Liveable Despite Extreme Heat: The Role of Smart Surfaces for Bhopal as Model for Urban India

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By early April 2022, India's cities were baking and, as documented in a Bloomberg article entitled "India Endures Record Heat Wave: The Only Reason Is Global Warming", accelerating global warming means heat extremes are just getting worse. India's cities on their current trajectories are also becoming darker with fewer trees - further accelerating the impacts of this life threatening trend. To remain liveable, India's cities must change course and adopt city wide cooling strategies. Those that do will experience declining peak summer temperatures, lower energy bills, less air pollution and health threats, less urban flooding and increased employment. Cities that continue with business as usual will not be able to protect their citizens or remain liveable in the years to come. This analysis explores the heat threat to India's cities and how cities, potentially, led by Bhopal can show the way to a cooler, more liveable future.

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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.

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**Context**

India is under particular threat from climate change. Between 2018 and 2019, India had the largest absolute increase in heat-related mortality of any country. [i] As documented in a 2020 McKinsey 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 (35° C wet bulb) even for healthy individuals resting in the shade, and this could occur as early as

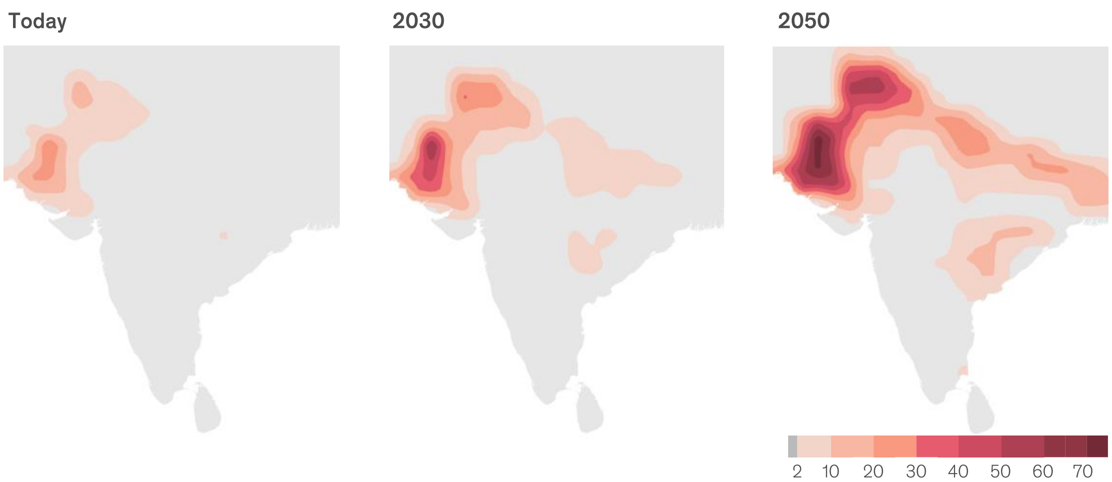


*Figure 1:India is becoming increasingly vulnerable to deadly extreme heat: Lethal heat wave probability in India % annually. (Higher CO2 concentration scenario). Source: McKinsey, 2020.*

the next decade.

Since 1901, India's average temperature has risen by around 0.7°C, or 1.26°F, according to an IMD report. India's rising temperatures are well-documented to be driven by anthropogenic climate change.

Bhopal, like most Indian cities is a growing risk of extreme heat. While Bhopal has initiated a number of discrete strategies on climate mitigation it is still losing tree cover and increasing dark impervious surfaces – contributing to increasing urban heat. But Bhopal, like most Indian cities has yet to develop or adopt a city-wide cooling strategy – doing so will be essential to protecting the future of Bhopal and its citizens.

