

# RETHINKING SMOG MITIGATION IN PUNJAB: POLICY EFFECTIVENESS, GOVERNANCE GAPS, AND INCENTIVE-BASED SOLUTIONS

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(CGP # 07-268)

## 6<sup>TH</sup> RASTA CONFERENCE

Friday 15th, Saturday 16th & Sunday 17th May 2026

*ONLINE*

*This document is unedited author's version submitted to RASTA.*



**RASTA – PIDE & Planning Commission Competitive Research Grants**  
Competitive Grants Programme for Policy-oriented Research  
PAKISTAN INSTITUTE OF DEVELOPMENT ECONOMICS

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## **ABSTRACT**

This study evaluates the effectiveness of existing SMOG mitigation policies and initiatives in Pakistan and assesses the feasibility of adopting a Carbon Credit-Based Reservation System (CRS) to address the growing smog challenge. The analysis focuses on policies and initiatives implemented by the Government of Punjab, with particular attention to Lahore, where traffic congestion has significantly deteriorated air quality. Transport is identified as the dominant contributor, accounting for approximately 83% of Lahore's smog, while industrial and agricultural emissions are also examined to ensure a comprehensive assessment across all major pollution sources, as reported by the Urban Unit, Government of Punjab. The first phase of the study involved a desk review of selected smog-related policies, emphasizing provincial regulations and monitoring mechanisms. This was followed by qualitative interviews with key stakeholders to assess on-ground implementation and policy effectiveness. Findings challenge the prevailing narrative on transboundary smog impacts. While transboundary air pollution exists, smog levels are primarily driven by internal urban land-use changes. Prevailing wind pattern analyses show no scientific evidence linking smog mainly to stubble burning in neighbouring countries or short-term events such as Diwali. Moreover, the absence of formal cross-border coordination highlights a critical governance gap. In agriculture, stubble burning persists due to poor adoption of mitigation technologies such as Happy Seeders, which remain inaccessible to small farmers. Financial tools like Kisan Cards are difficult to monitor and prone to diversion. In the transport sector, poor fuel quality, substandard engine oils, and weak coordination between the Energy and Transport Departments limit the impact of EV initiatives. The industrial sector remains largely neglected, with enforcement focused mainly on brick kilns, which contribute less than 15% of smog emissions. To explore incentive-based solutions, the study evaluated the Green Credit Program, launched in December 2024, through interviews with over 686 respondents. Results show that 55% of commuters are willing to shift to cleaner transport, potentially reducing emissions by up to 38%, provided alternatives are reliable, affordable, and convenient.

## **PREFACE**

This research study aims to conduct a critical evaluation of the effectiveness of existing SMOG mitigation policies and initiatives in Pakistan. The primary objective is to analyse the feasibility of adopting a Carbon Credit-Based Reservation System (CRS) as a market-based mechanism to promote sustainable practices to combat smog.

There are several contributors as reported by Urban Unit, Government of Punjab including transport as a big culprit. According to sectoral emission report, published by Urban Unit, accounting for nearly 83% of the city's SMOG emissions in Lahore and 38 percent in Punjab Pakistan. Therefore, the transport sector remains the focal point of this research. Furthermore, the study also examines the roles of industrial activities and agricultural practices to ensure a comprehensive and holistic evaluation of government interventions across all major emission sources, as highlighted by the Urban Unit, Government of Punjab.

The research is structured in three phases: an initial desk review of existing SMOG-related policies, particularly at the provincial level, followed by qualitative interviews including end users, stakeholders and policy makers to validate policy implementation against ground realities and assess their practical effectiveness.

