The Economic Burden of Excess Heat on India's Education Sector: How Smart Surfaces Can Achieve Citywide Cooling

Approximately 250 million children were enrolled in around 1.5 million schools across India in 2020. Nearly 50% (120 million) of these children go to privately managed schools, which constitute nearly a third (45 million) of all the schools in India. A huge chunk of these private schools caters to low-income households. 45.5% of the students pay a school fee of less than $6.25 per month and about 70% pay less than $12.50 per month. Considering the need for improving the education sector, the Government of India allocated INR1.13 lakh crore (~USD14billion) in the 2023-24 Union Budget for raising the projected expenditure on school and higher education by around 8.3% compared to 2022-23.

Indian schools have one of the lowest student-teacher ratios — about 8% of schools have only one teacher. The Samagra Shiksha is a centrally sponsored scheme of the Government of India that prescribes pupil-teacher ratio or PTR for primary level as 20:1 and 30:1 for upper primary and secondary. The national PTR in 2021-22 stood at 26 for primary, 19 for upper primary, 17 for secondary, and 27 for higher secondary. However, there are significant variations across states and union territories. For instance, in 2021-22, Madhya Pradesh state had a primary PTR of 25 and also had the most (~16,630) one-teacher schools. Overall, there is a need to improve PTR in Indian states to facilitate better individual attention and enhance the overall quality of education.

The average classroom size varies in India. While Indian schools are able to manage their PTR over the years, most schools still fail to comply with the prescribed average size of classrooms. The national level board of education in India for public and private schools — Central Board of Secondary Education (CBSE) — mandates that every classroom must provide at least 1 sq. m/10.7 sq. ft. of space per student. This number is significantly low when compared to US where the average classroom size is about 46 sq. ft. per student.

India is an incredibly hot country that currently experiences close to 50 days each year with an average temperature over 29°C/84°F, compared to seven days over 29°C in the United States. Excess heat has direct economic costs in terms of health care expenses, loss of labor productivity, increased energy consumption for cooling, damage to agriculture, and impact on water resources. Indirect costs may include damage to infrastructure, increased demand for electricity, and effects on tourism. Inadequate infrastructure and a lack of trained teachers coupled with the high economic costs of extreme weather events due to climate change has burdened the Indian education sector.

There is a need to deploy efficient and effective cooling strategies across schools in India to mitigate impacts of excess heat and heat waves, which will only grow worse with global warming. The challenge is greater and deeper than it seems. Per the 2021-22 report of the Ministry of Education, about 86.6% of Indian schools have a functional electricity connection. A 2017 study estimated that the total built-up area of India's educational buildings (including schools and universities) is at 451-484 million sq. m and the energy consumption is at 7.73 - 11.34 Billion Units or kWh. With an unreliable power supply and a lack of basic ventilation, such as fans, deploying air-conditioners as a cooling strategy for schools is out of the question.

Categories	Number (A)	Built Up Area per building (Sq m) (B)	BUA (Million Sq m)	EPI (kWh per Sq m per year) (C)	EC per Category (In Billion Units)
Schools					
Primary	677694	150 - 160	101 - 108	20 - 25	2.03 - 2.71
Upper primary	340075	301 - 310	102 - 105	20 - 25	2.04 - 2.63
Secondary	108268	554 - 560	59 - 60	30 - 40	1.79 - 2.42
Higher Secondary	87454	1313 - 1320	114 - 115	30 - 40	3.44 - 4.61
Colleges					
Rural	23098	1500 - 2000	34 - 46	22 - 27.5	0.762 - 1.270
Urban	15399	2000 - 2500	30.7 - 38.5	33 - 44	1.02 - 1.70
Institutes of National Importance	75	20000 - 25000	1.50 - 1.88	44 - 55	0.066 - 0.103
Stand Alone Institutions	12276	500 - 600	6.14 - 7.37	22 - 33	0.135 - 0.243
Total			451 - 484 Million Sq m		7.73 - 11.34 Billion Units

Figure 1:Educational Building Stock Estimates and Modelling (Kumar, 2017)

The thermal comfort range for students in naturally ventilated classrooms in India is wider than the standard range, suggesting a potential for adaptation to higher temperatures. The students (10-18 years age) feel comfortable within operative temperature range of 15.3–33.7 °C for 80% acceptability (Jindal, 2018). This range exceeds the comfort temperature range as specified by Indian and international standards (ASHRAE) for the adult population. Despite high heat tolerance among Indian students, the need for an integrated cooling strategy is crucial to mitigate discomfort, promote a conducive learning environment, and contribute to the overall well-being of students in the face of intense heat challenges.

