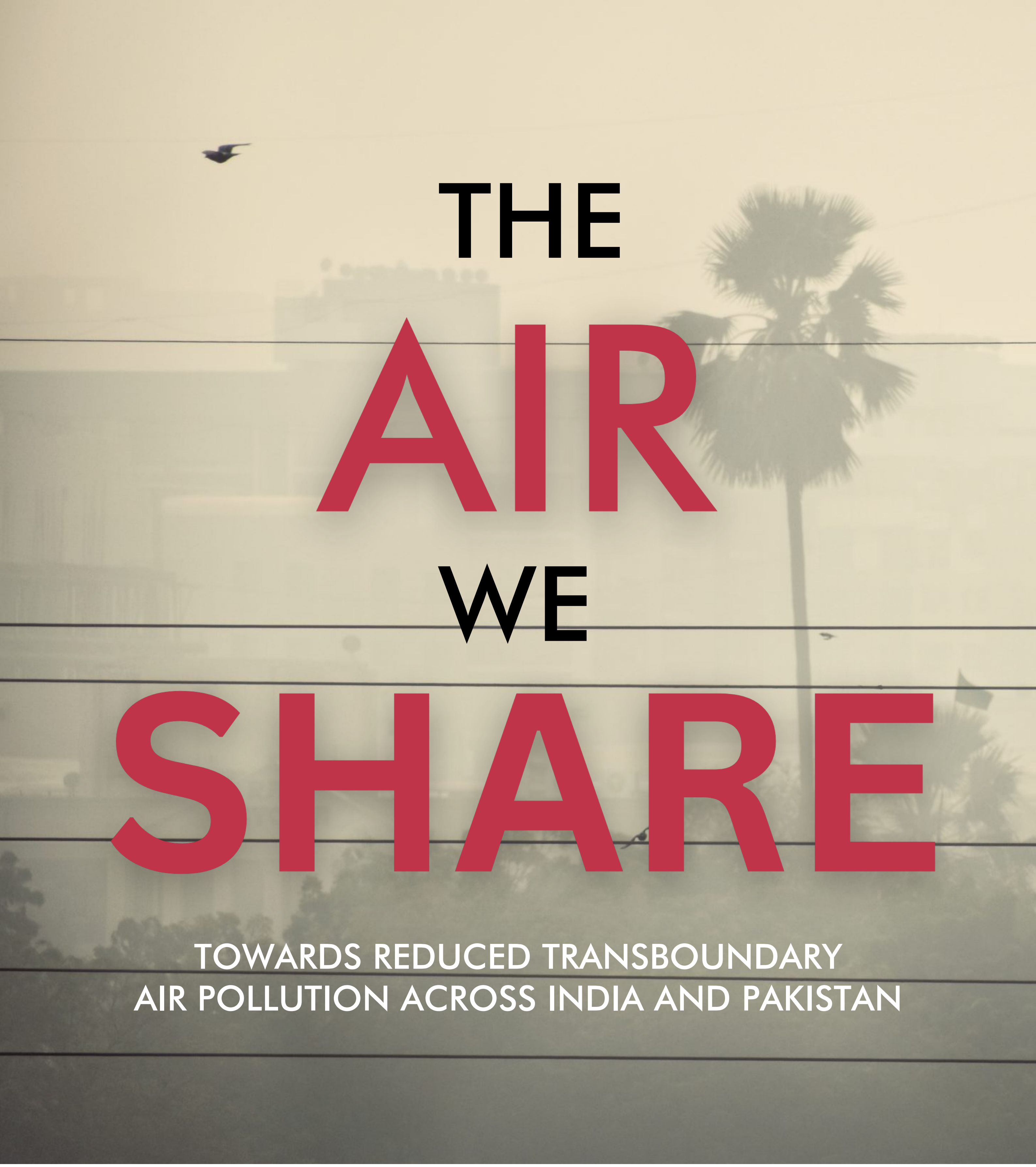

THE AIR WE SHARE

TOWARDS REDUCED TRANSBOUNDARY AIR POLLUTION ACROSS INDIA AND PAKISTAN

A REPORT BY THE INDO-PAK CLIMATE COLLECTIVE

CSDR
COUNCIL FOR STRATEGIC AND DEFENSE RESEARCH

SDPI
Sustainable Development Policy Institute

ABOUT THIS REPORT

This report, created through collaboration between the Council for Strategic and Defense Research (CSDR) and the Sustainable Development Policy Institute (SDPI), addresses the urgent need for India and Pakistan to work together on tackling air pollution. It explores common challenges such as crop residue burning (CRB), vehicular pollution, and inadequate/subpar air quality monitoring across the Indo-Gangetic Plain. By taking an interdisciplinary approach, the report examines how the region's economies, industries, and populations are interconnected and impact the environment. Leveraging the Indo-Pak Climate Collective (IPCC) platform, the report provides policy suggestions for effective transboundary air pollution reduction/mitigation strategies. It empowers stakeholders to join forces in sharing knowledge and crafting policies that benefit both countries, ultimately leading to cleaner and healthier air in South Asia.

ABOUT COUNCIL FOR STRATEGIC AND DEFENSE RESEARCH

CSDR is a research-focused think tank founded in January 2020 by Dr. Happymon Jacob (Associate Professor, School of International Studies, JNU), and Lt. Gen. DS Hooda (Former. Northern Army Commander, Indian Army). CSDR combines academic research with policy advocacy and strategic consulting to help governments, businesses, and institutions navigate complex challenges and seize new opportunities in an increasingly complicated world. Our areas of expertise include foreign policy, geopolitical risk, connectivity and geoeconomics, defense and aerospace, military strategy, strategic technologies, conflict resolution, peacebuilding, climate change, energy security, and tech policy. We specialize in the Indian subcontinent, Eurasia, and the Indo-Pacific.

ABOUT SUSTAINABLE DEVELOPMENT POLICY INSTITUTE

Islamabad based Sustainable Development Policy Institute is a non-profit organization aimed at promoting sustainable development in Pakistan. It conducts policy-oriented research, provides policy advice to the government and other stakeholders, facilitates civil society-government interaction, disseminates research findings, and contributes to national research capacity and infrastructure. SDPI aims to catalyze the transition towards sustainable development, providing expertise and advisory services, conducting multidisciplinary research, and fostering collaboration with like-minded organizations.

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Introduction

India and Pakistan frequently grab global attention due to the significant rise in air pollution levels, especially in cities like New Delhi, Lahore, and Karachi during winter. An Air Quality Index of 50 is generally categorized as 'healthy', but in these cities, levels often exceed the 300 mark, making the air dangerous to breathe[1]. Industries, transportation, construction, crop residue, and waste burning contribute to high ambient air pollution levels. Emissions in one country can impact air quality across other countries, particularly during the winter months in the Indo-Gangetic Plains (IGP) witness peculiar meteorological conditions that prevent the dispersal of polluted air. This dangerous and oftentimes hazardous air quality impacts the environment, health, and economic activities. According to the Air Quality Life Index, air pollution has reduced average life expectancy by 3.9 years in Pakistan, with Lahore experiencing a reduction of 7 years.[2] According to the World Air Quality Report 2023, Delhi was the most polluted city in the world, with its average PM2.5 concentration in 2023 at 92.7 (µg/m3).[3]

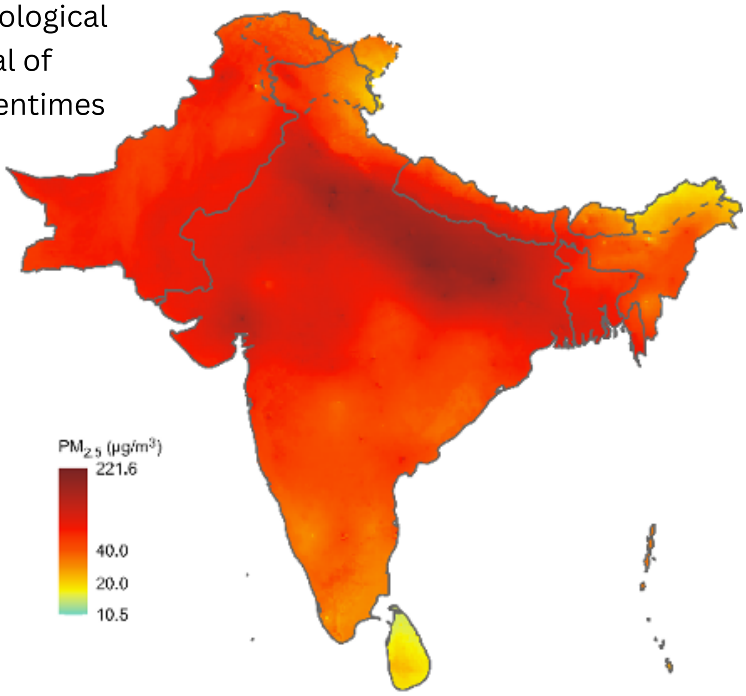


Figure 1 - Annual average PM2.5 levels across South Asia in 2019 (From State of Global Air) [4]

Transboundary Smog: A Visible Symptom of a Larger Problem

An airshed is an area where pollutants from industry, transportation, and other human activities become trapped because of local weather and topography, so they cannot disperse easily. Of the six major airsheds in South Asia, a prominent one is the West/Central Indo-Gangetic Plain: Punjab (Pakistan), Punjab (India), Haryana, part of Rajasthan, Chandigarh, Delhi, Uttar Pradesh; which spans a vast area in both countries.[5] This airshed is heavily impacted by transboundary smog. Caused by factors such as vehicular pollution, crop residue burning, and coal-fired power plants, smog leads to high PM2.5 emissions, which harm human health. Under particular weather conditions, 30% of air pollution in New Delhi can come from Pakistan's Punjab province.[6] Activities that contribute to poor air quality are rampant across both sides of the border. However, the geopolitical equations shared by the two countries make the transboundary management of air pollution difficult. Very often, India accuses Pakistan of burning rice stubble, which impacts air quality in New Delhi, and Pakistan accuses India of not controlling its industrial and vehicular pollution and burning waste, which affects the air quality in Punjab and other regions. Both sides have imposed bans and fines on crop residue burning

with little impact. While cooperative mitigation strategies could help address the issue, focus on cross-border endeavors to tackle climate issues is often lost amidst politically fraught relations between the two countries.

The analysis of weather conditions in the Indo-Gangetic Plains has displayed the accumulations of pollutants, particularly during the winter months in cities like Lahore and Delhi.[7] Farmers have often relied on the convenience of crop residue burning after harvesting rice in late October/early November to prepare the fields to plant wheat. The pollution from this, along with vehicular and industrial emissions in densely populated regions, is trapped due to meteorological conditions across both countries, enveloping them in smog for prolonged periods. **Due to its severity and duration, smog has now been called the 'fifth season' in both countries.**

Health Impacts of the Hazardous Air We Breath

The consequences of air pollution are evident in South Asia, where exposure is linked to chronic respiratory and cardiovascular diseases, diabetes, and cancer, with neonates and children being particularly vulnerable.[8] Certain air pollutants—such as benzene and formaldehyde—are known carcinogens. Prolonged exposure to these substances in the air may increase the risk of developing lung cancer and other respiratory cancers. In 2019, India recorded 1.67 million deaths attributable to air pollution [9], while in Pakistan, 16% of total deaths were linked to it, including over 50% of Chronic Obstructive Pulmonary Disease (COPD) fatalities and 40% of lower respiratory infections.[10]

Studies show a surge in hospitalizations during high pollution periods and adverse impacts on respiratory and cardiovascular health. The correlation between air pollution and health is well-documented, yet marginalized communities, especially in India, face heightened risks due to limited healthcare access and pervasive exposure. Further, in both countries, large sections of the population belonging to low-income groups are engaged in blue-collar jobs. With high environmental exposure, the impact of air pollution is felt on a larger scale by members of these groups. With little access to healthcare and greater exposure to direct outdoor air pollution, members of low-income communities face severe health impacts due to increasing air pollution.[11]

Need for Bilateral Cooperation on Air Pollution between India and Pakistan

Constituting the West/Central Indo-Gangetic Plain, India and Pakistan face similar climate impacts as they are part of a common ecological sphere and are connected by major river systems. Both countries experience similar temperatures and seasons, and their economies rely mainly on agriculture, catering to a growing population and rapid industrialization. Air pollution in both countries stems from similar sources.

At present, both countries rely completely on subnational and national-level strategies to manage and reduce air pollution. However, as they share a common airshed, one-sided mitigation strategies will not be successful if not reciprocated by similar action that achieves comparable results on the other side. Moreover, concentrating solely on addressing the smog 'season' without offering actionable recommendations for addressing air pollution throughout the year may offer only temporary respite. Both countries are known to activate reactive emergency measures once air quality levels have surpassed a certain threshold. This may even be an instance of doing ‘too little too late’ to result in any significant air quality improvement.

India and Pakistan need to shift their use of air quality monitoring data for a more anticipatory and preparatory approach to air pollution management. This would also need better air quality monitoring capacity than presently exists in both countries. This needs to be supported by bilateral collaboration on knowledge sharing, capacity building, and policy-co creation and implementation to achieve comparable results that reduce air pollution levels throughout the year in the entire IGP airshed. **To tackle the problem of air pollution, formal cooperation at a bilateral level and the recognition of a shared responsibility towards air quality across the IGP airshed is needed.** On a larger scale, with six airsheds covering South Asia, the urgency to adopt feasible measures across South Asian Cities is rising every year.

The foundational building block of such cooperation is a bilateral conversation on air pollution involving climate scientists and foreign policy experts focusing on climate cooperation. Such endeavors hold the potential to develop policy pathways to achieve complementarity between relevant stakeholders in both countries, extending to the South-Asian region.

Indo-Pak Climate Collective (IPCC)

The Indo-Pak Climate Collective (IPCC) is constituted by a group of experts from India and Pakistan and is hosted by the Council for Strategic and Defense Research (CSDR) in New Delhi, India, in partnership with the Sustainable Development Policy Institute (SDPI) in Islamabad, Pakistan. It is a platform to promote bilateral cooperation on various aspects of Climate Change mitigation, adaptation, and Transboundary Environmental Governance (TEG). The IPCC aims to cultivate a constituency of stakeholders like climate change, development, and disaster experts along with civil society members working at the grassroots level, members of local/provincial environmental governance and research institutions, and experts on climate diplomacy and cooperation who will be engaged in a multi-stakeholder effort to curate policy pathways and knowledge on Indo-Pak Climate Cooperation across various shared issues.

In its inaugural year, the IPCC focused on the issue of Transboundary Air Pollution and brought together six experts who engaged with each other in a year-long

Research-Policy-Dialogue effort to develop this report. The experts in the inaugural year of the IPCC are:

- Dr. Babar Shahbaz - Director of Agriculture, University of Agriculture, Faisalabad, Pakistan
- Dr. Bhargav Krishna - Fellow, Sustainable Futures Collaborative, New Delhi
- Maryam Shabbir Abbasi - Program Manager, University of Vermont, USA
- Dr. Pallavi Pant - Head - Global Health, Health Effects Institute, Boston
- Ahmed Khaver - Research Associate - Info Change, Islamabad, Pakistan
- Polash Mukerjee - Independent Consultant, Los Angeles, USA

The IPCC benefited from the expert guidance of Project Advisors Mr. Chandra Bhushan (CEO of iFOREST—India) and Dr. Abid Suleri (Director—SDPI—Pakistan). The IPCC is made possible with the generous support of the German Federal Foreign Office through the German Embassy in New Delhi.

Chapter 1

Sustainable Solutions to Crop Residue Burning and Air Pollution Cycle in India and Pakistan

Dr. Bhargav Krishna, Dr. Babar Shahbaz, Annanya Mahajan

Crop residue burning (CRB), or stubble burning, is common across much of India and Pakistan. Its prevalence is most highly concentrated in the agricultural belts of the Indo-Gangetic Plain (IGP) that straddles both nations. This region contributes substantially to both nations' agricultural productivity and food security, primarily through growing staple crops, rice and wheat. **While CRB occurs sporadically in different parts of both countries throughout the year, the seasonal burning occurring annually between October and November, coupled with unfavorable meteorological conditions in the IGP, results in extreme air pollution across the whole region. The byproduct of a short transition between growing seasons, the particulate matter (PM2.5) released as a result of CRB in the North-east of Pakistan and North-west of India is carried downwind to other parts of the IGP, with substantial focus afforded to the impact it has on the air quality of India's National Capital Region due to prevailing low winds and colder temperatures.** The PM2.5 levels measured in the region during this period routinely exceed World Health Organization guidelines for acceptable levels of exposure by 20-100 times, causing a public health emergency. This chapter aims to unpack the scope of CRB across both countries, understand the proximal and distal causes, current policy interventions, and how both countries could sustainably address this issue in the long run.

Scope of the Problem

CRB is common across large tracts of India and Pakistan with crop stubble associated primarily with wheat and rice crops being burned on harvesting. **Data collected through satellite observations over the last decade reveal a generally rising trend between 2015 and 2021, with a dip in 2022. This trend holds across both countries, specifically in the hotspot states of Punjab and Haryana in India, contributing ~65% of the total fires documented in the region, straddling the border between the two countries covering the IGP.** Figures 2 and 3 document the trend in fire counts across the region and in Punjab and Haryana, respectively.