The results clarify one of the major claims regarding transboundary smog impacts in Pakistan. While transboundary air pollution does exist, the findings show that smog levels are largely driven by internal urban land-use modifications. The study finds no scientific evidence linking smog primarily to stubble burning in neighboring countries or to short-term events such as Diwali. This conclusion is supported by prevailing wind pattern analyses. Furthermore, no formal cross-border policy or institutional collaboration currently exists to address transboundary pollution, highlighting a significant governance gap. In agricultural scenario, efforts to control stubble burning within the country remain largely ineffective. Conditions attached to accessing technologies such as Happy Seeders are often unsuitable for small and marginal farmers, limiting adoption. Despite commitments outlined in the SMOG Control Strategy 2024–2025, stubble burning continues, indicating persistent implementation and enforcement challenges. Financial control mechanisms such as Kisan Cards are also difficult to monitor, with evidence from similar programs showing frequent diversion of agricultural loans toward urgent household needs, making strict utilization enforcement unrealistic. The transport sector continues to be a major contributor to air pollution due to poor-quality fuel, substandard engine oils, and weak interdepartmental coordination. While electric bikes and other EV initiatives are being introduced, the absence of effective liaison between the Energy and Transport Departments undermines their impact. Meanwhile, the industrial sector remains the most neglected area of intervention. Regulatory oversight is largely limited to brick kilns—responsible for less than 15% of smog emissions, while other high-emission industries face minimal compliance enforcement. In line with the study's objective to assess the feasibility of incentive-based emission reduction mechanisms, this study evaluated the effectiveness of a carbon reservation-type system at a time when the Government of Punjab had already launched the Green Credit Program in December 2024, with active implementation beginning in the first quarter of 2025. Given Pakistan's economic constraints and large population, direct monetary incentives for emission reduction are unlikely to be fiscally sustainable. However, alternative incentive mechanisms show promise. This study evaluated the recently launched Green Credit Program (36 Climate Actions) through qualitative

interviews with over 686 respondents, with a focus on air pollution control measures. Findings indicate that 55% of commuters are willing to shift to cleaner transport options, which could reduce emissions by up to 38% in the coming years—provided that reliable, affordable, and efficient mobility alternatives are available. The study also reveals that practical factors such as time, cost, and convenience outweigh environmental considerations for most users, underscoring the need for low-emission transport solutions that compete effectively on speed, price, and comfort.

The authors extend their sincere gratitude to their mentors, Dr. Iftikhar Ahmed and Dr. Muhammad Aman Ullah, whose expert guidance, critical insights, and constructive feedback were instrumental in shaping this study on SMOG mitigation and policy evaluation in Pakistan. The authors are also thankful to their colleagues at the Pakistan Institute of Development Economics (PIDE) for their valuable discussions and continued encouragement throughout the research process. Special appreciation is extended to PIDE, Islamabad, for providing institutional support, data access, and research environment necessary to conduct this assessment of provincial SMOG control initiatives and the Green Credit Program.

It is our sincere hope that the findings and policy insights generated through this study will contribute meaningfully to the academic discourse on Smog policies and climate governance and will support policymakers and government officials in designing evidence-based, coordinated, and sustainable strategies for building smog free environment in mega cities of Pakistan.

The authors would like to express their sincere gratitude to the Research for Social Transformation and Advancement (RASTA) Competitive Grants Program, Pakistan Institute of Development Economics (PIDE), Islamabad, for providing the financial support and valuable guidance throughout the course of this research. The support received from RASTA CGP has been instrumental in the successful completion of this study.

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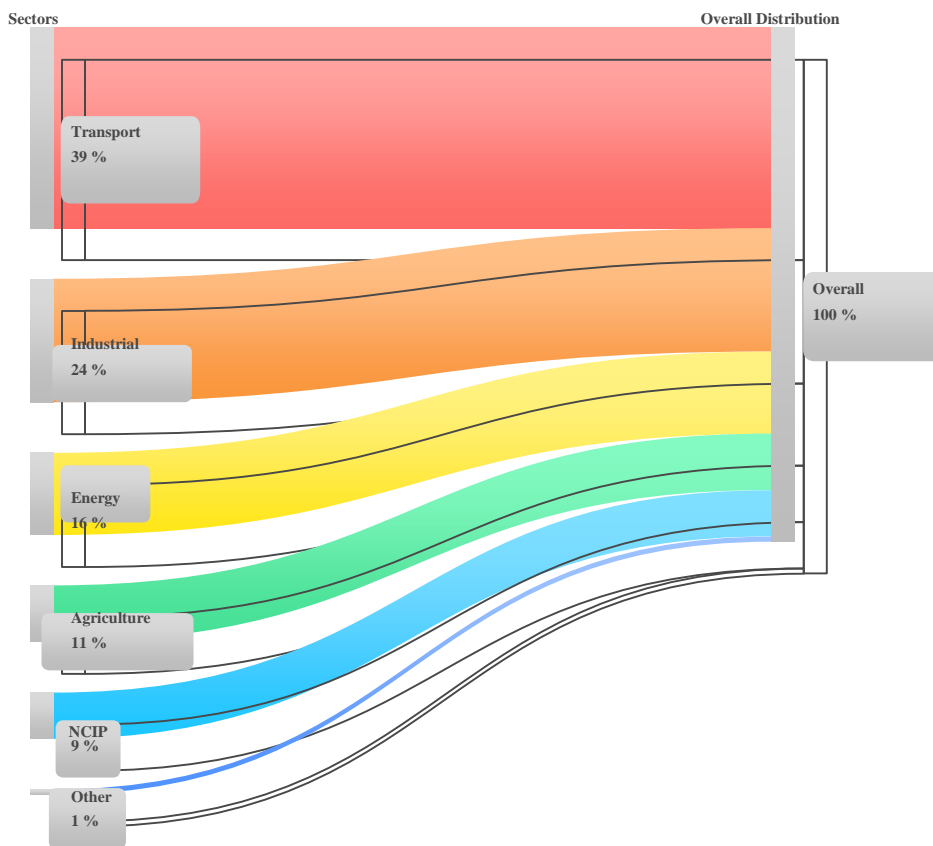
## **ABBREVIATIONS**

