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CLIMATE ACTION IMPROVES HEALTH FROM CLEANER AIR
IN AHMEDABAD, INDIA

Climate change, extreme heat, and air pollution are connected public health threats: burning of fossil fuels produces health-harming air pollution as well as carbon dioxide emissions that contribute to rising global temperatures. Extreme heat in India already causes significant health problems, contributing to nearly 47,000 early deaths in 2019.[1] According to Indian experts, climate change could increase future annual average temperatures as much as 2.4 °C (approximately 4.3 °F) by the 2080s relative to the 1976-2005 average.[2] Keeping people safe from sweltering heat is an increasingly critical health challenge as global temperatures rise.

Air conditioning (A/C) offers lifesaving relief from extreme heat, as recognized in India's Cooling Action Plan.[3] Although only 6 percent of Indian households were estimated to have A/C access in 2019,[4] the Indian government projects nationwide cooling demand could grow eight-fold by the 2030s compared to recent years (2017 to 2018).[5] Electricity use for A/C in India is already increasing because of rising temperatures;[6] if India powers rising A/C demand by burning fossil fuels—rather than by harnessing cleaner, renewable energy sources—it may trigger higher emissions of dangerous air pollution and worsen the climate crisis itself.

Figure 1: **Top: Smoke rises on a winter morning in Ahmedabad, one of India's non-attainment cities for health based airquality standards; Botttom: Rising temperatures are leading to increased demand for air conditioners and cooling.**

Credits: NRDC (top), Jerry Wang (bottom)

In addition to extreme temperatures, outdoor air pollution also imposes an enormous public health burden in India, contributing to an estimated 980,000 deaths in 2019,[7] when the country's annual fine particulate matter ($PM_{2.5}$) air pollution level averaged 91.7 μg/m^3, more than double the national annual $PM_{2.5}$ air pollution limit of 40 μg/m^3.[8,9] Country-wide, air pollution from coal combustion in thermal power plants and industrial activity contributes to 169,000 premature deaths annually.[10] India launched its National Clean Air Programme (NCAP) in 2019 to provide a roadmap for reducing unhealthy air pollution levels nationwide, especially in cities not yet attaining the National Ambient Air Quality Standard (NAAQS) for $PM_{2.5}$ air pollution.[11]

Air pollution reduction strategies in India include efforts to better control emissions from aging coal-fired power plants nationwide, 47 of which have been operating for 34 years each, on average.[12] Importantly, premature mortality from air pollution in the twelve current Indian "megacities" (population >10 million, including Ahmedabad, Mumbai, Pune, Kolkata and others) increased significantly from 2005 to 2018,[13] in part because of sulfur dioxide air pollution emissions from industry and coal-fired power plants that increased by 50 percent from 2007 to 2016.[14] In 2022, India's Ministry of Power announced plans to reduce power generation from some coal-fired utilities because of availability of more cost-effective renewable energy.[15]

QUANTIFYING CITY-LEVEL BENEFITS OF CLIMATE ACTIONS

Despite robust estimates of the health harms of air pollution in India on a broad scale, there is limited evidence quantifying these dangers at a local level using city-specific population, health, and air pollution exposure data. Research that describes not only the health toll of air pollution but also the air quality and health-related co-benefits of climate solutions that reduce fossil fuel use and bolster human resilience to rising temperatures can provide a rationale for stronger mitigation and adaptation policies. Ahmedabad, a city in the western Indian state of Gujarat, is one of 132 non-attainment cities in India that exceed current health-based air quality limits,[16] and which are implementing action plans to achieve NCAP targets to address chronic air pollution problems. The Torrent Power Plant, located in the heart of Ahmedabad is one of the oldest coal-fired power plants in the country, having started operation in 1934. The power plant has undergone numerous phases of expansion to meet increasing power demand in the region.[17]

Figure 2: **Left: The Torrent coal-fired power plant began operation in 1934 and contributes to air pollution in Ahmedabad; Right: A woman in Ahmedabad painting her home roof with solar reflective paint in 2018.**

(Credits: NRDC (left), Mahila Housing Trust (right)).

