India

The health benefits of response actions to air pollution and extreme heat in Ahmedabad

Case study prepared by:

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FOCUS

Overview

Climate change, extreme heat and air pollution are inter-connected public health threats. Extreme heat in India is already associated with significant, excess, all-cause mortality (Azhar *et al.*, 2010), while air pollution contributed to an estimated 980,000 deaths in 2019 (Pandey *et al.*, 2020). In the same year, only 6% of Indian households were estimated to have access to air conditioning (A/C) (Romanello *et al.*, 2022), and the demand for associated cooling energy is predicted to grow eight-fold by the 2030s. If India powers this demand by burning fossil fuels it may trigger higher emissions and worsen the crisis.

India's National Clean Air Programme (NCAP) provides a roadmap for reducing air pollution and includes controlling emissions from aging coal-fired power plants, which increased by 50% between 2007 and 2016. However, despite robust estimates of the health harms of air pollution in India, there is limited evidence quantifying these dangers at a local level.

Figure 1: The Torrent coal-fired power plant contributes to air pollution in Ahmedabad (Credit: Natural Resources Defense Council (NRDC))

Ahmedabad

Ahmedabad, in the western state of Gujarat, is one of 132 Indian cities that exceed current health-based air quality limits (Central Pollution Control Board, 2021). It is also one of India's megacities with a population above ten million and where premature mortality from air pollution has increased significantly between 2005 and 2018 (Vohra, *et al.*, 2022).

There are several reasons why the city is an ideal setting to investigate air quality and the health benefits of climate change response actions. First, one of India's oldest coal-fired power plants is located in central Ahmedabad (Figure 1). Second, the city experiences extreme air quality problems, and third, there is a civic appetite to improve public health. The city's pioneering Heat Action Plan, for example, includes adaptation measures such as a cool roofs initiative (Figure 2), which involves painting existing roofs with solar reflective paint to reduce indoor heat (Knowlton *et al.*, 2014).

Thus, the research aims to:

1. Describe the health toll of air pollution in the city;
2. Identify health-related co-benefits of climate solutions that reduce fossil fuel use;
3. Provide a rationale for stronger mitigation and adaptation policies.

Figure 2: A woman in Ahmedabad painting her home roof with solar reflective paint (Credit: Mahila Housing Trust)

Team

The collaborating team included researchers from the Indian Institute of Tropical Meteorology (IITM), the Gujarat Energy Research and Management Institute (GERMI), the Public Health Foundation of India/Indian Institute of Public Health-Gandhinagar (IIPH-G), and the Natural Resources Defense Council (NRDC), based in the United States (US).

Methods

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

Climate and air quality scientists at IITM collected monitoring data for 2018 and modelled air quality for two different scenarios in 2030:

1. Business-as-usual (BAU), in which Ahmedabad continues to rely heavily on its coal-fired power plant and takes no further action to expand cool roofs beyond the existing 5% coverage;
2. Combined mitigation and adaptation (M&A), in which the city takes strong climate actions to completely substitute fossil fuel power with renewable energy and expand its cool roofs programme to cover 20% of available roof area (Vellingiri *et al.*, 2020).

Public health scientists at NRDC and IIPH-G collected baseline mortality data, developed population estimates for 2018 and 2030 and analysed the different air quality projections to estimate city-wide health effects in 2030 under the BAU and M&A scenarios.

Researchers then estimated the air quality and health co-benefits of potential climate change mitigation and adaptation actions in Ahmedabad by 2030, and explored two main actions that could be implemented at city level:

1. Mitigation of climate pollution through control of emissions from the Torrent Power Plant;
2. Adaptation to extreme heat via expansion of cool roofs across the city (Figure 2), which lowers indoor temperatures and reduces citywide demand for energy to power A/C.

The team linked models (Figure 3) to explore the air quality-related health effects of these responses, with a particular focus on fine particulate matter ($PM_{2.5}$), the most dangerous air pollutant regulated under India's National Ambient Air Quality Standards (NAAQS).

Population and demographic data for modelling

BenMAP-CE (Benefits Mapping and Analysis Program-Community Edition) is an open-source software application used widely in health impacts research. The team

