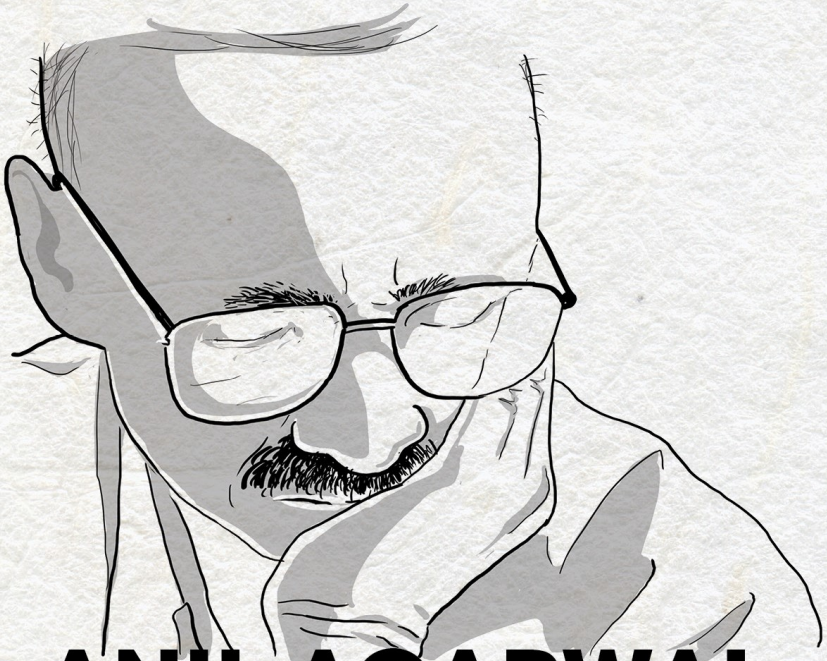

ANIL AGARWAL DIALOGUE 2026

Air quality, data and air pollution sources– connecting the dots to inform action

Anumita Roychowdhury

With Sharanjeet Kaur, Jyoti Kumari
Shubham Srivastava, Kalyani Tembhe

Classroom 4: Air pollution source apportionment, monitoring, estimation and health impacts

Air quality data hit the headlines

Data quality and allegation of data manipulation in Delhi

- **Sprinkling water near monitors; setting up new monitors in clean areas**
- **Switching off monitors & data blackouts on high-pollution nights,** particularly Diwali 2025,
- **"Capping" AQI -- the 500-limit cap:** Activists petitioned the CAQM to remove the AQI cap of 500 – that the system often fails to represent the true magnitude of the crisis.
- **Removal of "Outliers":** Allegations that extremely high pollutant readings are flagged as "outliers" and removed by CPCB, even when weather conditions support such spikes.
- **Sensor overload:** Monitoring equipment not designed to measure hazardous concentrations, leading to sensor failure or intentional shutdowns to protect the machines.
- **Monitors in green areas and adequacy of monitoring in the country**

Downplaying health impacts

- **Denial of pollution-linked deaths:** -- denying direct deaths linked to pollution, citing a lack of "causal confirmation"
- **Neurological & reproductive crisis:** Doctors from AIIMS and other hospitals have warned of a **neurological crisis** and reproductive issues (reduced fertility, low birth weight)

*The **Supreme Court** (Nov 2025) directed Delhi government to file an affidavit on the efficiency and integrity of pollution-measuring equipment.*

How the budget and the 16th Finance Commission have ignored dedicated funding of NCAP

- **Net reduction in direct funding:** A marginal rise in overall MoEFCC budget (~8%)' "Control of Pollution" scheme slashed by 16% (Rs 209 crore), -- from Rs 1,300 crore to Rs 1,091 crore.
- **Marginalized NCAP support:** Funding for the NCAP is now spread thin across 131 cities, -- roughly Rs 8–10 crore per city—"pittance" for structural shifts.
- **16th FC's (2026–2031) narrow focus:** Tied 50% of local body grants specifically to "Water and Sanitation" and "Solid Waste Management." No dedicated "Million-Plus Cities Challenge Fund" for air quality performance.
- **Absence of Airshed funding:** No dedicated regional budget for the Indo-Gangetic Plain (IGP) or Delhi-NCR
- **Funds utilization is poor**
- **Reduced budgets disincentivize states** from building the technical capacity for long-term projects.
- **The goal to add 1,000+ new Continuous Ambient Air Quality Monitoring Stations (CAAQMS) is at risk**
- **Inaction to cost India approximately USD 36–40 billion annually** in healthcare costs and lost productivity.

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How and what do we know about air quality?

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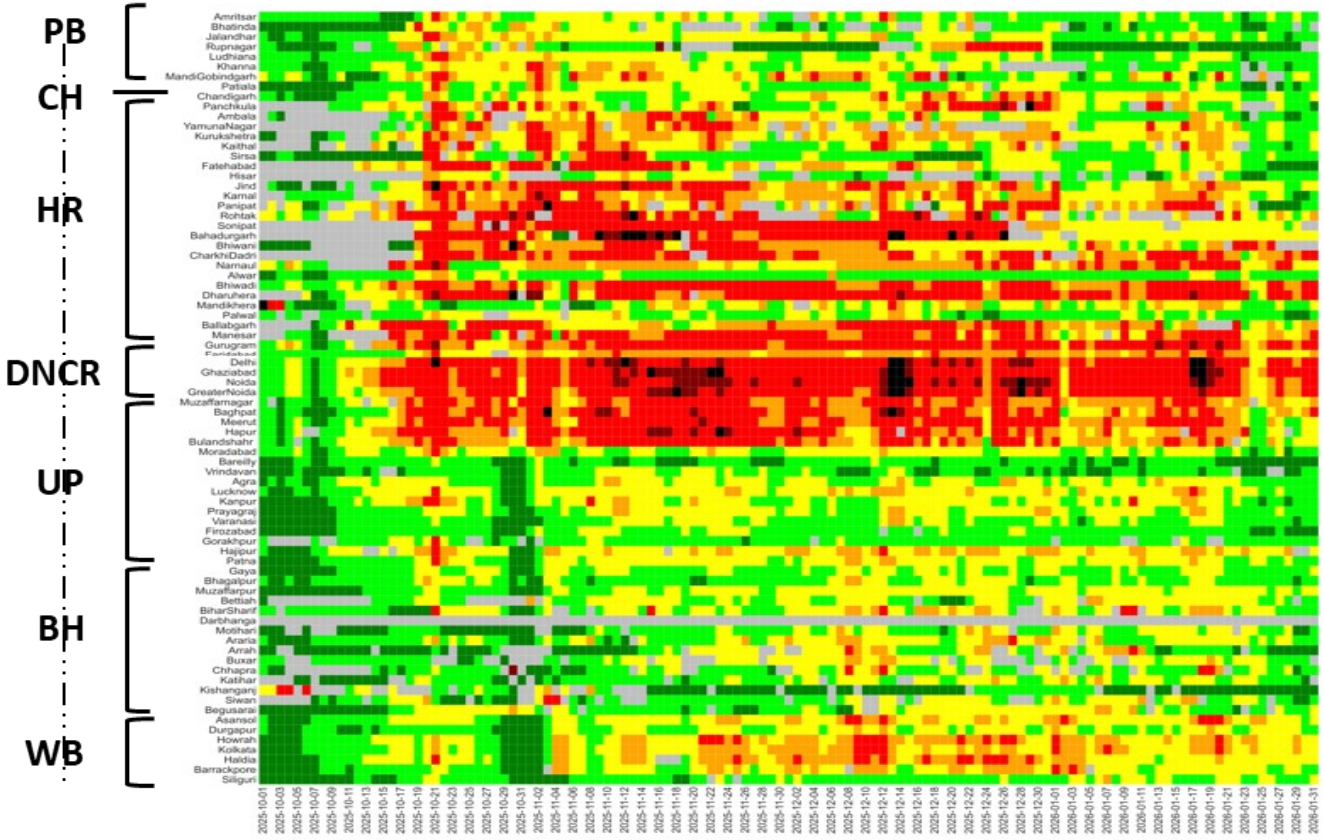
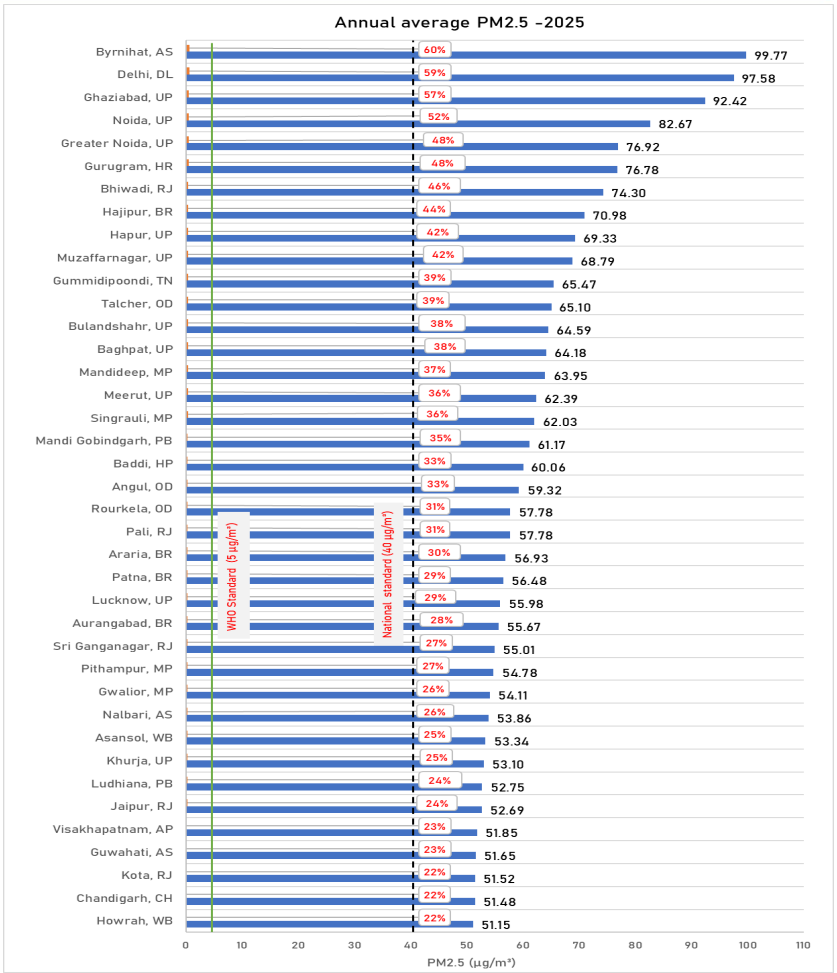
2025-26 Winter Build up of PM2.5 concentration across IGP



Note: Average PM2.5 concentration is based on mean of daily values recorded at CAAQM stations given it has adequate data. Data is from Oct 1, 2025 – Jan 31, 2026

Source: CSE analysis of CPCB's real time air quality data



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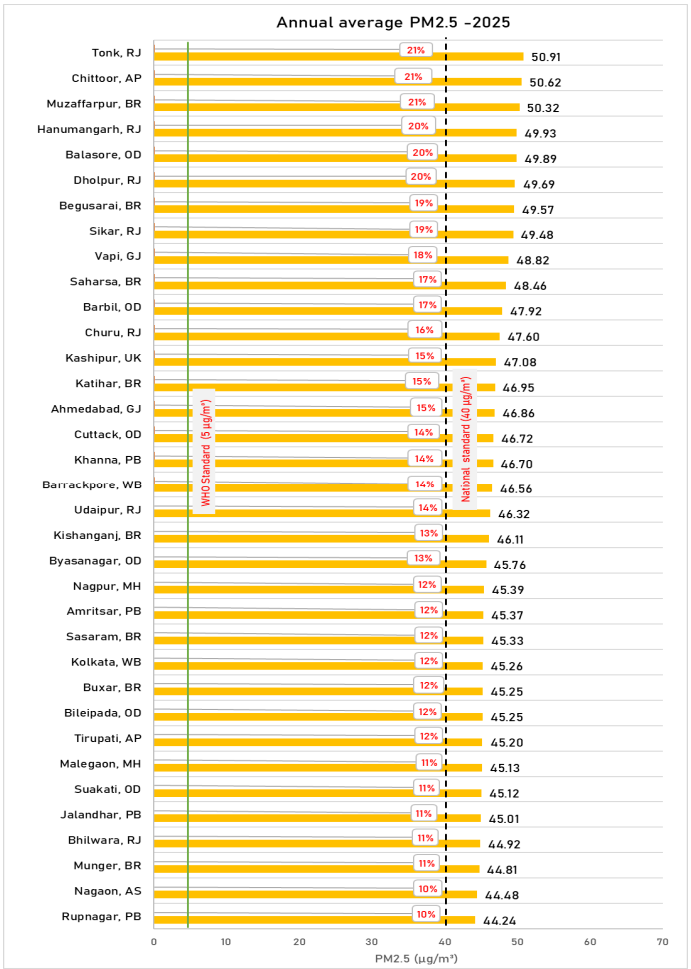
PM2.5 Exceedance Levels & big reduction Targets - 2025

Out of 299 city stations, 228 have sufficient (60%) data
119 cities out of 228, are meeting the annual standard.

