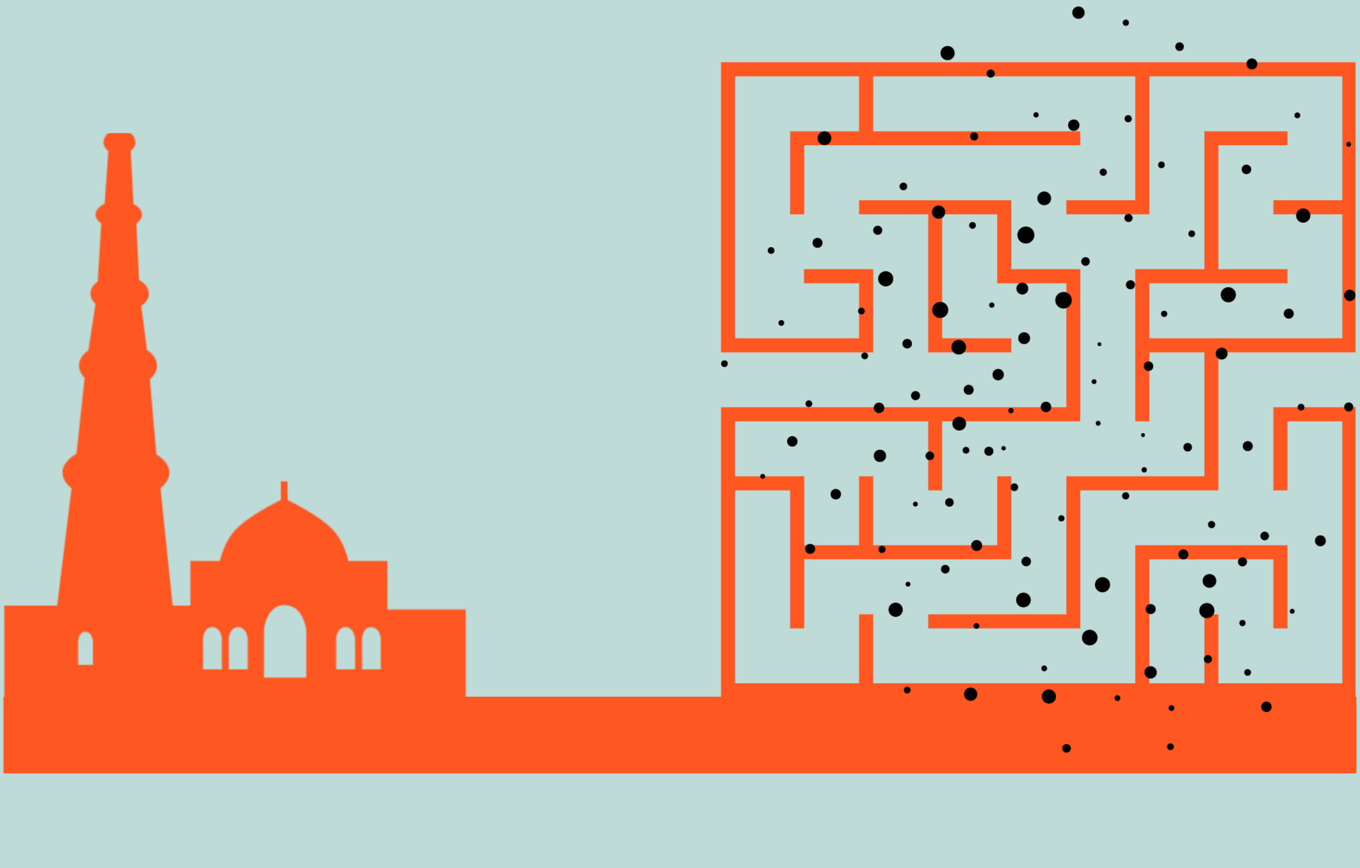
Five Reasons Why Delhi's Air Pollution Problem is Complex

Sarath Guttikunda



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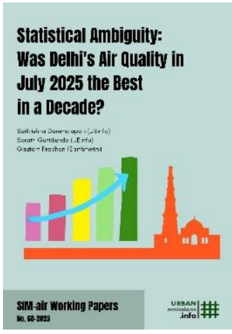