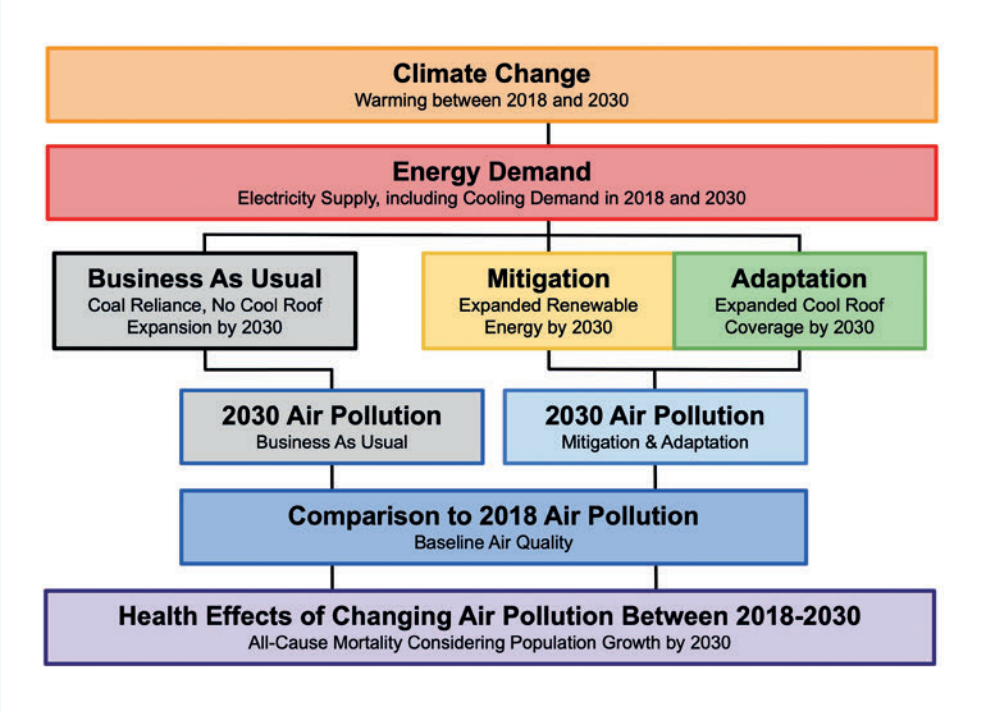

Figure 3: Flowchart depicting project model integrating projections of climate warming in Ahmedabad (orange box), energy supply and cooling demand (red box), and two 2030 comparison scenarios that shape air quality modelling (BAU, grey box and a combined M&A scenario, yellow and green box). Air quality modelling and monitoring data (boxes with blue outlines) were analysed using a health impact assessment approach (purple 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., 2023)

used this model to estimate exposure to air pollution by applying population-based weighting to air pollution output. The resultant dataset incorporated spatial, population growth and age structure profiles from several data sources.

Health metrics and baseline health estimates

Due to the lack of cause-specific mortality and morbidity data for Ahmedabad, researchers utilized all-cause mortality as the health metric. Researchers then compared $PM_{2.5}$ air pollution conditions for baseline 2018 versus those under the two future scenarios for 2030 (BAU and M&A) and quantified the health co-benefits from avoided mortality using BenMAP-CE.

$PM_{2.5}$ exposure-response

The team calibrated BenMAP-CE with the Ahmedabad population estimate for 2030. The Global Exposure Mortality Model (GEMM) (a widely used risk estimator for health impact assessment of air pollution) was then used to integrate air quality and health data from 16 countries with high annual $PM_{2.5}$ exposure levels (up to 84 micrograms per cubic metre (µg/m3)) (Yin *et al.*, 2018).

As shown in Figure 3, the baseline for analysis in the 2018 model included the demand for cooling energy and sources of energy (coal-fired power plants or renewables) to meet current electricity needs. Researchers then estimated demand in 2030, considering changes driven by population growth, economic development and climate warming. Energy modelling then informed the level of air pollution generated from thermal coal plant electric power, in 2018 and in 2030 BAU and M&A scenarios.

Results

Climate change and energy demand

Analysis shows that due to increases in both population and temperature, demand for energy to provide cooling in Ahmedabad could nearly triple by 2030. Encouragingly, renewable energy capacity in Gujarat is expected to expand by a factor of five over the same period as a result of India's national commitment to provide half the country's energy from renewable, non-fossil fuel sources by 2030 (Joshi *et al.*, 2022). Further, expansion of cool roofs from 5% to 20% of the total residential area would reduce cooling energy demand by 0.21 terawatt-hours (TWh) by 2030, and the energy savings would more than offset the city's climate change-driven increase in electricity demand.

Air quality

$PM_{2.5}$ air pollution levels averaged 71.04 µg/m3 in 2018 and modelling suggests air quality will further deteriorate if the city takes a BAU approach. In contrast, if Ahmedabad executes a robust M&A approach, annual $PM_{2.5}$ air pollution would slightly decrease to 70.94 µg/m3. This is still well above the national annual limit (NAAQS) of 40 µg/m3, but a significant outcome considering anticipated growth in both population and energy demand over the same period (Central Pollution Control Board, 2020).