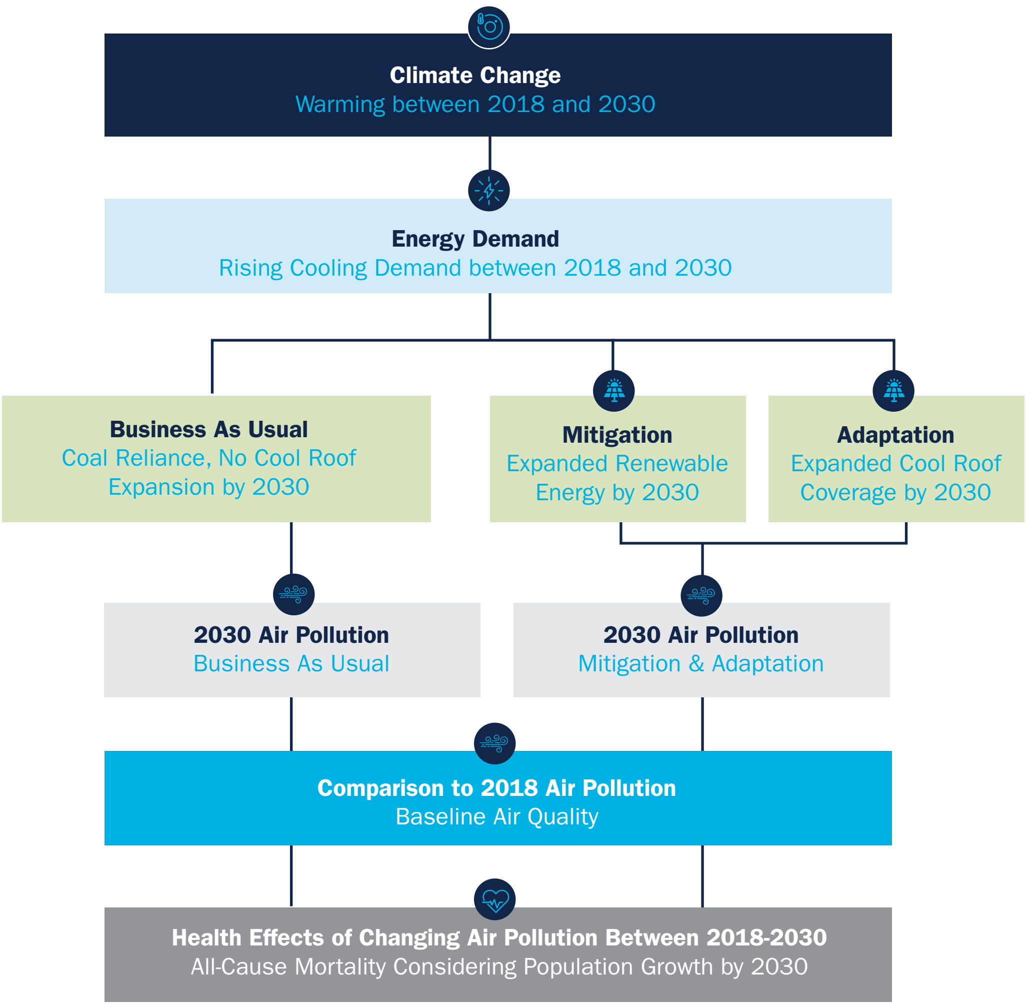
Because of the convergence of fossil fuel reliance, air quality problems, and city interest in improving public health through its pioneering Heat Action Plan[18] and a comprehensive air pollution monitoring, forecasting, and health risk communication strategy,[19] Ahmedabad provides an ideal setting for investigating the near-term air quality and health benefits of climate change response actions (mitigation and adaptation).

CLIMATE, ENERGY, AIR QUALITY, AND HEALTH EXPERTS TEAM UP

Conducting an interdisciplinary modeling analysis with local data and expertise, our team estimated the air quality and health co-benefits of potential climate change mitigation and adaptation actions in Ahmedabad by 2030. We explored two main actions implementable at the city level: (1) mitigation of climate pollution through control of emissions from Ahmedabad's coal-fired Torrent Power Plant (Figure 2, left), a scenario of interest because pollution controls at this plant and others located in urban areas are being prioritized to reduce risks to nearby population centers[20] and (2) adaptation to extreme heat via expansion of cool roofs across the city (Figure 2, right), an intervention that helps to lower indoor temperatures at the household scale[21] and reduce citywide demand for energy to power A/C.