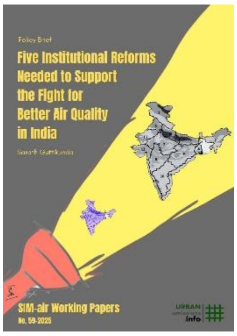

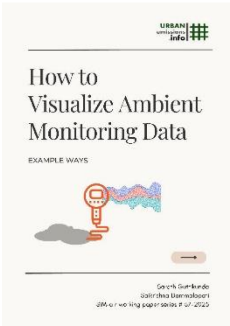

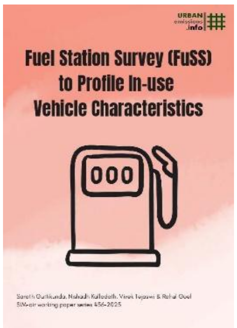

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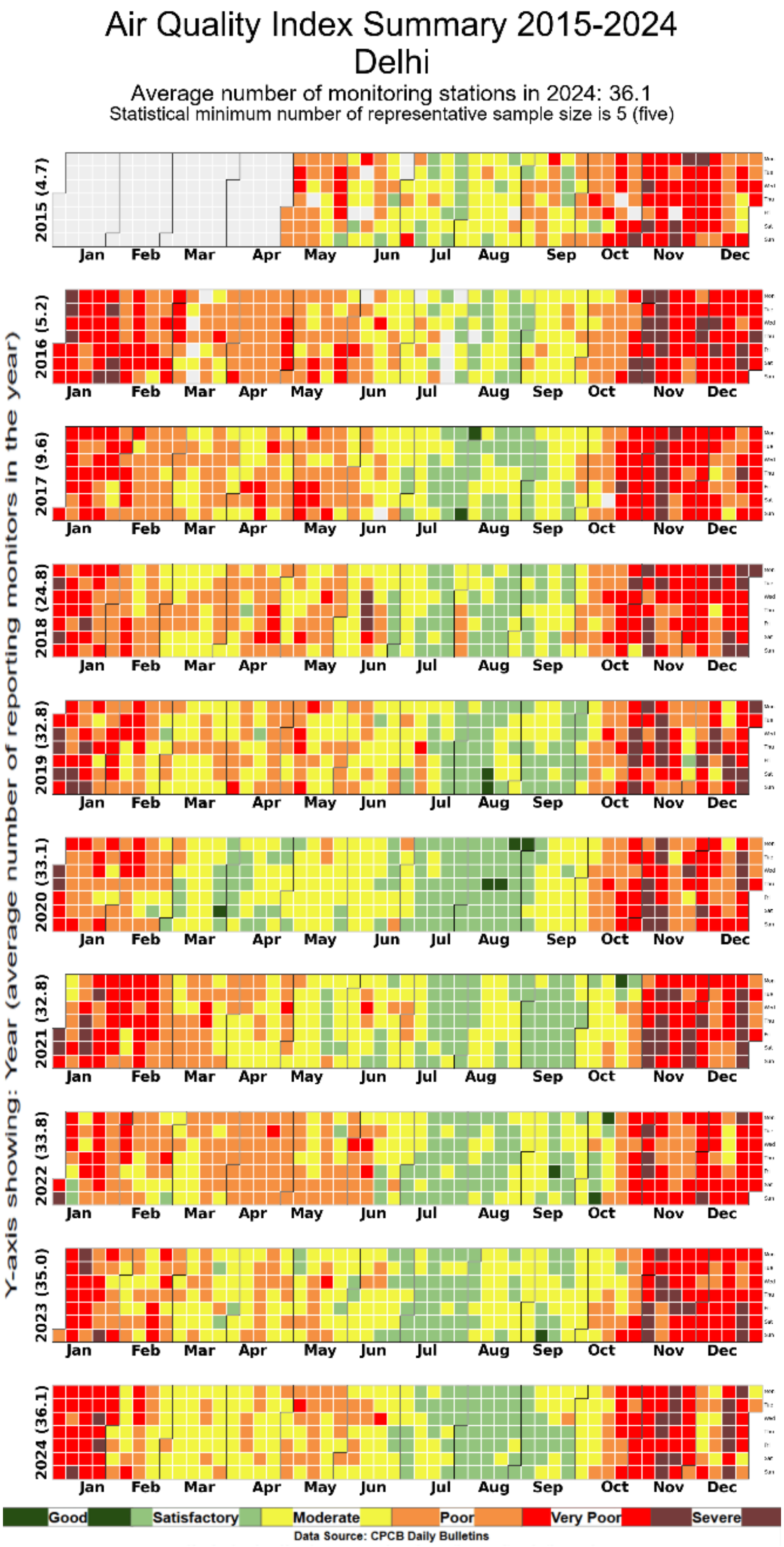
Policy Brief

Five Reasons Why Delhi’s Air Pollution Problem is Complex



Delhi's struggle with air pollution has persisted for a long time, and the city has consistently been ranked among the most polluted urban centers [1]. As a major political and administrative hub, Delhi's air pollution problem remains a recurring and prominent topic, constantly in the public eye [2]. This persistent issue has kept the city in the news, drawing significant international interest from both the media and the research community [3,4]. While the problem is year-round, media and public attention to the topic is the most before and during the winter months (Oct-Feb), when the pollution levels are the highest.

This is a complex reality, as it has occurred despite a great deal of positive work and concerted efforts to combat the issue [1,5-9].