Per a 2010 study by the Tata Centre for Development, India historically experienced ~5 days/year where the nationwide average temperature exceeded 35°C. In 2050, under a high emissions scenario, this will more than triple to ~16 days. By 2070, a majority of India would experience land surface temperatures as high as in the Sahara today (mean annual temperature ≥29°C), if the current emissions trajectory continues.[ii] 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 by 2030.[iii] Beyond the immediate mortality risks of extreme heat, the broader health and economic costs from excess heat are complicated, multiple, and cumulatively extremely costly to society. For example, extreme heat prevents outdoor exercise for much of the year, increasing prevalence of diabetes and obesity and thwarting cognitive development in youth.

Rising heat and humidity levels is also projected to increasingly 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 labour force, some 380 million people. A NASA study examining how temperatures impact worker productivity and accuracy found that high temperatures have a large negative effect on worker productivity and accuracy (error rates go up).

- 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.

The health threat to India will be further exacerbated by continuing urbanization because cities are hotter than surrounding countryside. This urban-rural temperature differential is commonly known as the Urban Heat Island effect and is largely attributable to high densities of dark, heat-absorbing surfaces and declining greenery in cities.

India is already dealing with the costs of rising extreme heat. India as of 2020 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. 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%[iv] of the population are 14 or under – meaning 300 million Indian children are at increasing risk of excess heat.

This extraordinary threat requires that Indian cities rapidly adopt city-wide cooling strategies. The only viable cost-effective city-wide cooling strategy is a set of surfaces solutions called 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 – with even larger cooling in lower income darker neighborhoods. And this strategy would protect health, reduce energy bills, cut air and water pollution, create jobs and deliver a substantial contribution to climate change mitigation all with large net benefits to cities.

**The Options**

To cope with extreme heat events, air conditioning is the preferred choice for those who can afford it. However, up half a billion slum dwellers in India may lack the income to purchase or run even a fan.[v] And power grids fail regularly, especially in the hottest 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 an ineffective strategy to mitigate rising urban heat. Very recently, the Indian Express reported that "there was unmet power demand of 10.29 GW on April 29, 2022 even as the highest supply on that day was at 200.65 GW. The demand for power is expected to rise further in coming days as the weather department has predicted that heatwave sweeping through the country will intensify." Far more effective and affordable than increasing expensive, unreliable and polluting private air conditioning 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 enhance competitiveness.

**The Solution – Smart Surfaces**

The extraordinary heat risk to India requires that Indian cities such as Bhopal adopt a city-wide Smart Surfaces cooling strategy as the only available way to achieve city wide cooling despite global warming. Adoption of Smart Surfaces would allow Indian cities to cool by at least 3˚C city-wide – and deliver a significant contribution to climate change mitigation.

The Smart Surfaces Coalition is a rapidly growing group of 40+ organizations committed to enabling and supporting cities in adopting Smart Surfaces. The Coalition's leadership council ranges from the President of the World Cement Association to the Executive Director of the American Public Health Association and includes former COOs of both the International Finance Corporation (Rashad Kaldany, who is a co-author of this document), and the InterAmerican Development Bank.

City-wide adoption of Smart Surfaces by cities such as Bhopal would decrease urban 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 and operating air conditioners, increased economic productivity, reduced health costs and heat risks, 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.[vi] A 3-part series in *Risk & Insurance* documents how urban Smart Surfaces adoption protects and strengthens the credit rating of cities.

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 mixed-humid (hot summers, cool winters) 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 10:1. These measures include increasing albedo (reflectivity) of parking lots and flat dark roofs,