High pollution is not limited to major metros; small and medium towns are also heavily impacted:

- **Byrnihat (Meghalaya):** Remains the **most polluted city** for the second consecutive year; *(25% improvement, still 60% more reduction needed)*
- **Highly Polluted Smaller Cities:** Eg Ghaziabad and Noida require over 50-60% reduction.
- **Widespread Problem:** 19 cities, including smaller ones like Greater Noida, Gurugram, Bhiwadi, Hajipur, Hapur, Muzaffarnagar, Gummidipoondi, Talcher, Bulandshahr, Baghpat, Mandideep, Meerut etc. **need to cut levels by 30-50%.**

Note: Average PM2.5 concentration is based on mean of daily values recorded at CAAQM stations given it has adequate data. Cities with data availability of 60% have been considered in this analysis.
Source: CSE analysis of CPCB real time data



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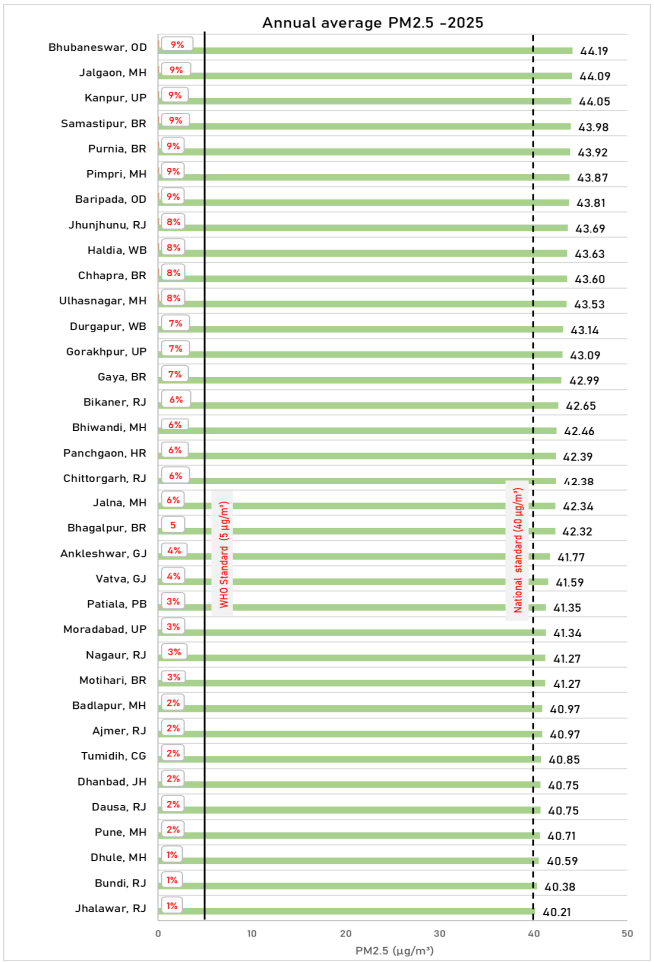
2025 PM2.5 Annual average - Other cities

10 - 20% reduction needed:
Tonk, Chitoor, Muzaffarpur, Hanumangarh, Ahmedabad, Udaipur, Amritsar, Kolkata, Nagpur etc.

Cleanest City in 2025:
Tirunelveli in Tamil Nadu has the lowest level at 15 µg/m³.



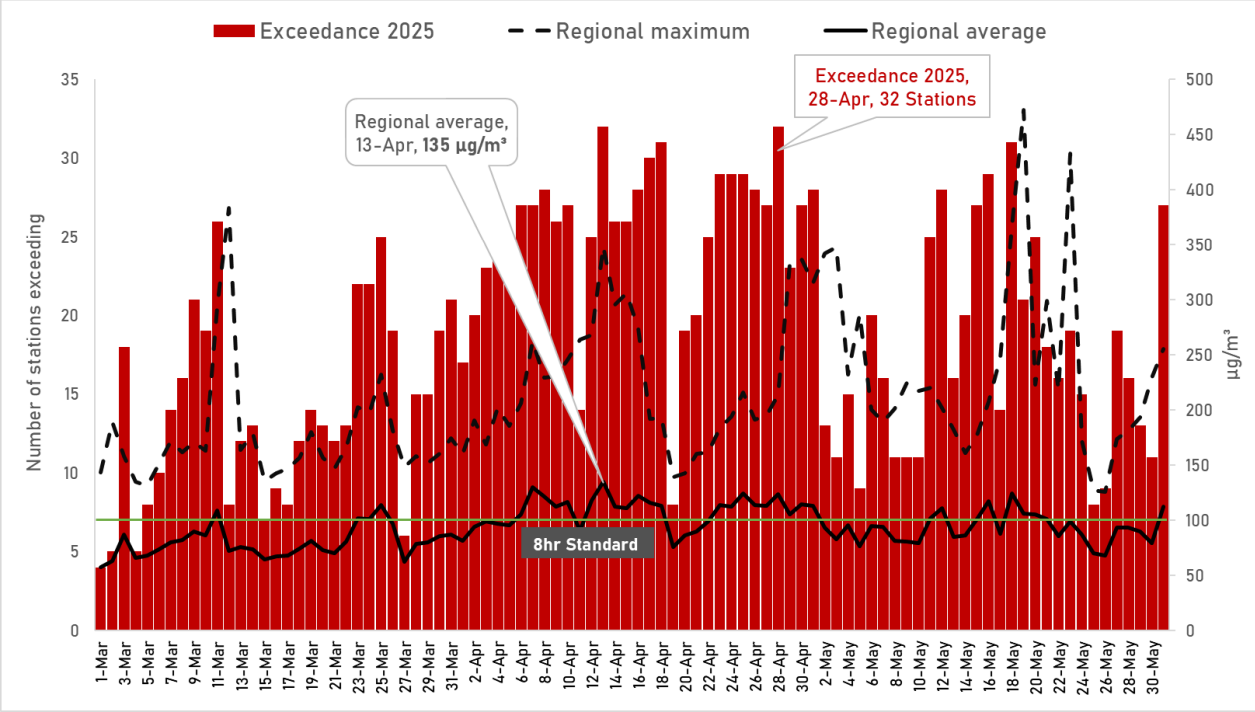
Note: Average PM2.5 concentration is based on mean of daily values recorded at CAAQM stations given it has adequate data. Cities with data availability of 60% have been considered in this analysis.
Source: CSE analysis of CPCB real time data

Emerging rogue in town -- Ozone (O3) Problem – Onset of multi-pollutant crisis

- Ground-level ozone is emerging as a critical summer-time pollutant, with exceedances measured against the 8-hour standard of **100 µg/m³**:
- **Delhi-NCR:** During the summer of 2025 (March-May), ozone exceedances were reported on **all 92 days**.
- **Kolkata and Howrah:** Kolkata reported exceedances on **22 out of 92 days**, while neighboring **Howrah** saw much higher levels with **58 out of 92 days**.
- **Mumbai:** Summer ozone exceedances were reported on **32 out of 92 days**.
- **Bengaluru:** Reported exceedances on **45 out of 92 days**.
- **Ozone hotspots are often located in areas with low levels of NO2 and PM2.5**, indicating a complex chemical relationship between these pollutants.

Daily variation in ground-level ozone exceedances in Delhi-NCR

2025 summer ground-level ozone exceedances were reported on all
92 days between 1 March and 31 May 2025



Note: Based on exceedances recorded at the monitoring stations at Delhi, Gurugram, Faridabad, Ghaziabad, Noida and Greater Noida. Exceedance is computed as daily maximum 8-hr average crossing the ground-level ozone 8-hr standard, i.e. 100 µg/m^3. Period of study is 1 Mar to 31 May 2025. Source: CSE analysis of CPCB real time data.

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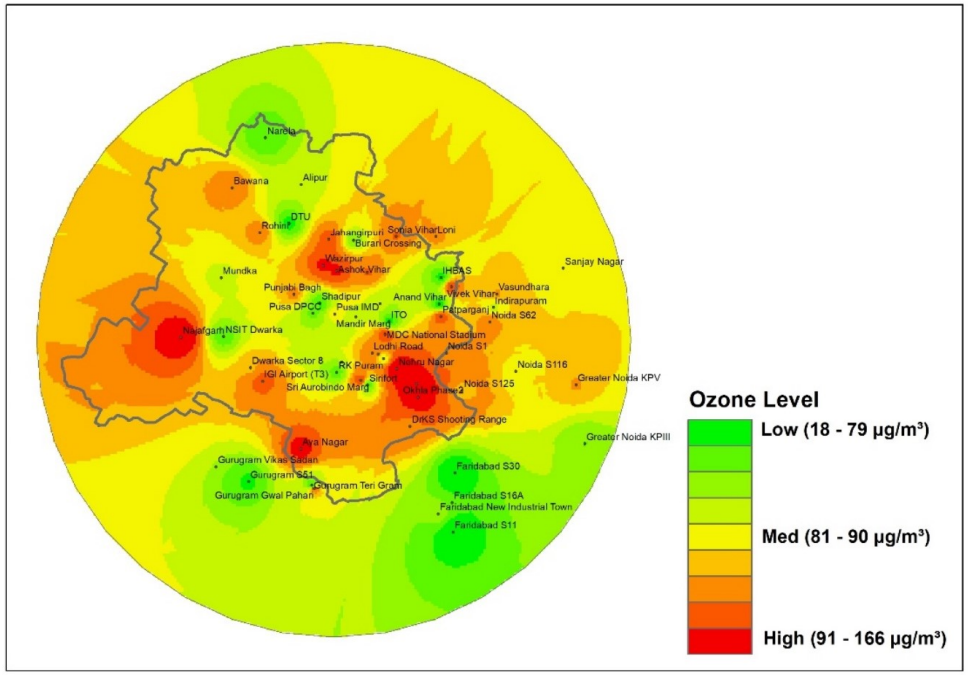
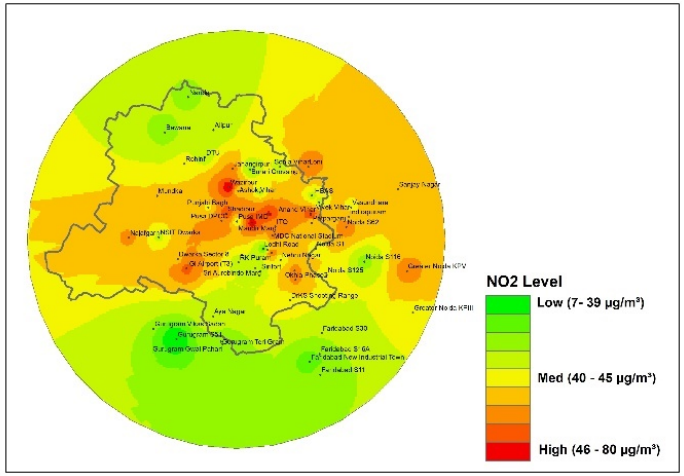
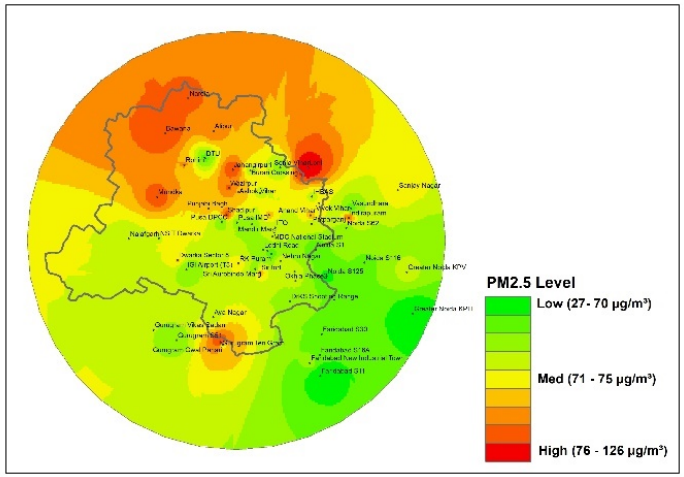
Delhi: Ground-level ozone hotspots are located in the areas with low levels of NO2 and PM2.5



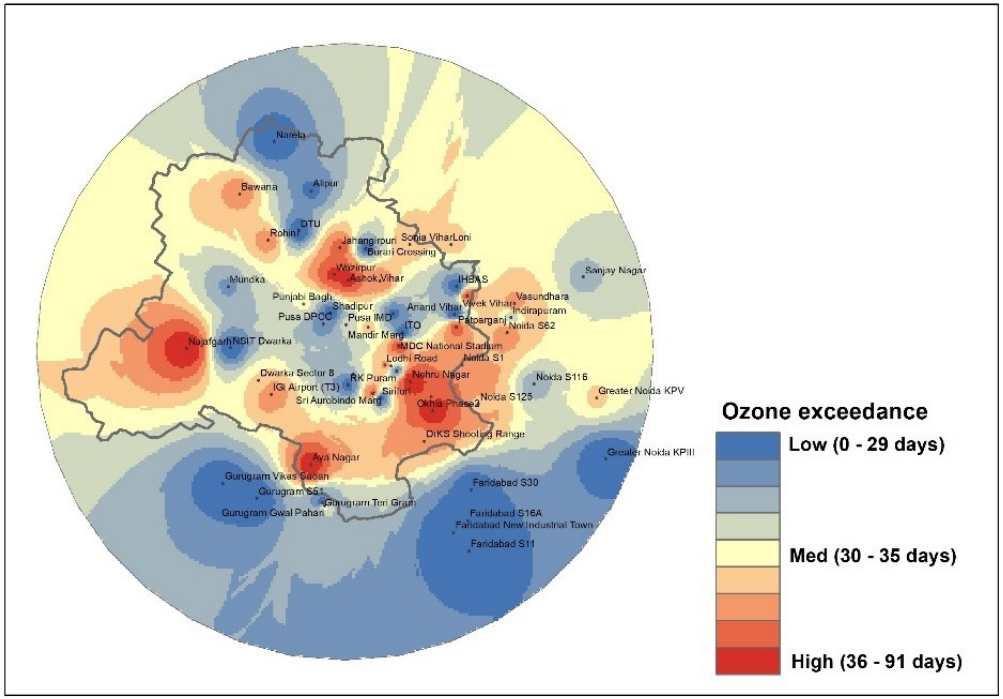




Note: Seasonal average computed as mean of monthly averages based on daily 24-hr average for PM2.5 and NO2, while daily maximum 8-hr average is used for ground-level ozone. Summer is defined as March to May. Data till 31 May 2025. Source: CSE analysis of CPCB real-time data.