- In the 1990s, Delhi's judiciary ordered public transport to switch from diesel to CNG, then taxis, 3-wheelers and later extending to personal passenger vehicles and small freight vehicles. This intervention continues to be a pivotal decision in Delhi's air quality management history.
- India introduced vehicle and fuel standards in the 1990s, upgrading over 25 years to Bharat Stage VI norms, which now ensures all new vehicles are cleaner across the country, along with incentives for electric vehicles.
- The Eastern and Western Peripheral Expressways, opened by 2018, rerouted heavy diesel trucks away from Delhi, easing congestion and lowering the share of their exhaust emissions in the city.
- The Delhi Metro expanded to 400 km across 10 lines with 250+ stations, carrying millions daily and limiting the growth of private vehicles on the roads.
- Cleaner fuels like piped gas, LPG, and electric stoves now power many households, though biomass remains common in poorer areas.
- Despite better collection and segregation push, Delhi's landfills at Ghazipur, Okhla, and Bhalaswa are over capacity.
- Solar capacity in India has surpassed 100 GW; in Delhi, smart metering and grid upgrades support renewable integration.
- The NCAP launched in 2019 aimed to cut PM by 20–30% by 2024 in 130+ cities, stressing dust control from roads, construction, and material handling, which has helped reduce PM_{10} levels [10].

Here are the FIVE reasons why Delhi's air pollution is still complex to address.

1. Numbers game: Delhi is a megacity with 20+ million inhabitants
2. Urbanization: Expanding Delhi's footprint
3. Landlocked: Delhi cannot solve this problem alone
4. Geography and Climate Change
5. Blame games: Delhi's intersecting emission sources

Numbers game: Delhi is a megacity with 20+ million inhabitants

Delhi has access to the most advanced vehicle standards, fuel quality norms, and regulatory frameworks in India. The city has adopted cleaner fuels like CNG, implemented Bharat Stage-VI emission norms, and expanded mass transit options like the metro, and is now pushing for electric buses replacing CNG. These measures reflect serious policy effort and technology adoption.

However, managing pollution in a city of this scale is ultimately a numbers game. Over 20 million residents need access to energy for cooking, heating, and daily living. While many households use LPG and electricity, biomass fuels such as wood, coal, and agricultural residues remain common, especially in low-income settlements, informal construction sites, and peripheral neighborhoods (approximately 15% of the total population[1]). These fuels continue to contribute substantially to indoor and outdoor emissions.

In winter, when temperatures fall below 14–15°C, heating demand increases sharply. Households and workers often burn whatever fuels are accessible, including biomass, coal, wood, and even waste materials. These combustion practices add to the city's emissions burden just as atmospheric conditions become less favorable for dispersion. Cold-season meteorology compounds the challenge: lower wind speeds and reduced mixing heights trap pollutants closer to the ground, intensifying exposure [11].

Transport demand adds another layer. Delhi has over 12 million registered vehicles, with thousands more entering daily from satellite cities. While new emission standards make vehicles cleaner at the individual level, the sheer growth in numbers and their usage on the roads offsets these benefits. Personal mobility demand continues to rise, yet the bus fleet has not kept pace. In 2000, Delhi required at least 15,000 buses; today, the fleet stands at fewer than 6,000, even as the metro operates close to full capacity. This imbalance sustains reliance on private vehicles, worsening congestion and emissions.

Other urban pressures amplify the situation. Population and commercial activity continue to expand, but waste management infrastructure has seen little capacity addition. As a result, open burning of waste persists across many parts of the city. Similarly, construction demand has increased with population growth, contributing to high levels of dust from roads, building sites, and material handling.

[1] The number is based on the 2011 census and has been updated using data on LPG connections and fuel supply constraints since the last survey. However, under the stacked fuel methodology, this still represents an underestimation.

All these factors highlight that Delhi's pollution challenge is fundamentally a numbers game. As demand for energy, mobility, and infrastructure grows, and with limited capacity to reduce emissions proportionally, the city continues to face a complex and persistent air quality problem.

2 Urbanization: Expanding Delhi's footprint

Since 1975, Delhi's urban built-up area has expanded rapidly, increasing at least fourfold. This growth was closely tied to the evolution of its road network. What was once contained within a single ring road expanded into a second, and by the late 2010s, the airshed was reshaped by the construction of larger bypasses, including two major expressways forming an outer ring. These new corridors were designed to ease movement, accommodate expanding residential and commercial areas, and divert freight traffic away from the city center. The continuous addition of roads, highways, and flyovers reflects the rising mobility demand in a city where both population and economic activity have grown significantly.