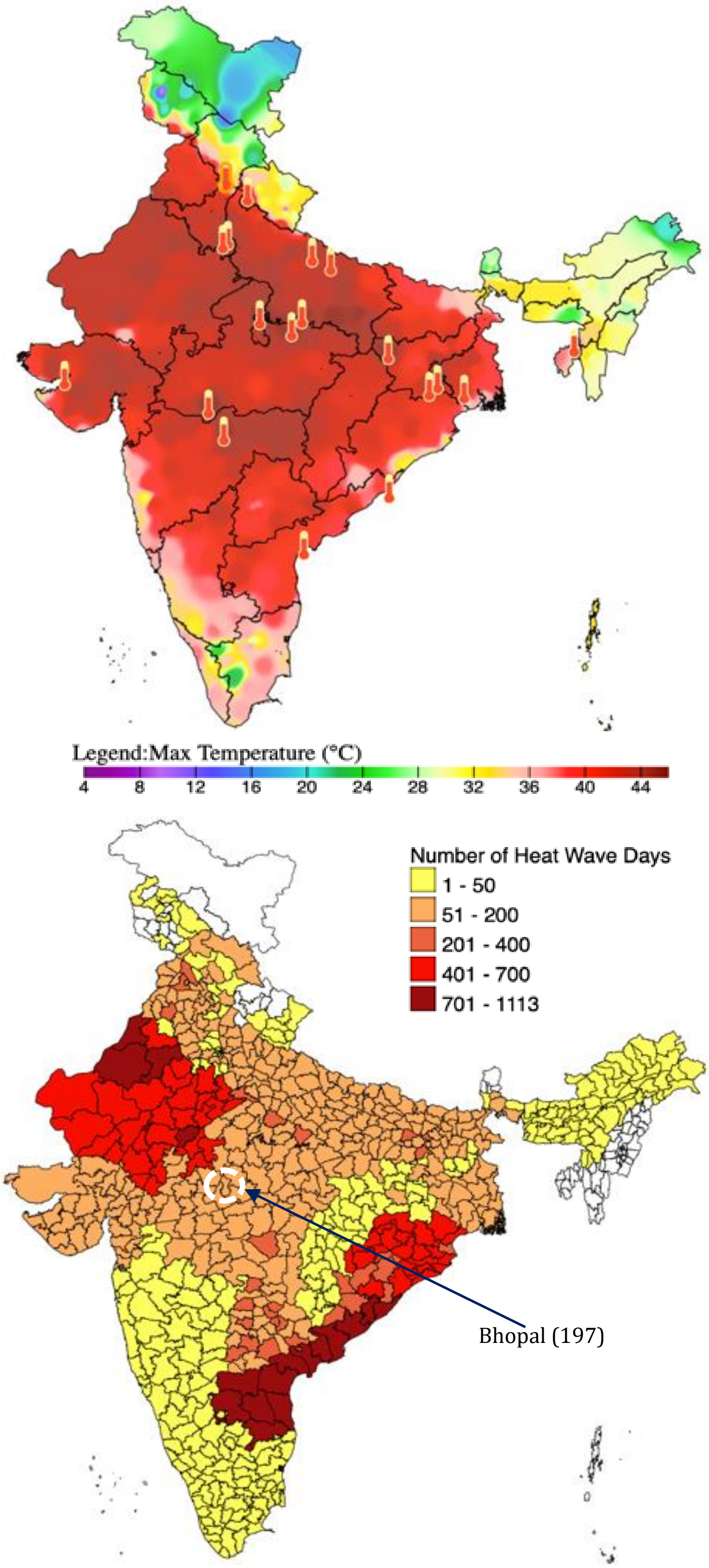


*Figure 2:Heatwave status (top) and Total number of heatwave days district wise from 1969 to 2019(bottom). Source: India Meteorological Department, 2022*

expanding use of porous surfaces and increasing tree coverage – particularly in lower income neighbourhoods 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. See coverage in Bloomberg, US News and World Report, and Popular Science.

This and similar analyses were built leveraging a powerful Smart Surfaces cost-benefit analytic engine. The engine is customizable to each city and allows users to model dozens of scenarios and identify the most effective and cost-effective Smart Surfaces strategy to achieve key city objectives around climate mitigation, summer cooling, and financial performance.