AQI	Air Quality Index
CO	Carbon Dioxide
NO <sub>2</sub>	Nitrogen Dioxide
SO <sub>2</sub>	Sulfur Dioxide
CRS	Carbon Credit-based Reservation System
IGP	Indo-Gangetic Plain
NCAP	National Clean Air Policy
NEP	National Environment Policy
PM	Particulate Matter
SDG	Sustainable Development Goal
AQMS	Air Quality Monitoring Systems
EMC	Environmental Monitoring Centre
SME	Small to Medium-sized Enterprise

## INTRODUCTION

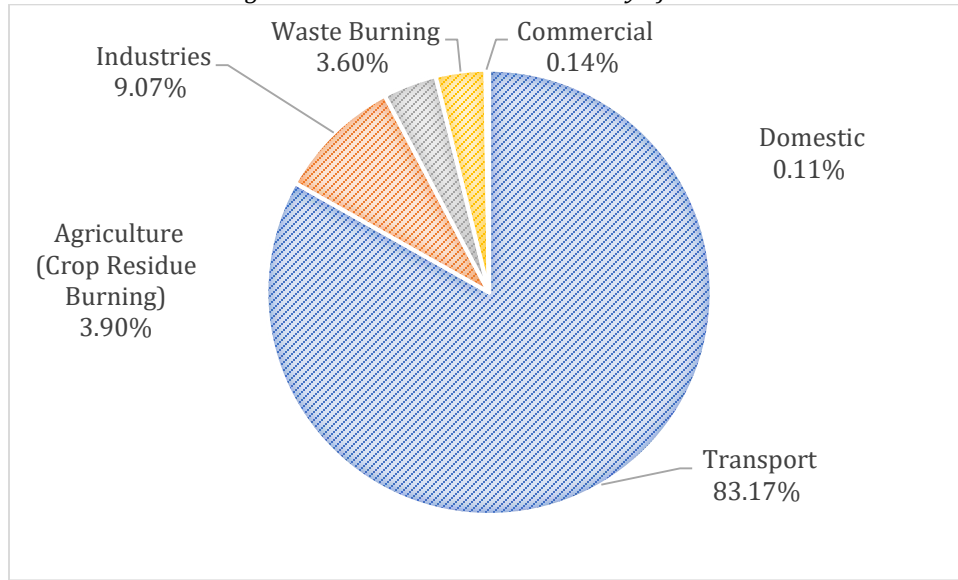
Smog is a recurring air pollution annually in Asia (Majeed et al., 2024). Lahore is located within the Indo-Gangetic Plain (IGP) (Waris & Tariq, 2024). Lahore is the most irrigated city and provides plenty of moisture for the accumulation of air pollution. The smog situation is further worsened by the loss of green cover around Lahore (urbanization) and open burning (Nasar-u-Minallah, 2024). Transport is considered the vital sector of the urban system, essential for facilitating economic activities, connecting communities, and ensuring the smooth movement of people and goods (Zhang et al., 2025). However, the associated challenges, i.e. traffic congestion, air pollution and increasing greenhouse gas emissions, cannot be ignored, and these challenges are seen as endemic in the developing countries (Li et al., 2020). This rise in vehicle numbers contributes to environmental degradation and public health concerns in cities (Iram et al., 2025). In Punjab, Transport is a major contributor, with 39 percent responsible for air pollutants as reported by the Urban Unit (shown in Figure 1) (Bajwa & Sheikh, 2023). Furthermore, another report entitled "Lahore Sectoral Emission Inventory" also stated that the transport sector is responsible for 83 percent of air pollutants, as shown in Figure 2 (Ayub, 2023).