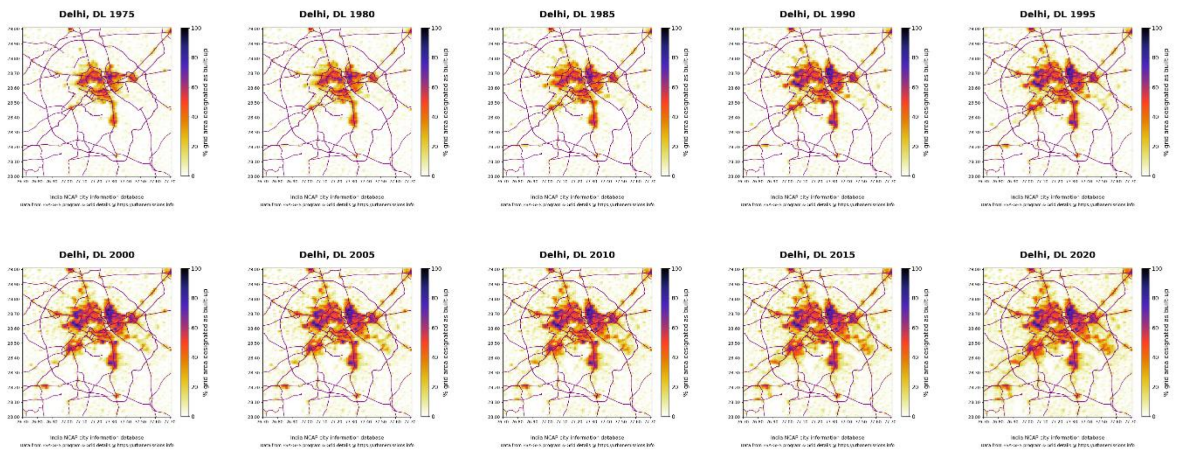


Figure: Global Human Settlements layers (Source: Copernicus, EU)

While the road network has expanded, congestion levels have not decreased. Instead, traffic volumes have grown alongside road capacity, leading to persistent delays and slower travel speeds. According to the TomTom Traffic Index, traffic congestion in Delhi remains a persistent challenge, particularly during rush hours. A typical 10-km morning commute now takes about 25 minutes, while evening travel slows further to around 30 minutes. In 2024, it is estimated that drivers spent nearly 76 hours stuck in traffic compared to free-flow conditions -- an increase of 3 hours and 21 minutes over 2023 levels. This rising congestion highlights growing pressure on the city's mobility infrastructure and demonstrates that new and more roads alone cannot keep pace with mobility demand, and without parallel investment in public transport, safe walking and cycling infrastructure, and community engagement to encourage behavioral shifts, the traffic-related emissions and congestion problems will continue to remain a challenge.

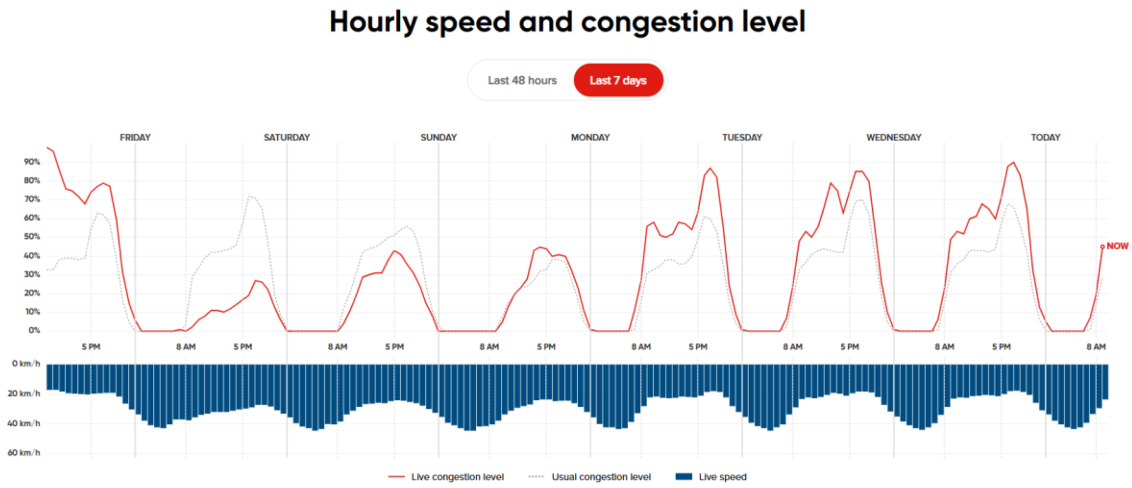


Figure: Snapshot of live traffic conditions and congestion levels compared to business as usual (historical) averages – August 14-21, 2025 (Source: TomTom Traffic)

The rapid increase in the urban built-up area is also a proxy for the growing demand for energy, amenities, and commercial facilities. Each new housing cluster, shopping complex, or industrial zone requires electricity, water, and waste services, which in turn leads to higher emissions and greater pollution loads. The link between built-up growth and energy demand highlights how expansion is not just about land use but also about the scale of supporting infrastructure that drives resource consumption.