**Bhopal – a priority city for Smart Surfaces adoption**

When determining cities to support, the Smart Surfaces Coalition considers carefully a range of factors to ensure the engagement is maximally impactful. In selecting an Indian city, SSC considered the below:

a) city population of at least 1–2 million

b) strong political leadership interested in and capable of leading on Smart Surfaces adoption in the near term

c) city that is deeply engaged with SSC India partner – TERI

Bhopal – the capital city of the state of Madhya Pradesh – is both a Smart City and an Atal Mission for Rejuvenation and Urban

Transformation (AMRUT[1]) city. The population of the city is ~2.5 million and its climate is classified as composite in the Climate Zone Map of India.[vii] Bhopal has a humid subtropical climate, with cool, dry winters, hot summers and a humid monsoon season. Summers start in late March and continue through mid-June, and have average temperatures around 30 °C (86 °F). In May, the peak of summer, highs regularly exceed 40 °C (104 °F).

The all-time high temperatures in Bhopal were 46.7 °C, recorded in May 2016, and 45.9 °C, recorded in June 2019. In early April 2022, the Indian Mereological Department (IMD) issued a warning for heatwaves in districts of Bhopal city when the maximum temperature reached 41.8 °C. Day-time temperatures of this magnitude have historically been rare outside of May and June, but such occurrences have become increasingly frequent early in April.

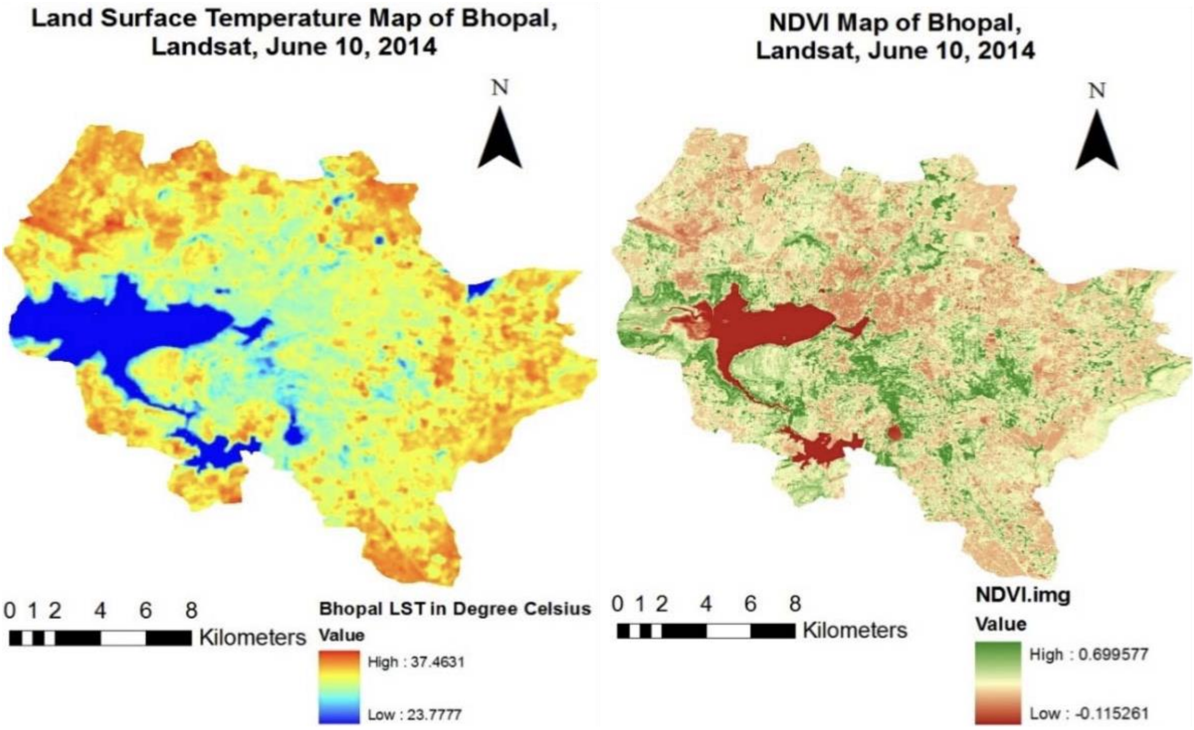


*Figure 3: Land surface temperature (LST) map (left) and Normalized difference vegetation index (NDVI) maps of Bhopal. Source: Ali, Patnaik, & Madguni, 2017. Microclimate land surface temperatures across urban land use/ land cover forms. Global J. Environ. Sci. Manage.*

Loss of greenery combined with expanding dark, impervious surfaces (concrete, asphalt, dark roofs) has sharply increased urban temperatures in Bhopal. As per weather data, the mean maximum temperature of 33.2 °C in 2010 increased to 42.0 °C in 2019.