ANIL AGARWAL DIALOGUE 2026

Hotspots of Ground-level ozone exceedance in the core Delhi-NCR



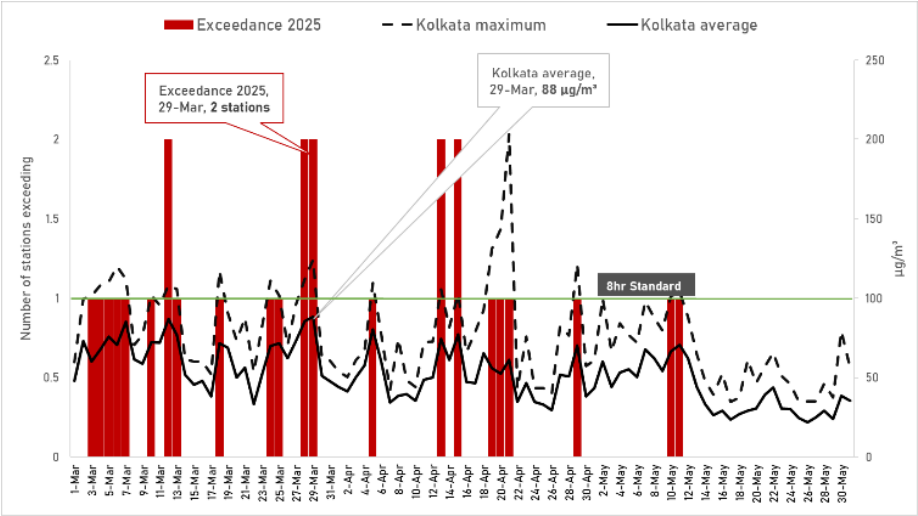
S.No.	Station	Number of exceedance days
1	Nehru Nagar, Delhi	92
2	Najafgarh, Delhi	82
3	Okhla phase II, Delhi	81
4	Ashok Vihar, Delhi	77
5	AyaNagar, Delhi	77
6	Wazirpur, Delhi	72
7	Major Dhyan Chand National Stadium, Delhi	68
8	Patparganj, Delhi	64
9	CRRI Mathura Road, Delhi	62
10	Sri Aurobindo Marg, Delhi	60

Note: Based on exceedances recorded at the monitoring stations at Delhi, Gurugram, Faridabad, Ghaziabad, Noida and Greater Noida. Exceedance is computed as daily maximum 8-hr average crossing the ground-level ozone 8-hr standard, i.e. 100 µg/m^3. Summer is defined as March to May. Data till 31 May 2025. Source: CSE analysis of CPCB real-time data.

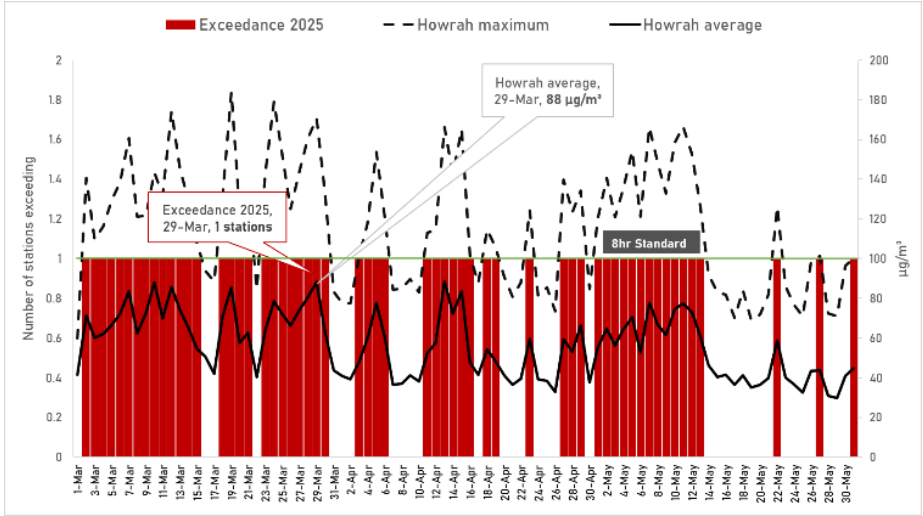
Daily variation in ground-level ozone exceedances in Kolkata and Howrah

Ground-level ozone exceedances were reported on 22 out of 92 days in Kolkata and 58 out of 92 days in Howrah

Kolkata



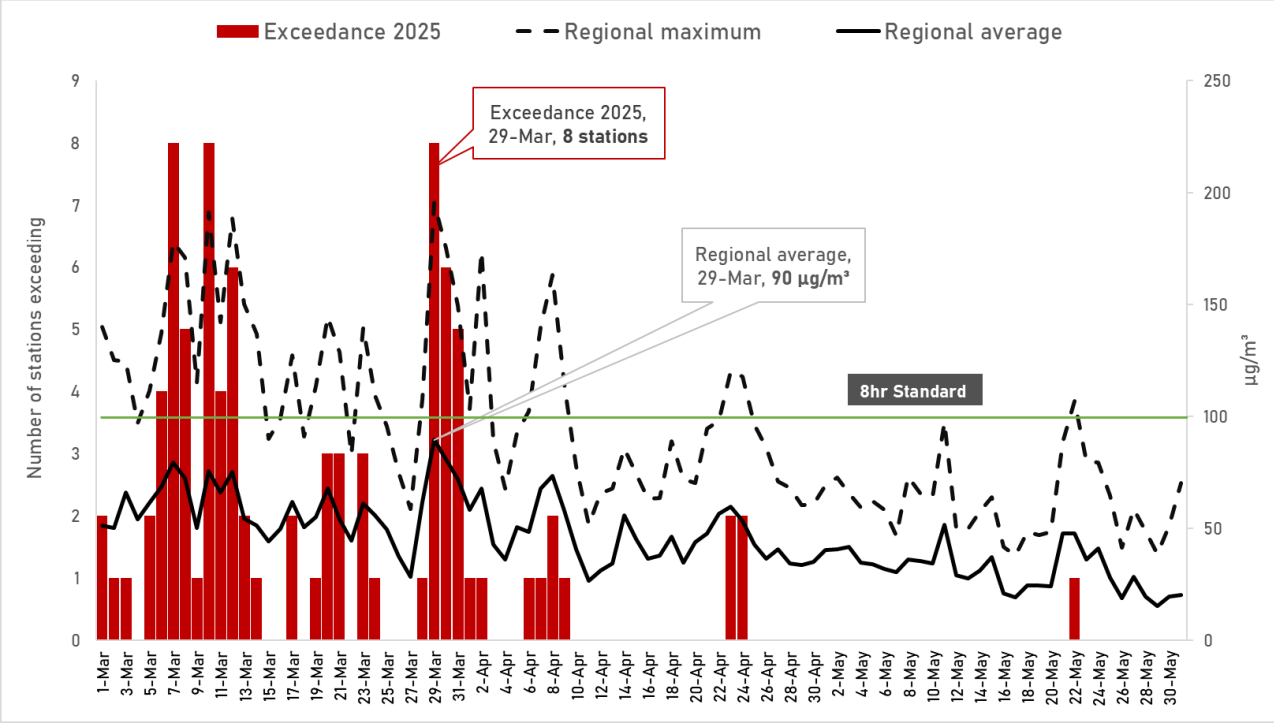
Howrah



Note: Based on exceedances recorded at the monitoring stations of Kolkata and Howrah. Exceedance is computed as daily maximum 8-hr average crossing the ground-level ozone 8-hr standard, i.e. 100 µg/m^3. Period of study is 1 Mar to 31 May 2025. Source: CSE analysis of CPCB real time data.

Daily variation in ground-level ozone exceedances in Mumbai

2025 summer ground-level ozone exceedances were reported on 32 out of 92 days between 1 March and 31 May 2025



Note: Based on exceedances recorded at the monitoring stations of Mumbai. Exceedance is computed as daily maximum 8-hr average crossing the ground-level ozone 8-hr standard, i.e. 100 µg/m^3. Period of study is 1 Mar to 31 May 2025. Source: CSE analysis of CPCB real time data.

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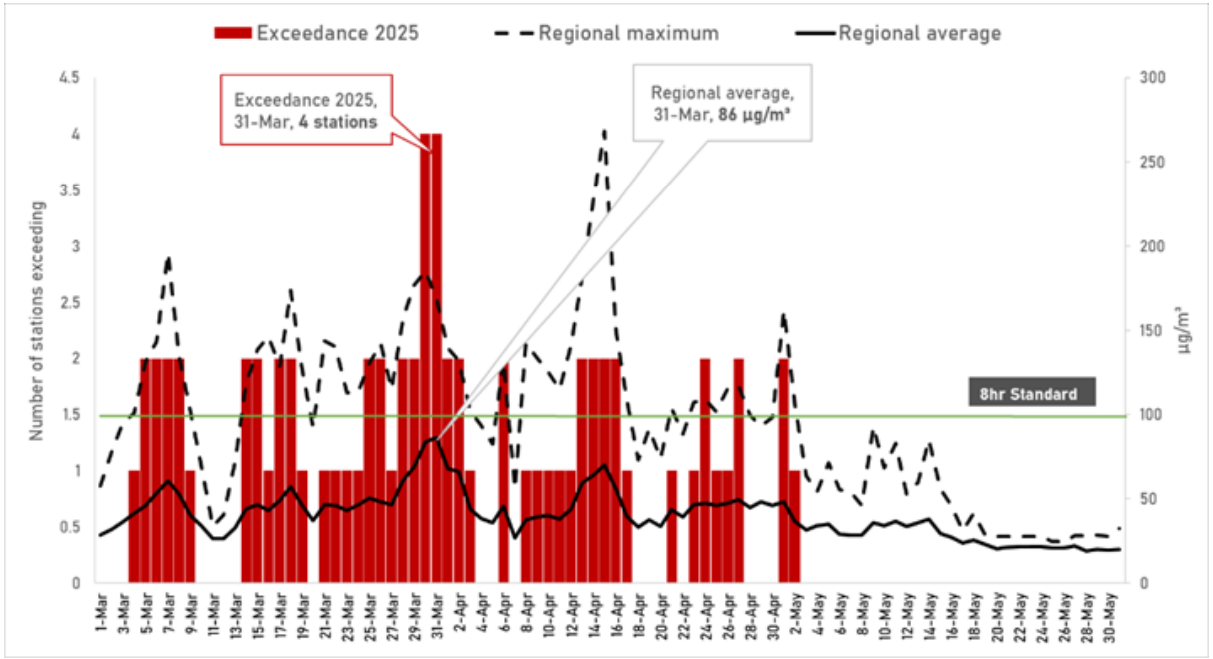
Daily variation in ground-level ozone exceedances in Bengaluru (Mar- May 2025)

Ground-level ozone exceedances were reported on 45 out of 92 days in Bengaluru



Note: Based on exceedances recorded at the monitoring stations of Bengaluru. Exceedance is computed as daily maximum 8-hr average crossing the ground-level ozone 8-hr standard, i.e. 100 µg/m^3. Period of study is 1 Mar to 31 May 2025. Source: CSE analysis of CPCB real time data.

ANIL AGARWAL DIALOGUE 2026

How and what do we know about air quality?

Understanding the data: Expanding monitoring network

2026 Health Effect Institute assessment:

- **Expansion of monitoring network:** Since 2017, the number of PM2.5 stations increased by **344%** (from 78 to 346), and PM10 stations rose by **462%** (from 61 to 343)
- **Uneven coverage:** While large cities may have many stations, others have only one, and **rural areas remain largely unmonitored**.
- **Largest number of CAAQM in mega cities -** Delhi – 40, Mumbai 30, Bengaluru and Hyderabad – 14, Pune 13, Ahmedabad 9, Chennai 9, Kolkata 7.
- **Out of 130 NCAP cities 102 have real time monitors**.
- **Only 30 cities meet the criteria of 4 CAAQMs.**
- **46 cities have only one CAAQM each** (eg Talcher, Srinagar, Surat, Vishakhapatnam etc). Vadodara, Ranchi, Rae Bareilly do not have any CAAQM. NCAP cities like Vadodara, Nellore, Ranchi Rae Bareilly have none
- **70% cities lack minimum representative coverage raising concerns around reliability of data representativeness**

Understanding the data and the trend....

2026 Health Effect Institute assessment and CSE Breathing space 2020

Data completeness, availability and method for trend analysis

- **Improvement in Data Completeness:** Data reliability has improved; by 2024, approximately **82% of stations** met the aspirational completeness criteria, compared to only 18%–22% in 2017.

- **Compliance Status: PM10:** - Non-compliance remained unchanged - **over 90% of stations** consistently exceeding the National Ambient Air Quality Standard (NAAQS) each year.

- **PM2.5 exceeding NAAQS:** Stations exceeding the NAAQS decreased by **33%** between 2017 and 2024, yet **over 60%** of stations still fail to meet the standard.