Figure 1: Air Pollution Emission Inventory of Punjab Pakistan (1990-2020)



Source: Government of Punjab (2020).

Figure 2: Sectoral Emission Inventory of Lahore



Source: Government of Punjab (2023)

The second prominent factor is the burning practice of crop residues, particularly in the rice regions of Punjab, which is a major contributor to smog in Pakistan (Irfan et al., 2015). After the harvest season, farmers often burn crop residues as a quick and cost-effective method of clearing fields for the next planting (Lin & Begho, 2022). These burnings release a substantial amount of PM<sub>2.5</sub>, CO, and other pollutants into the atmosphere. The timing of these burnings often coincides with weather conditions that favour the formation and trapping of smog, exacerbating the severity of the issue (Dutta et al., 2024). While, Smog has numerous dangerous socio- economic effects, health consequences stand as the most threatening. Health consequences include many respiratory and other diseases which reduce life expectancy and create mental health problems (Chanana et al., 2023). Since the alarming levels of smog first experienced in 2016, pollution has only been on the rise with only the exception of 2020 when a significant decline in smog was seen in Lahore due to permanent closures of the city system in response to COVID19 (Avis & Richards, 2024). This threat necessitates urgent smog mitigation, adaptation and resilience focused policy formulation, its implementation and its evaluation. There are several contributors as reported by Urban Unit of Government of Punjab indicating transport as a big culprit. It further explores the feasibility of implementing a Carbon Credit-Based Reservation System (CRS)/Green Credit Program in Lahore to reduce emissions across key sectors and enhance public engagement.

### 1.1. Scope of the research

It was outlined in the inception report that although Lahore began experiencing air pollution in the 1990s due to rising industrial activity and vehicle emissions, smog (a combination of smoke and fog) manifested itself as after 2<sup>nd</sup> November 2016, when Lahore's Air Quality Index (AQI) began surpassing hazardous levels, often exceeding 300 (severe pollution). This phenomenon continued to worsen as Lahore was ranked as one of the most polluted cities in the world in 2019. In last decades, several platforms shared about the leading causes of this persistently increasing air pollution that include vehicle emissions, industrial pollution (factories and brick kilns), and stubble burning (crop

residue burning). Moreover, NASA satellite observations reinforce that agricultural stubble burning in India, is a major contributor to the smog that affects both countries, especially Pakistan. Qamar uz Zaman Chaudhry, national climate change expert and former Director General of Pakistan's Meteorological Department, said "*The main source of the pollutants in our lower atmosphere is Eastern Punjab where all the coal-based industries are centered (across the border in India).*"