[1] Atal Mission for Rejuvenation and Urban Transformation (AMRUT) mission was launched with a focus to establish infrastructure that could ensure adequate robust sewage networks and water supply for urban transformation by implementing urban revival projects. The purpose of AMRUT is to (i) ensure that every household has access to a tap with assured supply of water and a sewerage connection; (ii) increase the amenity value of cities by developing greenery and well maintained open spaces (e.g. parks); and (iii) reduce pollution by switching to public transport or constructing facilities for non-motorized transport (e.g. walking and cycling).

Bhopal has only 11% of its geographical area under tree cover, which is much below the state average of 25% (Forest Survey of India, 2019). As per the latest assessment (Forest Survey of India, 2019), Bhopal has lost 25.33 sq. km of forest area (7.2 percent of its forest cover between 2015 and 2017) according to a satellite survey conducted by Indian Institute of Science, Bengaluru. At the present rate of tree felling, coverage be reduced to 4.1% by 2030.

The climate vulnerability of Bhopal is projected to shift from 'moderate' to 'high' under RCP 8.5 scenario. Another major city in Madhya Pradesh, Indore with a population of ~3.2 million is projected to shift to 'very high' climate vulnerability from 'moderate' levels by 2050.

Per a January 2022 study titled "Climate Change and Environment Action Plan of Bhopal District", Bhopal is projected to experience warming of 2–3°C under RCP 4.5 and warming of 2–5°C under RCP 8.5. The study also estimated that between 2005 and 2019 the total greenhouse gas (GHG) emissions of Bhopal increased by 2 92 % (from 0.57 million tonnes CO2e in 2005 to 2.21 million tonnes CO2e in 2019) with a compound annual growth rate of 10.25%. These estimates represent GHG emissions from 12 categories covering three major sectors – energy; agriculture, forestry and other land use; and waste. The energy sector (direct fuel combustion in transport, agriculture, residential etc.) is the largest contributor to the city's GHG emissions.

| Temp max (°C) | March | April | May | MAM (Average of March, April & May) |
|---|---|---|---|---|
| Observed | 34 | 39 | 41 | 38 |
| Simulated | 33 | 38 | 41 | 37 |
| RCP4.5 | | | | |
| 2030s | 35 | 39 | 42 | 39 |
| 2050s | 35 | 40 | 42 | 39 |
| RCP8.5 | | | | |
| 2030s | 35 | 39 | 42 | 39 |
| 2050s | 36 | 40 | 43 | 40 |

| Warm days (%) | March | April | May | MAM (Average of March, April & May) |
|---|---|---|---|---|
| Observed | 10 | 10 | 10 | 10 |
| Simulated | 9 | 10 | 9 | 9 |
| RCP4.5 | | | | |
| 2030s | 30 | 32 | 39 | 34 |
| 2050s | 39 | 45 | 56 | 47 |
| RCP8.5 | | | | |
| 2030s | 32 | 36 | 46 | 38 |
| 2050s | 51 | 59 | 69 | 61 |

*Figure 4: Observed (1986-2005), simulated (1986-2005) and projected (RCP4.5 and RCP8.5 emission scenarios). Mean monthly and seasonal maximum temperature (°C) (left), Mean monthly and seasonal warm days (%) (right). Source: Vasudha Foundation, 2022*

**Bhopal – status quo**

The Green and Blue Master Plan aims to make Bhopal the most liveable and environmentally sustainable city in the country using the latest smart growth planning methods. One of the main objectives of the plan is to develop and implement policies, programs, and projects that mainstream integrated urban planning and environmental management that will enhance social and environmental sustainability. As part of the Urban Forest Creation and Management, the city plans to create multi-functional spaces under urban forestry in strategic locations, which are diverse, healthy, and accessible to all. It also includes targeted tree planting to improve water quality and reduce urban flooding.