This project estimated the city-wide air quality and health benefits of those two climate change response actions by the year 2030. Our team linked models (Figure 2) to explore the air quality-related health effects of these responses, with a focus on fine particulate matter ($PM_{2.5}$), the most dangerous air pollutant regulated under India's NAAQS.[22]

Figure 3: Flowchart depicting project model integrating projections of climate warming in Ahmedabad (dark blue box), energy supply and cooling demand modeling (light blue box), and two 2030 comparison scenarios that shape air quality modeling (business-as-usual, green box and a combined mitigation and adaptation scenario, green box). Air quality modeling and monitoring data (light grey and blue boxes) were analyzed using a health impact assessment approach (dark grey box) to arrive at air quality effects on all-cause mortality in the city in 2030, relative to a 2018 baseline.



(Credit: Limaye et. al (2022)).

Our collaborating team included expert researchers from the Indian Institute of Tropical Meteorology (IITM), the Gujarat Energy Research and Management Institute (GERMI), the Indian Institute of Public Health-Gandhinagar (IIPH-G), and NRDC:

- **Energy policy experts at GERMI** estimated Ahmedabad's electricity demand in 2018 and 2030, considering how demand for air conditioning is expected to rise due to climate warming, population growth, and economic expansion.[23] This team also considered the growth of renewable energy capacity and opportunities to substitute fossil fuel-generated electricity with power provided by solar and wind sources.

- **Air quality scientists at IITM** collected air quality ($PM_{2.5}$) monitoring data for 2018 and modeled air quality for two different 2030 scenarios: (1) a business-as-usual scenario in which Ahmedabad continues to rely heavily on its thermal coal-fired power plant to meet city energy needs and takes no further actions to expand cool roofs (beyond existing 5 percent roof area coverage), and (2) a combined mitigation and adaptation scenario in which the city takes strong climate actions to substitute fossil fuel power with renewable energy, a plausible future given the growth of renewable energy capacity in Gujarat,[24] and expands its cool roofs program to cover 20 percent of available building roof area.

- **Public health scientists at NRDC and IIPH-G** applied mortality data from the Ahmedabad Municipal Corporation, developed population estimates for 2018 and 2030, and analyzed the different air quality projections modeled by IITM scientists to estimate city-wide health effects in 2030 under the business-as-usual scenario and in a future with strong climate action on mitigation and adaptation. Projected health effects in 2030 are relative to a common 2018 air quality baseline.

KEY FINDINGS

The findings of this study, summarized below, are available as an open-access article in the peer-reviewed scientific journal *Environmental Research: Health*.[25]

Climate Change and Energy Demand

Our energy analysis shows that demand for energy to provide cooling in Ahmedabad could nearly triple between 2018 and 2030 as the city population increases from 8.5 to 9.3 million and climate warming increases the average annual temperature by 0.8°C in 2030. However, renewable energy capacity to supply energy in Gujarat is expected to expand by a factor of five over that period, part of India's national commitment to provide half the country's energy mix from renewable, non-fossil fuel sources by 2030.[26]

Expansion of cool roofs from 5 to 20 percent of total roof area would reduce cooling energy demand by 0.21 Terawatt-hours (TWh) in 2030 from 2018. That energy savings would more than offset the city's climate change-driven 2030 increase in cooling demand from 2018 (0.17 TWh); the reduction in cooling energy demand is equivalent to avoiding 191,000 metric tons of carbon dioxide pollution from a thermal coal-fired power plant, emissions equivalent to 81.4 million litres of petrol.[27]