Some of the well-cited and published studies such as (Garg, Jagnani, & Taraz, Temperature and Human Capital in India, 2020) and (Garg, Jagnani, & Taraz, Human Capital Costs of Climate Change : Evidence from Test Scores in India, 2017) have found that excess heat significantly impacts the test scores of children in schools in India. They also found that high temperatures reduce math and reading test scores, specifically highlighting the impact on poor populations in agrarian economies. An additional 10 days in a year above 29°C reduces math and reading test scores by 0.03 and 0.02 standard deviations respectively. This is equivalent to reducing the effective years of schooling the child has received by 0.35 years. Assuming that students enter the labor market at age 20 and work for 40 years, 10 additional hot days will lead to a 3% decrease in wages. These findings highlight the urgent need for adopting a citywide cooling strategy to mitigate the impact of excess heat on children's academic achievement in India.

The exposure to air pollution is increasingly one of the greatest public health challenges faced by the rapidly urbanizing Indian cities. The air pollution levels in India have been consistently above the World Health Organization (WHO) recommended levels for the past decade. The economic cost of air pollution in India due to lost output from premature deaths and morbidity is about $36.8 billion (27.4–47.7) and 1.36% of India's gross domestic product (GDP) (World Bank, 2023).

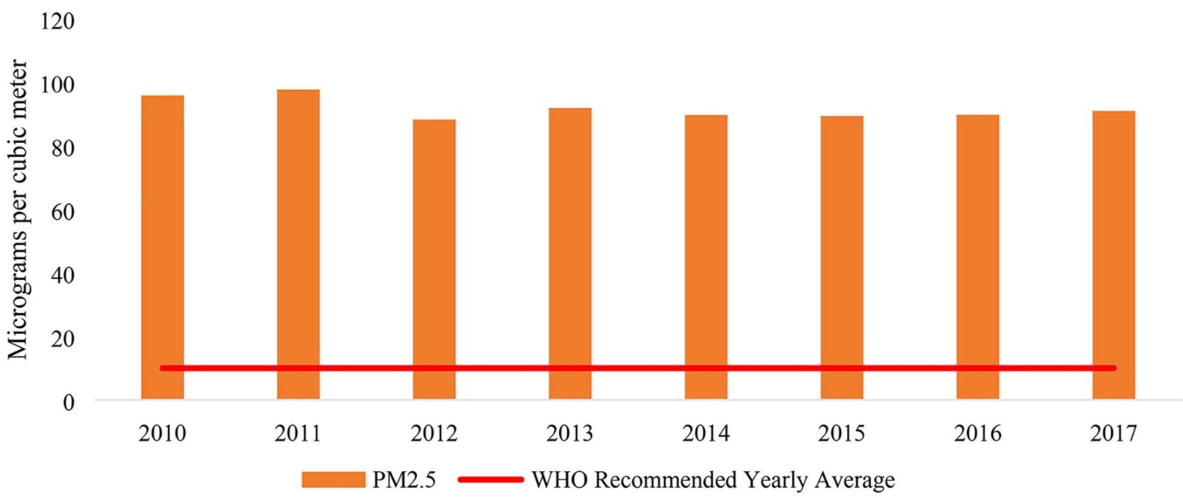

Figure 2: High levels of air-pollution levels in India in comparison to WHO recommended yearly average level (Balakrishnan & Tsaneva, Air pollution and academic performance: Evidence from India, 2021)

A study (Balakrishnan & Tsaneva, Air pollution and academic performance: Evidence from India, 2021) has correlated the impact of air pollution on academic performance of students. Using a large-scale dataset from 2008 to 2014, the study shows that high levels of air pollution significantly reduce varying levels of reading outcomes by 1.11–2.39%

and math outcomes by 0.53–1.90%, with girls and older children demonstrating a larger decline.