- **PM2.5 trends:** Out of 211 stations monitored 67.7% showed decreasing trends (Varanasi, Kolkata, Dewas, Jodhpur, Mumbai. Lucknow, Kanpur, etc) 32.2% increasing trend (Asansole, Mandi, Chandigarh, Gobindgarh etc)

- **Regional Hotspots:** The Delhi National Capital Region (NCR) continues to dominate the list of the most polluted monitoring stations for both PM2.5 and PM10.

Challenges with constructing air quality trends

Citywide averages often "flatten" data, masking the fact that air quality can improve at one station while worsening at another within the same city.
(Source HEI 2026)

Simple annual data availability averages (like a 75% threshold) are insufficient because they can hide gaps of 2–3 months, potentially **missing entire peak pollution seasons**. (CSE Breathing Space and HEI)

Comparing just two years (e.g., a "base year" vs. a "final year") is misleading as it is highly sensitive to one-off spikes or anomalous events like the COVID-19 lockdowns.

Need to fix the stations for estimating long term trend for reporting compliance (Breathing Space)

How these challenges should be addressed?

Adopt granular completeness criteria: Stations must provide data for at least **18 hours/day, 23 days/month, and 11 months/year** to be considered representative.

Use 3-Year rolling averages: Instead of annual comparisons, 3-year rolling averages should be used to provide a more stable and reliable signal of sustained change over time.

Station-level assessment: Analysis should focus on individual station averages rather than citywide averages to capture localized patterns and avoid distortion.

Weather Normalization: Simple removal of seasonal cycles makes the underlying trend clearer for routine reporting.

Meteorological normalization: For research and accountability, using models to "remove" weather impacts reveals underlying improvements that variability might otherwise mask.

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Where is pollution coming from?

Assessment of pollution sources, seasonal variation in source contributions and regional influence

CAQM report from January 2026: Yhe experts conducted a meta-analysis of multiple studies conducted between 2015 and 2025 *rather than relying on a single report.*

Identification and selection of these studies include:

- **Time Period:** The analysis focused on research and data from various papers and technical reports published between **2015 and 2025**.

- **Geographic Focus:** Availability of studies is uneven across the region, with **most existing studies focusing specifically on Delhi**.

- **Data Rationale:** Because indicative numbers for the larger NCR are sparse, the meta-analysis for this report was primarily **based on the studies carried out for Delhi**.

- **Selection Criteria:** The review was limited to studies from **domain experts and peer-reviewed publications** to ensure technical integrity.

- **Methodological Diversity:** The identified studies utilized various approaches, including **receptor-based (top-down)**, **dispersion-based (bottom-up)**, or **hybrid methodologies**.

Studies have their limitations

Several factors make direct comparison between different studies complex:

- **Methodological diversity**: Studies use different approaches (receptor-based/top-down vs. dispersion-based/bottom-up), sampling strategies, and modelling frameworks
- **Varying assumptions**: Differences in emission inventories, chemical profiles, source classification, and boundary conditions lead to variability in results.
- **Spatiotemporal heterogeneity**: Most studies focus on Delhi, leaving sparse data for the larger NCR
- **Dynamic nature**: Air quality is highly sensitive to the specific time period, monitoring locations, and recent policy interventions (like fuel standard changes).
- **Uncertainty**: Bottom-up methods rely heavily on the accuracy of emission inventories, while top-down methods are sensitive to location and source profiles
- **Data resolution**: Meta-analysis is needed because individual reports provide indicative rather than absolute estimates.
- ***Varying results due to differences in time periods, locations, and modelling assumptions, this meta-analysis reconciled those variations and established a unanimous expert opinion.***

Combustions sources dominate pollution impacts

Combustion-related activities are identified as the primary drivers of pollution, especially during peak episodes:

- **Combustion sources**—including transport, biomass burning, and industry—collectively increase their contribution during winter.
- **Transport**: Consistently the most prominent source within Delhi, contributing approximately **23% in winter** and **19% in summer**.
- **Biomass Burning**: This includes municipal solid waste (MSW), residential heating, and crop residue. It accounts for **20% in winter** compared to **12% in summer**.
- **Industry & Power**: Includes furnaces, boilers, and thermal power plants (TPPs), contributing **9% in winter** and **14% in summer**.

The problem of secondary pollutants

Secondary pollutants are formed in the atmosphere from precursor gases (SO2, NOx, NH3, VOCs) and present unique challenges:

- **Significant Burden**: They represent a major portion of total particulates, accounting for **27% of PM2.5 in winter** and **17% in summer**.
- **Formation Complexity**: They are not emitted directly but formed through chemical transformations influenced by sunlight, moisture, and temperature.
- **Winter Intensification**: Colder conditions and frequent fog accelerate "gas-to-particle" conversion, particularly for ammonium nitrate.
- **Mitigation Difficulty**: Because they do not originate from a single controllable point, they require a multi-sectoral strategy targeting all primary combustion sources.
- **Precursor Attribution**: It is scientifically challenging to pinpoint which primary source is responsible for specific secondary particles

Seasonal variation in source contributions and regional influence

The contribution of different sectors shifts markedly between the summer and winter months:

Winter Shifts: Combustion sources and **secondary particulates** rise significantly. Stagnant conditions and a low Planetary Boundary Layer (PBL) trap these pollutants near the ground.

Summer Shifts: The share of **Dust (Road, Soil, C&D)** is much higher in summer (**27%**) than in winter (**15%**) due to drier conditions.

Crop Residue Impact: While its annual average may be low, stubble burning can contribute between **1-3% to up to 40%** of Delhi's pollution load during the peak harvesting season in October-November.

Transboundary Effect: Around **two-thirds** of Delhi's PM2.5 originates from outside the city (NCR districts and beyond), complicating the estimation of local vs. regional impact.

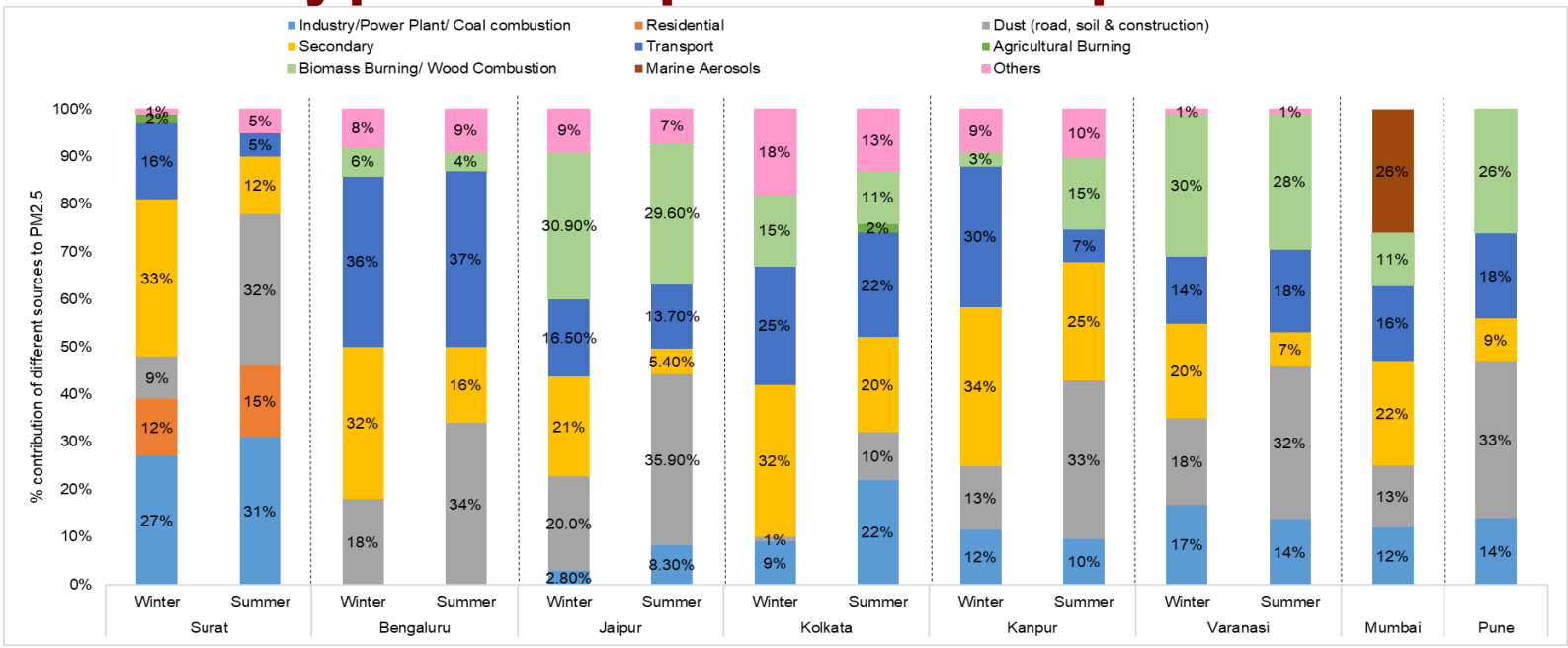
Dominant pollution sources impacting air quality in Delhi from sources within NCR and beyond – CAQM report

Sector	Winter		Summer	
	Contribution (%)	Range (%)	Contribution (%)	Range (%)
Transport	23	19-24	19	18-21
Industry (includes TPPs)	9	8-10	14	9-15
Dust (Road + Soil + C&D)	15	10-18	27	25-31
Biomass Burning (includes MSW, residential, crop-residue burning)	20	17-23	12	11-14
Secondary Particulate (from gaseous emissions)	27	24-28	17	16-19
Other sources	6	-	11	-

Percentage contribution to PM2.5 concentrations. Typical average PM2.5 Concentration in Summer (Mar-June): 73 µg/m³ and in Winter (Nov-Feb): 178 µg/m³ *Other sources refer to small dispersed and unclassified sources not typically categorized within the above mentioned major sectors

Source: CAQM

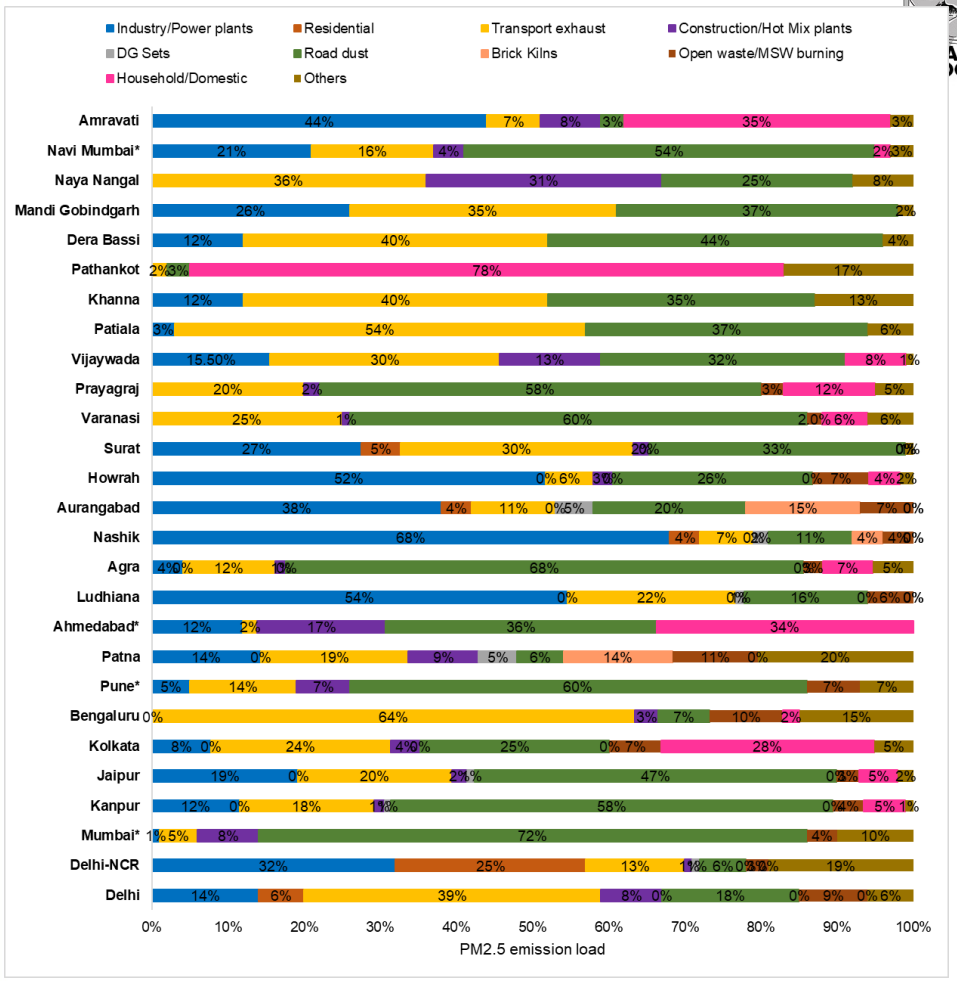
Source Apportionment Studies in other cities: Vehicular and Secondary pollution as persistent urban pollution drivers



Transport and secondary pollution account for **nearly one-third to half of urban PM2.5** in major cities, indicating that reducing vehicular emissions can have both direct and seasonal air quality and climate benefits.

- **Transport is a major and consistent contributor** to PM2.5 across cities-- reaching 30-37% in Bengaluru and Kanpur
- **Secondary particulate matter contributes roughly 20-34% of PM2.5 in many cities, with higher winter shares,** reflecting strong precursor emissions (especially NOx) from vehicles and other combustion sources.