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Air Quality

Air monitoring data used in an IITM model[28] show that $PM_{2.5}$ air pollution levels averaged 71.04 $\mu g/m^3$ in 2018. Our air pollution modeling suggests that if the city takes no additional climate mitigation actions by 2030 (business-as-usual scenario), local air quality will further deteriorate, as the annual $PM_{2.5}$ pollution level rises to 75.18 $\mu g/m^3$. In contrast, if Ahmedabad implements strong clean energy and cool roofs actions (mitigation and adaptation scenario), annual $PM_{2.5}$ air pollution would decrease (by 0.10 $\mu g/m^3$) from 2018 levels to 70.94 $\mu g/m^3$ in 2030. While that level exceeds the national annual $PM_{2.5}$ air pollution limit (NAAQS) of 40 ug/m^3, avoiding an increase in air pollution from 2018 to 2030 is a significant outcome, considering anticipated growth in both the city population and cooling energy demand over that period.[29]

Health

We combined city population projections for 2030, baseline health data, and air pollution epidemiology evidence with air quality modeling results using the Benefits Mapping and Analysis Program-Community Edition, BenMAP-CE,[30] (Figure 4) to estimate the health effects of $PM_{2.5}$ air pollution in 2030 under the business-as-usual vs. the combined mitigation and adaptation scenario. **Using an established air quality health impact assessment tool, we found that the air quality benefits of mitigation and adaptation actions result in up to 1,414 fewer annual all-cause premature deaths city-wide in 2030, compared to the business-as-usual future (i.e. without additional steps to reduce fossil fuel reliance or expand cool roofs).**

Furthermore, our health modeling for 2030 scenarios also demonstrates that Ahmedabad could achieve even more significant health benefits with even greater ambition to improve air quality. Compared to a business-as-usual 2030, we estimate that the city could avoid up to 6,510, 9,047, or 17,369 premature deaths annually by 2030 if NCAP targets, NAAQS limits, or World Health Organization $PM_{2.5}$ air quality guidelines (WHOAQG) are achieved, respectively (Figure 5).[31]

Figure 4: Data components integrated in Benefits Mapping and Analysis Program-Community Edition (BenMAP-CE) (Credit: NRDC).

