# A Framework to Quantify Cooling Demand Related Risks for Urbanized Regions across India.

**Authors:** Aradhana Yaduvanshi[1], **Riddhi Singh**[1,2] and Rohini Kumar[3], (1)Indian Institute of Technology Bombay, Department of Civil Engineering, Mumbai, India, (2)Indian Institute of Technology Bombay, Interdisciplinary Programme in Climate Studies, Mumbai, India, (3)Helmholtz Centre for Environmental Research GmbH – UFZ, Leipzig, Germany, Computational Hydrosystems, Leipzig, Germany

Global warming poses a grave challenge to Indian energy policy as rising temperatures coincide with population growth and lifestyle changes. Quantifying the probable changes in cooling requirements and associated uncertainties would be essential to aid long-term energy planning. Often, a temperature time series derived variable - cooling degree-days (CDDs), is used as a proxy for cooling requirements. Here, we assess the historical (1951-2019) and projected (2006-2100) CDDs across all administrative units (districts) of India. The projected CDD values are evaluated for the 1.5°C, 2°C and 3°C levels of global warming as identified by five general circulation models under three representative concentration pathways. Following this, we propose a risk assessment framework that combines hazard (CDD), exposure (population) and vulnerability metrics. To account for uncertainty in future population projections, five socio-economic pathways (SSPs) were employed. We design three risk indicators that use (1) only GDP, (2) only electricity source (proportion of renewable to non-renewable), and (3) both GDP and electricity source, as metrics for vulnerability. We then quantify the risk related to CDD for ten most urbanized districts in India for the year 2011 and the three warming levels. We note a 0-15%, 10-30% and 15-50% rise in median CDD values across all districts of India under the 1.5°C, 2°C and 3°C levels of global warming, respectively. For the year 2011, the highest CDD related risk is identified for Delhi, Mumbai, and Kolkata, in that order, respectively, when vulnerability metric considers only GDP. However, when the source of energy (renewable vs. non-renewable) is considered, Kolkata followed by Delhi and Chennai attain the highest risk ranking. We find no change in risk related rankings under the three warming levels, indicating that the risk is primarily driven by the exposure and vulnerability metrics. Our results indicate that the current national cooling action plans can benefit from the proposed risk-based indicators.