Source: Based on the recent source apportionment and emission inventory available online



Emission inventory of PM2.5

- **Combustion-related sources dominate**—industry/power plants, transport exhaust, DG sets, residential fuel use, brick kilns, and open waste burning together form the dominant load.
- **Transport exhaust a major contributor**:~40-65% in northern cities such as Delhi, Patiala, Khanna, Dera Bassi, Naya Nangal, Pathankot. ~20-30% in other cities like Aurangabad, Pune, Ahmedabad, Surat, Vijayawada.
- **Industrial/power plant emissions dominate in several western cities** (Navi Mumbai, Surat, Nashik, Aurangabad, Ahmedabad), showing a different combustion profile compared to the north.
- **Implication for action:** Effective PM2.5 reduction must prioritise combustion control and precursor gas management, with strategies designed around exposure hotspots, not just source inventories.

Note- * cities where emission load is given for PM and not specific to PM2.5

Source: Based on recent emission inventory studies available

Move beyond the current limitations and expand the scope of studies

Expansion of study area: Recognizing that most current studies focus on Delhi, need comprehensive data for the larger NCR region where indicative numbers are currently sparse.

Integrated modeling approaches: To obtain a holistic picture, the report recommends using both "Top-Down" (Receptor Modeling) and "Bottom-Up" (Chemical Transport Modeling) methods together to offset the inherent limitations and uncertainties of each.

Meta-analysis framework: Instead of relying on single reports, need continuous meta-analysis of peer-reviewed studies to reconcile variations in time periods, locations, and modeling assumptions.

Real-time apportionment: Ongoing efforts toward real-time source apportionment studies to better understand dynamic daily and seasonal shifts in pollution sources.

Taking action...

Difficult to attribute changes solely to the National Clean Air Programme (NCAP) *due to overlapping factors such as meteorological variability, economic shifts, and other national sectoral programmes in key sectors of pollution*

National Clean Air Programme (NCAP)

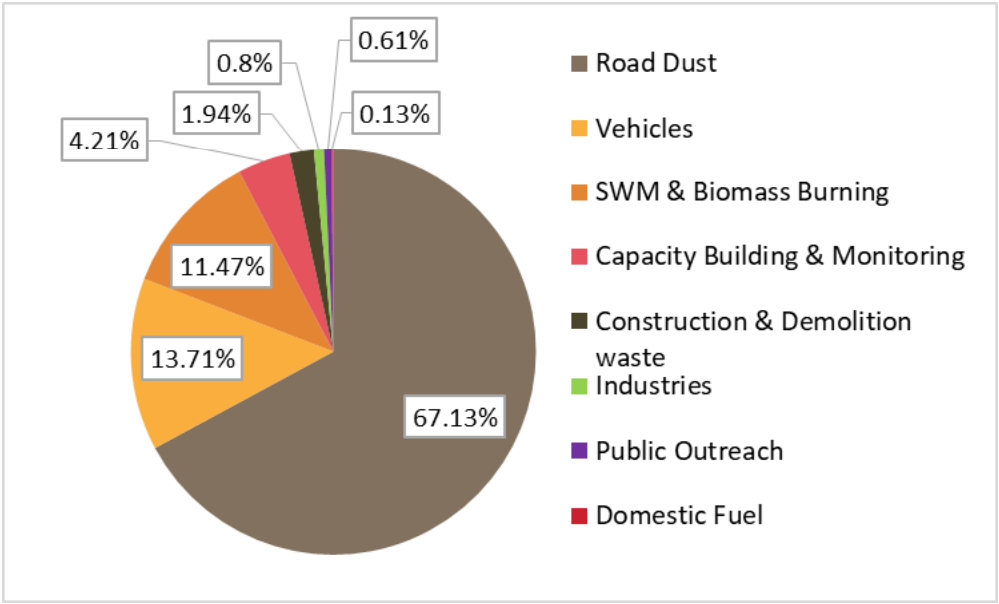
Sector-wise expenditure: Dust management hogs major share of spending

PM10 based performance-linked funding is locking in more resources for dust control

- **Out of 11,211.13 Cr (as of September 2024) -**

  - **Road dust sector- 5098.04 Cr (67.13%)**
  - **Vehicle sector - 1041.18 Cr (13.71%)**
  - **SWM & biomass burning- 871.06 Cr (11.47%)**
  - **C&D waste- 147.33 Cr (1.94%)**
  - **Industry sector- 60.75 Cr (0.8%)**
  - **Capacity building & monitoring- 319.72 Cr (4.21%)**
  - **Public outreach- 46.33 Cr (0.61%)**
  - **Domestic fuel- 9.87 Cr (0.13%)**

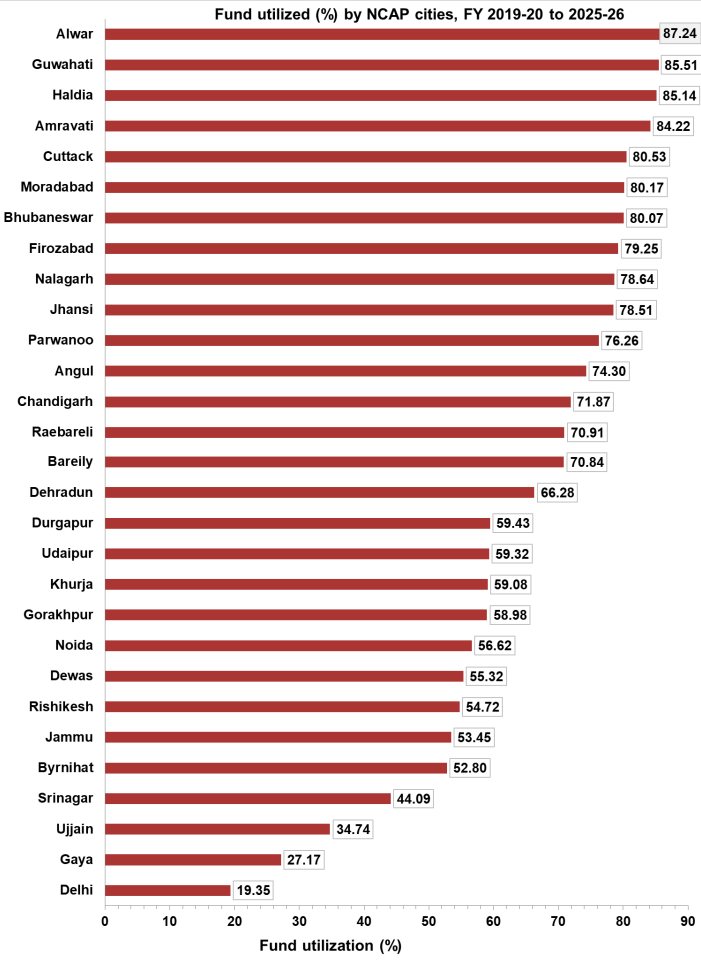
Sector-wise expenditure in 130 NCAP cities, FY 2019-20 to 2023-24 (as of Sept. 2024)

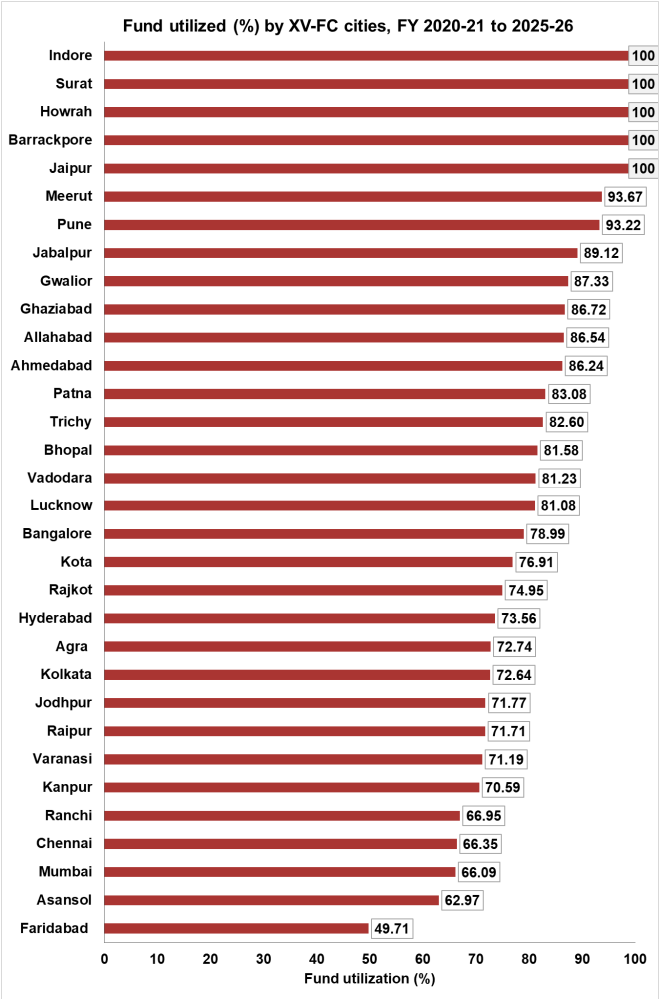


Source: PRANA Portal, as on September 7, 2024 [Based on the total funds released: Rs 11,211.13 crore)

National Clean Air Programme (NCAP)

Fund utilized by NCAP cities, FY 2019-20 to 2025-26





Source: PRANA Portal accessed on 18th February 2026

National Clean Air Programme (NCAP)

Fund utilized by NCAP cities, FY 2019-20 to 2025-26

- **NCAP funding - 2019-26 (as of 18th February 2026)**
  - **70% utilisation: Alwar, Guwahati, Haldia, Amravati, Cuttack, Bhubaneshwar, Firozabad, Nalagarh, Jhansi, Angul, Chandigarh, Bareily, Raebareli and Parwanoo**
  - **Over 50% utilisation: Byrnihat, Jammu, Dewas, Noida, Udaipur and Durgapur**
  - **Below 40% - Ujjain, Gaya, Delhi**

- **Weak correlation between fund utilization and air quality improvement.**
- Eg, **Bhubaneswar, Angul, Haldia, Guntur, Talcher, Akola** etc. spent over 70% of their allocated funds but failed to meet PM_{10} reduction targets.
- **Bareilly** utilized 70% of its funds and reduced PM_{10} levels by 72%, significantly exceeding its target.
- **Srinagar** used only 44% of its funds and achieved a 34% reduction in PM_{10} levels against a target of 25%.

- **15th Finance grant during FY 2020-26 (as of 18th February 2026)**
  - **Over 90% of their allocated funds. Seven cities—Indore, Surat, Howrah, Barrackpore, Jaipur, Meerut, and Pune**
  - **over 75% of their funds: Cities such as Kota, Bengaluru, Lucknow, Bhopal, Patna, Ahmedabad, Ghaziabad, Gwalior, and Jabalpur**
  - **Less than 50%: Faridabad, Jamshedpur, Vijayawada, and Visakhapatnam have utilized**

- **Weak correlation between fund utilization and improvements in air quality.**
- Eg, **Indore**, which utilized 100% of its funds saw PM_{10} levels *rise* above permissible limits from 82 µg/m³ (2017–18) to 85 µg/m³ (2024–25), a 3.7 per cent increase.
- Increased expenditure does not necessarily translate into improved pollution outcomes.

Funding and nature of interventions

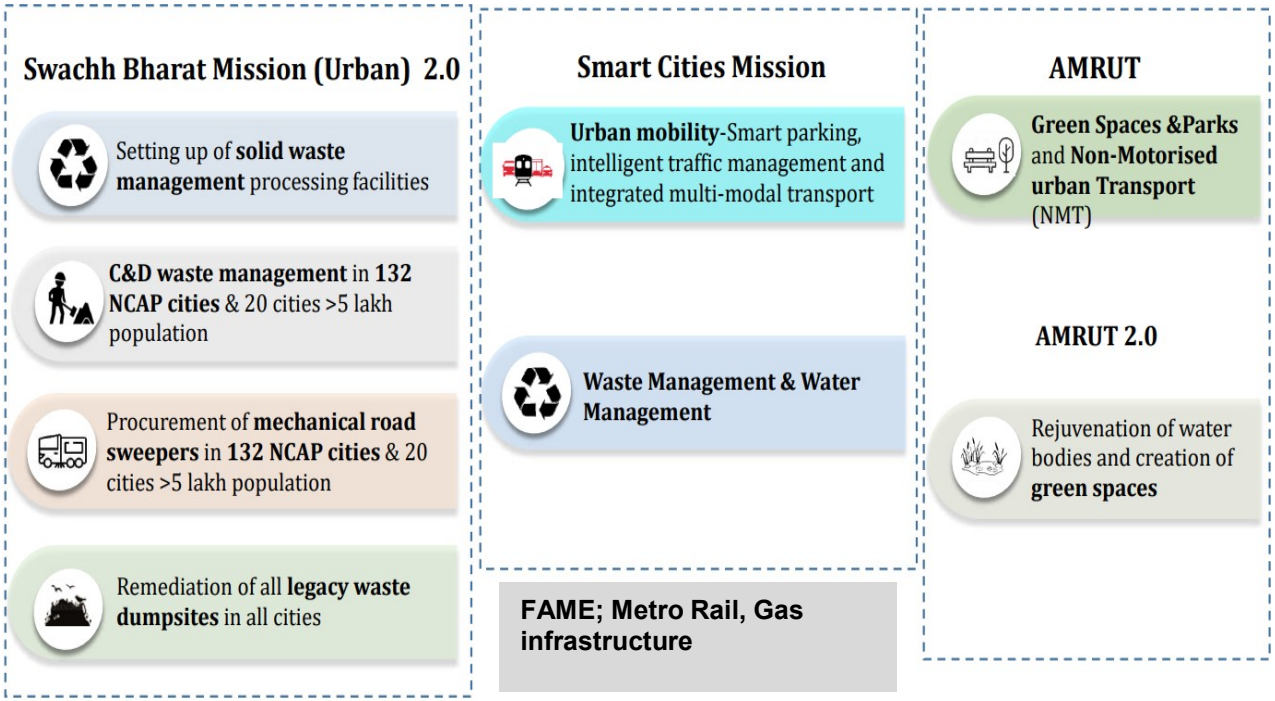
- **XV-FC is the dominant funding source**
- **NCAP acts as a catalytic fund**, contributing modestly -- mechanical sweeping and waste remediation.