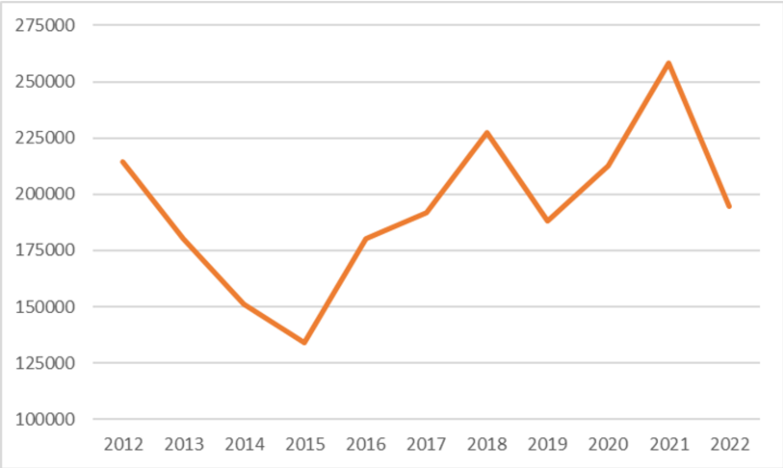


Figure 2. Total fire count in Pakistan and India [Data sourced from NASA FIRMS] [12]

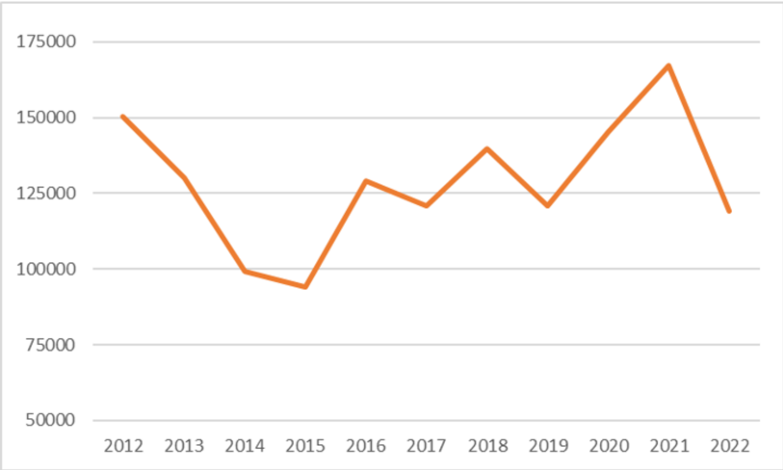


Figure 3. Fire count in Punjab and Haryana, India [Data sourced from NASA FIRMS] [13]

Within these annual counts, we also observe two distinct seasons of CRB coinciding with the harvest of the rabi (wheat) and kharif (rice) crops (Figure 4). These periods are around April-May and October-November, respectively.

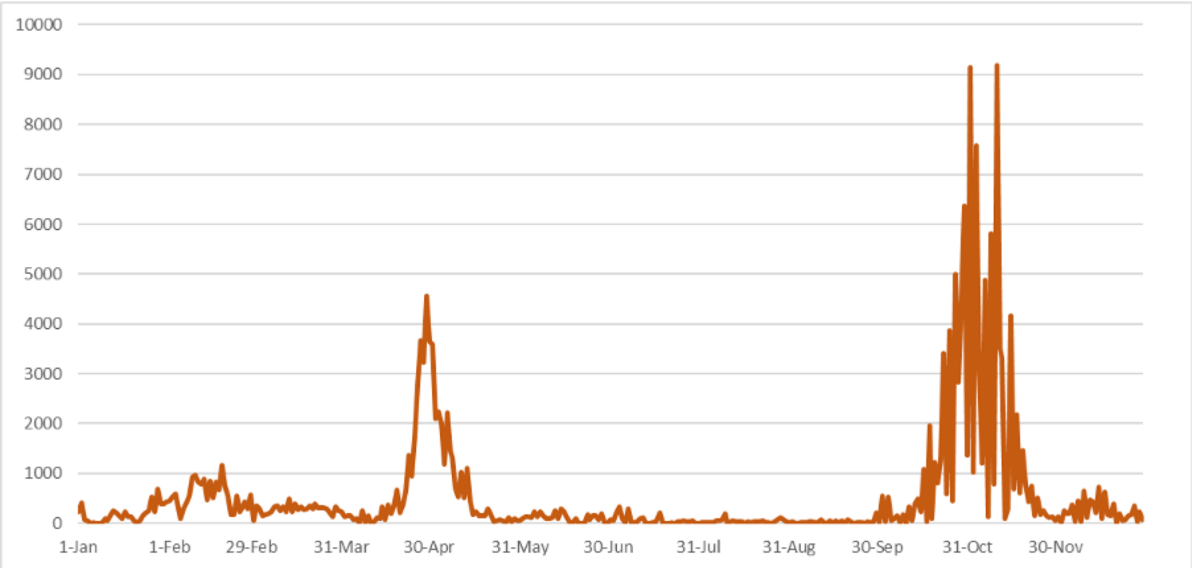


Figure 4. CRB seasons [Data sourced from NASA FIRMS][14]

To obtain a more accurate estimate of the scale of CRB, one can analyze the burned area in addition to the fire count. While both measurements are subject to spatial and temporal limitations (due to the nature of data collected by satellites), triangulation of evidence can give us a reasonably accurate picture of CRB trends (Figure 5).

Deshpande et al. found that, **between 2011 and 2020, there was a 49% rise in agricultural burnt area (ABA)[15] in India.[16] Of this, Punjab was responsible for 48% of the total ABA, making it the state with the highest ABA contribution. In 2020 alone, 2 million hectares of agricultural burnt area was calculated in Punjab.** They explain that factors such as differences in rice variety cultivated and livestock owned by farmers lead to variations in the extent of residue burning across different regions. However, they caveat that these are not the sole explanatory factors. The study also highlights the increasing contribution to residue burning from non-IGP states in the summer, most notably Madhya Pradesh.

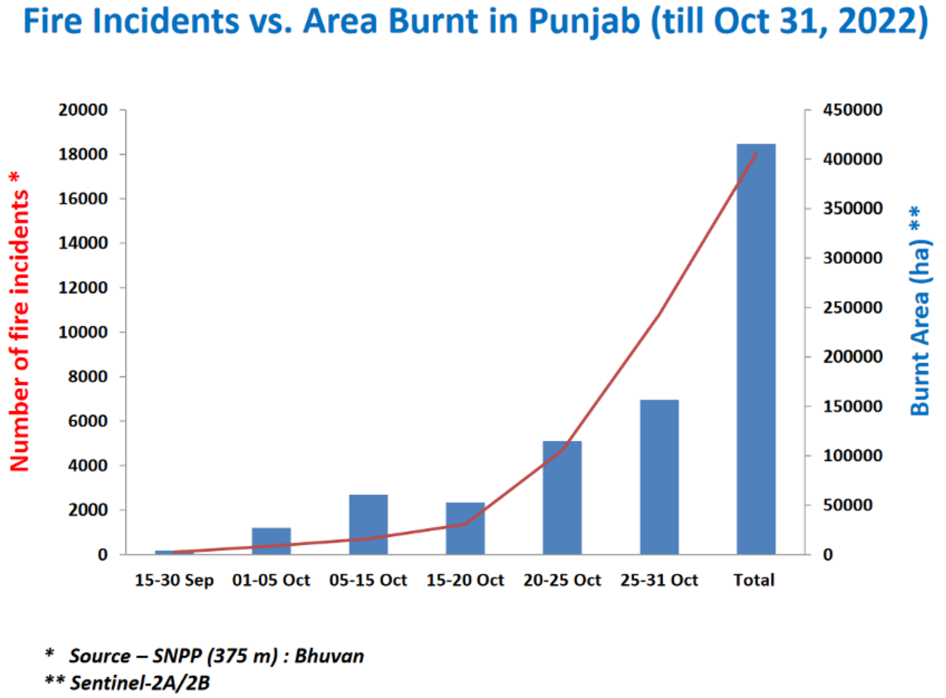


Figure 5: Triangulating fire incidents and burnt area data in Punjab, India[17]

When looking at burnt area in Punjab alone, data from the National Remote Sensing Centre (NRSC) of India shows a rising trend in CRB in the state (Figure 5). The cumulative area burnt in Punjab between 15th Sept to 31st Oct was 2.14 lakh hectares in 2021, which then increased to 4.15 lakh hectares in 2022 for the corresponding period.[18] While data on burnt area for 2023 is yet to be compiled, data on crop fire events suggest fewer locations with active crop fires in Punjab in 2023 compared to 2022.[19] **In the province of Punjab in Pakistan, about 5 million tons of rice residue are burnt out of 8.5 million tons produced yearly. Due to the limited resources of the farmers, prevailing management practices, and a short**

time for land preparation for the next crop, rice straw accounts for a substantial percentage of residue. But rice is not the only crop whose residue is burnt with burning of wheat residue, which is also reported to have increased in Pakistan.[20] According to FAO (2018), on average, 61% of the crop area of wheat is burned; however, the burning of maize and sugarcane residues is not common in Pakistan.[21]

Crop Residue Burning and "Smog" Season

The contribution of CRB to air quality in the region is substantial in the immediate aftermath of the burning itself, while its impact over the course of a year is limited. The former is salient for two reasons – the short-term health impacts of hazardous levels of air pollution and the meteorology of the region, which contributes to the pollution generated by crop burning to 'hang' over the region for several days or weeks, manifesting as a prolonged "smog" season. Various studies have estimated that the seasonal contribution of CRB to ambient PM2.5 loading in the national capital region of India is between 30-35%.[22] Studies have also shown a significant increase in ambient black carbon concentration in the NCR due to CRB, with estimates ranging from 43-60%.[23] In Pakistan, CRB was estimated to contribute 15-20% of the air pollutant emissions.[24] The result of this added air pollution loading is a substantial deterioration of ambient air quality in the region, with PM2.5 concentrations ranging from 150-700 µg/m3 in winter,[25] between 10-40 times above the guidelines for acceptable exposure as per the World Health Organization.[26]

Crop Residue Burning- Health and Environmental Impacts

The health impacts of air pollution have been well documented globally, with a growing Indian evidence base adding to the wealth of evidence on the detrimental effects of short and long-term exposures, particularly to PM2.5.

Health and economic effects of CRB are also felt locally within communities that practice CRB, with a study by Chakrabarti et al. noting that living in districts with the top quintile of fires per day was associated with a 3-fold higher risk of acute respiratory infections.[27] They also found that eliminating CRB would avert 149,000 disability-adjusted life years (DALYs) lost yearly, with an associated economic benefit of $1.53 billion over five years. A survey conducted by Mor et al. in the state of Haryana in India found a significant correlation between CRB and respiratory issues. The effects were stronger for those below the age of 18 and above the age of 60.[28]

While the direct health costs of CRB on communities in India have not been extensively studied, research by **Raza et al. from Pakistan highlighted the increased household spending on treating chronic and acute illnesses during the burning season.[29] The study, conducted in three selected districts, found that**

households spend 8.80 to 13.35 US$ on chronic and acute diseases during the burning season. Many respondents also reported a decline in work productivity due to pollution, indicating secondary economic effects beyond direct health costs.

The practice of burning crop residue can also lead to a decrease in organic matter, loss of essential nutrients from the field, and reduction in moisture content of the soil. Studies have shown that frequent residue burning would result in low agricultural production and harmful effects on soil health.[30] CRB results in the deterioration of organic matter in the soil and changes the chemical and physical properties of soil,[31] reducing the soil's capacity to hold carbon and nitrogen.

Proximal and Distal Causes of CRB and Smog Bind: Policies that Led to the Problem

A. India

In aiming to understand the proximal and distal causes of CRB in India, we will contain our analysis to Punjab and Haryana, the two states that contribute to the largest number of fires and associated impact on air quality.

Changes in cropping patterns

Facing a crisis of food security and largely reliant on imported food grains, India laid out landmark reforms in the 1960s that would revolutionize agriculture to ensure food security. The Green Revolution, as it would come to be known, involved technological, economic, and institutional reform, leading to an almost exclusive focus on the cultivation of the two primary cereal crops (paddy and wheat) to ensure adequate availability of food and increased caloric intake.[32] Over the last 50 years, the impact of these reforms has led to **substantial changes in cropping patterns across Punjab and Haryana, with the area under paddy cultivation growing 10-fold (from 4.7 lakh Ha in 1966 to 45.5 lakh Ha in 2018) and the area under wheat cultivation growing 2.5-fold. Simultaneously, other crops traditionally grown in the region (including maize, pulses, and oil seeds) declined substantially. Therefore, 84% of arable land in Punjab and Haryana in India is used for paddy-wheat cropping (2018 figures), with many farmers relying on CRB as a cost-effective solution to clear the residue.**

Technology and mechanization

The rapid growth of the paddy-wheat duopoly in these states was also aided by a combination of seed technologies and farming mechanization. The adoption of high-yielding varieties developed by the Indian Council of Agricultural Research (ICAR) over the previous three decades has seen these states outperform others in the country on yield per hectare of both crops. For instance, while West Bengal is

the largest rice producer in the country, Punjab and Haryana outrank it in terms of yield per hectare.[33]Simultaneously, the rising labor cost and the focus on increasing yields also made farmers in these states more open to adopting mechanized farming.[34]

Economic Incentives and Structures

Economic incentives have contributed in two ways to the cropping patterns and the subsequent practice of crop residue burning. **First, the introduction of state-specific credit or subsidy schemes for boring and pumping to enhance groundwater usage; second, free electricity provision for pump sets has led to greater adoption of paddy in this region.[35]** This was despite it being mainly unsuited to the area, given the high water requirements of the paddy crop. Further, the **establishment of the minimum support price for crops like paddy and wheat and a guaranteed buyer creates an incentive structure that was necessary when it was first rolled out but has continued well beyond its need.[36]** Reforming these mechanisms has proven challenging, given how local economies in both states are deeply tied to these long-established practices.

Second-Order Policy Effects

To stem the rapid deterioration of groundwater reserves in both states, the respective state governments introduced legislation in 2009 to restrict groundwater use during the dry summer months of April and May, between the harvest of the rabi crop and the sowing of the kharif crop.[37] These sub-soil water conservation acts pushed the sowing season further down the calendar, resulting in a significant shortening of the time between the harvest of the kharif paddy crop and the sowing of the rabi wheat crop during the October-November period. **This shortening of the harvest period, coupled with mechanized harvesting and rising labor costs, ultimately led farmers to burn the remaining rice stubble after harvest as it was the most cost-effective option.[38]**

B. Pakistan

Burning of crop residue and stubble is mostly practiced after the harvest of rice in October-November and wheat harvest in April-May, mainly in the Punjab province of Pakistan. **The story of CRB in Pakistan has similar proximal and distal causes as that in India. However, one important differentiator is growing the non-basmati variety of rice, which produces much more stubble.[39] For centuries, basmati rice has been grown in the rice belt of Punjab. However, there is an increasing trend of cultivating non-basmati varieties, and consequently, there has been a decrease in the cultivation area of basmati varieties during the last 5-7 years.** Burning being the least expensive method, it is widely practiced to dispose of the stubble, as farmers have less than a month to prepare for the wheat crop.

Crop Residue Burning Around the World

Globally, burning leftover vegetation to prepare land for sowing the next crop (or other farming activities) is a long-standing practice. According to a World Bank report, China, India, and the USA are the top countries in terms of CRB, followed by Brazil, Indonesia, and the Russian Federation. Many African countries, such as Tanzania, Nigeria, Ghana, and South American countries, including Mexico and Brazil, have the most intensive rate of CRB per hectare of harvested land. For example, agricultural waste is burned in Mexico to eliminate unwanted waste after harvesting rice, corn, beans, and wheat. Burning branches from fruit orchards and vineyards is also a common practice.[40]

Recently, Antwi-Agyei et al. conducted a study to highlight the decision-making of smallholder farmers related to the utilization and management of crop residues in rural Ghana and found that the farmers were utilizing residues in multiple ways such as leaving them on the farm to decompose, using it as livestock feed and burning. They also found that most farmers burn their crop residues to prepare their lands for the cultivation of the next crop due to the short interval between harvesting and planting.[41]

Preparing rice straw for open burning

Ali Mohammadi (distributed via imaggeo.egu.eu)

Labor scarcity and lack of awareness about alternate solutions regarding residue burning were also the major factors affecting farmers' decision regarding residue burning. Similarly, in South Asian countries, the burning of crop residues is widespread.[42] Some studies indicated that burning rice straw is a common practice in the Terai region of Nepal.[43] The main factors affecting farmer behavior regarding crop residue burning in Nepal are ownership of livestock and the use of combined harvesters.[44]

The practice of CRB in South Asia is influenced by several agricultural practices such as crop cycle, crop type, harvesting season, farm mechanization, agricultural labor, transportation cost, and profitability of alternate options. A study in Bangladesh found that farmers who burn rice crop residue save about $110 per hectare per season compared to those who do not burn.[45] According to Lin and Begho, farmers see burning as an inexpensive and quick way to dispose of crop residue.[46] Shortage in the agricultural labor force aggravates the problem. Similarly, in East Asian countries (China, Vietnam, and the Philippines), rice and wheat residues are burned to save time and resources, lack of markets for husks and straw, and some agronomic beliefs.[47] Over the past few decades, an increasing trend in straw-burning practices was seen in China due to a rapid economic boom in some relatively underdeveloped regions.[48] Countries across the world have taken several measures to control crop burning. For example, China's policy of providing straw-recycling subsidies has substantially reduced straw-burning activities.[49]

Reducing Crop Residue Burning: Current Policy Responses in India and Pakistan

From the perspective of existing legal frameworks, the policy response to CRB has been challenging since the environmental laws of both countries are not explicitly designed to tackle such a diffuse source of pollution. There are differences, however, in the foci of the core policy approach of both countries, namely the National Clean Air Program in India (NCAP-IN) and the National Clean Air Policy (NCAP-PK) in Pakistan.[50] NCAP-IN is focused primarily on reducing all sources but from the perspective of identifying and tackling the issue at the level of cities, with 132 classed as 'non-attainment'. By contrast, the NCAP-PK views the problem through the sectoral lens with key measures planned across five sectors – transport, industry, agriculture, waste, and household. The inclusion of agriculture and household air pollution are key differentiators for the nationally focused NCAP-PK. However, while there are differences in the policy frameworks, there are broad similarities in the ultimate implementation of these policies.