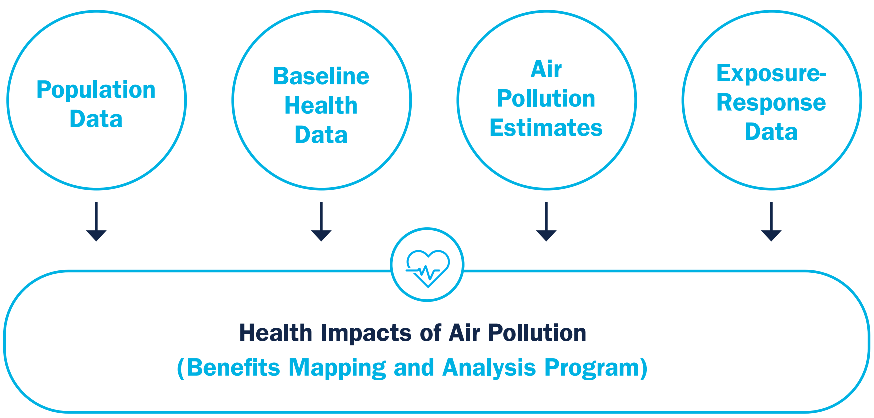
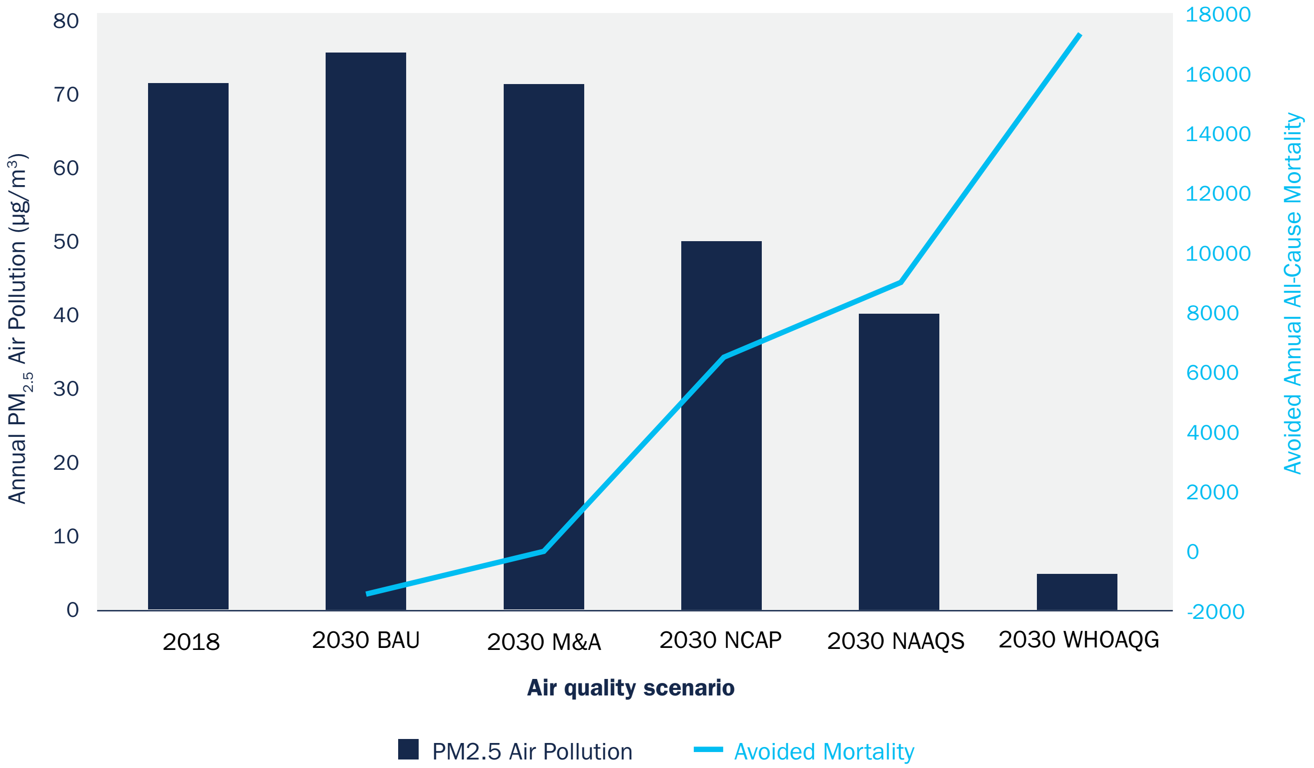


Figure 5: **Key air pollution and health results: BenMAP-CE input air pollution values (blue bars) and health effect estimates (blue line) under 2018 baseline, 2030 business-as-usual (BAU), 2030 mitigation and adaptation (M&A), 2030 NCAP (National Clean Air Programme) attainment, 2030 NAAQS (National Ambient Air Quality Standards) attainment, and 2030 WHOAQG (World Health Organization Air Quality Guideline) attainment. Health effects are for each scenario compared to baseline air quality for 2018. For avoided all-cause mortality, negative values indicate excess deaths in 2030 relative to 2018, positive values indicate avoided deaths in 2030 relative to 2018 (Credit: Limaye et al. 2022) (Left axis values apply to blue bars; right axis values apply to blue line).**



A Framework for Estimating Health Benefits of Clean Air

Because the threats of climate change, extreme heat, and air pollution to public health are intertwined, so are the solutions. This study shows that shifting India even further and faster away from fossil fuels and towards clean energy and stronger heat adaptation through cool roofs can help reduce deadly air pollution, keep people cooler and healthier, and reduce the carbon dioxide pollution that fuels climate change. By incorporating climate, energy, cooling, land cover, air pollution, and local health data, the comprehensive modeling method we deployed is scalable to estimate local air quality and health co-benefits in diverse situations. **Our findings show that city-level climate change response measures can produce significant co-benefits for air quality and health in the near-term.**

Our sequence of climate, energy, air quality and health modeling provides a blueprint for future studies to estimate local air quality and health co-benefits of climate change responses in India. Such research can help the public understand how climate action in India can deliver cleaner air. It can also strengthen understanding of health implications of policies in India that affect energy use and air quality, such as the India Cooling Action Plan,[32] India's climate change goals under the United Nations Framework Convention on Climate Change,[33] and further implementation of the National Clean Air Programme.[34] Our findings on avoidable premature deaths from air quality improvements strengthen the health argument for scaling up climate solutions across the country.