The impact of air pollution is not just limited to physical health but also extends to mental health. Per the outcomes of a study done for 6 representative Indian states, namely Assam, Karnataka, Maharashtra, Rajasthan, Uttar Pradesh, and West Bengal, (Balakrishnan & Tsaneva, Impact of Air Pollution on Mental Health in India, 2023), for every 1 unit($\mu g/m^3$) increase in PM 2.5, there is roughly a 10.3% increase in the probability of reporting depression symptoms. It also leads to 1.49% increase in the probability of feeling sad and a 2.44% increase in the probability of lacking energy for two weeks or more.

Excess heat in India has been linked to increased hospitalization, particularly among infants and children. Studies have found a significant increase in all-cause mortality during heat waves (Azhar, et al., 2014), with a 146% rise in the probability of mass heat-related mortality for every 0.5°C increase in summer mean temperatures (Omid Mazdiyasni, 2017). This is consistent with research in the United States, which found a 3% increase in all-cause hospital admissions, particularly for renal and respiratory diseases, during extreme heat (Gronlund, 2014). These findings suggest that the increasing frequency and severity of heat waves in India due to climate change are likely to lead to a further rise in hospitalizations, particularly among vulnerable populations such as children and the elderly.

The confluence of education, climate, and health in India presents intricate challenges demanding urgent attention. The education sector grapples with disparities in infrastructure and student-teacher ratios. The adverse impacts of excess heat, exacerbated by climate change, are evident in reduced academic performance, necessitating innovative citywide cooling strategies. Simultaneously, escalating air pollution has serious effects on both physical and mental health, underscoring the pressing need for comprehensive interventions. As India addresses the economic costs of extreme weather events, particularly in the education sector, Indian cites must adopt a citywide Smart Surfaces cooling strategy. Deploying Smart Surfaces citywide would allow Indian cities to cool by at least 3˚C—while delivering a large contribution to climate change mitigation.

Works Cited

Garg, T., Jagnani, M., & Taraz, V. (2020). Temperature and Human Capital in India. *Journal of the Association of Environmental and Resource Economists, 7*(6).

Garg, T., Jagnani, M., & Taraz, V. (2017). Human Capital Costs of Climate Change : Evidence from Test Scores in India. *Economics, Environmental Science*.

Balakrishnan, U., & Tsaneva, M. (2021). Air pollution and academic performance: Evidence from India. *World Development , 146*.

World Bank. (2023). *Catalyzing Clean Air in India.*

Balakrishnan, U., & Tsaneva, M. (2023). Impact of Air Pollution on Mental Health in India. *The Journal of Development Studies*(59:1), 133-147.

Azhar, G. S., Mavalankar, D., Nori-Sarma, A., Rajiva, A., Dutta, P., Jaiswal, A., . . . J. Hess, J. (2014). Heat-Related Mortality in India: Excess All-Cause Mortality Associated with the 2010 Ahmedabad Heat Wave. *PLoS ONE*.

Omid Mazdiyasni, A. A. (2017). Increasing probability of mortality during Indian heat waves. *Science Advances*.

Gronlund, C. J. (2014). Heat, Heat Waves, and Hospital Admissions among the Elderly in the United States, 1992–2006. *Environmental Health Perspectives, 22*.

Goyal, S., & Pandey, P. (2009). How do government and private schools differ? Findings from two large Indian states.

Jindal, A. (2018). Thermal comfort study in naturally ventilated school classrooms in composite climate of India. *Building and Environment*.

Kumar, S. K. (2017). *Transforming the Energy Services Sector in India – Towards a Billion Dollar ESCO Market.* New Delhi: Alliance for an Energy Efficient Economy.