A. Legal Mechanisms

The first response of both countries to the issue of stubble burning was to criminalize the action. In 2017, the Lahore High Court constituted a Smog Commission that formulated the first-ever smog policy subsequently approved by the Government of Punjab.[51] In addition to various other interventions, this policy authorized the government (Home Department) in 2019 to impose a seasonal ban on and a tied fine of up to Pak. Rs. 50,000 per acre.[52] The provincial government declared smog a catastrophe in 2021 and directed the Punjab Disaster Management Authority (PDMA) to take necessary action against CRB and decrease emissions in the province. **It is unclear as of date whether these punitive measures have yielded the desired success.**

In India, the initial response was to criminalize the action and impose penalties ranging from INR 2500 to INR 15,000 on every act of crop burning by farmers (penalties varied based on the land holding size).[53] This proved ineffective since farmers were unwilling to utilize alternative approaches, and authorities were unwilling to penalize farmers. While the act of CRB has been illegal under law since 1981, the implementation of this writ remains sporadic despite interventions from the Supreme Court and the National Green Tribunal, which have asked State governments through district-level bureaucrats to implement these harsh measures stringently.[54] **In response to farmer appeals, the act was decriminalized in 2021 in India.[55]**

B. Technological Solutions

The next approach in both countries was to identify and provide equipment necessary to manage crop residue insitu. In India, the Union Ministry of Agriculture and Farmers' Welfare allocates funds towards the subsidized purchase of stubble management equipment including happy seeders, combine harvesters, rotavators, and super straw management systems, among others. **As of March 2021, a combined total of INR 2440 crores (~$298 million) has been spent on the purchase and distribution of these subsidized equipment. This investment has seen a dramatic increase in the number of these machines available to farmers, especially in Punjab, with the current stock of happy seeders and super seeders capable of managing crop residue in ~66% of the arable land under non-basmati rice varieties. [56]**

In Pakistan, the Government of Punjab in 2020 attempted to address the problem of stubble burning by providing 500 rice farmers with Happy Seeder and Rice Straw Shredder.[57] Rice growers were provided an 80% subsidy per machine for rice crop residue management, and on-farm training on these machines is also part of the project.[58] However, the number of machines is rather low, considering that many farmers live in the rice belt of the Punjab. Capacity building and awareness are very important factors in adopting agricultural machines to minimize CRB. For instance, Rafiq et al. recommended an awareness and capacity-building campaign regarding the use of machines to reduce open-field burning of crop residue and the use of crop residue for bio-energy consumption.[59]

The challenge in providing in-situ management options for farmers in both countries is that it requires some level of investment from the farmers themselves (who may not be financially able), and this equipment is used for a limited period during the year and is required to be available at scale to thousands of farmers during a short window of 2-3 weeks, making it a logistical challenge.

C. Alternative Uses of Crop Residue: Ex-Situ Management

In contrast to in-situ crop residue management—which aims to dispose of the residue locally—ex-situ approaches provide alternative uses for the residue to create additional economic value for farmers while reducing air pollution. India has taken several steps to encourage ex-situ stubble management, such as the pelletization of stubble to be co-fired in boilers, using stubble to produce ethanol, and converting residue bales into useful end products for consumers. However, to be successful in residue disposal, ex-situ stubble management requires several complex steps:

- Farmers must have customized farm implements such as rakers and balers already in place to turn their crop residue into bales. These implements either have to be purchased by farmers or they must be made available on rent through farmers collectives and other organizations at scale during the short harvesting period.
- Extensive logistics networks have to be created to transport and store straw bales across every district.

- Appropriate regional facilities must be created with skilled labor available to convert the straw bales into the end product needed by industry.
- Final products must be delivered to end users at a competitive cost so that they can economically utilize them in their processes.

Each of these significant hurdles come with substantial costs further minimizing the use of ex-situ options by farmers. The private sector is crucial in promoting the successful utilization of ex-situ solutions. The private sector can create economic opportunities and respond to the region's potential economic value chain created by crop residue. This can be achieved by creating jobs and increasing economic returns for the farmers.[60] A few biogas and waste-to-energy plants have been set up in India (Punjab and Haryana) with Public Sector Undertakings (PSUs) support. However, the private sector is yet to enter the field and increase crop residue markets' scale and economic viability.[61] **The Haryana state government recently approved the "Haryana Ex-Situ Management of Paddy Straw Policy 2023" to respond to this need. While the policy is yet to be implemented, it aims to attract private investment and increase linkages between agriculture and industry.[62]**

D. Payments for Adopting Alternative Crop Residue Management Solutions

One of the most prevalent narratives attributes stubble burning to alternative methods of removing stubble being relatively more expensive. This could be in the form of hiring labor to manually clear the field, utilizing machines that cut stubble, utilizing fuel and tractors for the machines, or even utilizing straw balers, among others. To this end, the Punjab and Haryana state governments introduced a payment for small and marginal farmers in 2019. However, they could not cover many farmers due to a shortage of funds. A study in Punjab found that upfront payments made to farmers effectively reduced instances of stubble burning by 50-80% relative to two groups of farmers: farmers that were not paid at all; and farmers paid after verifying they did not burn stubble.[63]

How to Sustainably Address the Problem of Crop Residue Burning in India and Pakistan

While emphasizing an "all-of-the-above" stratagem with respect to approaches adopted by governments in Pakistan and India to curb the problem of CRB, we also strongly recommend that any suite of solutions should focus on the long-term goal of crop diversification. We also argue that punitive measures such as fines are unlikely to be successful as they are often implemented with little understanding of local contexts. Drawing upon prevailing practices in certain regions of India and Pakistan, as well as insights harvested from experiences in other nations, we present some short, medium, and long-term strategies to sustainably tackle CRB.

A. Short-Term Strategies

One of the most prevalent narratives attributes stubble burning to alternative methods of removing stubble being relatively more expensive. This could be in the form of hiring labor to manually clear the field, utilizing machines that cut stubble, utilizing fuel and tractors for the machines, or even utilizing straw balers, among others. To this end, the Punjab and Haryana state governments introduced a payment for small and marginal farmers in 2019. However, they could not cover many farmers due to a shortage of funds. A study in Punjab found that upfront payments made to farmers effectively reduced instances of stubble burning by 50-80% relative to two groups of farmers: farmers that were not paid at all; and farmers paid after verifying they did not burn stubble.[63]

Ex-situ stubble management

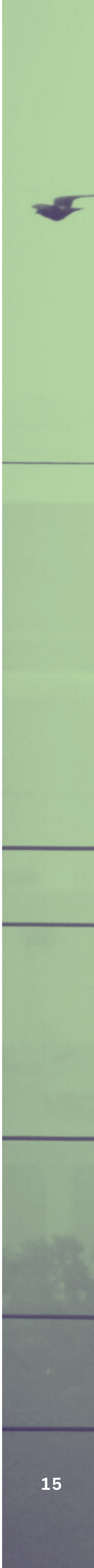
Governments should prioritize encouraging and incentivizing small and medium enterprises (SMEs) that utilize crop residue as a raw material, particularly in the regions where CRB is prevalent. Globally, crop residues are commonly used in paper and cardboard production, with wheat and rice residues being the main raw materials. Paddy waste can also be used as packing material for perishable products such as fruits and vegetables. India has recently implemented some steps to encourage ex-situ stubble management, such as the pelletization of stubble to be co-fired in boilers, conversion into ethanol, and the conversion of residue bales into useful end products for consumers.

Financial assistance for crop residue management machinery

Various machines such as happy seeders, combine harvesters, rotavators, and super straw management systems have been used in both countries, albeit with limited uptake. Providing financial assistance and subsidies to farmer collectives and cooperative societies can facilitate widespread adoption and effectively address the issue of stubble burning. Further R&D on such initiatives and disseminating innovations holds good potential for sustainable agricultural practices.[64] The role of the private sector is also essential here, with the need to redesign and deploy (at scale) combined harvesters that leave shorter stubble in the field.[65]

Capacity Building for Farmers

Enhancing farmers' capacity and disseminating information about residue management practices is essential to manage crop residue sustainably. Farmers can be trained about alternate and more cost-effective use of crop residues through coordinated efforts of extension service providers from the public and private sector, as well as civil society organizations.[66] A recent review on the economics of crop residue management noted that while financial and technological



incentivization are important first steps, increasing public awareness and farmer choices is essential to drive sustainable cropping practices.[67]

B. Medium-Term Strategies

Carbon farming

From the perspective of sustainable crop residue management, Carbon farming offers a solution to control greenhouse gas emissions from agriculture and contribute to sustainability.[68] The European Union (EU) has championed Carbon farming as a sustainable strategy to improve soil health and increase carbon sequestration. This initiative, part of the EU Green Deal, is designed to ensure the EU becomes climate-neutral by 2050.[69] The success of the EU's Carbon Farming project provides a valuable model for India and Pakistan to sustainably manage their crop residues.

Payment-for-ecosystem services (PES)

Payment-for-ecosystem services (PES) can play a crucial role in curbing residue burning and promoting eco-friendly agricultural practices. This approach involves compensating farmers for committing to environmentally sustainable land management practices. In Pakistan, for instance, PES could be implemented through a conditional cash transfer program facilitated by social protection platforms such as Ehsaas BISP, with support from the Department of Agriculture.[70] This would incentivize farmers to adopt more sustainable practices, leading to a reduction in residue burning and improved soil health.

Bioenergy production from crop residue

Studies conducted in several countries highlight the significant potential of crop residues for bioenergy production. Rice straw, maize stalks, cotton stalks, sugar cane bagasse, wheat straw, have all been identified as viable biomass sources for biofuels and other chemicals.[71] The production of Biofuels from crop residue could be a particularly beneficial solution for South Asian countries, given their high fuel demand. To fully realize this potential, governments need to develop a concrete and feasible business model, establish a robust supply chain system, and create storage facilities for residue in regions with a high incidence of crop burning.

C. Long-Term Strategies

Diversification of cropping patterns

Shifting away from the almost exclusive focus on paddy and wheat towards other crops responsive to the local agroecological potential.[72] Currently, the agriculture ministries of India and Pakistan are focusing on pilots of crop diversification. However, the quantum of funds allocated to this program is much smaller than what has already been spent on farm equipment to tackle stubble burning.[73] Strategically deploying these funds to ensure that there is a rollout of a planned and effectively executed pilot program on crop diversification in select districts would go a long way toward developing a model that can be scaled to more districts. Examples from India showcase how a well-planned and sustainably scaled crop diversification program can succeed (see page 18). Crop Diversification is a complex process because farmers have become accustomed to the rice-wheat cropping pattern for centuries. Some issues need to be tackled when undertaking crop diversification on a large scale.

Developing supply and value chains and choice of crops

Developing supply and value chains within the region and the choice of crops that reflect the needs of local farmers both from the perspective of yield and financial earnings. Previous pilots have focused on instituting an MSP for maize but without a guaranteed buyer. Future efforts could shift focus in two directions – encourage farmers growing non-basmati varieties to shift towards basmati or provide alternative cash crop options such as oil seeds or pulses, which have similar land yield rates per hectare.[74]

Engaging civil society in awareness programs

The active involvement of civil society in awareness-building and information dissemination activities is a crucial factor in the success of any crop diversification program. Drawing from the experience of the Odisha Millet Mission, it's evident that civil society organizations possess significant human resources and often have established connections with the communities. Their role in driving local-level change in collaboration with governments cannot be overstated.[75]

Coordinating efforts across the stakeholders

Beyond the agricultural sphere, a comprehensive effort is necessary to coordinate actions across the stakeholders of the crop residue value chain. At the governmental level, implementing inter-sectoral policies and establishing convening institutions can significantly reduce the costs associated with transitioning to more sustainable cropping patterns. The recent Stubble Management Policy 2023 by the Government of Haryana is an excellent example of such coordination, involving the departments of Agriculture & Farmers Welfare, New and Renewable Energy, and Micro, Small, and Medium Enterprises.[76]

Case Study: Odisha Millet Mission (OMM)

In 2017, the Government of Odisha introduced the state millet mission to revive the production and consumption of millets. Arising out of a consultative process involving state and non-state actors, the program was the first of its kind, focusing on production and consumption. Through this focus on consumption, the initial goal was to target the high malnutrition rates in Odisha's tribal districts through the proliferation of a more nutritive diet.[77]

The program's success was largely due to the involvement of civil society organizations (CSOs) and community-based organizations (CBOs). Recognizing their effectiveness as interlocutors, each block in the seven districts with the highest tribal populations was assigned to these organizations. This approach was particularly significant during a period of growing distrust between the State and civil society in the rest of the country, showcasing the program's unique and successful strategy.[78] By 2021, the program grew to cover 14 districts and 76 blocks, and as of date, it has now reached all 30 districts in Odisha and 177 blocks. As a result, over 250,000 farmers are now engaged in the production of millets in the State. The approved budgetary outlay over five years for the OMM is Rs. 2808 Cr with an additional program budget of Rs. 580 Cr.[79] This figure compares favorably with the outlay towards farm equipment in Punjab and Haryana to address the stubble burning crisis, as the primary crop displaced in Odisha due to the OMM was paddy.[80]

The OMM also introduced a new mechanism called millet mandis (markets), where millets are procured directly from farmers at a rate of ~Rs. 30 per kg. Given the notification of a minimum support price for procuring millets directly from farmers and compared to the price available at agriculture markets for rice (~Rs. 18 per kg), this scheme proved to be beneficial not just from the perspective of crop diversification, soil health, and nutrition, but also in financial terms to farmers. To mainstream millets into the diet of Odisha citizens, the government first introduced ragi laddus in the state's Integrated Child Development Scheme, supported by the district mineral funds. Subsequently, the State government also began distributing millets through its public distribution system, becoming only the third state to do so.

Several lessons can be learned from this experience with respect to a longer-term crop diversification strategy in India and Pakistan. First, introducing indigenous species that were originally part of the diet can serve multiple purposes (nutrition-enhancing, climate-resilient, and water-sensitive).[81] Second, establishing institutional and policy structures to undergird the delivery of such a large-scale program is essential.[82] Third, understanding the financial needs of farmers and identifying pathways not only for production but also guaranteed procurement and distribution in advance are necessary to drive progress. And finally, civil society can serve as key interlocutors in raising awareness and delivering state policy effectively locally.[83]

Conclusion and Way Forward

The shared experiences of India and Pakistan in dealing with CRB highlight the relevance of this research to both countries. This chapter aimed to outline the key challenges and a sustainable path to reduce the impact of seasonal smog associated with this practice. Given the similar conditions and geographical proximity, India and Pakistan can greatly benefit from the sharing of knowledge and best practices around sustainable crop residue management. We have laid out several short-long term strategies that can be implemented in a phased manner by both countries as they work toward a long-term goal of diversifying cropping patterns. These steps, if taken in a planned and consultative manner, can have substantial benefits in reducing transboundary air pollution produced by CRB.

In addition, we see several immediate opportunities for both countries to learn from each other's experiences as they work together to address CRB's contribution to winter smog simultaneously. The first is the case of CRB and basmati. Basmati fodder is softer and has lower silica content, making it easier to use as animal fodder.[84] This practice has already been tested in India and can also be adopted in Pakistan, where basmati stubble continues to be burned.[85] Second, Pakistan's private sector has been able to conduct substantial research on agricultural technological innovation and work towards farmer welfare.[86] India can learn from such public-private coordination and emulate a similar strategy. Third, Pakistan has chosen a similar path to India in addressing CRB, primarily through technological interventions. While this may be a necessary short-term step, the lessons from the Indian experience show that any in-situ or ex-situ approach can only have limited success.

As we can see from several international cases and with Odisha's millet mission, several lessons can also be learned as we move towards sustainable cropping practices. First, all stakeholders (farmers, governments, civil society, and the private sector) must be engaged early in planning and through every implementation stage. Second, elements of the value chain beyond price guarantees are fundamental to identifying buyers and market routes essential for any cropping transition. Third, there is value in identifying and propagating indigenous crops that are often more climate resilient while contributing to improved health and nutrition. Fourth, integrating financial incentives to mainstream lower-carbon agricultural practices can help facilitate a more rapid transition. Finally, and in the interim, the reinvigoration of the Male Declaration principles and the South Asia Cooperative Environment Programme can promote knowledge sharing. As in the case of the ASEAN agreement on transboundary haze pollution, the benefit of such platforms goes beyond the sharing of data towards a more integrated approach to resolving a regional problem.[87] This integrated approach, teamed with nationally determined goals and associated timelines, could provide the basis for region-wide reductions in air pollution, particularly from CRB.