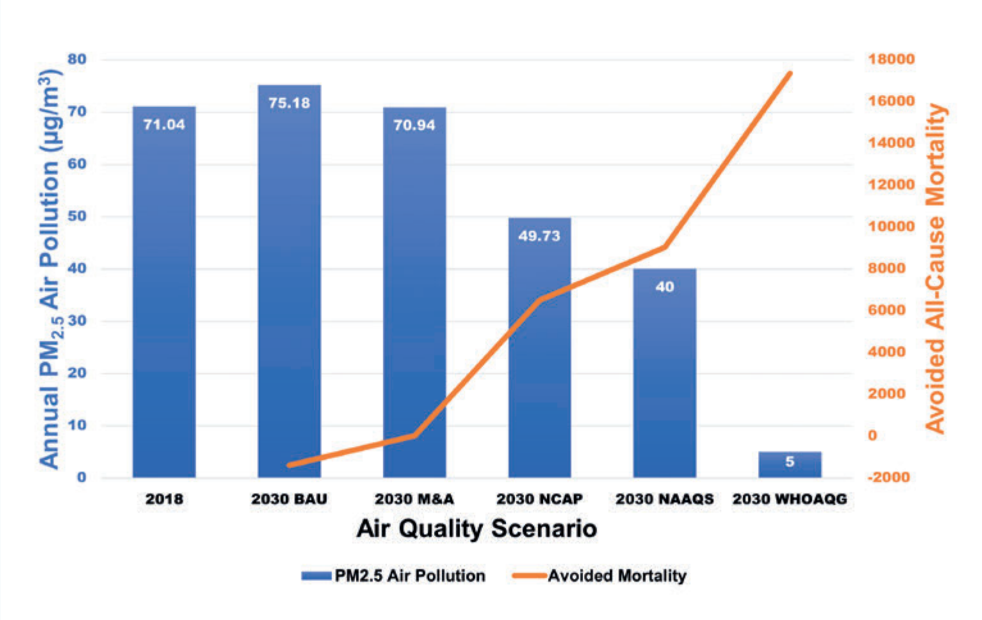

Figure 4: Key air pollution and health results: BenMAP-CE input air pollution values (blue bars) and health effect estimates (orange line) under 2018 baseline, 2030 business-as-usual (BAU), 2030 mitigation and adaptation (M&A), 2030 NCAP (National Clean Air Programme) attainment, 2030 NAAQS (National 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)

Health

The study combined city population projections for 2030, baseline health data, and air pollution epidemiology evidence with air quality modelling results using BenMAP-CE (Figure 4) to estimate the health effects of $PM_{2.5}$ air pollution in 2030 under the BAU versus M&A scenarios. Results show that the air quality benefits of M&A actions result in up to 1,414 fewer annual all-cause premature deaths, compared to the BAU scenario.

Modelling also demonstrates that greater ambition to improve air quality will result in more significant health benefits. By 2030, Ahmedabad could avoid between 6,000 and more than 17,000 annual premature deaths if NCAP targets, NAAQS limits, or World Health Organization $PM_{2.5}$ air quality guidelines (WHOAQG) are achieved (Figure 4).

Limitations

Computational constraints meant researchers did not undertake a year-round, meteorology-constant simulation, nor run a modelling method across a range of future years. As a result, the portion of air pollution change between 2018 and 2030 due to changing meteorology alone could not be determined.

Additionally, the team did not have access to cause- or age-specific daily mortality data for Ahmedabad. Therefore, researchers were unable to estimate potential health co-benefits for residents under 25 years old. Since children are especially vulnerable to air pollution health harms, the avoided mortality co-benefits will therefore be underestimated.

End-users

Municipal, state and central government pollution control managers have been briefed on the results of this study and on ways that health considerations can be better integrated into planning efforts, including for implementation of the National Clean Air Programme in Ahmedabad.

Lessons learned

1. Results demonstrate that local actions that respond to climate change through M&A policies can achieve substantial air quality and health co-benefits at the local level.
2. 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 carbon dioxide pollution.
3. Modelling provides a blueprint for future studies to estimate local air quality and health co-benefits of climate change responses. Such research can help the public understand how climate action can deliver cleaner air. It can also strengthen the understanding and implications of policies that affect energy use and air quality, such as the India Cooling Action Plan, India's climate change goals under the United Nations Framework Convention on Climate Change, and further implementation of the NCAP.

Policy recommendations

1. Move India's energy systems away from fossil fuels (coal, oil and gas) and towards renewable sources;

2. Implement low-cost adaptations to mitigate for extreme heat such as cool roofs that keep houses cool. These adaptations help deliver savings and reduce demand for energy;
3. Use well-established models that estimate the health impacts of air pollution, to strengthen support of health-protective policies;
4. Adopt interdisciplinary practices to enable comprehensive learning opportunities for team members, local policy makers and wider communities.

Acknowledgements

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Further information on this research is available at:

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