Activities	Unit	Progress under NCAP	Progress under XV-FC	Total Progress (NCAP + XV-FC)	Progress under Convergence of other schemes	Grand Total
End-to-end road pavement	Km	1,353	10,801	12,154	6,153	18,307
Road length swept through Mechanical Road Sweepers (MRS No. 396)	Km/day (No.)	5,550 (185)	3,720 (124)	9,270 (309)	2,610 (87)	11,880 (396)
Development of green area	Acres	745	3,591	4,337	1,041	5,378
C&D processing sites established	TPD	115	815	930	7,302	8,232
No. of electric buses purchased and deployed	Nos.	2	1,411	1,413	2,513	3,926
No. of EV charging stations established	Nos.	18	424	442	317	759
No. of PNG/Electric crematorium established	Nos.	28	146	174	25	199
Legacy waste sites remediated	Lakh MT	3	35	38	117	156

Source: Measures to control air pollution in major cities, Rajya Sabha, Starred Question No. 51, To be answered on 04.12.2025

National Clean Air Programme (NCAP)

Convergence funding: Leveraging central schemes for funding of clean air action in NCAP cities



What is needed?

Road dust: Gaps in action and next generation reforms

GAPS in action

Only road sweeping and sprinkling will not suffice

Next level of action

- **Temporary vs. Structural:** Current measures like vacuum cleaning are temporary; the lack of structural solutions like paved shoulders and greening allows dust to persist.

- **End-to-End paving:** Shifting from temporary vacuum cleaning to permanent structural solutions, including paving of road shoulders and "green buffers" along major traffic corridors.

- **Resuspension cycle:** Particles deposited on roads are repeatedly resuspended by traffic, acting as a persistent storage medium for pollutants.

- **Mechanical sweeping expansion:** Increasing the fleet of BS-VI compliant Mechanical Road Sweeping (MRS) machines to ensure daily removal of fine silt before it is resuspended.

VARANASI:
Leveraging Urban renewal and NCAP for clean air

Varanasi battling dust pollution -- nearly 84% of PM10 and 60% of PM2.5 levels.

NCAP initiative, and leveraging of **urban renewal – core city and riverbank re-development have reduced particulate level substantially**

Infrastructure level action

- **Riverfront redevelopment - 6.8-km stretch along the Ganga** with environmental restoration, parks, and public spaces.
- **Road Re-development (2020-2023)**: **270 km of pothole-free roads, 95% of road shoulders repaired and paved.**
- **Ring Road project** ease traffic congestion and **cut emissions from idling vehicles.**
- **Greenbelt development - 4.5 km of roadside and divider** turned into greenbelts; **vertical gardens in high-traffic areas**.
- **Afforestation - 1.70 hectares afforested** with **171,000** Miyawaki plants between 2021-22 and 2023-24.
- According to the PRANA portal, **about 218,936 trees have been planted in recent years.**
- **Kashi Vishwanath Corridor**: **Redeveloped (2019-2021) from 3,000 sq ft to 5 lakh sq ft**, with paving, landscaping, and improved pedestrian access.
- **Going forward important to leverage** the newly announced **Rs. 3,880-crore infrastructure development plan**

Enforcement measure

- **Street sweeping and water sprinkling** covered **1,280 km of roads (97% of total road length).**

Varanasi demonstrates that dust reduction is a much larger agenda -- an eco-system strategy through urban redevelopment and greening approaches

Urban redevelopment initiatives

End-to-end Pavement

Ring-road Construction

Landscape Beautification

MRF Plant

Clean transition – Floating CNG station

Redevelopment of Ghat

C&D Waste Recycling Plant

Varanasi -- multi–sectoral actions under NCAP and convergence funding

- **Floating CNG station at Namo Ghat** convert **735 out of 890 motorboats to CNG**, by Nov 2023, up from 583 in 2021–22.
- **Cremation practices -** Eco-friendly electric and CNG-based cremation facilities address substantial air pollution.
- **Electric Mobility - E-rickshaws dominate the city's EV segment,** with **auto-rickshaws seeing a sharp rise** in EV adoption in 2023–24 and 2024–25.
- -- Walking, cycling, and para-transit (autos/buses) account for **80% of modal share. An**
- **Three strategic parking facilities** (Godowlia multi-level and two basement parks at Town Hall & Benia Bagh).
- **Emission Monitoring - 66.92% of vehicles meet PUC certification standards**

C&D Waste Management

- **100% collection and processing (65 tonnes daily).**
- C&D recycling plant at Ramana, **(200 TPD capacity), processes 70–80 TPD.**

Solid waste management and circularity

•Generates ~950 TPD of solid waste; **94.94% collected, 85.78% processed.**

•**Composting plant: Karsara handles** 800 TPD;

•**Biogas plant: Shahanshahpur** processes 90 TPD; produces 3,150 kg CBG and 15 T organic manure.

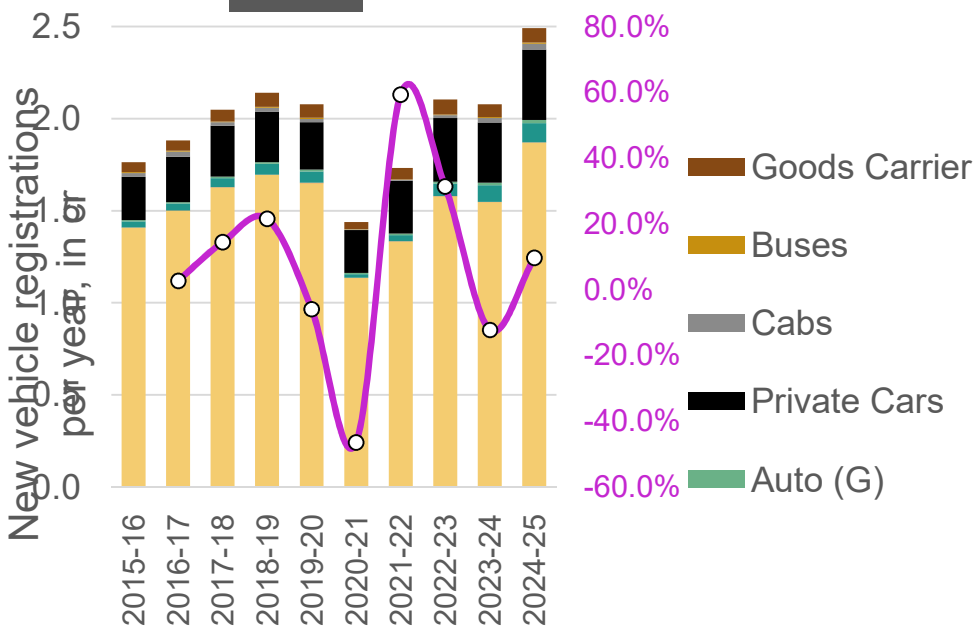
•**Waste-to-charcoal: Ramana plant** processes 600 TPD; produces 200 TPD charcoal.
•Three material recovery facilities (2 TPD each); three bio-methanation plants for organic waste.

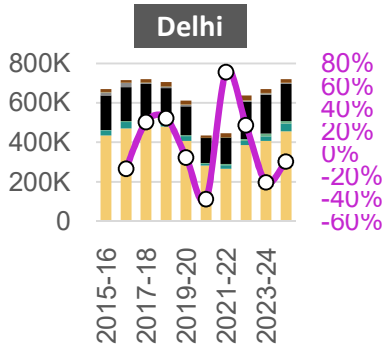
•**Waste-to-energy plants** set up by **NTPC (24 TPD)** and **Indian Oil Corporation (3 x 5 TPD units).**

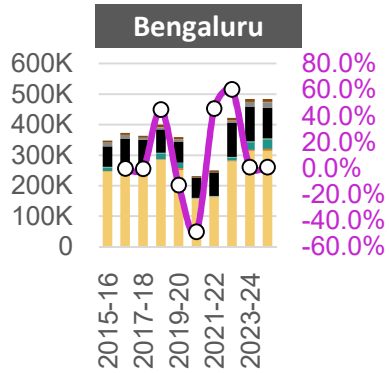
Use of solid fuels

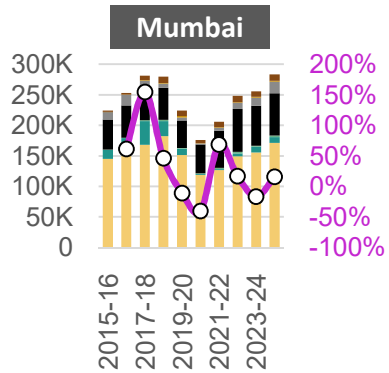
•**85% households use LPG**; the rest use wood, dung, coal, or crop residue.

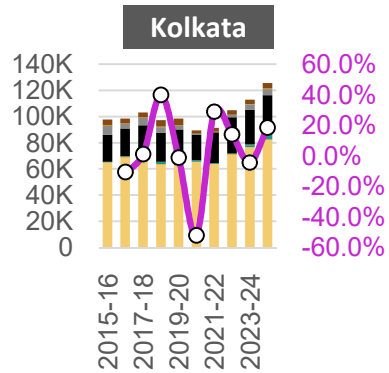
Transport : Motorisation trend, 201





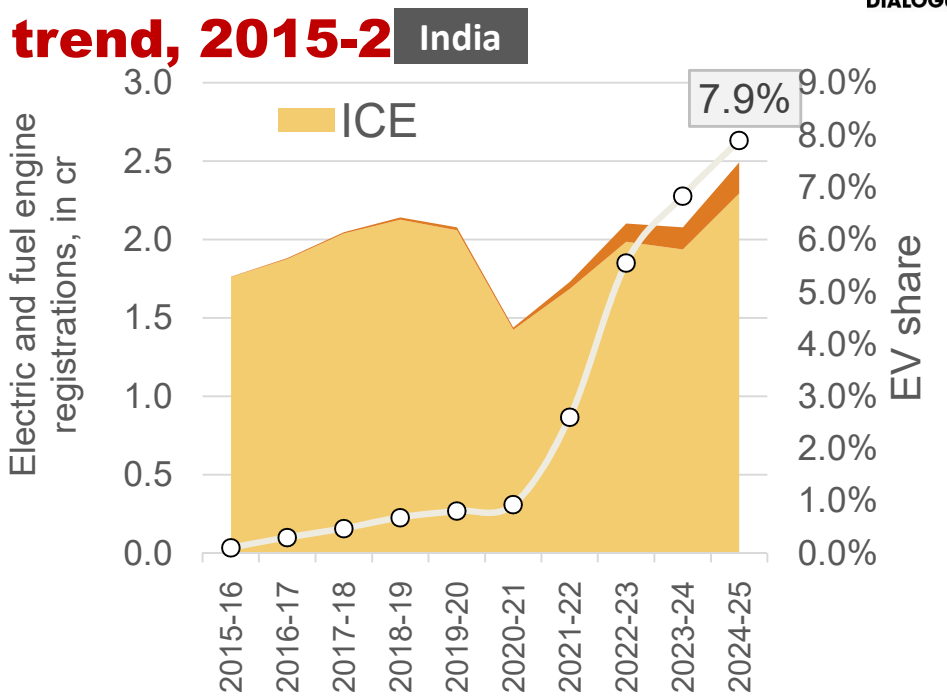


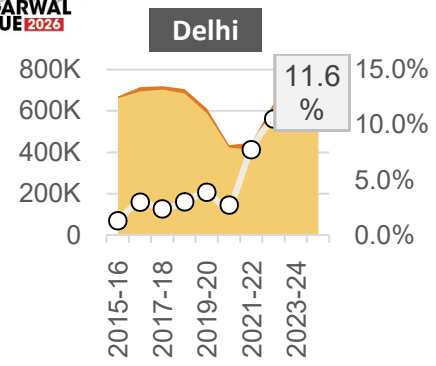


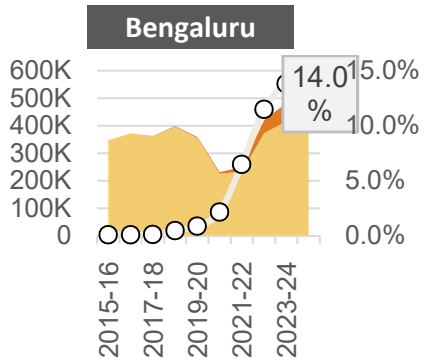


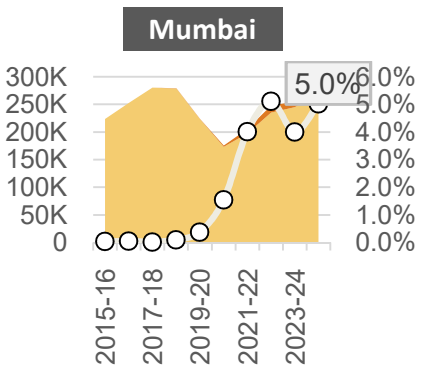
India is adding approximately **68,000 new vehicles every day**, with **9 out of 10 being personal vehicles**. **Delhi has the highest share of personal vehicles among the metros at 89.2%,** followed closely by **Kolkata (86.8%), Bengaluru (85.9%),** and **Mumbai (85.0%).** CAGR**: India: ~3.9%.** The market is expanding steadily; **Bengaluru: ~3.7%.** Mirroring the national trend; **Mumbai: ~2.6%.** Moderate growth; **Delhi: ~0.8%.** The growth curve is nearly flat over the decade - attributed to saturation and strict de-registration policies (10/15-year bans) forcing a replacement cycle rather than pure fleet expansion.