Chapter 2

Reducing Vehicular Pollution in India: A Crucial Variable in Year-Long Air Pollution Management

Polash Mukerjee

The transport sector holds particular significance among the various sources of ambient air pollution in South Asian cities. This is primarily due to two reasons. Firstly, at an individual level, people are exposed to emissions from vehicles to a much greater extent compared to other sources. Secondly, the increasing number of vehicles has led to a rise in vehicular emissions. The contribution of vehicular emissions to overall ambient air pollution levels has, therefore, been rising in most cities. Transport sector emissions also contribute significantly to greenhouse gas emissions and climate change. Therefore, action to clean up vehicular emissions can have long-term impacts beyond the localized health improvements caused by lower pollution.

India's transportation sector is extensive and varied, serving the needs of 1.3 billion people. The transport sector accounts for 10% of India's total energy consumption.[88] Although this figure is much lower than that of other countries, it is fast rising. The sector is heavily dominated by road-based transport - nearly 87% of the country's passenger traffic and over 60% of freight moves via roads.[89] India has the world's second-largest road network, at more than 6.3 million kilometers as of 2023.[90] This number is rapidly increasing, with more than 65000 kilometers of national highways alone being in various stages of development.

India is undergoing rapid urbanization, with 31.8% of its population residing in urban areas in 2011. This number is expected to rise to 38.6% in 2036 and continue until the middle of the century.[91] However, only a few cities have organized urban transport systems, and the share of public transport in larger cities has declined. Conversely, the motorization rates in India are in double digits, and there's a pressing need for improved environment-friendly mass transit systems to address growing concerns regarding pollution, congestion, and safety.

The Growth of India's Vehicle Sector

- India has approximately 389 million registered vehicles as of December 1, 2023.
- Two-wheelers account for about three-fourths of India's total vehicles, while cars make up around 13%.
- Vehicle registration in India surged at a remarkable rate of 9.83% annually between 2010 and 2020.
- Over 300 million vehicles have been registered in India since 2006, indicating explosive growth in less than two decades.
- This growth significantly outpaces the expansion of India's road network, primarily driven by developments in national and state highways.

This has resulted in tremendous vehicular congestion in India's towns and cities, significantly contributing to ambient air pollution. Delhi alone had close to 13 million vehicles at the end of 2023. Of these, less than half are scheduled to be disallowed from operating on the roads due to their higher pollution contribution. [92]

Moreover, **most of this growth has been driven by personal mobility vehicles – two-wheelers and cars. In contrast, buses and public transport vehicles have not kept up with this pace, as demonstrated by the decline of city bus services in many Indian cities.**

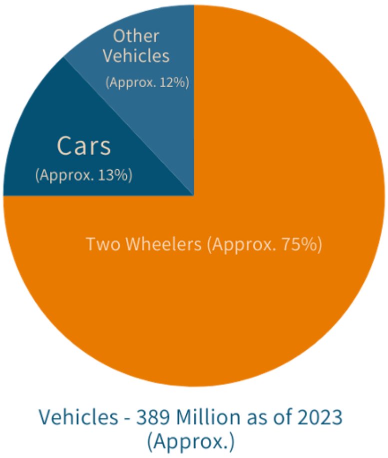


Figure 6 - India's Vehicular Build-Up as of 2023

Transport Sector Contribution to Air Quality Emissions in India

The transport sector significantly contributes to air quality emissions, releasing various atmospheric pollutants. Key pollutants associated with the transport sector include:

- Particulate Matter (PM): Vehicle emissions, including PM10 and PM2.5, penetrate the respiratory system and cause respiratory and cardiovascular problems.
- Nitrogen Oxides (NOx): Vehicle combustion of fossil fuels forms NOx, which contributes to ground-level ozone, fine particulate matter, respiratory issues, and smog.
- Carbon Monoxide (CO): Incomplete fuel combustion releases CO, hindering oxygen transport and posing health risks.
- Sulfur Dioxide (SO2): Vehicle combustion with sulfur-containing fuel emits SO2, which is linked to respiratory issues and acid rain formation.
- Volatile Organic Compounds (VOCs): VOCs from vehicle exhaust form ground-level ozone and smog, impacting respiratory health and the environment.
- Greenhouse Gas Emissions: Transport emissions, primarily CO2, drive climate change and global warming.
- Toxins: Vehicle emissions contain benzene, formaldehyde, and PAHs, with harmful health effects and carcinogenic properties.
- Black Carbon: Released during incomplete fuel combustion, black carbon contributes to respiratory and cardiovascular issues and climate change.

An October 2021 report [93] by the Centre for Environment, Energy and Water (CEEW) summarizes the transport sector's contribution to various pollutants in India, as found by relevant recent national-level emission inventories. The report finds that although there are significant variations in the finding of the various total emission loads, transport sector emissions remain a significant factor contributing to ambient air pollution loads. A summary of the contributions of the transport sector to national air pollution inventories is as follows:

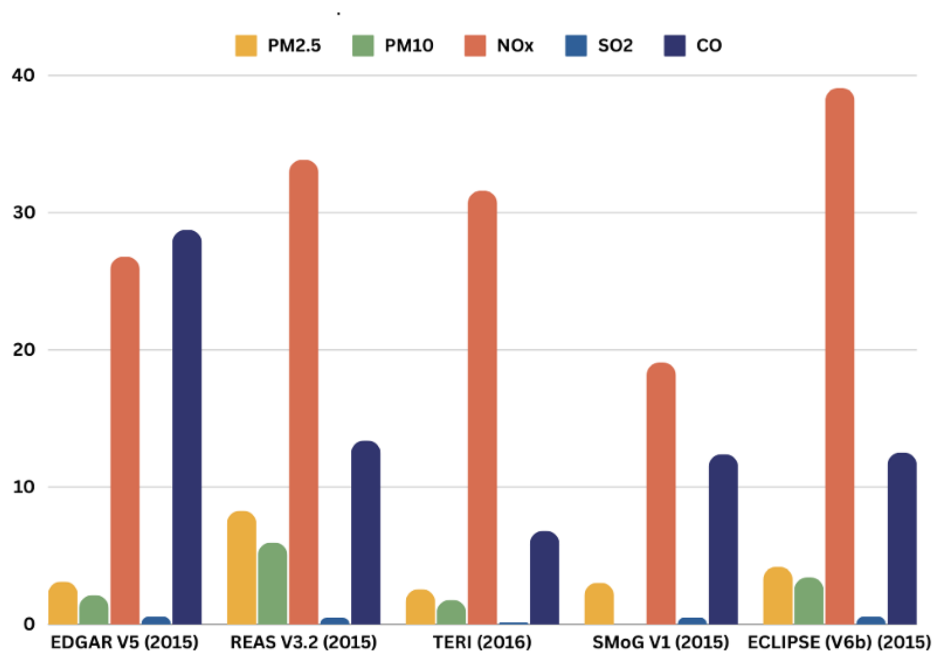


Figure 7: National Level Transport Sector Contributions to Air Pollutants in India

Emission Inventory	Contribution of Transport Sector				
	PM2.5	PM10	NOx	SO2	CO
EDGAR V5 (2015)	3.12%	2.12%	26.79%	0.57%	28.75%
REAS V3.2 (2015)	8.28%	5.97%	33.86%	0.48%	13.40%
TERI (2016)	2.56%	1.78%	31.61%	0.14%	6.81%
SMoG V1 (2015)	3.04%	NA	19.08%	0.49%	12.41%
ECLIPSE(V6b) (2015)	4.19%	3.41%	39.09%	0.57%	12.52%

Table 1: Summary of national-level transport sector contribution to various air pollutants in India[94]

The most significant contribution to ambient air pollution from the Transport sector is from Nitrogen Oxides and Carbon Monoxide – between 15 and 30% of the total emission load for the country. This is tremendously significant, as was demonstrated by the drastic improvement in air quality during the COVID-19-induced lockdown in 2020. Several studies note the dramatic reduction in general anthropomorphic, specifically, transport sector air quality pollution over large parts of India, notably the Indo-Gangetic plain. The reduction in pollutant ambient concentrations was noted to be in the range of 10-50% for particulate matter, nitrogen oxides, sulfur oxides, and ozone.[95] It's crucial to note that transport sources could have a significantly greater impact on urban ambient air quality than what is indicated by nationalized inventories. Given that vehicular emissions are especially significant due to the higher exposure to larger populations, the impact on respiratory health is a concern. Moreover, a comparison of city-based emission inventories and source apportionment indicates that transportation contributes much more to localized air pollution than indicated here.

From Tail-Pipe Emissions Towards a Life Cycle Approach

Other forms of transport emissions include non-tailpipe transport emissions. These are not directly emitted from a vehicle's tailpipe but are associated with the overall life cycle of the transportation system. Some components of non-tailpipe transport emissions include:

- Vehicle Operation and Maintenance – Particulate dust is generated by vehicular components, such as tires, brake pads, and emission control equipment, that may be released into the air
- Fuel/Energy Production and Distribution
- Vehicle Manufacturing and Disposal
- Infrastructure Construction and Maintenance
- Land-Use Changes

Addressing non-tailpipe transport emissions often involves adopting cleaner and more sustainable practices across the entire life cycle of the transportation system. This may include promoting renewable energy sources, improving fuel efficiency, adopting eco-friendly manufacturing practices, enhancing public transportation infrastructure, and encouraging sustainable land-use planning. Efforts to reduce the environmental impact of transportation need to consider the broader context beyond the immediate emissions from vehicle tailpipes.

Overview of Transport Regulatory and Governance Framework in India

Transport is a concurrent subject under India's constitution. This means that both the national federal government and various state and local governments have the authority to legislate laws governing transport regulations. However, regulations made by the Government of India supersede those made by State or local governments.

As evident from Table 2, the regulatory and governance framework for transport in India is multifaceted, involving coordination between various ministries, departments, and agencies at the central and state levels. In practice, this is a significant challenge, given the sheer size of the transportation sector and its various components across governance levels, geographies, and ownership types. A significant part of the transportation sector is also small-scale and informal, where regulatory reach has historically been challenging. However, this is gradually changing in recent years, with increasing digitization and financial inclusion.

Institution	Role
Ministry of Road Transport and Highways	Formulates and administers road transport policies, oversees national highways, and promotes road safety
Ministry of Heavy Industries and Public Enterprises	Develops and regulates heavy industries, including automobile manufacturing
Central Motor Vehicles Act (CMV Act)	Governs vehicle registration, driver licensing, and road safety standards
National Highways Authority of India (NHAI)	Develops, maintains, and manages national highways, pivotal for infrastructure planning
State and Union Territory Transport Departments	Enforce road transport regulations, manage vehicle registration, and issue driving licenses
State Road Transport Corporations	Provide public bus transportation services, manage bus fleets, and ensure transportation efficiency
Traffic Police	Enforce traffic laws, ensuring road safety and compliance with regulations
Bureau of Energy Efficiency (BEE)	Sets fuel efficiency standards for vehicles, promoting energy conservation and environmental sustainability
Urban Governments and Development Authorities	Engage in urban transport planning, including metro rail and bus rapid transit systems
Specialized Institutions	Indian Road Congress, Central Institute of Road Transport, and others focus on road and infrastructure development
Industry Associations	The Automotive Research Association of India, Society of Indian Automobile Manufacturers, and others drive industry standards and innovation

Table 2: The governance framework for Road Transport in India includes the following institutions and key Acts

Key challenges of transportation governance and regulatory framework in India

Capacity deficit

While several specialized technical institutions and strategic analysis cells exist, these are often centrally concentrated and understaffed. They can be slow to react to emerging technologies and trends and are often limited to higher levels of decision-making – at the federal level and rarely, if at all, at the state level. These cells are often also staffed by analysts and planners who may not be sufficiently empowered in decision-making.

Siloed operations and lack of inter-departmental and ministerial coordination

While there may be significant vertical coordination within specific verticals of transportation governance, this is often limited, if at all, when it comes to horizontal integration and consultative decision-making. An example is limited interactions between decision-makers representing environmental concerns – public health, energy efficiency, and climate action within the government and those representing transportation and infrastructure objectives.

Unplanned and haphazard decision-making

Rapid urbanization and increased vehicular traffic result in ad-hoc and short-sighted decisions, the effects of which often last for decades. Significant resources often need to be diverted to keep inefficient systems operational rather than implement greenfield solutions.

Resource and Infrastructure Gaps

Significant resources are needed to address insufficient and outdated infrastructure, particularly road and public transportation networks. The lack of reliable and accessible public transit options leads to an over-reliance on private vehicles, exacerbating congestion and pollution.

Policy Implementation and Enforcement

Inconsistent implementation and enforcement of transportation policies at the state and local levels pose challenges. There is a need for effective coordination and stricter enforcement to ensure compliance with regulations.

Policy Ambiguity and Delays

Delays in policy formulation, ambiguity in regulations, and a lack of clear direction can impede the private sector's involvement and hinder long-term planning.

Transport emission regulations in India: Beyond BS-VI

India has expressed a commitment to align with global best practices in emissions control. This includes exploring the possibility of transitioning to even more stringent standards in the future, such as adopting BS-VII or equivalent norms. While India has yet to start official discussions on BS-VII, Europe has announced Euro 7 pollution standards for new cars and vans applicable from July 2025 and for buses and lorries from 2027.[97]

The new Euro 7 norms propose adding ammonia limits, which help form urban smog. They also suggest further minimizing NOx and PM emissions by adding fuel-neutral emission standards. These standards, which apply to all types of vehicles, including zero-emission technologies, will go beyond the exhaust pipe emissions and impose additional limits for particulate emissions from brakes and tire microplastic emissions.

Emission limits have also been proposed for petrol vapor emissions that occur during refueling. This is important because hydrocarbons such as benzene, known to be carcinogenic and a direct contributor to the formation of ozone particles, are released.

Given the strong development pathway the Indian economy has been on in recent years, vehicular congestion is already a reality in most urban spaces in India. The anticipated rise in vehicular emissions will likely exacerbate ambient air quality and worsen air-quality-linked health outcomes. Given these parameters, initiating policy dialogues on the timely implementation of BS-VII as a preventive rather than curative policy intervention is critical.

Standard	Reference	Timeline of Implementation	Region
India 2000/ Bharat Stage I	Euro 1	2000	Nationwide
Bharat Stage II	Euro 2	2001	NCR*, Mumbai, Kolkata, Chennai
		April 2003	NCR*, 11 cities†
		April 2005	Nationwide
Bharat Stage III	Euro 3	April 2005	NCR*, 11 cities†
		April 2010	Nationwide
Bharat Stage IV	Euro 4	April 2010	NCR*, 13 cities‡
		July 2015 to April 2017	Nationwide, phased implementation
Bharat Stage V	Euro 5	n/a	
Bharat Stage VI	Euro 6	2020.04	Nationwide

* National Capital Region (Delhi)
† Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Secunderabad, Ahmedabad, Pune, Surat, Kanpur and Agra
‡ Above cities plus Solapur and Lucknow. The program was later expanded with the aim of including 50 additional cities by March 2015

Table 3: Timeline of implementation of tailpipe emission standards for passenger cars in India [97]

Clean mobility pathways

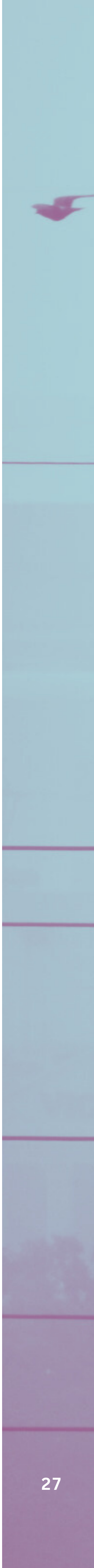
India has been progressively formulating and revising policies to promote the adoption of electric vehicles (EVs) as part of its efforts to address environmental concerns, reduce dependence on fossil fuels, and foster sustainable mobility. Since 2015, it has rolled out a series of favorable policies and interventions to facilitate the adoption of electric vehicles and mobility. As of early 2024, India has more than 3.8 million registered electric vehicles, with 1.5 million registered since April 2023. However, the overall penetration of electric vehicles remains low at 5.85%.[98]
A shift to electric mobility is hugely beneficial from the ambient air quality perspective, especially in cities with high traffic density. It reduces tailpipe emissions by a hundred percent and, coupled with advancements in clean energy generation, has the potential to reduce overall air pollution significantly. However, it must be said that a simple one-to-one replacement of internal combustion engine (ICE) vehicles with electric vehicles will not solve air quality and urban congestion issues.

The solution lies in the prioritized deployment of electric mobility options in the realm of public, shared, and commercial transportation. This means prioritized deployment of electric city buses, taxis, and three-wheelers for a higher modal share of total mobility. This will also necessitate demand-sided policy interventions – restricting personal vehicle ownership through a combination of fiscal disincentives and state-led mandates. **Another segment with large potential gains is freight vehicles – specifically medium and heavy-duty vehicles typically deployed within city limits for short-haul transport.**

Alongside the deployment of electric vehicles, we will also need a life cycle circular economy approach to vehicles at the end of their lives. The manufacture of electric vehicles includes long and complicated supply chains, including mining heavy earth metals and minerals - a process that has raised significant environmental concerns. The policy framework will also need to consider the higher quantum of waste generated at the end of a vehicle's productive life and ensure efficient recovery and reuse of these materials with minimal environmental impact.

Conclusion and Way forward

India and Pakistan are at different stages of developing and implementing effective policy interventions for transport emissions. There are definite areas where India has demonstrated leadership in effectively managing transport emissions, which can be areas of learning for Pakistan and others in the region. At the same time, there are similarities in the approach taken by policymakers and in the air quality issues that residents of both countries face.



