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Council for International Economic Understanding

Dalberg

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Unlocking India's Blue Skies Economy

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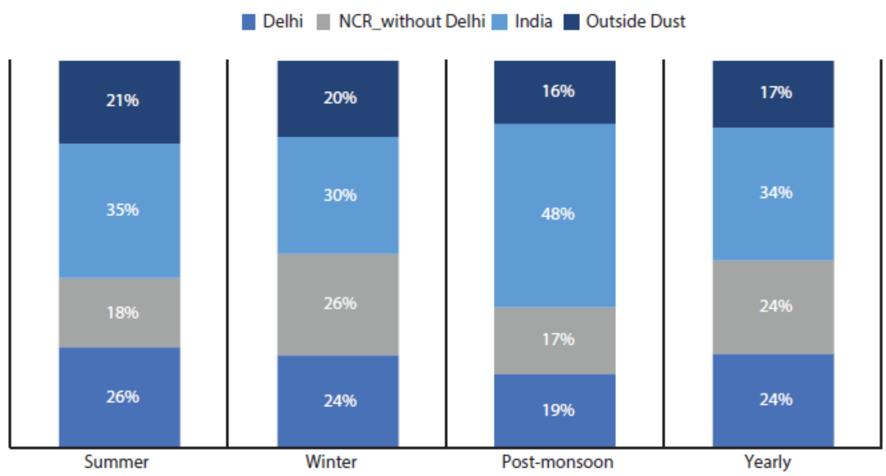
Finding Facts: Cracking the Code on Pollution Sources

Context and rationale

Air pollution in India is a complex and multi-dimensional challenge, primarily due to its transboundary nature, multi-sectoral sources, and seasonal variations. A major difficulty in measuring pollution is the movement of pollutants across borders, complicating the identification of their origin. The Indo-Gangetic Plain (IGP) is heavily impacted by pollution from neighboring countries like Pakistan, Bangladesh, and Nepal. On average, only about 20% of the pollution in Delhi originates within the city, with the rest being transported from surrounding areas. As shown in exhibit 1, Delhi's air quality is influenced by the National Capital Region (NCR), contributing up to 48% of PM2.5 concentrations post monsoon (when open agriculture residue burning is prevalent in the upwind states of NCR), 35% in summer and 30% in winter[1]. Additionally, sources outside Delhi-NCR, including neighboring states and countries, are responsible for 50-60% of PM2.5 concentrations on average. This transboundary impact worsens Delhi's pollution while also contributing to deteriorating air quality in downwind cities like Noida.

Exhibit 1: Geographical contribution to PM2.5 concentrations in Delhi-NCR

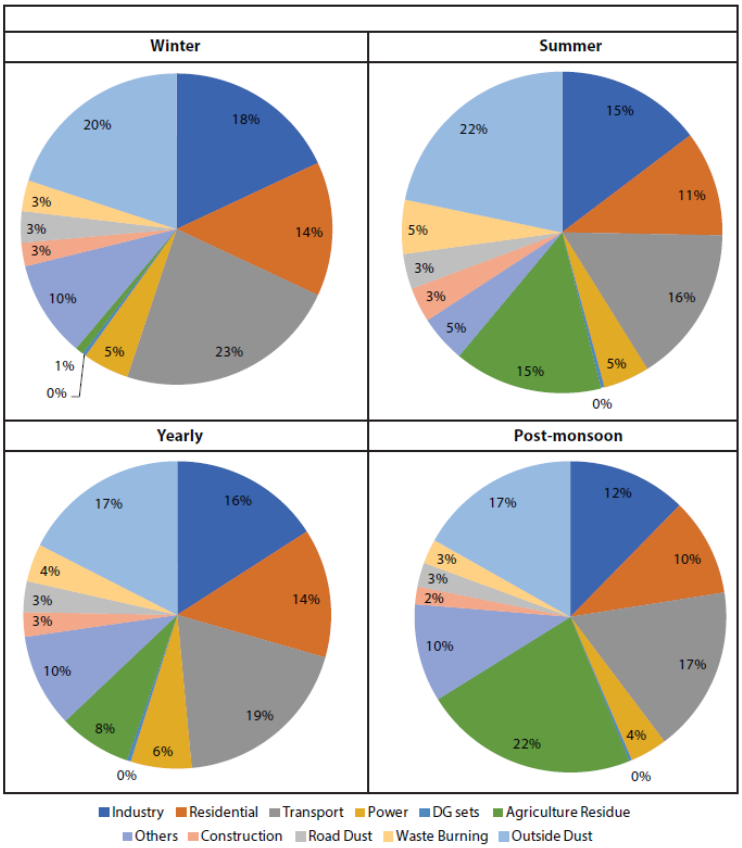


Moreover, air pollution stems from a variety of sectors, including transportation, industry, agriculture, and waste burning, each contributing differently across seasons. The overall contribution of these sectors to PM2.5 levels in urban areas like Delhi varies significantly (see exhibit 2 for details). Industries, including power plants, contribute around 22% of the annual PM2.5 load, followed by the transport sector at 19% and residential sources, which account for 14%[1]. Other sources, such as crematoria, ammonia, biogenic processes, airports, and restaurants, make up around 10%. Agricultural residue burning, while occurring only during certain months, accounts for 7% of the annual contribution, with this share significantly increasing during the post-monsoon period.