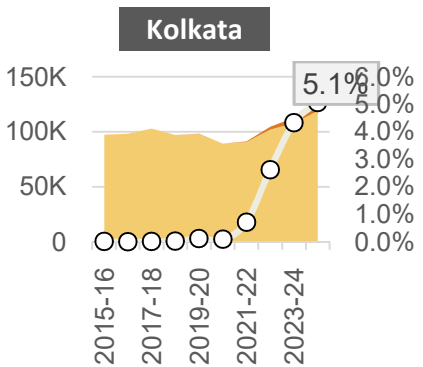
Electrification trend, 2015-2









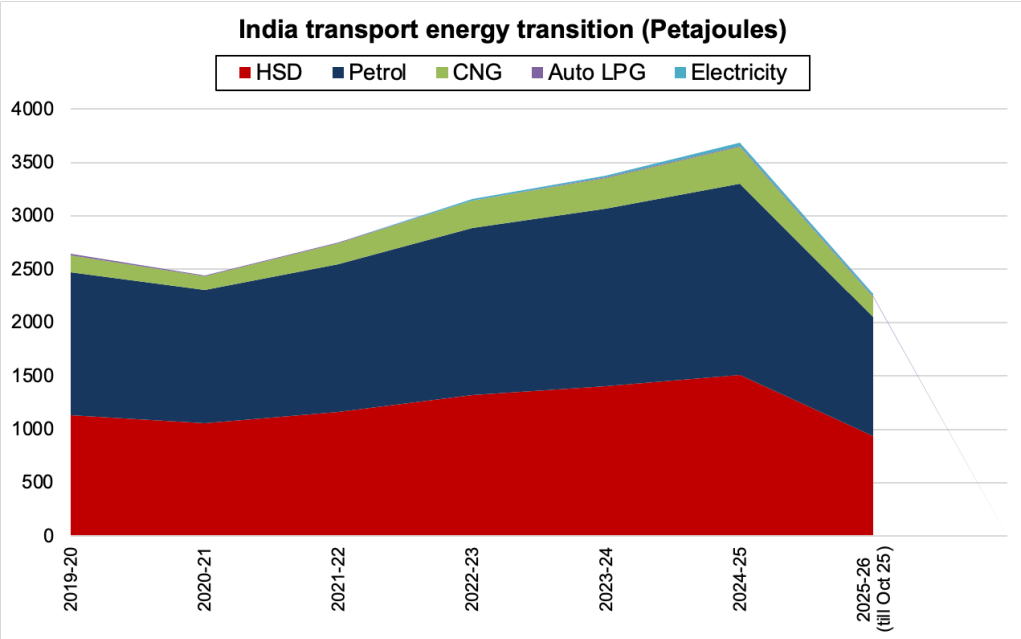


The **national EV share** jumped from **<1% to 7.9% in just five years**. **Two-wheelers and E-rickshaws remain the undisputed leaders, accounting for 87%** of all new electric registrations nationally. **Bengaluru's EV share in FY 2024-25 was 14%,** led by private vehicles (**75% of its EVs are Two-wheelers**); **Delhi's EV share was 11.6%,** led by e-rickshaws and two-wheelers (**43% of all new EVs registered were E-rickshaws**, followed by **Two-wheelers at 32%).** Mumbai and Kolkata had an EV share of 5% and 5.1% respectively. Both cities are led by **Two-wheelers (58% and 54% respectively**), but they also have a strong adoption of **Electric Private Cars (32% in Mumbai, 24% in Kolkata**).

Current Energy Mix: Transition is Slow

- In **2024–25**, India's on-road transport energy mix: **Petrol: 49%**, **Diesel: 41%**, **CNG: 9%**, **Electricity: 1%**
- **Electricity consumption in transport is increasing, but from a very low base.**
- **CNG is functioning as the default transition pathway, not just a stepping stone.**

India on-road transport sector energy transition (petajoules) till October 2025



Note: To calculate the electricity consumed by the transport sector, the CEA Public charging station data for heavy duty chargers was used for bus and goods carries. For other vehicle categories CEA methodology for medium and long term power demand forecast was used to estimate annual electricity consumption

Source: CSE analysis based on CEA and PPAC data

Transport: Gaps in action and next generation reforms

GAPS in action

Rapid Fleet Growth and daily regional influx: Explosive increase in Internal Combustion Engine overwhelming the technological gains

A significant lack of integrated public transport and safe infrastructure for pedestrians and cyclists increases dependence on personal vehicles.

Non-Exhaust Emissions: Current actions often overlook significant non-exhaust emissions, such as brake wear, tire abrasion, and resuspended road dust.

Next level of action

Ambitious target for vehicle fleet electrification

Hyper-Scaling Zero-Emission Zones: Establishing "Low Emission Zones" (LEZs) to promote only EVs and BS-VI compliant vehicles.

Upscaling public transport and last-mile integration: Prioritizing e-buses and integrating paratransit (e-rickshaws) with Metro hubs to reduce reliance on personal vehicles

Differential Travel Incentives: Implementing differential congestion pricing and staggered work hours to flatten peak-hour traffic volumes and reduce idling emissions.

Cross learning platform:
Bhubaneswar: Mo Bus – transforming public transit

Rapid System Transformation: Established in 2018, the Mo Bus service has modernized and upscaled the urban transit network.

Extensive Operational Reach: Operates a fleet of ~390 buses across 67 routes, covering a network of 500+ km.

Affordability & State Support: Backed by state budgetary provisions to ensure accessible pricing for all passengers.

Multimodal Connectivity: Integrated feeder services featuring electric autos and public bicycle sharing.

Robust Infrastructure: Equipped with comprehensive transit facilities, including dedicated bus stops and depots.

Advanced ITS Technology: Utilizes vehicle tracking, passenger information systems, and electronic ticketing to enhance service delivery.

Customer-Centric Redressal: Features quick and effective grievance systems for enhanced passenger convenience.

Empowered Front-line Staff: Drivers and conductors are extensively trained in professional customer handling.

Inclusive HR Practices: Comprised of 50% women conductors and 100% Mo E-Ride drivers from marginalized groups through targeted skilling.

Bhubaneswar: Impact of rapid upscaling

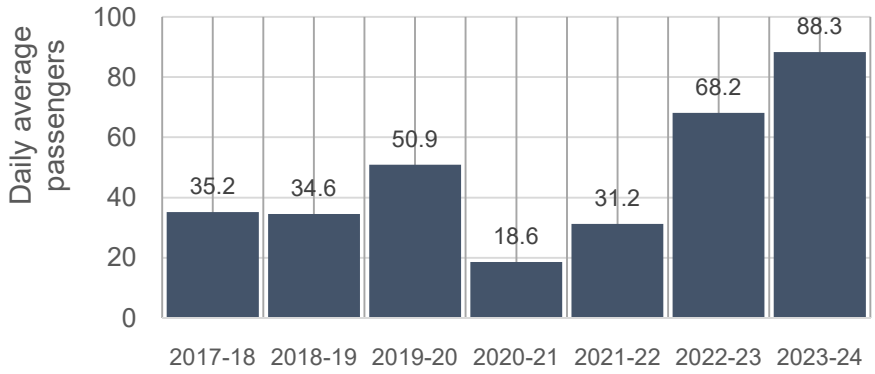
- **Ridership increased 200%** in 5 years, from 33,000 (2018) to **2.5 lakh daily (2023)**;
- **57% of users shifted from private transport**.
- **Operational routes increased from 21 to 67,** -- covering Bhubaneswar, Cuttack, and Puri under CRUT.
- **Gender equity**: **40% Mo Bus conductors are women**, all Mo E-Ride drivers are women or transgender persons.
- **Upscaling service 9 other cities**, beginning with **Rourkela in 2023**, making it a **replicable state-wide model**.
- GIZ survey: **91% rated onboard staff "very good"**, **85% of women** rated priority seating well, **98% of elderly** praised ease of boarding.

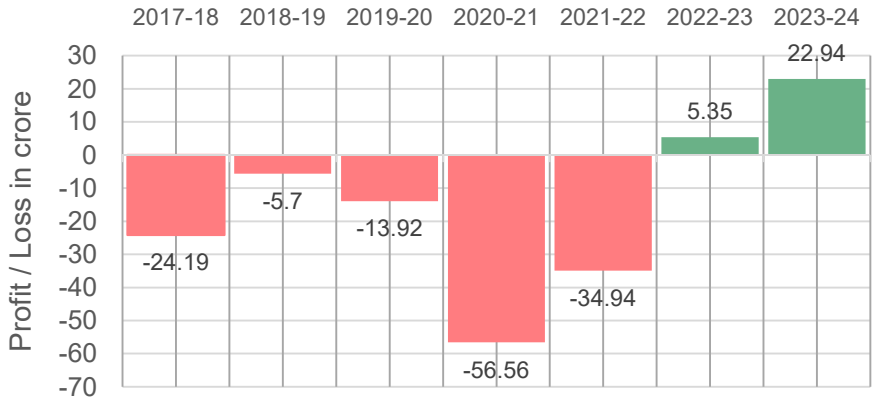
Emerging good practices - Kochi

Kochi metro

- **Multi-modal transport ecosystem –** *Metro, water metro and bus services.*
- **Electrifying water and bus transport --** electric ferry and feeder bus.
- **Unifying auto unions to improve last mile services:** to provide smooth and connected first and last mile journey experience to daily commuters.
- **Solar energy generation to run metro and water metro -- 55% of electricity needs of metro – solar power**; **Water metro -- 100% solar energy**
- **Convergence framework: Walking and cycling infrastructure:** Public bicycle facilities in major footfall areas like Fort Kochi, coastal roads etc. – **Leveraged Smart City support**

Kochi – Impacts





Kochi metro ridership increased by 250% in 2023–24 over its first year,

E**arns operational profits.**

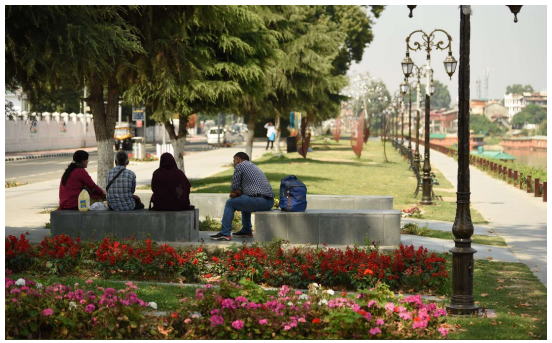
Water metro crossed 3 million riders in 18 months, -- daily ridership reaching **15,000 on peak days**.

Feeder bus ridership on Info-park route grew **from 40 to 220** per bus.

83% of users are satisfied with metro connectivity

Emission savings from modal shift: **CO_2 avoided: 16.4–16.7 million kg/day**, **PM: 950–2,058 kg/day**, **NOx: 12,439–14,278 kg/day**.

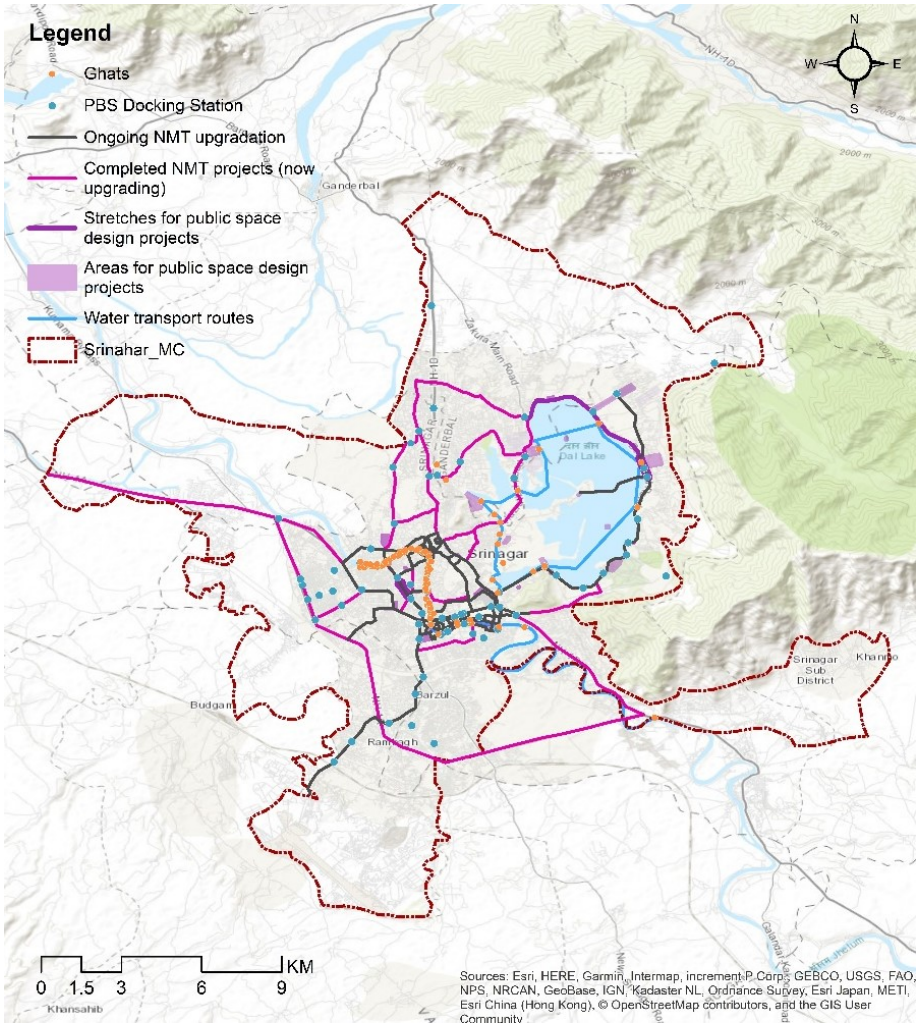
Srinagar: Leveraging urban re-renewal for mobility



City-wide integrated mobility networks to improve accessibility and connectivity – Smart City Mission

- **City-wide walking and cycling infrastructure** --redesigning road network with pedestrian walkways, cycle tracks, improved junction design, road signages.
- **Redeveloped public spaces** through creating traffic free zones, green spaces, providing street furniture.
- **Redeveloped 45 ghats** to make them destination points along with improved water transport facilities.
- **E-bus services** (100 buses with 16 routes), 750 e-rickshaws and 1100 public bi-cycle sharing cycles with 200 stations, and planning to initiate e-boat services.
- **Off-street parking facilities to reduce on-street parking** demand in central city area.