Areas where India could share learnings with Pakistan

- Regulatory control and modernization of vehicular tailpipe emission standards.
- Regulatory control and standardization of automotive fuel.
- State support and long-term policy stability to enable the adoption of technology pathways to clean mobility, such as the state-led deployment of electric vehicles, alternate fuels, and ecosystem-building measures.
- Participatory decision-making and governance:

1. Development and implementation of pathways for regulatory control of the automobile sector, including implementing emission control technologies.
2. Consultative policy formulation and implementation involving industry representatives and associations from the automotive ecosystem.
3. Strategic exposure to the domestic automotive market and long-term policy decisions to ensure global competitiveness.

Areas that require policy attention

- Managing emissions from legacy automobiles, especially older heavy-duty vehicles. This will require the deployment of better in-use vehicular emission controls.
- Developing protocols for processing end-of-life vehicles and components, including used EV batteries and pollution control components.
- Demand-sided interventions and vehicle restraint policies, such as:

1. Improved and accessible public transport for improved modal share in mobility.
2. Measures to reduce vehicular congestion include incentivizing shared transport and discouraging personal transport (parking policy, fiscal measures).
3. Reduction in emissions intensity through measures for improved energy efficiency.

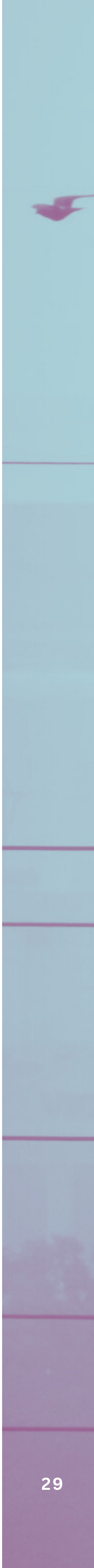
- Regulations on non-tail-pipe vehicular emissions – from tires, brake systems, and more.

Methods of coordination and international cooperation

There is also a need for greater coordination between stakeholders from both countries (and others in the region) – decision-makers, researchers, industry associations, regulatory boards, and others. This can be achieved through measures such as:

- Creating a common platform for regular and targeted information sharing and data exchange between stakeholders at various levels, such as regular summits and conferences.
- Capacity building exercises for regulatory officials and policy planning personnel.
- Assessing the need and possibility of joint transport infrastructure – focus on operational issues such as coordination in planning and implementation.

- Building and strengthening common platforms to seek targeted investment in critical areas, such as infrastructure, improved local governance, and greater international cooperation at global multilateral forums.



Chapter 3

Towards Reduced Vehicular Pollution in Pakistan: Ample Opportunities, Serious Challenges

Ahmed Khaver

In recent decades, rapid urbanization and industrialization in Pakistan has led to a surge in vehicular traffic, both in urban centers and along intercity routes. This escalation has resulted in a corresponding increase in emissions of harmful pollutants such as carbon dioxide (CO2), nitrogen oxides (NOx), particulate matter (PM), sulfur dioxide (SO2), and volatile organic compounds (VOCs). Besides degrading air quality, these emissions pose significant health risks to the human population. Furthermore, the transport sector's emissions severely exacerbate climate change. CO2 emissions, primarily derived from the combustion of fossil fuels in vehicles, constitute a major driver of global warming and climate disruption.

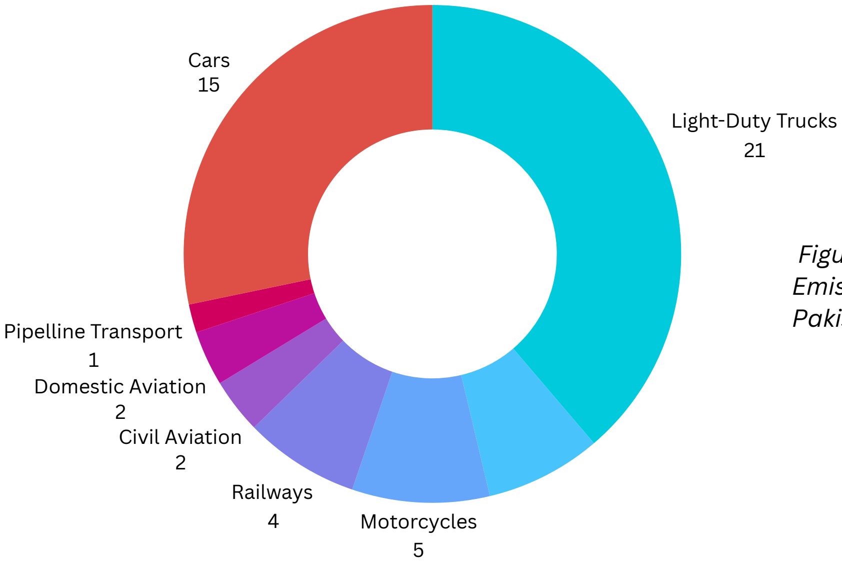


Figure 8: Transport Sector Emissions by Category in Pakistan

The transportation sector in Pakistan has exhibited the highest emission growth rate among all sectors, contributing to approximately one-fourth of the country's total carbon dioxide emissions. According to the 2018 UN Food and Agriculture report, transportation significantly contributes to environmental degradation, accounting for 43% of emissions in Punjab, Pakistan.[99] A breakdown of total emissions per sector shows industry contributing 25%, agriculture 3%, and the power sector 28%.

More recently, in 2023, in the case of the city of Lahore, the emissions inventory shows that the transport sector alone is responsible for 83% of total emissions. [100] Looking at a more detailed and lengthier set of data reveals that in the province of Punjab, from 1990 to 2020, the average emissions from the transport sector amounted to 36% percent, ahead of industry (24%) and agriculture (15%). [101]

In 2022, Pakistan's air quality was ranked the third worst in the world, primarily because of industrial and vehicle emissions and crop burning. According to the World Health Organization's (WHO) guidelines, current levels of air pollution mean that the average Pakistani would live 2.7 years less than they normally would. The Lahore district suffers the most, with average citizens losing 5.3 years of life.[102]

Looking at Pakistan's average PM2.5 concentration, the numbers show an alarming 14.2 times higher concentration than WHO annual air quality guideline values, while Lahore and Karachi were 9 times and 6.4 times higher, respectively, in 2022.[103] The transportation sector primarily contributes to air pollution by generating PM (2.5 and 10), Volatile Organic Compounds (VOC), Nitrogen oxide, Carbon monoxide, and other carcinogens.

Standard	**Petrol**				**Diesel**			
	CO (g/km)	**HC+NOx (g/km)**	**NOx (g/km)**	**PM (g/km)**	**CO (g/km)**	**HC+NOx (g/km)**	**NOx (g/km)**	**PM (g/km)**
Euro I	2.72	0.97	*	-	2.72	0.97	*	0.14
Euro II	2.2	0.5	*	-	1	0.7	*	0.08
Euro III	2.3	0.35	0.15	-	0.66	0.56	0.5	0.05
Euro IV	1	0.18	0.08	-	0.5	0.3	0.25	0.025
Euro V	1	0.16	0.06	0.005	0.5	0.23	0.18	0.005
Euro VI	1	0.16	0.06	0.005	0.5	0.17	0.08	0.005
PM limits were introduced from Euro 5 onwards.								
*NOx emissions were not separately specified from HC emissions; instead, they had a combined limit till Euro 2.								

Table 4: Emission of Air Pollutants by Use of Petrol and Diesel per Gram/Kilometer in Pakistan

Cardiovascular diseases such as heart attacks and strokes are linked to pollutants like PM10, PM2.5, CO, and NO2, which are by-products of the combustion engine doing its job. Prolonged exposure to these substances is also associated with an elevated risk of lung cancer. Additionally, a study in the New England Journal of Medicine highlights that children exposed to vehicular pollution may experience developmental difficulties and diminished lung function. Moreover, exposure to PM10, PM2.5, NO2, and O3 has been correlated with premature deaths, particularly among individuals with pre-existing heart or lung conditions.

High sulfur content in fuels used in Pakistan contributes to PM and Nitrogen oxide emissions. Although there was originally a plan to decrease the highest permissible sulfur content in all fuels from 10,000 ppm to 500 ppm by 2008, it was continually pushed back. The delays occurred until 2010, 2012, and finally, 2017. The rationale behind these extensions was the need for additional time for oil refineries to undergo necessary retrofitting.[104]

Institution	Responsibilities
Pakistan Environmental Protection Act (PEPA)	PEPA enforces NEQS for pollutants, with penalties including fines, closure, and imprisonment. The Pollution Charges Rule, 2001, faced resistance, including from influential groups. Provincial agencies are also mandated to adhere to these standards.
Provincial Environmental Protection Departments (EPD)	Provincial governments, like Punjab, established their own environmental protection standards following the federal government's lead with the National Environmental Quality Standards for Motor Vehicle Exhaust and Noise 2009
Punjab Environmental Quality Standards	Provincial EPDs, like Punjab EPD, enforce environmental standards, including air quality and industrial emissions, targeting specific polluters to improve air quality despite limitations.
Transport Department	The Punjab Transport Department introduced the Vehicle Inspection and Certification System (VICS) to replace the outdated "Ramp and Stamp" Motor Vehicle Examination (MVE) system. VICS focuses on controlling emissions and ensuring the safety of public and commercial vehicles, but its implementation varies across districts.
The Punjab Transport Company	The company plays a crucial role in reducing urban emissions and tackling smoke-related issues. It regulates emissions through permits for public service vehicles, imposing penalties and suspensions, especially during smog season.

Table 5: Overview of Transport Regulatory Authorities and their Role in Pakistan

Improving Fuel Quality Standards in Pakistan: Persisting Issues

Pakistan's journey in improving fuel quality standards, transitioning from Euro 2 in 2012 to Euro 5 in 2020, has been marred by significant challenges and irregularities. Despite these advances, the country has struggled with non-compliance, adulteration, and industry resistance, highlighting a complex narrative of environmental progress amid economic and regulatory hurdles. However, the transition to Euro 5 in 2020, driven by the urgent need to address severe air pollution and fulfill global environmental commitments, encountered numerous obstacles.

Standard	Implementation in Pakistan	Key Fuel Improvements	Engine Technology Advancements
Euro II	2012	• Reduced CO emissions • Better combustion for less unburnt fuel • Restriction on NOx emissions • Introduction of oxygenated fuel components • Sulfur content in diesel reduced to 0.05% (500 ppm)	• Enhanced for both petrol and diesel fuels. • Improved engine calibration • Introduction of exhaust gas recirculation (EGR).
Euro V	2020	• Emphasis on diesel engine emissions, especially particulate emissions.[105] • Lower sulfur content in fuel, reduced to 0.001% (10 ppm) in diesel.[106]	• Mandatory particulate filters to pass Euro 5 standards. • Advanced engine management systems • Use of selective catalytic reduction (SCR) for NOx reduction.[107]

Table 6: Fuel Quality Standards and Timeline of Implementation in Pakistan

The transition to the Euro-5 fuel standard for petrol and diesel aimed to reduce sulfur content from 500 parts per million (ppm) to 10 ppm, significantly cutting emissions and improving urban air quality. The move was expected to bring immediate environmental benefits and help address the alarming pollution levels in cities like Lahore and Karachi. However, oil marketing companies (OMCs) expressed concerns about the practicality of importing and distributing the new fuel, given the significant cost implications and the lack of supportive infrastructure.

Historically, luxury fuels like RON-97 have been taxed at a higher rate[108], reflecting their use in high-end vehicles. The government has applied a petroleum development levy of Rs. 30 per liter and a 17% General Sales Tax to RON-97,[109] under the premise that those who can afford luxury cars should also contribute more to taxes for premium fuels. This policy contrasts with the lower levy/taxes imposed on RON-92, a standard fuel, which has seen reduced levies and sales tax in efforts to alleviate the financial burden on the general populace.

The vehicular industry also faced challenges in adapting to Euro 5 standards. Most locally assembled vehicles comply with the older Euro 2 standards despite the upgraded fuel quality. This discrepancy undermined the benefits of cleaner fuel because the vehicles were not optimized to utilize it efficiently.

In the petroleum sector, upgrading refineries to produce higher-quality fuel was a significant undertaking, resulting in the continued production of lower-grade Euro 2 petrol. The industry also faced issues with fuel additives, particularly high manganese content, which was found to damage engines, exacerbate pollution, and pose health risks. In recent developments, there has been some friction between the government and the oil refineries regarding the new policy.

The challenges in implementing the Pakistan Oil Refining Policy 2023 between refineries and the government are complex and arise from several concerns raised by the refineries. These challenges encompass critical areas such as taxation, incentives, contractual matters, and the lack of consultation during policy formulation.

Firstly, the refineries have expressed concerns regarding continuing the 7.5% deemed customs duty on High-Speed Diesel (HSD) beyond the stipulated six-year period outlined in the policy. This issue highlights the uncertainty and the potential financial burden on refineries after the incentive period expires.

Secondly, tax exemptions on incremental incentives provided by the policy have raised questions and need further explanation. The refineries seek clarity regarding applying for these exemptions and whether they will be subject to changes in taxation policies over time.

Moreover, the lack of adequate consultation with refineries during the policy formulation stage has resulted in these challenges coming to the forefront during the implementation phase. Effective stakeholder engagement and consensus-building could have addressed some of these concerns at the outset.

The challenges in implementing the Pakistan Oil Refining Policy 2023 highlight the need for transparent, consultative, and well-defined policies to ensure a successful and harmonious collaboration between refineries and the government. Clear guidelines, fair dispute resolution mechanisms, and consideration of refineries' financial sustainability are crucial for the policy's successful execution.

Public Transit systems in Pakistan: In Need for Environmentally Conscious Revitalization

In Pakistan, the rapid rise in private vehicle ownership, particularly motorcycles, far exceeds the growth rate of public transportation vehicles. This trend results from demand and supply-side factors, including population growth, rising household incomes, and the relative affordability of private vehicles. Pakistan, one of the most populous countries in the world, has seen a notable population increase from 132.352 million in 1998 (16.4 Population by Sex, Urban/Rural Areas, 1998 Census) to 207.774 million in 2017.[110] This demographic shift, combined with urbanization and migration to cities, has exacerbated traffic congestion in metropolitan cities. The increase in private vehicle ownership, particularly motorcycles, is partly due to their affordability and the availability of credit facilities for vehicle purchases.[111]

The heavy reliance on private vehicles leads to increased road congestion, deteriorating air quality, and higher CO2 emissions. For instance, an average car produces 180 grams of CO2 per kilometer, while a bus emits 650 grams of CO2 per kilometer, implying that each additional bus can significantly reduce CO2 emissions per kilometer traveled.

Effective traffic management systems and policies that encourage the utilization of public transport are crucial for tackling these challenges. Potential interventions include stringent licensing requirements, promoting ride-sharing services, and implementing measures such as banning motorcycles on congested roads or allocating separate lanes. Moreover, shifting from private cars to public transport can help reduce smog and air pollution, a critical issue in urban centers like Lahore, where smog blankets the city annually from October to December.[112]

Vehicle Type	Lifespan Years	Lifespan Mileage (km)
Motorcycle	5 years	100,000 km
Suzuki Car/Van	6 years	160,000 km
Car 1300 CC	6 years	200,000 km
Car 1600 CC	7 years	250,000 km
Jeep, Station Wagon, Bus Truck, 2000 CC and above	8 years	200,000 km

Table 7: Vehicles and their Estimated Lifespan with Mileage

As part of an austerity measure, the Federal Government of Pakistan has banned purchasing new vehicles for officials until June 2024. This directive is currently in effect and applies to all ministries and divisions except for the Foreign Ministry and diplomatic missions.[113]

A notable prevalence of older models characterizes the vehicle line-up in Pakistan's auto industry. Pak Suzuki, for instance, has the oldest average lineup with models like Ravi and Bolan, which have been in the market for nearly 44 years. Other manufacturers like Honda Atlas and newer entrants like Chery and Haval offer significantly newer models, averaging 3 to under 5 years. This contrast underscores a market where both dated and current-generation vehicles coexist, reflecting varying degrees of technological advancement and model modernization within the country's transportation sector.[114]

Greenhouse gas emissions from the transportation sector are steadily increasing:

Year	Emissions (MtCO2e)
2012	35.4
2030 (Projected)	80.7

Table 8: A Projected Increase of 128% Over an 18-year period

Transport Mode	2012	2015	2020	2025	2030
Road Passenger Vehicles	21.1	23.5	29.1	36.1	45.2
Road Freight Vehicles	11.6	14.5	18.9	24.2	30.6
Aviation	1.5	1.7	2.4	3.2	4.3
Rail	0.2	0.3	0.4	0.5	0.7

Table 9: Ratio of Transport Modes and their Projected CO2 Emissions by 2030

Conversely, implementing sustainable transport policies, particularly integrating electric vehicles (EVs) as outlined in the National Electric Vehicle Policy (NEVP), is expected to lead to marked reductions in fuel consumption and emissions.