The current total solar installed capacity of Madhya Pradesh (MP) stands at 2.46 GW of which only 3.1% is solar rooftop (MNRE). GoMP provides a 30% subsidy to domestic consumers for installing solar panels on rooftops or on the ground. Public buildings get a 45% subsidy and certain government undertakings are eligible for a subsidy of 50%. Despite these efforts, the state is deficient by around 3.24 GW of the state target of 5.7 GW installed solar capacity by 2022.

**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 relying on private purchase and operation of air conditioners would increase costs for hundreds of millions of people, heat cities by up to 1°C, 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 mean AC units will not have power to operate and 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.

India is the country with the largest population at extreme risk from urban heat. Bhopal is a major city representative of the cities in India at greatest risk from urban warning and climate change. Given the strength of Bhopal's leadership and commitment to urban quality of life issues, Bhopal is an ideal city to lead Indian modelling, adoption and demonstration of Smart Surfaces as city wide cooling strategy.

By adopting Smart Surfaces city-wide, Bhopal and other Indian cities can cool themselves by at least 3˚C, protecting all citizens, greatly reducing projected need for and use of air conditioning, improving health outcomes and slowing global warming. India is recognized as a global leader for its national cooling strategies, while some cities like Delhi are already leaders in increasing tree coverage. Through city-wide adoption of Smart Surfaces, 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**
**]and Info**

Madhya Pradesh State Action Plan on Climate Change (SAPCC), Housing and Environment Department, Government of Madhya Pradesh. - Ministry of Environment, Forest & Climate Change (MoEFCC), Government of India has advised all the states to revise their respective State Action Plan on Climate Change (SAPCC) in view of the UNFCCC Paris Agreement on Climate Change and Nationally Determined Contributions (NDCs) agreed by India in Paris CoP, 2015 to reduce Green House Gas emissions.
Madhya Pradesh Climate Change Knowledge Portal, Housing and Environment Department, Government of Madhya Pradesh.
Green and Blue Master Plan, Smart City Bhopal, Government of India.
Climate Change and Environment Action Plan of Bhopal District, Vasudha Foundation, 2022.
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.

Definition of Heatwaves as per National Action Plan on Heat Related Illness, July 2021
In India, heatwave is considered if the maximum temperature of a station reaches at least 40°C or more for plains, 37°C or more for coastal stations and at least 30°C or more for hilly regions. Following criteria are used to declare a Heatwave:
**A. Based on Departure from Normal**
Heatwave: Departure from normal is 4.5°C to 6.4°C
Severe Heatwave: Departure from normal is >6.4°C
**B. Based on Actual Maximum Temperature (for plains only)**
Heatwave: When actual maximum temperature ≥ 45°C
Severe Heatwave: When actual maximum temperature ≥47°C
To declare a heatwave, the above criteria should be met for at least two stations in a Meteorological sub-division for at least two consecutive days. A heatwave will be declared on the second day.

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[i] The 2021 report of the Lancet Countdown on health and climate change: code red for a healthy future.
[ii] Future of the human climate niche, May 2020. PNAS.
[iii] Climate risk and response: Physical hazards and socioeconomic impacts. Will India get too hot to work? November 2020. McKinsey Global Institute.
[iv] Population ages 0-14 (% of total population) – India. World Bank, 2020.
[v] Sustainable Energy for All (SEforALL), Chilling Prospects: Providing Sustainable Cooling For All, 2018.
[vi] Ibid, 81.
[vii] Energy Conservation Building Code. Bureau of Energy-Efficiency, Ministry of Power, Government of India, 2017.