Srinagar: impacts



- **Footfall and economic activity** revived in redeveloped Lal Chowk and Polo View.
- **Business hours increased by 3–4 hours**,
- Business owners along the upgraded corridors **renovated older structures**, aligned building façades with the area's improved aesthetic.
- **Public space upgrades led to private investment inflows**, including a new hotel by Radisson on the Jhelum waterfront.
- **After the ghats were restored, Uber initiative of introducing shikara bookings online on their app**
- Within **one year**, the new e-bus fleet helped to avoid **8,403–9,018 tons CO_2**, **19–22 tons NOx**, and **0.3–0.5 tons PM**.

Industry: Gaps in action and next generation reforms

GAPS in action

- **Numerous small, unorganized units** operate in unauthorized or peripheral areas without controls.
- **Illegal burning of industrial waste** (plastic and rubber, etc) along with fugitive emissions
- **Clean technology transition:** Many small-scale units in industrial clusters still use small outdated boilers and furnaces that need urgent upgrades to clean fuels.
- **Regional coal Impact:** Eleven thermal power plants continue to operate across the NCR, impacting regional air quality

Next level of action

- **Stricter particle emission Caps (50mg/Nm^3)** across all 17 categories of highly polluting industries
- **Clean Fuel Transition (electricity, PNG etc):** Completing the 100% transition of industrial clusters
- **Digital Monitoring:** Deploying Continuous Emission Monitoring Systems (CEMS) in small and medium enterprises (SMEs) to ensure real-time compliance and eliminate "ghost" emissions.

Upscaling targeted solutions for big impact

Centralised common boiler technology: This technology can replace large number of polluting standalone tiny boilers in textile, pharma and chemical zones that are highly polluting.

- **Regulatory action**: **Gujarat Pollution Control Board** promoting this technology in industrial areas **Surat, Vapi, Ankleshwar clusters** replace more than 600 individual boilers -- particulate load down 70–80 %.
- **Industrial case study**: Improves thermal efficiency from 65% to 83% –cutting coal use — cuts SO_2 and PM emissions by a quarter.

Foundry sector: Clean furnace: Extremely polluting single blast cupolas dominate the MSME sector.

- **Regulatory action**: **Rajasthan State Pollution Control Board** has directed foundry units to shift from single blast cupola furnaces to divided blast cupola furnaces..
- **Industrial case study** 18–20 % reduction in coke use and 30% reduction in CO emissions

common boiler pipeline laying

PNG based furnace

Brick-kilns: switch from fixed chimney bull's trench designs to induced-draft zig-zag kilns – cut particulate emissions by up to 70 % and coal use by 30%

Regulatory action in Delhi-NCR – Improved kiln, switch to biomass based fuels, PNG etc.

Industry case study: Model kiln in Jhajjar records just 10 kg day^{-1} of SPM – after adding a metal stack, flue-gas expansion joints, solar-powered ID fans and a three-ring green belt that doubles as a dust filter. Substantially reduced emissions, energy use, and fugitive emissions.

Upscaling targeted solutions for big impact

Controlling fugitive emissions from stone-crushing:

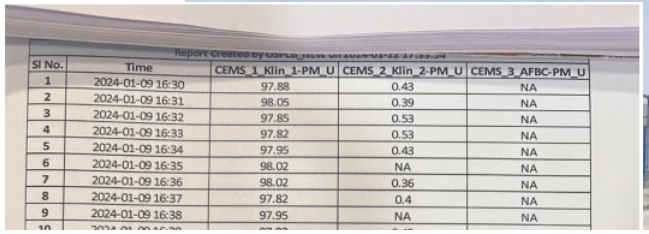
Regulatory action: Tamil Nadu Pollution Control Board proactively regulating stone crushing units through siting policies, strict dust control, and in-situ renewable power generation.

Industry case study: (Kakade Stone Crusher (Pune)- 33% tree Extensive and advanced controls, 1 MW solar farms; PCS Industries (Tamil Nadu) adds real-time air quality monitors and recycles 50 m³/day of water for dust suppression.

Circularity - Compressed Biogas

- **Notable growth in the Compressed Biogas (CBG)** enterprises.
- **State regulatory initiative**: Madhya Pradesh, Bihar and Gujarat offer capital grants, tax breaks, and interest subsidies to support project development.
- **Indore case study --** the CBG initiative -- convergence of energy, economy, waste, and climate goals.

Smart monitoring with CEMS: Odisha SPCB -- used for transparent monitoring, enforcement, and performance feedback.



Sl No.	Time	CEMS_1_Klin_1-PM_U	CEMS_2_Klin_2-PM_U	CEMS_3_AFBC-PM_U
1	2024-01-09 16:30	97.88	0.43	NA
2	2024-01-09 16:31	98.05	0.39	NA
3	2024-01-09 16:32	97.85	0.53	NA
4	2024-01-09 16:33	97.82	0.53	NA
5	2024-01-09 16:34	97.95	0.43	NA
6	2024-01-09 16:35	98.02	NA	NA
7	2024-01-09 16:36	98.02	0.36	NA
8	2024-01-09 16:37	97.82	0.4	NA
9	2024-01-09 16:38	97.95	NA	NA

Overview of the Banaskantha CBG plant

Gas holder

OSPCB records actual emission and reported data

ed conveyor belts

Covered screen with door arrangements

Waste burning: Gaps in action and next generation reforms

GAPS in action

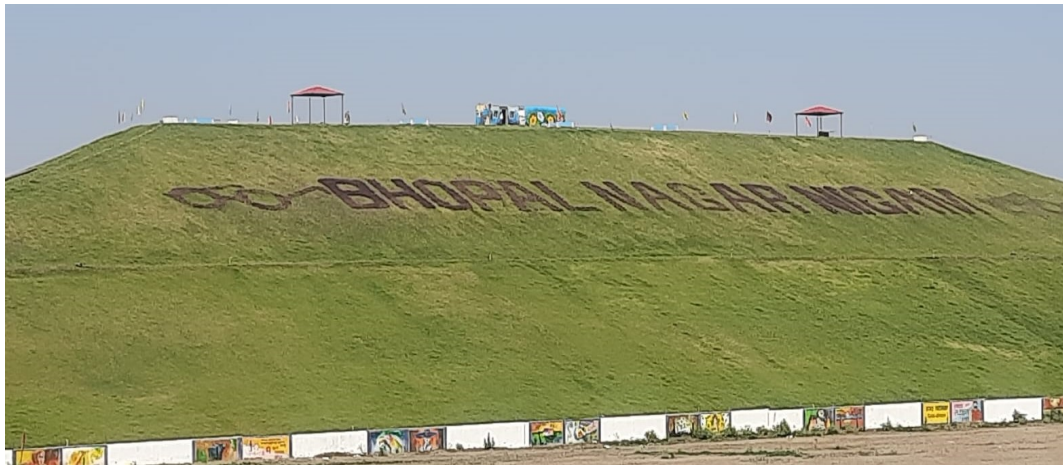
Municipal waste management gaps: Lack of systems and infrastructure for 100% collection, segregation and material recovery.
Landfill Fires: Massive "legacy waste" remains a major fire hazard- rate of remediation slow
Transboundary Impact of biomass burning: Seasonal crop residue burning
Solid fuel burning in households- lack of alternatives: Low-income households often lack affordable energy alternatives

Next level of action -- Swachh Bharat Mission 2.0 - performance linked funding

100% collection, segregation, material recovery and remediation of legacy waste. Divert at least 80% of new waste from landfills
Expanding clean cooking subsidies to ensure 100% LPG or electric cooking for low-income urban households
In-situ & Ex-situ stubble management: Scaling up bio-decomposers; creating a robust value chain for crop residue -- *straw-based power generation, bio-CNG/bio-ethanol plants, biomass pallets as industrial fuel, paper / particle board/ compressed agriculture panel furniture/ packaging etc.*)

Action has begun– Reclamation of land from landfills

Bhopal reclaims 37 acres of legacy waste



Waste economy: Building the value chain

Thiruvananthapuram – Kerala: ULBs provide subsidies to households for setting up on-site residential composting and biomethanation facilities.

- **Nearly 40% of households are properly managing their biodegradable waste at source** with individual compost units or community-level facilities.

Compressed biogas (Bio-CNG) for vehicles and industry (BIS specs IS 16087:2016)

Digestate Fermented Organic Manure - has high nutrient content. India can generate 370 million tons of bio-manure per year from various feedstock; from municipal solid waste another 0.031 million per day or 11.45 million ton per year.

Urban India has potential to generate about 2523 TPD of Bio-CNG

2023-2024 Union budget: Allocation of 10,000 crore rupees for 200 CBG plants and 300 community and cluster plants under the Gobardhan scheme

Waste burning: Gaps in action and next generation reforms

GAPS in action

- **Proper management of fugitive dust from C&D activities**
- **Enforcement at Scale:** Rapid urban expansion often outpaces environmental controls, requiring more rigorous enforcement of dust-control measures at all sites.
- **Recycling Gaps:** There is a need for 100% collection and recycling of debris, along with better market uptake for recycled materials.

Next level of action

- **Remote Monitoring Portals:** Mandatory registration of all C&D sites >500 sqm on a centralized web portal for real-time remote monitoring via sensors and cameras.
- **Recycling capacity and mandatory Recycled Material Uptake:** Enforcing policies that require a minimum percentage of recycled C&D aggregates (bricks, paver blocks) in all new public infrastructure projects.
- **Advanced Suppression:** Moving from simple manual sprinkling to automated anti-smog guns on high-rise buildings and wet-jet technology for stone cutting.

Construction & demolition waste – Build market

Construction industry – high growth story
More than 90% of waste can be brought back as construction material
Reduce dependence on virgin material
BIS standards for recycled aggregates
Value chain – reuse without value addition and recycling with value addition

Implement ward-wise comprehensive strategy:

- **Segregation and on site management**
- **Transportation of C&D waste**
- **Bulk waste generators responsibility**
- **Recycling for material recovery**

Delhi

Supreme Court Extension Project used **1.8 million Recycled C&D waste blocks**.

Recycled products from C&D waste

Manual Casting Unit manufactured various products in Chandigarh

RCC Bollard

RCC Manhole

RCC Road Gully

Brick

RCC Direction/Sign Board

PCC Flower Pots

Stacked Products

Stacked Paver Block

Addressing funding gaps

- **Funding must converge across multiple streams rather than relying on a single "pollution" budget**
- **Vertical Alignment:** Aligning the 16th FC grants for urban development with NCAP targets so that "Sanitation" funds also cover dust suppression and mechanical sweeping.
- **Sectoral Convergence:** Merging budgets for **Renewable Energy (Rooftop Solar)**, **Transport (FAME-III)**, and **Agriculture (Stubble Management)** into a unified Clean Air Mission.
- **Airshed Financing:** Moving toward a regional funding model where the Centre, States, and Municipalities pool resources to tackle pollution across state borders (e.g., Punjab's farm fires affecting Delhi's air).
- **Develop tools of funding clean air action**: Pimpri Chinchwad – Municipal bonds issued for walking and cycling infrastructure; Polluter pay in Delhi etc

Step forward...

Upscale good practices in key sectors of pollution

- Build stronger and deliberate synergy with sectoral programmes/funding to mainstream clean air indicators in key sectors of pollution control – transport, industry, waste, households and fugitive emissions.

- **Need convergence of all funding** – to influence all other funding lines available in all sectors.

- **Performance benchmark requires not only clean air targets but also sectoral targets to drive action** – Take PM2.5 and not PM10 to benchmark for air quality improvement.

- **Sectoral targets and mandates are needed** while planning scale for systems, infrastructure and design improvements for implementation. Improve programme and project deign for impact

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- **Adopt a good practice model to provide detailed guidance framework** to cities/regions on scope and design of sectoral action and build institutional capacity

- **The NCAP funding should be catalytic to upscale priority measures in key sectors and unlock more resources at** the national and state level by leveraging other funding strategies to deliver on clean air objectives

- **Stronger state level policy and mandate will be critical to make clean air programme and spending purposeful and effective.**