Rapid urbanization requires efficient and affordable public transit systems to avoid the crowding of cities and to ensure smooth mobility and lesser emissions. Pakistan's public transport system was deregulated in the early 1980s. Since then, private operators have provided urban transport services, with the government assisting with fare control and route licensing. Due to a lack of institutional ability to regulate these solo transport providers, transportation authorities routinely fail

to supervise the quality and efficiency of the public transport system.[115]

Pakistan's public transport system comprises an array of options, including traditional buses and modern Bus Rapid Transit (BRT). Pakistan's urban centers have actively pursued Bus Rapid Transit (BRT) systems to address their growing transportation needs amidst rapid urbanization. Lahore's Metrobus, operational since 2013, spans 27 kilometers and is a major step toward decongesting city traffic. The Islamabad-Rawalpindi Metrobus, introduced in 2015, provides a critical link between these administrative and commercial hubs. Peshawar's BRT, known as Trans Peshawar, launched in 2020, offers a modernized bus service with dedicated lanes to improve the city's mobility.[116]

Pakistan's public transit system grapples with many challenges: inadequate infrastructure, struggles to keep pace with the explosive urban growth of cities like Karachi and Lahore, and limited funding restricts the expansion and modernization of services. Operational inefficiencies undermine service reliability, such as unreliable scheduling and poor maintenance.[117] The regulatory framework governing transit operations is often fragmented and ineffective, impeding coordinated development across the sector. **Environmental concerns are heightened by outdated, diesel-powered fleets contributing to urban pollution, while safety and security issues deter potential users. The slow adoption of technology, crucial for efficient transit management and user experience, reflects a broader resistance to change within the sector.[118]**

Strategic investments are essential to upgrading Pakistan's public transit system and infrastructure and fleet quality, focusing on sustainability through electric vehicles. Integrating transportation development with urban planning and encouraging public-private partnerships can provide the necessary funding and innovation. Regulatory frameworks need reforming for better coordination and efficiency across transit modes and adopting technology (such as digital ticketing and real-time tracking systems) can enhance user experience and operational reliability. Safety upgrades, staff training, and inclusive design will improve service appeal and accessibility. Public awareness campaigns and research into local commuting patterns can inform service adjustments and promote public transit use as a viable alternative to private cars.

Clean Mobility: Options and Challenges

Pakistan has recently approved the National Electric Vehicles Policy (NEVP), an ambitious initiative targeting a significant shift toward electric vehicles (EVs). The NEVP sets specific goals for various vehicle categories, envisioning that by 2030, EVs will constitute 30% of new sales for passenger vehicles and heavy-duty trucks, 50% for two- and three-wheelers, 50% for buses, and 30% for trucks. The targets turn even more ambitious by 2040, aiming for 90% EV market share in each category.

Economically, reducing reliance on imported fossil fuels could yield substantial savings, with positive repercussions for public health due to decreased emissions. Projections based on various scenarios indicate that a shift towards electric mobility is crucial for the sustainability of Pakistan's transport sector. The NEVP's targets for electrification could significantly transform the sector, aligning it with international efforts to mitigate climate change and promote a cleaner environment. [119]

The infant EV industry, represented by the Pakistan Electric Vehicles Manufacturing Association (PEVMA), is expected to benefit from the policy. Incentives include lower taxes, such as a reduced 1% GST for EVs compared to the 17% applicable to regular vehicles, decreased import duties for charging equipment, and subsidized electricity rates for charging station operators.

The electric vehicle landscape in Pakistan is witnessing a transformative shift, primarily driven by a strategic joint venture between prominent Chinese and Pakistani enterprises. This collaboration, featuring leading electric vehicle manufacturer Benling Group, Chinese battery producer Dongjin Group, and renowned Pakistani automaker Crown Group, is poised to advance electric mobility solutions in the country. The joint venture is focused on producing electric two-wheelers and three-wheelers, which are integral components of Pakistan's public transportation system, particularly in densely populated urban areas grappling with air pollution and traffic congestion. The initiative addresses the pressing need for environmentally friendly and cost-effective transportation solutions and contributes significantly to lowering carbon emissions and enhancing the country's transportation industry.

The success of the NEVP hinges on effective implementation, requiring coordinated efforts across relevant ministries and overcoming barriers such as model availability, infrastructure development, and consumer understanding. Moreover, a reliable power supply is essential in a country where the electric power sector has been historically volatile, with frequent brownouts and blackouts. Additionally, the widespread adoption of EVs is anticipated to improve urban air quality, reduce noise pollution, and mitigate health costs associated with pollution in urban areas. The NEVP represents a crucial step towards a sustainable and transformative shift in Pakistan's transportation sector, but ongoing support, coordination, and infrastructure development will be essential for its success.

What can Pakistan learn from the Indian experience?

India made significant strides in reducing emissions by transitioning to low-sulfur fuel. In April 2017, the Indian government launched the Bharat Stage (BS) VI emission standards, which mandated a maximum sulfur content of 10 parts per million (ppm) in diesel and petrol and more stringent tailpipe emissions. This move significantly reduced harmful emissions from vehicles, including sulfur dioxide, oxides of nitrogen, and particulate matter. **Pakistan can follow India's lead by implementing similar low-sulfur fuel standards. It is essential for Pakistan to collaborate with the oil industry to produce and distribute cleaner fuels in the country. Ensuring the implementation of Euro 5 and stricter adherence and regulation is essential.**

India has been investing in improving its public transportation infrastructure, including the expansion of metro rail networks and the promotion of bus rapid transit (BRT) systems in major cities. These initiatives aim to reduce the reliance on individual vehicles and encourage the use of more sustainable modes of transport. Although Pakistan has also introduced services as such, there is still a need to accommodate the public. **Investing in efficient and sustainable mass transit systems can help reduce the number of private vehicles on the road, leading to lower emissions and improved urban air quality.** Developing integrated and well-connected transportation networks should be a priority.

India has been encouraging developing and adopting green technologies, such as hybrid and electric vehicles. Likewise, Pakistan can foster innovation in the automotive industry by incentivizing the production and adoption of green technologies. Encouraging the development of electric and hybrid vehicles can help reduce emissions and dependence on fossil fuels.

The Indian government has introduced comprehensive policies and initiatives to address emissions in the transport sector. For example, the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme promotes the adoption of electric and hybrid vehicles by providing financial incentives and subsidies. The "Make in India" campaign also encourages domestic production of vehicles and components, reducing reliance on imports and boosting the local electric vehicle industry.

<u>Recommendations: Increasing Domestic Capacities and Collaborating with India</u>

Based on the discussion and issues raised above, some steps that can help reduce the vehicular pollution component of air pollution in Pakistan are:

- **There is a need for policy and legislative strengthening of motor vehicle exhaust values. The values are outdated as they were set up before establishing Euro 5 standards.** Moreover, stringent application of emission standards is required to enforce penalties and repercussions for violation of any standards.
- A significant number of vehicles operate on roads that are not Euro 5 compliant. **Phasing out of old diesel-powered engines, especially in heavy vehicles, must be prioritized for a healthy transition towards a cleaner environment.** In this regard, Khyber Pakhtunkhwa province has taken the initiative, with the Peshawar Bus Rapid Transit beginning to decommission old, corroded passenger buses and vans and repurposing them as scrap metal. To encourage this practice, the

transportation authorities offer compensation of up to Rs 1.5 million in exchange for outdated vehicles and have already acquired 148 such vehicles. Likewise, other provinces must prioritize the transition of public buses and rickshaws to cleaner fuel alternatives, such as hybrid and electric options.

- **To initiate any meaningful change, there is an urgent need to focus on capacity building within transport and environmental protection departments, ensuring they have adequate equipment and human resources.** The lack of monitoring equipment and expertise has rendered institutions toothless. Such upgrades will also help with regular and timely inspection of additives in fuel across the country. The Pakistan Environmental Protection Agency has taken initiatives to improve air quality by inspecting vehicular emissions. However, these projects remain ad hoc and scattered.
- **Upgrading existing industrial infrastructure to ensure a smooth transition of vehicle engines from Euro 2 standard to Euro 5 and 6 is essential.** Encourage and engage refineries to produce cleaner fuels with lower sulfur content. A higher quality of fuel can significantly reduce vehicular emissions. This requires a firmer negotiation with the private oil refineries to quicken their upgrade projects under the new refinery policy 2023. Refineries and auto manufacturers have resisted changes towards Euro 5 standards, citing financial uncertainty. There needs to be cooperation between the Oil and Gas Regulatory Authority (OGRA) and the Oil Marketing Association of Pakistan (OMAP).
- The Planning Commission is the focal planning body at the federal level. There is a dire need for EV targets to be set and become part of the five-year plan. **The Planning Commission can prioritize projects that help the country reach its EV penetration targets.**
- **Working collaboratively with neighboring countries and drawing from shared experiences can accelerate and streamline the transition toward a cleaner environment. The smog issues faced by both India and Pakistan offer an opportunity for joint efforts on climate-related matters. Through knowledge sharing, collaborative research, and coordinated planning—particularly during the smog season—alongside engagement with multiple stakeholders in both nations, efforts across various sectors could mitigate the harmful effects of smog.** This collaborative effort on a common pressing issue can also serve as a confidence-building measure, fostering cooperation among scientific, bureaucratic, civil society, and private entities.

Chapter 4

Curbing Transport Emissions: Recommendations and Way Forward on Bilateral Coordination between India and Pakistan

Ahmed Khaver, Polash Mukerjee

India and Pakistan are at different stages of developing and implementing effective policy interventions for transport emissions. There are definite areas where India has demonstrated leadership in effectively managing transport emissions, which can be areas of learning for Pakistan and others in the region. At the same time, there are similarities in the approach taken by policymakers and in the air quality issues that residents of both countries face.

Areas where India could share learnings with Pakistan include:

- Regulatory control and modernization of vehicular tailpipe emission standards;
- Regulatory control and standardization of automotive fuel;
- State support and long-term policy stability to enable the adoption of technology pathways to clean mobility, such as state-lead deployment of electric vehicles, alternate fuels, and ecosystem-building measures;
- Participatory decision-making and governance:

1. Development and implementation of pathways for regulatory control of the automobile sector, including the deployment of emission control technologies;
2. Consultative policy formulation and implementation involving industry representatives and associations from the automotive ecosystem;
3. Strategic exposure to the domestic automotive market and long-term policy decisions to ensure global competitiveness.

Areas that require policy attention in both countries include:

- Managing emissions from legacy automobiles, especially older heavy-duty vehicles. This will require the deployment of better in-use vehicular emission controls;
- Developing protocols for processing end-of-life vehicles and components, including used EV batteries and pollution control components;
- Demand-sided interventions and vehicle restraint policies, such as:

1. Improved and accessible public transport for improved modal share in mobility;
2. Measures to reduce vehicular congestion, such as incentivizing shared transport and discouraging personal transport (parking policy, fiscal measures);
3. Reduction in emissions intensity through improved energy efficiency measures;

- Regulations on non-tail-pipe vehicular emissions – from tires, brake systems, and more.

Pathways for bilateral coordination and cooperation:

There is a need for greater coordination between a wide range of stakeholders from both countries– decision-makers, researchers, industry associations, regulatory boards, and others. This can be achieved through measures such as the following:

- Creating a common platform for regular, targeted information sharing and data exchange between stakeholders at various levels, such as summits and conferences:

For instance, for the modernization of the automotive industry, removing tariffs and regional trade barriers can create an expanded and stable market where market leaders can successfully influence laggards. This would include industry-to-industry coordination for enhanced information flow as well as technical capacities and resources towards increased accountability, efficiencies, and competitiveness.

- Capacity building exercises for regulatory officials and policy planning personnel:

Joint training and policy planning workshops may strengthen institutional capacities, leading to greater regional coordination and cooperation on policy decisions. For instance, the development of vehicular emission and fuel standards and their implementation may be synchronized for better effectiveness as a singular market. Similarly, policies to enable a localized circular economy are the need of the hour in cities and regions across both countries.

- Assessing the need and possibility of joint transport infrastructure – focus on operational issues such as coordination in planning and implementation:

Regional cooperation on policy and planning may include efforts toward developing self-sufficient and localized transport-related supply chains, including critical components such as clean fuel, batteries, and charging infrastructure. This will require joint investments and a stable and predictable policy framework. National and sub-national governments may coordinate on implementing floor minimum fiscal incentives and mandates to expedite the adoption of clean mobility technologies.

- Building and strengthening common platforms to seek targeted investment in critical areas, such as infrastructure, improved local governance, and greater international cooperation at global multilateral forums:

The formation of a coordinated bloc at global multilateral forums can help facilitate catalytic investments in critical areas such as the deployment of efficient and accessible public and shared mobility options, strengthening capacities for environmental governance, and developing well-trained and highly capable human resources. These areas traditionally depend on state-led investments but typically demonstrate a multiplier effect on economic and developmental outcomes. Similarly, regulatory compliance is an area that both countries have traditionally struggled with. R&D for developing and deploying modern technology and methods requires urgent policy attention.

The key to greater coordination and cooperation on transport emissions between India and Pakistan is breaking down barriers at multiple stages and across all stakeholders. Government-to-government learning is as much the need of the hour as is the formation of joint technical industry associations and research groups, as well as an integrated market. Special attention must be given to solutions that are unique to the region, such as the prevalence of small, lightweight, and efficient two- and three-wheeler mobility solutions, as well as the near-universal presence of a robust fleet of shared and common intermediate-para transit vehicles, in the form of share-rickshaws, tempos, and its various regional manifestations.

Chapter 5

Air Quality Monitoring in India and Pakistan - Status, Gaps and Future Directions

Dr. Pallavi Pant, Maryam Shabbir Abbasi

The issue of air pollution is particularly salient during winter months in South Asia, when levels of air pollutants are often several-fold higher than the national standards, as well as the WHO (World Health Organization) Air Quality Guidelines. In Pakistan, the period between November and February has been colloquially called the fifth season or the season of smog.[120]

While air pollution is a year-round problem,[121] the media tends to emphasize the issue more prominently during winter.[122] In some cases, the focus is placed on immediate and visible sources, such as crop stubble burning, rather than examining year-round sources, such as waste burning, transportation, or energy production. However, research has shown that air quality remains poor in the region year-round, with levels of PM2.5 often exceeding the least stringent Interim Target (35 µg/m3) under the WHO Air Quality Guidelines.

Across the South Asian region, sources of air pollution are common, and transboundary pollution can significantly contribute to elevated pollution levels.[123] Key sources include energy production and use, industries, transportation, construction and other dust, waste burning, seasonal sources (e.g., stubble burning), and those relatively unique to the region (brick kilns, tandoors, etc.) collectively contributing to high ambient air pollution.[124] Further, many of the region's population lack access to clean energy. As the pollution is not restricted to national boundaries, emissions in one country can impact air quality across other countries in the region.[125]

Air quality monitoring is a key building block for effective air quality management. Monitoring systems provide real-time data on pollutant levels, enabling prompt identification of pollution sources and formulation of targeted mitigation strategies. Continuous monitoring also allows assessment of compliance with air quality standards, safeguarding public health and the environment across local, national, and regional levels. Standardized data collection and decision-making systems are also crucial for bilateral or multilateral information exchange and provide a common starting point for knowledge sharing.

This chapter, relying on secondary data sources, provides an overview of the ambient (outdoor) air quality monitoring infrastructure in India and Pakistan and outlines key gaps and opportunities for collaboration and engagement across the two countries.

The Air Quality Monitoring Landscape in India

Regulatory air quality monitoring in India is mandated by the Air (Prevention and Control of Pollution) Act of 1981 and is overseen by the Central Pollution Control Board (CPCB). In 2009, India revised its National Ambient Air Quality Standards (NAAQS) and included, for the first time, a standard for fine particulate matter or PM2.5. In response, efforts were initiated to establish PM2.5 monitoring stations. In 2019, India launched the National Clean Air Programme (NCAP) which has provided further impetus for setting up Continuous Air Quality Monitoring Systems (CAAQMS) in cities across India.[126]

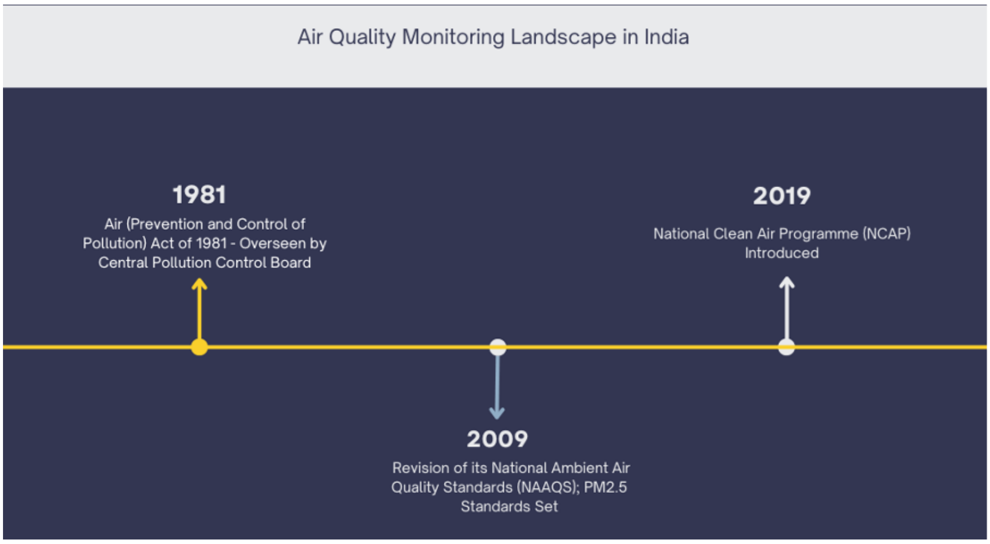


Figure 9: Efforts Taken to Improve the Air Quality Monitoring Landscape in India

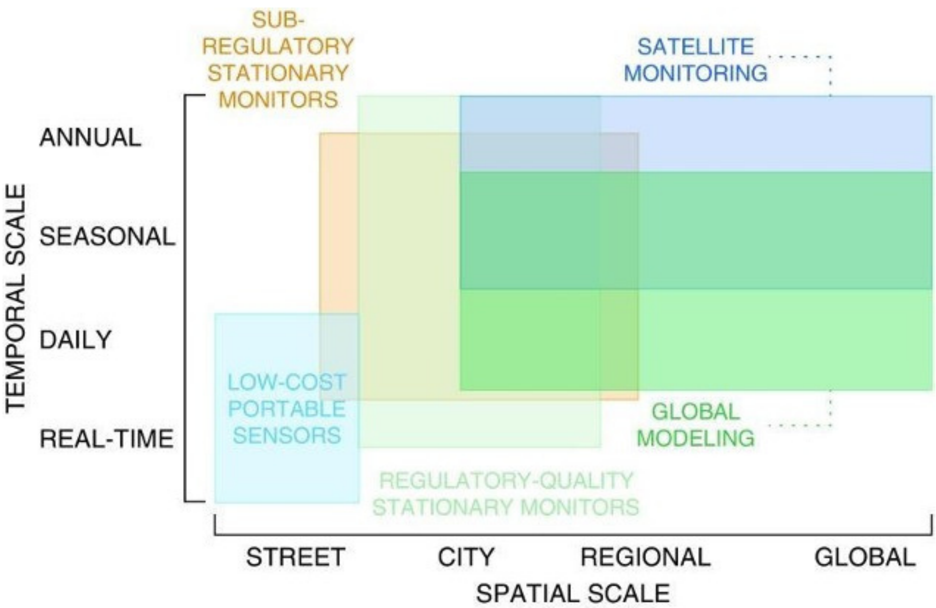


Figure 10: Relevant air quality monitoring methods at different spatial scales (reproduced from Cromar et al.[127]

Regulatory Monitoring Networks in India

India's flagship air quality monitoring program, the National Air Quality Monitoring Programme (NAMP), has existed since 1984. **Much of the data from the NAMP program is available publicly, but since data are not collected in real time, the datasets are often available with a considerable delay.** This network is widespread, but most stations are manually operated, with data collection up to 104 days yearly.[128] Four key pollutants are measured as part of this program: fine particulate matter (PM2.5), coarse particulate matter or respirable suspended particulate matter (RSPM / PM10), nitrogen dioxide (NO2), and sulfur dioxide (SO2). Data collected as part of this network is available via national and, in some cases, state-level government data portals.