POLICY RECOMMENDATIONS

1. Substituting Renewable Energy for Highly Polluting Fossil Fuels Benefits Health

Climate change mitigation actions that move India's energy systems away from burning fossil fuels (coal, oil, and gas) and towards greater use of renewable energy sources like solar and wind can help to reduce chronic urban air pollution problems. Better control of emissions from coal-fired power plants near population centers improves air quality and health locally in the near-term, while also helping to stabilize the global climate and slow global temperature rise.

2. Indian Cities Can Quantify Adaptation Benefits

Climate change adaptation responses to better prepare people for unavoidable climate impacts can deliver a range of benefits. For example, actions to reduce health risks from intensifying hazards like extreme heat, including low-cost cool roof installations in India, can help to deliver energy savings by reducing demand for energy to cool buildings—reducing strain on the electricity grid and lowering household energy bills.[35] More evaluation of adaptation interventions is needed to assess implementation costs and benefits including installation expenses, health improvements,[36] and health-related financial savings.[37]

3. Decisionmakers in India Should Consider Air Quality and Health Effects of Climate and Energy Policies

Using well-established models that estimate the health impacts of air pollution in India, researchers can strengthen the local evidence base in support of health-protective policies. When climate, energy, transportation, or other environmental policies are under consideration or being adopted, cities can analyze local air quality and health data to shape implementation approaches that account for air quality-related health effects.

4. Interdisciplinary Approaches Can Identify Ways to Reduce Climate Threats to Health

Interdisciplinary teams benefit from experience and expertise across different subject matter areas, and can provide comprehensive learning opportunities to team members, local policymakers, and wider communities. Integration of climate, air quality, energy, demographic, and health data and models can enable researchers to shape analyses that better reflect complex systems. Transparent reporting of methods, assumptions, and approaches[38] can foster more powerful climate change and health investigations in the future.

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ABOUT THE PARTNERS

Natural Resources Defense Council (NRDC)

The Natural Resources Defense Council (NRDC) is an international environmental organization with more than 3 million members and online supporters. Since 1970, our scientists, lawyers and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC works in the United States, China, India, Canada, Latin America, as well as on global initiatives to address climate change, protect nature, and promote healthy people and thriving communities. In India, NRDC works with local partners on transformative solutions to advance clean energy and climate resilience. **www.nrdc.org**

Indian Institute of Public Health, Gandhinagar (IIPH-G)

The Indian Institute of Public Health Gandhinagar (IIPH-G) is India's first Public Health University. IIPH-G aims to strengthen the overall health system in the country through education, training, research, and advocacy/policy initiatives. The institute started its operations in July 2008 with the commencement of its 1st batch of Post Graduate Diploma in Public Health Management. IIPH-G is India's largest public health university and is the hub for excellence in public health teaching, public health innovation, research and practice. **iiphg.edu.in**

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Development of Ahmedabad's Air Information and Response (AIR) Plan to Protect Public Health

Climate change and 2030 cooling demand in Ahmedabad, India: opportunities for expansion of renewable energy and cool roofs
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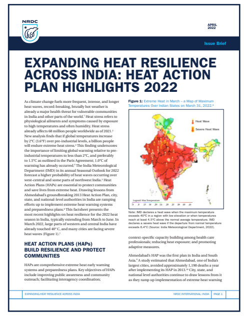
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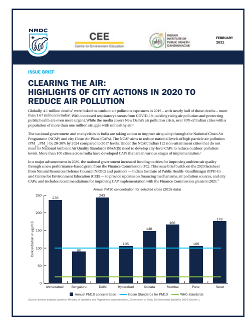
CLEARING THE AIR: HIGHLIGHTS OF CITY ACTIONS IN 2020 TO REDUCE AIR POLLUTION

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