More residential construction, both through horizontal sprawl into peri-urban areas and vertical growth in the form of high-rise apartments, expands the city's urban footprint and generates significant amounts of construction debris and dust. Demolition, excavation, and material handling all add to particulate pollution, with dust remaining a persistent challenge even after projects are completed.

Outside the city, this construction boom has spurred higher demand for building materials, particularly bricks. Brick kilns in the surrounding region are operating at larger scales to meet urban demand, creating additional emissions of particulate matter, black carbon, and gases that further degrade regional air quality [12].

Urban growth has a complex relationship with development and air pollution. Air pollution in this context is not merely a byproduct but an outcome of how development is planned and managed. Without careful integration of clean technologies, sustainable materials, and resilient infrastructure, urban growth risks locking cities into high-emission pathways. Conversely, if aligned with clean energy, efficient transport, and improved waste systems, growth plans can reduce future pollution burdens.

Landlocked: Delhi Cannot solve this problem alone

Delhi sits within the Indo-Gangetic Plain, which is recognized as one of the most polluted airsheds globally[2]. While the city has an administrative boundary, there are no physical barriers separating it from the wider region – the National Capital Region (NCR)[3]. This means that air masses and pollution flow freely across states and cities, making Delhi part of a continuous and shared airshed.

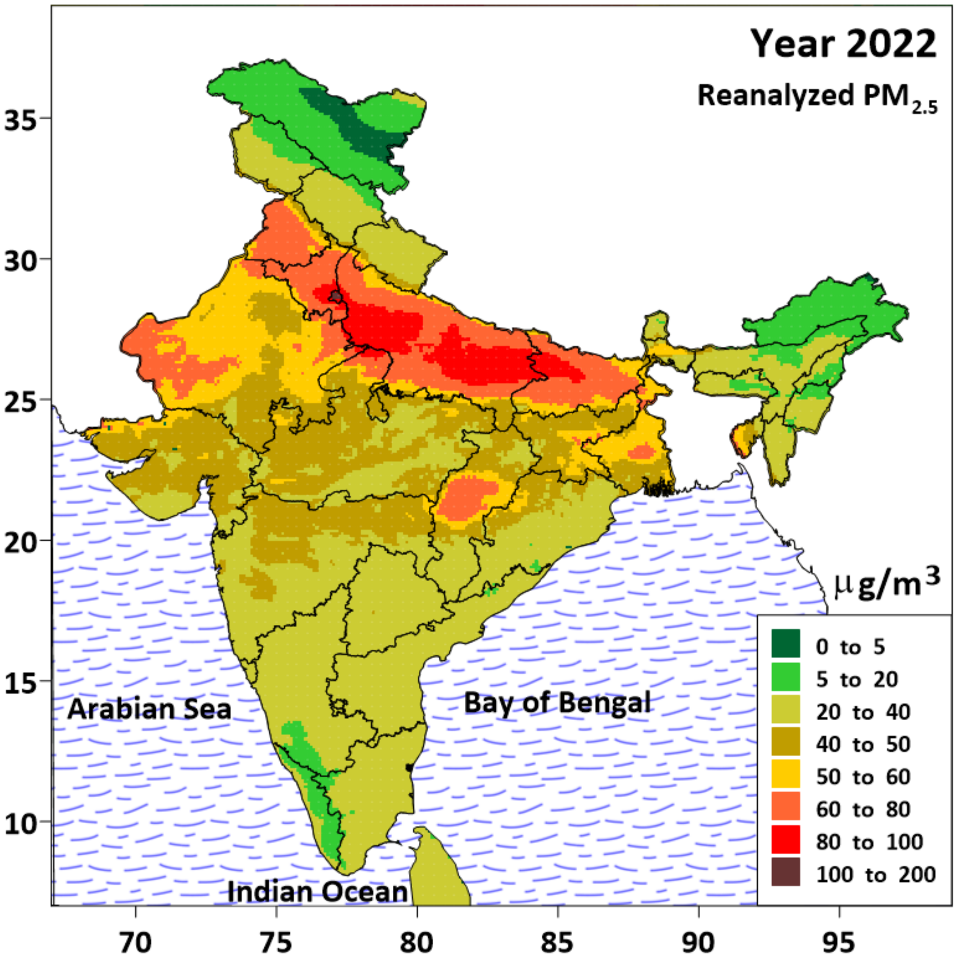


Figure: Reanalyzed $PM_{2.5}$ concentrations (Source: WUSTL)

Studies have estimated that of the annual average $PM_{2.5}$ pollution measured at the monitoring stations within Delhi, more than 50% of the load can be attributed to sources outside the city's administrative boundary [13]. From outside Delhi, we have

[2] Beyond Boundaries: Understanding Airsheds and Particulate Matter (PM2.5) in India, World Bank, 2025 https://www.youtube.com/watch?v=7QimV_5x68g