However, since the 2000s, there has also been a significant expansion of CAAQMS, i.e., monitoring stations that can collect real-time air quality data. **In the last five years, there has been a rapid increase in the number of CAAQMS across India, although gaps remain.** Notably, most regulatory air quality monitoring stations are in urban areas, and coverage in rural areas remains sparse.[129] All data from CAAQMS are fed into a central repository maintained by the Central Pollution Control Board.

The Central Pollution Control Board operates both the NAMP and the CAAQMS networks under the aegis of the Ministry of Environment, Forest and Climate Change (MoEFCC). State pollution control boards and other national and state-level agencies are also involved in operating and maintaining the regulatory stations.

	Total Monitoring Stations	Cities	States	Union Territories
NAMP	804	344	28	6
CAAQMS	261	134	23	

Table 10: Monitoring Stations within the NAMP and CAAQMS Networks in India. Data from CPCB [130]

In a select number of large cities—including Delhi, Mumbai, Pune, and Ahmedabad—a second network of real-time air quality monitors is operated as part of the SAFAR-India project (System of Air Quality and Weather Forecasting and Research). **The SAFAR-India initiative, in addition to measuring air quality, provides air quality forecasts for up to three days in advance for each of the four cities.** This initiative is supported by the Ministry of Earth Sciences and is run by the Indian Institute of Tropical Meteorology (Pune) together with partner institutions, including the India Meteorological Department (IMD) and the National Centre for Medium-Range Weather Forecasting (NCMRWF). In each city, the initiative maintains a network of

~10 CAAQMS and automatic weather stations.

An additional government-supported monitoring network is MAPAN, Modelling Atmospheric Pollution and Networking, wherein comprehensive, long-term air quality monitoring is conducted in key cities nationwide.[131] Compared to NAMP or CAAQM stations, these monitoring sites are not strictly for regulatory purposes. The network is coordinated by the Indian Institute for Tropical Meteorology (IITM), and data from the sites are used primarily for scientific research and analysis.[132]

Finally, a few states are also adopting hybrid monitoring models, while others are setting up large-scale, low-cost monitoring networks. For example, in Bihar, India, low-cost sensors have been installed across all districts in the state.[133] Such sensors offer the opportunity to monitor air quality in real time and are cheaper, more portable, and easier to use than conventional, reference-grade monitors.[134] Such monitors are also easier to install and can be run on solar energy, allowing broader coverage in low-resource or remote areas. Especially in regions with at least one reference-grade monitor, low-cost sensors offer an opportunity to generate hyperlocal data. However, the efficacy of low-cost sensors depends on several variables, including temperature and relative humidity, age of the sensor, and type of pollution particles.[135]

India also has an industrial emissions monitoring network called the Continuous Emissions Monitoring System (CEMS), an automated system that continuously monitors emissions from industrial sources such as power plants, factories, and incinerators. CEMS measures pollutants in real time, providing accurate data on emission levels. This data helps industries comply with environmental regulations and identify opportunities for improving air quality.

Air Quality Monitoring: Other Initiatives in India

In many cities, including some in South Asia, low-cost sensors have been utilized by civil society and the citizenry to measure air quality, especially when government data is not available or accessible. In other instances, in the absence of reference-grade monitoring data, local governments have deployed low-cost sensors to generate initial information on air pollution.

Private enterprises, including Airveda, Respirer Living Sciences, and Oizom, have also deployed networks of low-cost sensors across cities, and in some cases, across the country. Most such networks monitor PM2.5 levels, and access to data is often restricted or behind a paywall. This is not unlike comparable low-cost monitoring networks in other regions of the world. Similarly, philanthropic support has helped establish and run low-cost monitoring networks in several cities and states across India. In a few cases, low-cost monitoring networks have been set up as public-private partnerships, and data have been used for scientific research and policy applications. However, since research study or philanthropic support is often time-bound, several sensor networks have been implemented and taken offline upon project completion (e.g., a pilot sensor network in Mumbai)[136]. In limited cases, the data remain available upon reasonable request.

Academic and research institutions have also played an important role. The CoE - ATMAN[137] (Center of Excellence – Advanced Technologies for Monitoring Air-quality iNdicators) at the Indian Institute of Technology-Kanpur has partnered with several sensor companies to support developing, incubating, and testing new technologies. CoE has partnered with local and state governments to establish air quality monitoring networks and has conducted detailed scientific analysis to determine best practices and use cases for various technologies.

In 2020, Dey et al. published a multi-year, high-resolution ambient PM2.5 dataset for India using a combination of satellite-derived and ground-monitoring data.[138] The data has since been used for many applications, including studies to assess the health effects of exposure to air pollution.

Despite the expansion of air quality monitors, key gaps remain. With that in mind, a hybrid approach for air quality monitoring has been proposed for India; this would include a combination of ground-based air quality monitoring stations and low-cost sensors, together with satellite-based data.[139] Ghosh et al. propose a similar approach and outline opportunities for different monitoring regimes at different scales.[140] Furthermore, there has been an argument for a fit-for-purpose approach towards air quality measurements drawing on a hybrid monitoring network and serving the country's scientific, communication, and policy needs, as described by Gani et al.

The health case for monitoring and managing air pollution

Exposure to air pollution has been linked with a variety of health effects, including chronic respiratory and cardiovascular diseases, other non-communicable diseases such as diabetes and cancer, as well as impacts on neonatal and children's health.[141] In India alone, in 2019, 18% of the total deaths were linked to exposure to air pollution.[142] In Pakistan, 16% of the total deaths in 2019 were linked to exposure to air pollution; this includes more than 50% of all COPD (chronic obstructive pulmonary disease) deaths and 40% of all deaths due to lower respiratory infections.[143] In the last decade, the literature on the association between exposure to air pollution and health effects has grown substantially in South Asia, with several studies in India exploring the effects of both short- and long-term exposure to air pollution. Exposure to poor air quality has been linked to various health effects – higher hospitalizations during periods of high pollution, impacts on respiratory[144] and cardiovascular health [145], and other related outcomes.[146] In both countries, exposure to household air pollution has also been linked to childhood health impacts, including poor respiratory health[147] and impacts on newborns' health.[148]
It is abundantly clear that sufficient evidence has been published on the association between air pollution and health, including many studies led by investigators based in South Asian countries.

The Air Quality Monitoring Landscape in Pakistan

In Pakistan, data on air quality is available through several initiatives from the government, academia, private sector, and international governments and agencies. In 1997, the Pakistan Environmental Protection Act (PEPA) was developed; it provided the base for creating environmental protection agencies at the federal and provincial levels. It also provided the basis for developing National Environmental Quality Standards (NEQs), which set permissible limits for industrial and ambient air pollutants. According to PEPA, the permissible hourly and annual limit for PM2.5 is 15 µg/m3, and the limit for 24 hours is 35 µg/m3. Federal EPA falls under the Climate Change Ministry of Pakistan. In March 2023, Pakistan adopted its National Clean Air Policy, which includes a framework for mitigation and an accountability mechanism to curb air pollution.[149] The policy suggests concrete actions related to the top five sectors contributing to air pollution, i.e., transportation, agriculture, industry, waste, and residential.

In 2010, Pakistan made an 18th amendment to its constitution, providing more powers to the provinces, including the environment, among other domains. Every province now has its environmental policies and environmental protection agencies to regulate environmental quality standards; the agencies are responsible for monitoring sources of pollution, including air pollution, and making the data available to the public. In 2012, the Punjab Government revised certain rules and regulations under PEPA 1997 to improve the air pollution issue. Other provinces followed suit and created the Balochistan Environment Protection Act in 2012, the Sindh Environmental Provincial Act in 2014, and the Khyber Pakhtunkhwa Environmental Protection Act in 2014. All provincial governments have also created Environmental Protection Councils with an independent body of experts. However, coordination for these meetings at the provincial level is still a challenge.

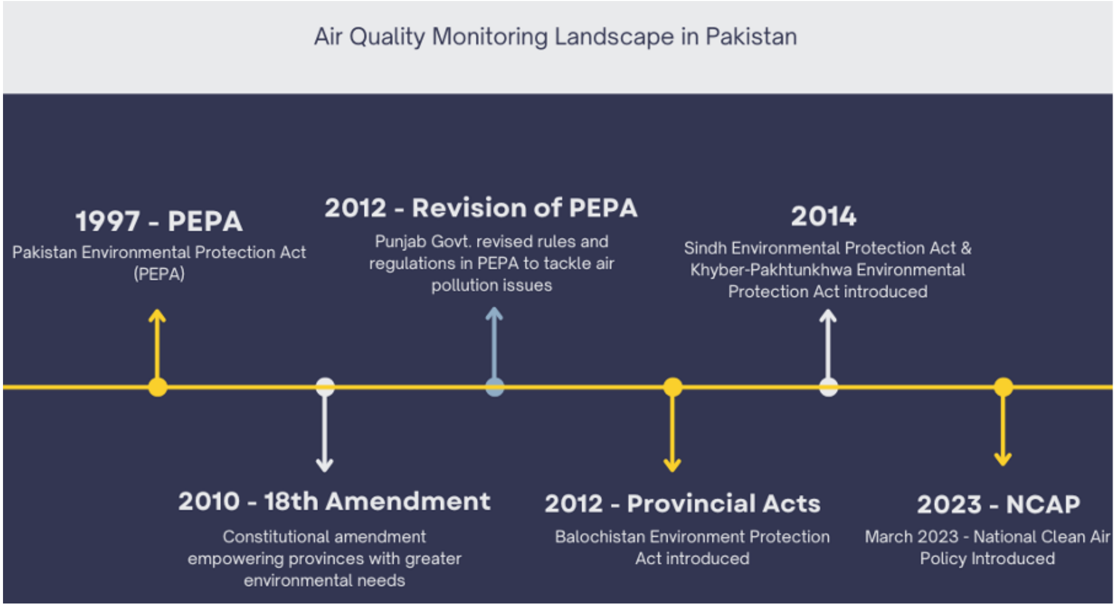


Figure 11: Efforts to Improve Air Quality in Pakistan

Pakistan has a relatively low number of monitoring stations compared to India. There are 30 recorded air quality monitoring stations, including reference-grade monitors and low-cost sensors.

Regulatory Monitoring Networks in Pakistan

The Federal Environmental Protection Agency monitors air quality in the twin cities of Pakistan, i.e., Islamabad and Rawalpindi, and monitors pollutants including NO2, SO2, and PM2.5. Since 2018, data have been posted weekly on social media platforms, i.e., X and the EPA website;[150] older data isn't available to the public. Provincial EPAs also monitor air quality, but often, the data is only in physically, manually maintained records.[151] Due to pressure from the media and civil society, the Punjab EPA began sharing data on its website in 2020, but it isn't consistent. **There are a total of five air quality monitors, and all are in Lahore, Punjab. Many large cities, e.g., Peshawar (Khyber Pakhtunkhwa), do not have a single reference-grade monitoring station.[152]**

Air Quality Monitoring: Other Initiatives in Pakistan

The Pakistan Air Quality Initiative (PAQI) is a major private data provider in several cities and currently operates four monitoring stations in Islamabad, Peshawar, Lahore, and Karachi, which provide real-time satellite data. PAQI is a community-driven initiative, and volunteers in major cities have installed low-cost air quality monitors available through IQAir. Summary data on concentrations of PM2.5 and air quality index values are available through AirVisual, a mobile app and website. In Khyber Pakhtunkhwa, the Peshawar Clean Air Alliance (PCAA), a volunteer association that includes environmental law experts, academics, civil society leaders, and development practitioners, provides data through low-cost sensors. Air quality data is also available through other data providers, including academia, corporations, and US and Australian embassies in Pakistan. National University of Sciences & Technology (NUST) is also involved in monitoring by utilizing locally made conventional air quality measuring gadgets.[153]

In Pakistan, modeled pollution exposure estimates have also been produced using land-use regression methods[154] and satellite data applications.[155] Such estimates provide a starting point for understanding nationwide spatial variability in pollutant exposures.

In 2018, the World Bank committed $200 million to the Punjab Government on air quality topics, including expanding the air quality monitoring infrastructure, strengthening local capacity, and providing air quality data to the citizens. The Punjab government underperformed for various reasons and could not deliver this project. However, recently, the World Bank has committed another $200 million to the Punjab government, and the government has committed an additional $73 million to improve the EPD's (Environment Protection Department) capacity, installing more air quality monitors, disclosing pollution information, establishing vehicle emission standards, promoting green investments by polluting industries, and creating green financing opportunities.

Comparative Assessment of Monitoring Approaches in both Countries

There are limited instances of comparable monitoring systems across India and Pakistan. One point of exception is that across both countries, PM2.5 levels are monitored in large cities by the US Embassies and Consulates, and data are made publicly available; this includes New Delhi, Mumbai, Chennai, Kolkata, and Hyderabad in India, and Islamabad, Karachi, Lahore and Peshawar in Pakistan.[156] Of note, US embassies and consulates are often located in cleaner parts of a city, and thus, there are concerns that the air quality levels measured in those locations may not adequately and appropriately reflect city-wide air quality. The World Bank has also invested significantly in air quality and is supporting air quality monitoring in both countries; it is also working across South Asian countries, including India and Pakistan, to foster integrated action on air pollution.[157]

In the last decade, air quality monitoring has rapidly expanded across India, and as of 2023, there are more than 1000 reference-grade monitoring stations across the country. The coverage is not yet optimal, but when combined with local sensor networks and satellite-derived air pollution estimates, a clear picture of air quality across India is beginning to emerge. On the other hand, progress has been slower in Pakistan, partly due to limited government intervention. Air quality monitoring is mostly community-driven (20+ stations across the country), and there are limited government-run monitoring stations (5 stations across the country). Overall, it is reasonable to conclude that, to an extent, there has been greater adoption of the basket of technologies available for air quality monitoring in India (compared to Pakistan), and government agencies are increasingly using a combination of methods to track air quality.

While efforts have been made in Pakistan to leverage the available data streams, including satellite and land use data, to produce air pollution estimates, there isn't a single set of national-scale PM2.5 exposure estimates that can be consistently used for research or policy applications.

Notably, air quality data is increasingly being used for public engagement and outreach in both countries. In India, there have been a series of targeted public campaigns to raise awareness of air pollution and its health impacts, especially during winter. For example, Mahila Housing Trust trained women construction workers as AQI or air quality index ambassadors in Delhi and provided them with portable air quality monitors.[158] Leveraging the data, the women ambassadors raised awareness of the issue of air pollution and mobilized their local community to act. Similarly, in Pakistan, the Pakistan Air Quality Initiative (PAQI) has worked with a network of volunteers to monitor and map air pollution across the largest cities using low-cost sensors.[159]

In India, AQI is routinely included in media reports across print and digital media, especially in English-medium platforms. Furthermore, data have also been used for public accountability for air quality policies, including tracking data on air quality as part of the NCAP program.[160] Similarly, in Peshawar, Pakistan, a group of concerned citizens formed the Peshawar Clean Air Alliance (PCAA),[161] a non-profit organization to improve air quality in the city. The group has set a time-bound, quantitative target of increasing the total number of clean air days in Peshawar to over 100 a year by 2025. To achieve this, they've successfully engaged the local government (Government of Khyber Pakhtunkhwa) and local and international funders to support the installation of low-cost air quality monitors as well as analytical reports and awareness campaigns.[162]

The breakpoints and descriptions used to define and describe different categories often vary by country and are based on national air quality standards and other available health evidence. Furthermore, countries also include different combinations of air pollutants in estimating the AQI values.