[1] TERI, Cost effectiveness of interventions for control of air pollution in Delhi

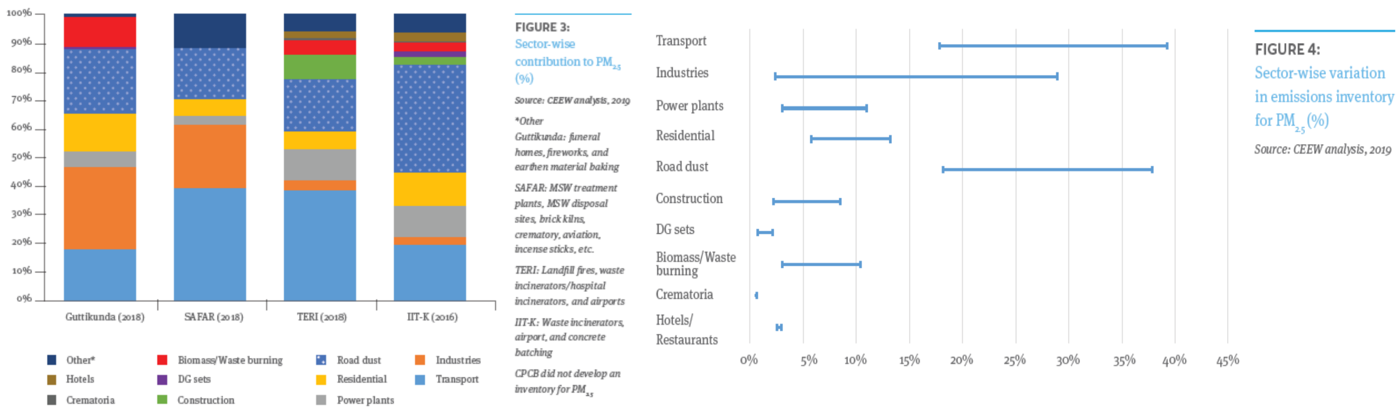
Seasonal variations play a critical role in shaping the patterns of air pollution, as the contributions from various sources fluctuate depending on weather conditions, agricultural cycles, and industrial activity. These variations are especially pronounced in urban areas, where pollution levels can shift dramatically between seasons. For instance, in Delhi, during the winter months, local emissions, particularly from the transport sector, become more dominant, contributing up to 23% of the PM2.5 levels[2] (see exhibit 2 for more details). This is due to the formation of secondary particulate matter from increased nitrate production under cooler, slower wind conditions. Agricultural residue burning also peaks in the post-monsoon and summer seasons, contributing significantly to pollution during these months, with a marked rise to 24% in November. On the other hand, road dust and construction-related pollution, which are mostly linked to drier, windier conditions, contribute more in the summer.

Exhibit 2: Yearly and seasonally averaged source contribution to prevailing PM2.5 concentration (which includes both primary and secondary particulates) in Delhi in 2019



Despite the critical role of source apportionment studies in understanding air pollution, the current body of research in India is marked by significant variations and varying methodologies, making it difficult to draw consistent conclusions. A comparison of five major source apportionment studies by the CPCB, IIT Kanpur, TERI, SAFAR, and Guttikunda reveals significant variability in estimating sectoral contributions to PM2.5 in Delhi (refer to exhibit 3)[2]. The transport sector is the largest contributor to PM2.5, with estimates ranging from 17.9% to 39.2%, influenced by differences in survey locations, vehicle fleet composition, and fuel use data. Road dust, another major contributor, varies between 18.1% and 37.8% for PM2.5. The contributions from power plants and industries also differ widely, with industrial emissions ranging from 2.3% to 28.9% for PM2.5, due to differing definitions of industrial activities and emission estimation methods. For instance, Guttikunda (2018) included sources like brick kilns and construction dust, while CPCB (2010) did not. These discrepancies stem from variations in sampling methods, emission factors, and the inclusion of secondary pollutants, highlighting the need for standardized data collection and emission factor usage to improve air quality management strategies.

Exhibit 3: Sector-wise contribution and variation in emissions inventory for PM2.5 (%)



The lack of standardized and comprehensive source apportionment studies hampers effective air quality management in India. While initiatives like the National Clean Air Programme (NCAP) have been launched to address this issue, aiming to reduce PM concentrations by 20-30% by 2024 through source apportionment studies in 102 cities, the progress has been uneven[3]. Many cities still lack robust data on pollution sources, leading to generic policies that may not address specific local challenges. For example, the studies alluded above on Delhi NCR identified major sources of PM2.5 and PM10, but without consistent methodologies across different regions, comparing and integrating such data remains difficult. This inconsistency underscores the need for mandated, standardized source apportionment studies to inform targeted interventions.