[3] The National Capital Region (NCR) is a planning region centered around Delhi that includes districts from Haryana (14), Uttar Pradesh (8), and Rajasthan (2), includes major satellite cities such as Gurgaon, Noida, Ghaziabad, and Faridabad, which are key hubs for residential growth, commerce, and industry. For reference, NCR covers an area 37 times that of Delhi. NCR was created to promote balanced development, reduce migration pressures on Delhi, and manage resources across an integrated urban system. And the regional also shares common challenges of infrastructure demand, transportation, and air pollution, requiring (challenging) coordinated policies and planning across state boundaries.

seasonal dust storms that carry large amounts of mineral dust that add to coarse particulate pollution; agricultural fires, especially during post-harvest periods, release smoke and fine particles that travel across states with prevailing winds. The population count of IGP (~600 million) is among the highest in the world, driving intense demand for housing, transport, energy, and goods. Agriculture also plays a central role in the regional economy, with links to both food supply and industrial production chains. In addition, Delhi lies at the intersection of major freight corridors, with a heavy movement of trucks and commercial vehicles transporting goods across the country in both east–west and north–south directions. IGP also hosts many power plants[4], heavy industries, and brick kilns, which together release substantial amounts of emissions [12,14,15]. These overlapping regional sources create a complex background level of pollution, making Delhi's local air quality highly dependent on external factors.

Even if Delhi implements strong local measures to control emissions within the city boundary (such as zero emission transport, zero waste burning, zero dust on roads, and clean cooking), the benefits are offset by high levels of transit pollution and cross-boundary inflows. Neighboring satellite cities, which are rapidly expanding in population and economic activity, also demand large amounts of energy and commercial inputs. Their emissions add to the urban burden, limiting the impact of interventions taken only within Delhi.

In this context, ***Delhi's air quality management cannot be approached in isolation***. Any meaningful progress requires regional coordination (going beyond NCR and across IGP airshed) and shared goals (aka clean air for all).

4 Geography and climate change

Delhi experiences significant seasonal diversity, with a dramatic swing in temperatures between the cold and hot seasons. Average daily high temperatures in the cold season, from December to February, are around 23°C. This is in stark contrast to the hot season, which runs from April through July, where average daily highs peak above 40°C in late May. The difference between these seasonal high temperatures is a substantial 17 degrees Celsius. Winter nights are distinctly cold, with average daily low temperatures dropping to a minimum of 8°Cin January. This pattern is a feature of the geography in northern latitudes, where temperatures begin

[4] While the power plants within Delhi's immediate vicinity and in Delhi are closed or converted to operating on gas, this installed capacity is under 1000 MW. In June 2025, Delhi recorded its highest peak demand more than 8000 MW; most of this originates from the power plants in the IGP region. https://www.thehindu.com/news/cities/Delhi/delhi-records-highest-peak-power-demand-on-june-11/article69685542.ece

to fall at the start of winter and remain low for the duration of the season. Low temperatures demand space heating, which begins when the surface temperatures start to drop below 15°C in November, resulting in more surface emissions and consequently air pollution.