The AQI Story in India and Pakistan

One of the most common ways air quality data is disseminated to the public is by air quality index or AQI. The AQI is a color-coded, multi-point numeric scale used to communicate about levels of air pollution to the public; the higher the index value, the higher the levels of air pollution. In India, the National Air Quality Index (NAQI) was introduced in 2015 and has been used to communicate air quality levels nationwide. The data is available through an app, Sameer, and an online data dashboard.[163] There is currently no indigenously developed AQI in Pakistan, and in cases where AQI is reported, the US AQI framework is often used. Punjab Province established its own AQI in 2017 as part of the Policy on Controlling Smog 2017, and in 2023, revised the AQI cut-off values under the Punjab Clean Air Plan 2023.

Barriers to Improved Air Quality Monitoring in India and Pakistan

Significant challenges exist in the context of air quality monitoring across India and Pakistan. In some cases, these challenges present opportunities for transboundary cooperation, allowing both countries to leverage technical expertise and resources to foster a stronger air quality monitoring and management framework. A few key challenges are described below:

Resource and personnel constraints:

As described above, both countries have significant gaps in air quality monitoring, with large parts of both countries not being monitored for levels of air pollutants.

Limited resource availability creates significant barriers to expanding monitoring systems and effectively leveraging the data for policy decisions and public engagement.[164] Linked to this is the issue of personnel. It has been reported that state pollution control boards face difficulty hiring and retaining staff in India.[165] Similarly, there is a dearth of trained technicians and other personnel who can manage air quality stations or networks, including maintaining and calibrating instruments, within environment departments in India and Pakistan.[166]

Limited indigenous manufacturers for air quality instrumentation:

Both countries rely on international monitoring equipment vendors to purchase, maintain, and deploy reference-grade air quality monitors. Over time, this significantly raises costs for procurement and maintenance. In 2022, the Central Pollution Control Board in India recommended that states use indigenous air quality monitors rather than importing costlier instruments.[167] Companies, including Envirotech Ltd, are in the market in India, but there is a huge demand-supply gap. Similarly, in Pakistan, researchers at NUST have made a state-of-the-art air quality monitor that can be used for country-wide monitoring, but gaps remain.

Lack of trust in data:

Despite broader acceptance of various air quality monitoring approaches, concerns persist regarding data quality [168], including concerns regarding quality assurance and quality control. In some instances, the public does not trust the data provided by government agencies [169], while in other cases, community-led air quality monitoring initiatives are dismissed for the lack of scientific rigor or lack of standardized methods and equipment. For example, in 2022, the Central Pollution Control Board in India issued an order prohibiting states from using low-cost sensor-based data for public dissemination.[170] While there are limitations with low-cost sensors, they are reasonably accurate in predicting local air quality levels and have been used for public dissemination in many cities worldwide. In Pakistan, private data has been questioned for its accuracy and labeled unrealistic.[171]

Patchy data dissemination infrastructure:

Easy and reliable access to air quality data remains an issue in both countries. In India, the CPCB has, in recent years, consolidated data availability and now routinely provides data through its website, an API, and an app. Consolidated data is also made available via government portals, but significant proportions of the data remain in non-machine-ready formats. In Pakistan, on the other hand, the government provides no single platform where air quality information is made available regularly to the citizenry. Recently, the Federal Environmental Protection Agency in Pakistan started providing data to the citizens of Islamabad; Punjab (EPD) provides data occasionally, and the Sindh and Balochistan governments do not provide data. Administrative units also do not have air quality monitoring capabilities. Regular data is available only through non-government providers, but the government often disputes the validity of such data. A lack of coordination among government departments at different levels and between the federal and state/provincial governments impedes the process of strengthening the air quality monitoring networks in the two countries.

Opportunities for Collaboration on Air Quality Monitoring Across India and Pakistan

Considering the magnitude of the problem across the region, collaborative measures on a regional scale are likely to be crucial for effective solutions. Robust, long-term air quality data underpins evidence-based implementation programs, and therefore, a spatially representative and accessible air quality monitoring system is crucial for decision-making. Further, effective responses to India and Pakistan's year-round hazardous air pollution problem must be transboundary in nature. Pakistan, India, Nepal, and Bangladesh share a single airshed. Therefore, air quality management across this air shed necessitates a regional conversation, with the Indo-Pak bilateral being an important component. As argued above, a comparable monitoring system and associated data infrastructure can also make it easier to share data across countries and develop joint mitigation strategies. Promisingly, both India and Pakistan are increasingly investing in air quality monitoring and policy programs to address air pollution. However, it is important for this scientific case for regional collaboration on Air Quality Monitoring to make its way into each country's foreign policy. The recommendations below combine science and foreign policy for collaborative air quality management.

Below, we'd like to highlight three important opportunities for joint action on air pollution across India and Pakistan.

Expanding Collaboration and Engagement Between the Two Countries

Cross-border initiatives can facilitate the exchange of best practices, technology, and research data, fostering a coordinated approach to action on air pollution. However, there are a variety of hurdles. In 2019, teams in India, Pakistan, and Sri Lanka established a pilot project to measure air quality across the three countries. [172] This was a learning experience for all teams, resulting in a scientific paper and relevant air quality and climate messages, including in mainstream media. In the words of Abid Omar, founder of the Pakistan Air Quality Initiative and a collaborator on the pilot project,

"Comparable air quality data in the region forms the baseline for understanding and solving our regional air pollution crisis. With low-cost monitors gaining rapid use in areas without reference-grade equipment, using the same monitors in the cross-boundary project helped provide data that was directly comparable across both countries. Science and air quality do not see any political boundaries, and I hope for greater collaboration."

The two countries could jointly introduce new tools and levers that promote collaboration. For example, both countries can increase ease of business in relation to technology and knowledge transfer and create channels for communication and exchange across the two countries.

Collaboration on air quality monitoring provides a worthy cause to unite bilateral and regional efforts, provided that stakeholders in India and Pakistan, including think tanks, academia, and civil society organizations, conduct adequate foundational policy research. Due to the political equations shared by both countries, the impetus for such collaboration may have to be initially supported by partner countries. Investing in platforms supporting sustained collaboration on AQM-focused policy research across India and Pakistan, and even South Asia is therefore critical to facilitate official collaboration.

In the near term, an annual meeting on air quality management co-organized by a platform like the Indo-Pak Climate Collective could bring together the scientific community, government agencies, and civil society organizations. Such a collaborative approach can also help create formal or informal networks of experts across the two countries, fostering data sharing, insights, and best practices.

In the medium—to long-term, efforts could entail mechanisms for government agencies in Pakistan and India to share best practices and learnings on air quality monitoring and management through an annual science-policy forum. This could also be facilitated under regional cooperative agreements (such as the Malé Declaration) or programs led by international agencies (such as the World Bank or UN Environment) supporting work in both countries. Such an exercise can also help build support for the long-term strengthening of technical and scientific capacity across the two countries.

Sustained Investments for Strengthening Research Capacity and Training

Joint efforts to strengthen local technical and scientific capacity can help both countries install, operate, and maintain advanced air quality monitoring systems and use the data for decision-making.

In the near term, activities could involve:

- Small grant schemes or exchange programs jointly administered by both governments or through other donors to establish new research partnerships across India and Pakistan. India, for instance, has previously funded joint research projects on air pollution with UK and US research agencies, among others.
- An annual training program (e.g., a summer or a winter school) jointly led by eminent academic institutions on air quality monitoring methods for early career researchers from both countries.

There are examples from other regions that offer useful lessons:

The Aerosol, Clouds, and Trace Gases Research Infrastructure (ACTRIS) is a successful European network that facilitates systematic data collection on air pollution.[173] Initially focused on standardizing techniques and infrastructure, ACTRIS receives funding from the European Union and national governments, supporting data needs and research training. This independent initiative fosters scientific collaborations and provides long-term data for policymaking and evaluating interventions.

Similarly, the Megacity Initiative: Local and Global Research Observations (MILAGRO) was an international effort led by US and Mexican researchers to study air quality.[174] Jointly funded by government agencies, MILAGRO's data contributed to scientific understanding and policy decisions.

Strengthening Official Regional Cooperation and Engagement

Regional transboundary agreements on air pollution have been an effective mechanism for regional cooperation in the last few decades. The Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia was adopted in 1998 by the Governing Council of the South Asia Cooperative Environment Programme (SACEP) in Malé, Republic of Maldives. The Declaration bolstered intergovernmental discourse on air pollution across Bangladesh, Bhutan, India, Iran, the Republic of Maldives, Nepal, Pakistan, and Sri Lanka. Notably, this was the first, and to our knowledge, only regional agreement addressing transboundary air pollution in South Asia. Across five phases between 1998 and 2016, various activities were conducted, including air quality monitoring, regional coordination, and expert dialogues. While the Declaration remains in effect, after 2016, activities petered out due to lack of financial support. Promisingly, recent efforts have been made to reignite inter-ministerial coordination under the Declaration.[175] In the near term, it is important that both countries engage and actively participate in the ongoing discussions to revive cooperative action. It is vital that such an effort receives robust regional and national investment in air quality monitoring and management. In the longer term, this could involve the joint development of an air quality management framework for all of South Asia, considering local and regional sources of air pollution. However, this is easier said than done. Several barriers exist to effective engagement and joint action in the current geopolitical context.

Having said that, regional cooperation in South Asia could take many forms, including harmonized air quality standards based on the WHO air quality guidelines [176] or the development of common air sheds and common approaches for air quality management and source-specific emissions reduction. The case for coordinated, transboundary action could not be stronger; according to a World Bank analysis, meaningful reductions in exposure to ambient PM2.5 could be achieved if countries across South Asia introduce sector-specific measures to address air pollution.[177]

Successful examples from other regions in the box below offer some key learnings:

The UNECE Convention on Long-Range Transboundary Air Pollution (LRTAP) is a notable example of regional cooperation across 51 countries,[178] fostering a science-driven policy-making approach. Through engagement with experts and international networks,[179] the convention has successfully reduced emissions of pollutants like sulfur dioxide (SO2) and particulate matter, yielding significant public health improvements, particularly in Europe.[180] This consensus-based approach is relevant to bilateral cooperation between India and Pakistan.

Meanwhile, the Association for Southeast Asian Nations (ASEAN)[181] offers valuable insights into regional collaboration on air quality, emphasizing sovereignty while addressing transboundary haze issues.[182] ASEAN member states have implemented initiatives like the Regional Haze Action Plan (RHAP) and the ASEAN Agreement on Transboundary Haze Pollution (AATHP) to manage land and forest fires.[183] Coordinated data sharing, mutual assistance during emergencies, and respect for individual state policies underscore the importance of common terminology and coordinated action in addressing shared environmental challenges.

Overall, sources of air pollution and the likely basket of solutions are also similar across the South Asian subcontinent, including India and Pakistan. As such, joint efforts across science, advocacy, and policymaking can benefit both countries. This means encouraging bilateral exchanges between expert communities and policymakers and fostering shared expertise and a regional air-shed approach for effective air quality monitoring and management.

Conclusion: Towards Shared Responsibility

In this report, Indo-Pak Climate Collective members from India and Pakistan underline the need for both countries to find ways to address one of the most urgent environmental, health, and development challenges for South Asia: hazardous air quality.

The report captures foundational research to stimulate both countries' collaborative attitudes and policy thinking. While we can “see” the disastrously poor quality of air people breathe on either side of the border during the now infamous 5th season of Smog (November), the problem exists and intensifies daily for much of each year. Therefore, **the daily management of domestic and transboundary air pollution demands the collective, consistent, and sustainable efforts of stakeholders in India and Pakistan** – scientists, climate and foreign policy analysts, bureaucrats, and governments.

The chapters emphasize the need to formulate multi-pronged and cross-sectoral solutions, some of which will also require bilateral coordination between India and Pakistan. For instance, for **improving AQM, knowledge exchange, and training modules to develop personnel capacity and improve data dissemination would be an important step towards a regional air quality monitoring network that is “spatially representative and accessible.” Such a network is critical for developing a proactive and anticipatory approach to transboundary air pollution management, particularly during the smog season.** Shut-downs in both Indian and Pakistani cities during the Smog months cause huge economic loss, bring public life to a standstill, and severely impact public health. Emergency responses like the Graded Response Action Plan (GRAP) applied in New Delhi are reactive policy responses with steep costs. **An anticipatory approach would ensure sustainable measures are taken in preparation to prevent air quality from crossing a harmful threshold.**

Likewise, both India and Pakistan’s bureaucracies and governments can benefit from sharing knowledge bilaterally on best practices and lessons learned regarding short-term strategies such as ex-situ management, financial assistance schemes, and capacity building for farmers. This exchange can help address the issue of crop residue burning to some extent. Regarding the long-term strategy of diversification of cropping patterns, programs like the Orissa Millet Mission are a significant case study for both countries to draw lessons. **Neither country can afford the hubris of undertaking a long-term policy change like crop diversification in isolation and without consultations on similar experiments (like OMM) that have been attempted in its neighboring country.**

Regarding transport emissions, Pakistan faces unique challenges specific to the country. However, **India possesses valuable knowledge in implementing policy changes within the transport sector. Pakistan could greatly benefit from India's**

expertise, particularly in areas such as regulatory control, modernization, and participatory decision-making.

By and large, at present, hazardous levels of air pollution are managed through siloed sectoral efforts at sub-national and national levels in India and Pakistan, despite being a problem across South Asia that is most harshly experienced over a shared airshed extending from Punjab in Pakistan and across the IGP. **Its successful management demands coordinated efforts, nationally and regionally. In some sectors, bilateral coordination across research, policy, and institutional levels is required, for instance, to develop a regional air quality monitoring network. In others, collaboration on experiential knowledge sharing, modernization, and capacity building is the need of the hour.**

This report by the IPCC members outlines domestic and regional pathways to address the issue of extreme air pollution in India and Pakistan. Its successful transboundary management holds immense potential to provide peace dividends to both countries historically plagued by a cantankerous bilateral relationship. Against this political reality, the international community plays a critical role. Like-minded partner countries are supporting numerous clean energy transitions, technology transfer, and capacity-building efforts. However, **resource allocation and support for joint policy pathway ideation and research at a bilateral and regional scale hold the key for South Asia to meet the challenge of successful, efficient air pollution management.**

Endnotes

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INDO PAK CLIMATE COLLECTIVE 2023-24 MEMBERS

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Dr. Bhargav Krishna is a fellow at the Sustainable Futures Collaborative and a former Fellow at the Centre for Policy Research. His research focuses on health policy, environmental policy, and environmental epidemiology, particularly the effects of air quality and climate change on health. Previously, he led the Centre for Environmental Health at PHFI, overseeing work on air quality, climate, and health. He has served on government expert committees on air pollution and biomedical waste. Dr. Krishna holds a DrPH from Harvard, an MSc in Global Environmental Change from King's College London, and a degree from Anna University, Chennai. He teaches environmental health and health policy at PHFI and Azim Premji University. He co-founded Care for Air, a nonprofit promoting air pollution awareness among school children.

Dr. Babar Shahbaz

Dr. Babar Shahbaz is a Professor and Director at the University of Agriculture Faisalabad in Pakistan. He has held positions as Chair of Outreach at US Pakistan Center for Advanced Studies in Agriculture and Food Security and Consultant for UNEP and UNDP. He has postdoctoral fellowships from Korea Development Institute and Zurich University. His research and teaching focus on sustainable rural development, natural resource management, and agricultural extension. With over two decades of experience, he has authored or co-authored more than 75 peer-reviewed research papers, three books, and various policy briefs and articles.

Polash Mukerjee

Polash is a US-based independent researcher and policy advocacy professional with significant experience in environmental health and air quality management. As the former Lead for NRDC India's Air Quality and Climate Resilience program, he worked closely with national, regional, and city governments to strengthen institutional capacities and build community resilience to climate disasters, including extreme heat. Polash is recognized as a strategic leader in India's air quality management.

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Mr. Khaver is part of Info Change's Resilient Development Program and Economic Growth Unit. He focuses on environmental issues and has published papers on water pollution and private sector involvement in water stewardship. His interests span from cybersecurity to foreign policy analysis. His expertise includes political economy, foreign policy analysis, and public-private sector engagement for evidence-based decision-making. He collaborates closely with the Planning Commission on private sector engagement and e-commerce projects.

Dr. Pallavi Pant

Dr. Pant leads the Health Effects Institute's Global Health program, supporting rigorous science and communication of findings to policymakers, scientists, and advocates worldwide. With over a decade of experience in air pollution research and public engagement in low- and middle-income countries, she focuses on urban air quality, source apportionment, and exposure monitoring. She promotes public understanding of air pollution and its impacts and serves on editorial boards for Air Quality, Atmosphere & Health and PLOS Global Health. Pallavi holds a Master's in environmental sciences from TERI School of Advanced Studies, India, and a Ph.D. in Environmental Health from the University of Birmingham, UK.

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Chandra Bhushan (Project Advisor - India)
Mr. Chandra Bhushan, founder-CEO of iFOREST, is one of India’s leading public policy experts. For over two decades, he has tackled a range of environmental issues through research and writing, spearheading public policy campaigns. As an engineer and environmental planner, Bhushan combines technical expertise with socio-economic insights to address complex environmental challenges. His work spans global and local issues, including climate change, energy transformation, and environmental governance. Bhushan has authored 20 books and over 60 reports. He advises international institutions and is a member of the BASIC group on Climate Change. In 2017, he received the Ozone Award from the UN-Environment. Bhushan regularly contributes columns to major Indian media outlets.

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