The absence of national policies mandating standardized source apportionment studies contributes to the fragmented understanding of air pollution sources. This policy gap not only leads to reliance on disparate studies, which use varying scopes and methodologies but also makes it difficult to compare results meaningfully. For example, some studies use receptor models like Chemical Mass Balance (CMB) or Positive Matrix Factorization (PMF),

[2] CEEW The Council, What is Polluting Delhi's Air?
[3] PubMed Central, Addressing air pollution in India: Innovative strategies for sustainable solutions

while others rely on satellite data or source-specific emission inventories. These methodological differences can lead to inconsistent findings, such as differing estimates of the contribution of vehicular emissions or industrial sources. Without standardized source apportionment studies, formulating effective and localized air quality management plans remains a challenge

India can learn from other countries where source apportionment studies have been successfully integrated into air quality management frameworks. For instance, the European Union has established standardized methodologies for source apportionment (including receptor-oriented models and source-oriented models to identify and quantify pollution sources by analyzing chemical data and simulating pollutant dispersion), facilitating comparability and consistency across member states. Implementing similar standardized approaches in India could enhance the reliability of data and inform more effective policymaking. Additionally, integrating advanced technologies such as satellite monitoring, artificial intelligence, and machine learning can aid in real-time tracking of pollution sources and forecasting air quality. Collaborative efforts, both within India and with international partners, are essential to share knowledge, harmonize methodologies, and develop region-specific solutions to air pollution. Strengthening regulatory frameworks and ensuring consistent enforcement are also crucial steps toward achieving sustainable air quality improvements.

This session will bring together key stakeholders from government, industry, and academia to explore actionable solutions for improving source apportionment in India. The discussion will focus on the challenges hindering progress, as well as the opportunities to standardize methodologies and leverage emerging technologies for more precise and effective air quality management.

Potential Opportunities and Challenges

The opportunities to streamline source appropriation for air pollution reduction include:

- **Establishing a National Research Center to conduct standardized source apportionment studies** annually will improve methodological consistency and generate high-quality, region-specific data to guide interventions.
- **Publishing an Annual Report on key polluting sources** will enable systematic tracking of major emission contributors, supporting data-driven air quality policies and public transparency.
- **Integrating technologies like satellite imaging and AI for real-time pollution tracking**, along with adopting best practices from international models (e.g., EU's PMF[4] and SHERPA[5]), will improve precision in source apportionment and air quality management policies

[4] European Union, An introduction to the chemometric evaluation of environmental monitoring data using PMF
[5] Elsevier, A source apportionment and air quality planning methodology for NO2

- **Enhancing cooperation between states, industries, and neighboring countries** can address transboundary pollution, such as the impact of crop residue burning from Punjab and Haryana on Delhi's air quality

Key challenges would have to be overcome to leverage these opportunities. Some of these challenges include:

- **There is currently no single mandated agency or institutional mechanism** responsible for conducting source apportionment studies, leading to fragmented ownership and inconsistent accountability across central, state, and municipal levels.
- **Robust source apportionment studies require significant investment** in technology, modeling expertise, and field-level data collection, but budget allocations remain sparse and irregular, particularly in smaller cities and rural areas.
- **Many studies are conducted independently** by different academic institutions, government agencies, or NGOs, often without shared protocols or integration into a national framework, resulting in duplicative siloed efforts and incomparable datasets.
- **India's diverse climatic zones and variable atmospheric conditions complicate the modeling and standardization of source apportionment** across regions, necessitating highly localized approaches.

Key Focus for Discussion

With a focus on identifying challenges and potential unlocks to achieve India’s clean air goals, below are the key questions for the panel discussion:

- Why is there so much variation in source apportionment studies across India, and what are the reasons behind inconsistent data collection?
- Why are many source apportionment studies in India inconsistent and lacking standardized methodologies, and what steps can be taken to ensure more reliable, comparable data across regions?
- Why is reliable data on pollution sources unavailable for major cities and states, despite the need for targeted air quality management?
- Who holds the mandate for conducting comprehensive source apportionment studies, and why is it not being done effectively across the country?
- How can India establish a unified methodology for source apportionment studies to enable reliable data collection across regions and sectors?
- What role can emerging technologies like AI and satellite imaging play in real-time pollution tracking?

Session Flow

Firestarter - Finding Facts: Cracking the Code on Pollution Sources	
Opening Remarks (2 minutes)	• The emcee will provide a **brief context** on the critical role that data plays in uncovering the true sources of air pollution. • The emcee will **call all the panellists** on the stage and introduce them • The emcee will then hand the session over to the **moderator**
Moderator Opening Remarks (3 minutes)	The moderator will emphasize the **need for synergy between different stakeholders** to turn complex source attribution data into actionable, lasting air quality solutions.
Fireside Chat Conversation (20 - 30 minutes)	• Moderator asks panellists an **introductory question** to address • Panellists give **brief opening statements** • The moderator then asks **pointed questions** to panellists • Each panellist may choose to **build upon or challenge** the view of the previous
Closing thoughts and optional audience Q&A (5 minutes)	• Each panellist concludes with a **closing thought and key takeaway(s)** • They emphasize a **critical call-to-action** for the audience • Time permitting, the panellists may **answer questions** received from the audience