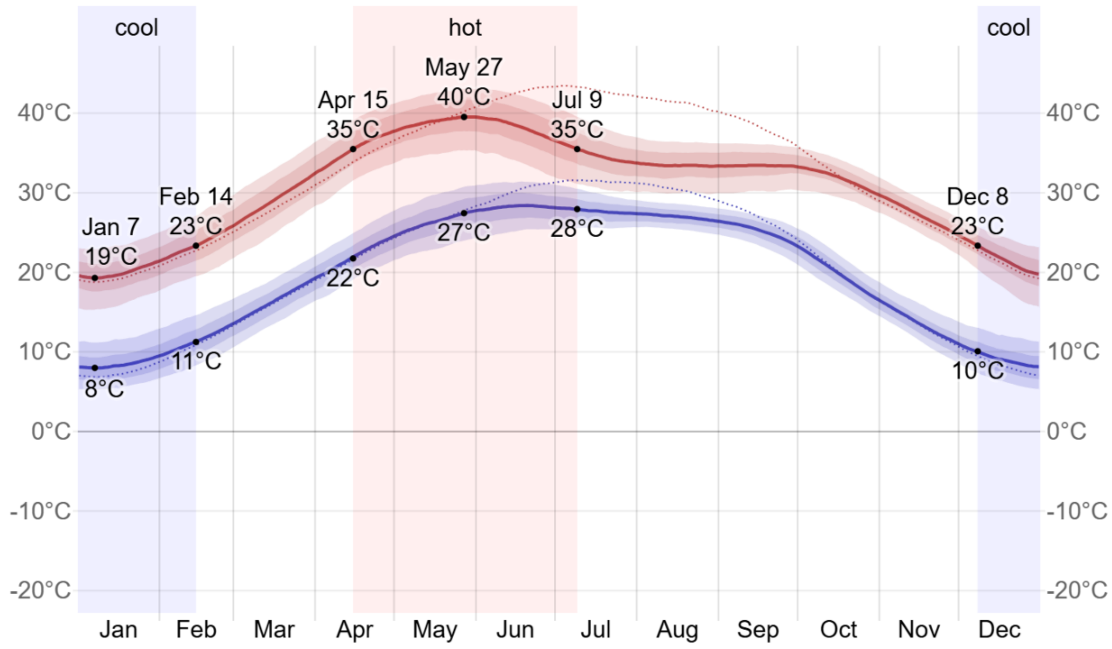


Figure: Historical average high and low temperature in Delhi. The daily average high (red line) and low (blue line) temperature, with 25th to 75th and 10th to 90th percentile bands. The thin dotted lines are the corresponding average perceived temperatures (Source: WeatherSpark)

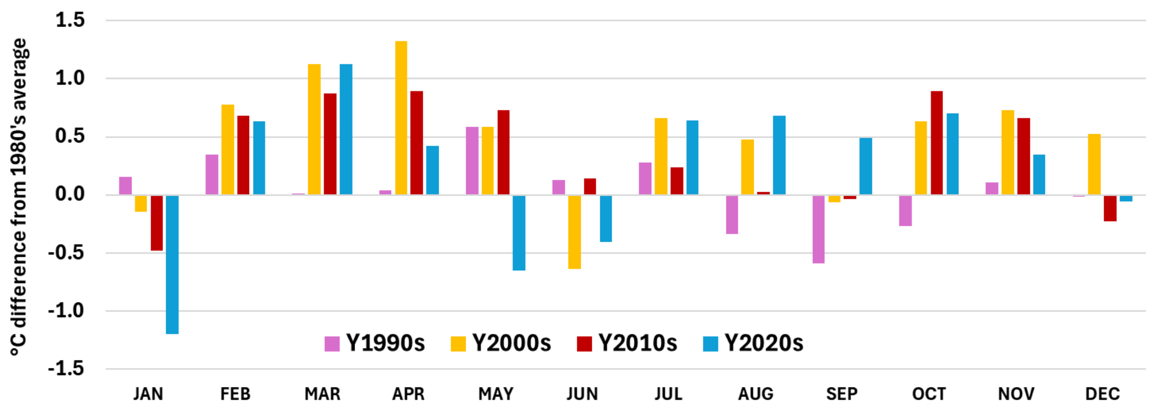


Figure: 2m-Temprature variation from 1980's average, extracted from ERA5 reanalysis field, averaged over the grids covering the Delhi airshed (Source: NCEP/NOAA PSL)

The impact of long-term climate change on surface temperatures is directly linked to changes in local air pollution and energy use patterns. The influence of climate change on Delhi's winters cannot be overlooked, as average winter temperatures have steadily declined over the decades. Data shows that since the 1980s, the mean temperature in January has fallen by about 1.2°C, while December averages have dropped by 0.1°C in the 2020s. Even small changes in winter averages have significant consequences, particularly for household and community energy demand. This additional combustion adds to the city's air pollution burden, especially during a season already characterized by poor atmospheric dispersion conditions.

This is an emission source, which cannot be avoided, and the only solution is the elimination of burning all biomass, fossil fuel, and waste materials, and a shift to cleaner alternatives like electric and gas heaters. Managing this source, however, will take more than a technical fix; it requires sustained community engagement, financial assistance, and institutional support. Low-income groups and neighborhoods need targeted help to transition, as they often rely on cheaper, readily available fuels for survival. Without this social and economic support, the shift to cleaner options will remain limited in scope and continue to be a major source of emissions during the critical months.

5 Blame Games: Delhi's intersecting emission sources

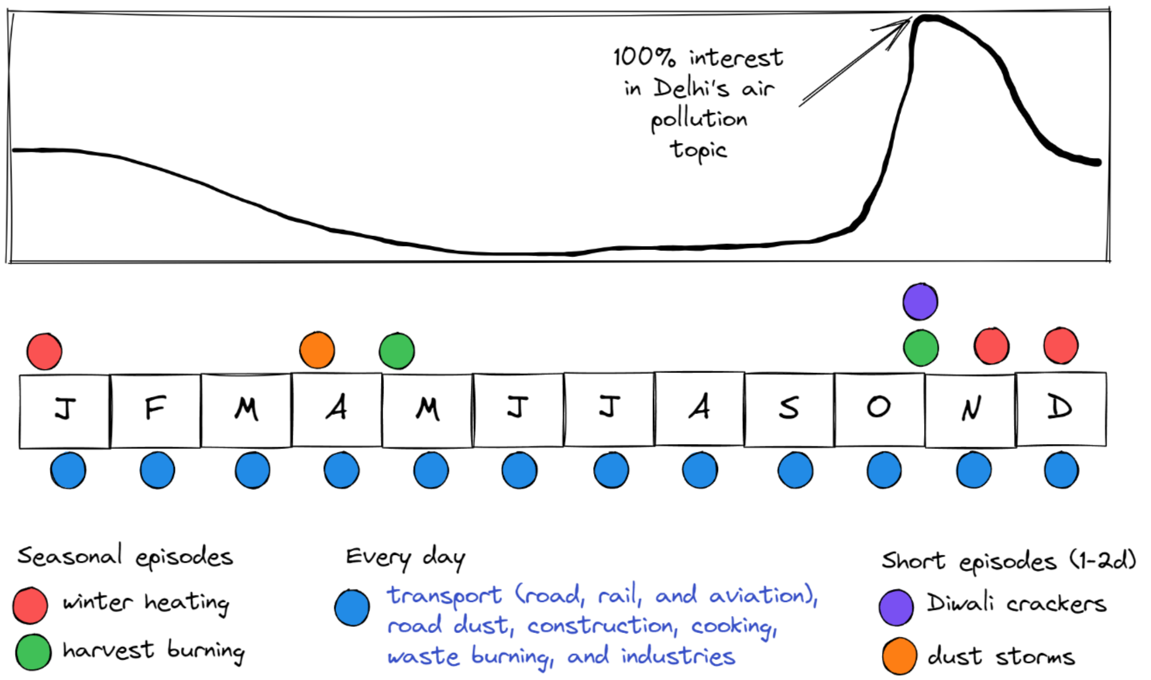


Figure: Illustration of public interest in "Delhi's air pollution" topic, extracted from Google Trends and a summary of pollution sources contributing to Delhi's air quality

Transport often receives undue blame as the primary cause of Delhi's air pollution. While vehicles are a visible contributor, it is a misconception to consider them the main culprit. Despite multiple source apportionment studies estimate transport's contribution from 10% to under 30% to annual $PM_{2.5}$ pollution loads (depending where the samples are collected for the study), the misunderstanding continues to exist [1,16-18].

Delhi and its surrounding region experience pollution from a wide variety of sources that operate year-round. These include emissions from residential energy use, industries, waste burning, and dust from construction and roads. In addition, certain sources are highly seasonal but add large loads when active, for example, winter heating, when households and informal settlements burn coal, wood, and other fuels to stay warm. This combination of constant urban sources and seasonal spikes makes Delhi's pollution problem complex, and transport is only one part of a much larger picture.

Public and media attention on Delhi's air pollution often peaks during Diwali and the post-harvest burning season. This has created a common misunderstanding that these events are the main causes of pollution in the city. In reality, post-harvest fires before the winter season occur for only about three weeks, and the Diwali spike lasts for a single night [19,20]. Despite their short duration, these sources receive a disproportionate share of coverage -- more than 70% of annual media reporting on air quality focuses on them [3,4]. This emphasis, while highlighting important seasonal contributors, overshadows the broader reality of year-round emission sources.

Diwali-related firecracker emissions and agricultural fires should not be dismissed; they add significant loads during their occurrence and need to be addressed through better enforcement and alternatives. However, focusing only on these events risks neglecting the constant, underlying emissions from transport, industries, waste burning, and household fuels that drive exposure across all seasons. Even though the monsoon brings temporary relief with cleaner air, the average exposure for residents remains high over the year.

Effective air quality management requires sustained attention to the daily, structural sources of emissions, alongside seasonal peaks.

Path forward

The objective of this brief is not to call for additional studies. Ample evidence already exists to identify where the key sources of the problem lie, and what patterns of emissions drive poor air quality.

The objective of this brief is also not to call for controlling urban growth. Expansion is a natural outcome of increasing population and economic activity. The focus, instead, should be on shaping this growth in ways that are sustainable -- by embedding cleaner energy choices, strengthening public and non-motorized transport, and building infrastructure that is resilient and less polluting.

Most importantly, the objective of this brief is to emphasize the need for regional coordination. Air pollution cannot be solved within city boundaries alone, and joint efforts across administrative lines are essential. Coordinated action across the Indo-Gangetic airshed has the potential to deliver greater benefits than fragmented measures taken in isolation.

Air quality can improve only when emissions from all contributing sources—large and small—are reduced to the maximum extent possible. Tackling just one sector or focusing on a few visible sources will not bring lasting improvements, since pollution in Delhi and across the region is the combined result of multiple overlapping activities throughout the year.

Effective management begins at the source of emissions, not after pollutants have already entered the air. Once in the atmosphere, pollution disperses, mixes, and becomes nearly impossible to capture. Technologies like air purifiers, smog towers, or mist fountains may create a sense of visible action but do little to address the actual problem [21]. At best, they provide limited, localized relief, but they cannot substitute for comprehensive source reduction.

Although air pollution is often presented as a complex issue involving science, health, and governance, the core principle of its management is straightforward: eliminate or minimize emissions at their origin.

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