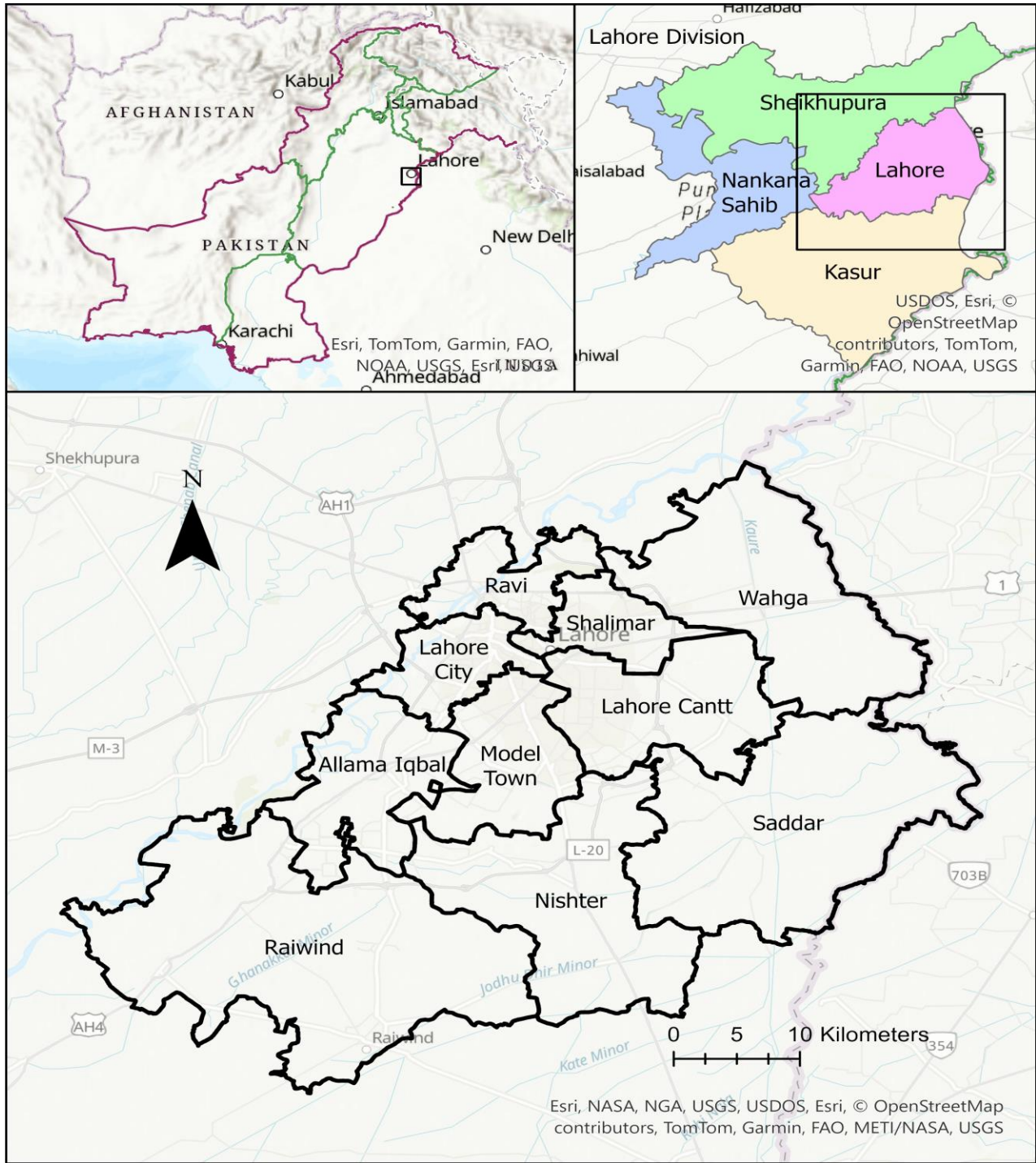
To combat smog Pakistan governments have introduced an array of policies and interventions ranging from Punjab's Smog Action Plans and brick-kiln modernization like zig zag technology in last 10 years. Yet despite these efforts, seasonal smog remains unchecked, with Air Quality Index (AQI) levels soaring above 1,000 on certain days since 2023. The worsening smog crisis underscores a fundamental concern,

*Are the shortcomings rooted in policy design, weak implementation, or inadequate regulatory mechanisms that have failed to prevent the decline in air quality despite extensive initiatives by the government?*

The scope of the study was limited to Lahore, Punjab **(Figure 3)** for the following reasons:

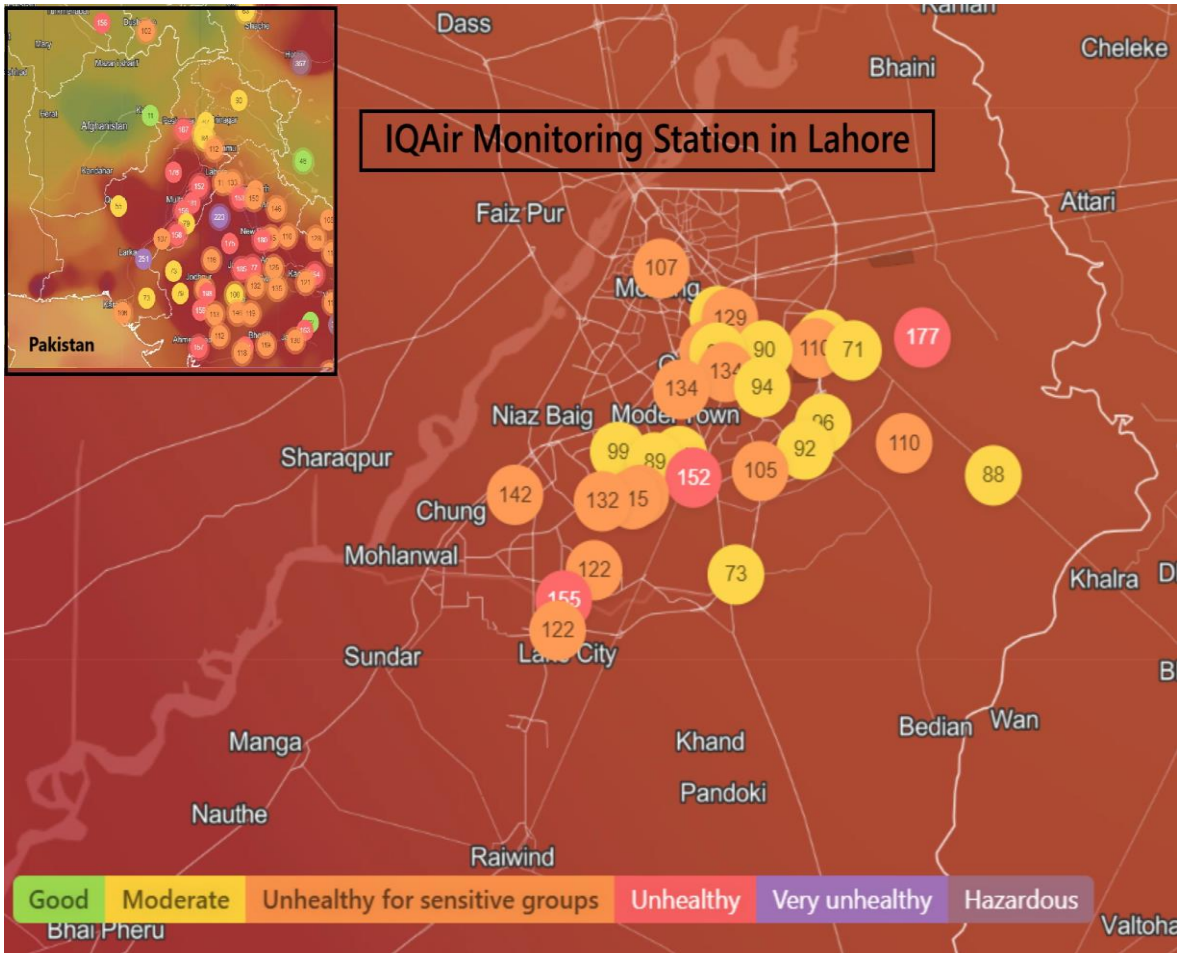
- Lahore, the cultural capital, is the 2nd largest city of Pakistan with a population of 13.9 million as per the digital census 2023.
- Lahore has persistently appeared as one of the world's most polluted cities (Arif et al., 2023) and has the most air monitoring stations and reliable data **(Figure 4)**, compared to other Central Punjab cities.
- Lahore is most vulnerable to transboundary effects from Indian Punjab (Majeed et al., 2024).
- The research team, being Lahore-based, has a natural advantage in limiting the scope to Lahore city.

*Figure 3. Lahore- Study Area*



Source: Author's compilations.

Figure 4. Monitoring Stations of Lahore



Source: IQAir (2025).

## 1.2. Objectives and Approach of the study

In current study's scope, proposed carbon credit-based reservation system (CRS) or on-going green credit program of Govt of Punjab offered a practical and rewarding way for people to create smog free environment. In this way, such credit-based mechanism can reduce emissions as long-term solution. This research assessed the existing policies and initiatives from government, non-governmental and large autonomous bodies. Later, operational feasibility, public acceptance, and environmental impact of credit mechanism in Lahore accessed in terms of affordability, and willingness. The following objectives have been setup for the current study:

1. Identifying the Smog mitigation, adaptation and resilience focused policies and initiatives undertaken by Government, Large Autonomous Organisations and Non- Governmental Sectors from 2016 onwards.
2. Policy evaluation of the existing policies and initiatives to determine success, challenges, limitations and future trajectories.
3. Assessment of the readiness to adopt and estimating the adoption impact on city's smog on carbon emissions
4. To create a public/social awareness of the severity of issue and its solution.

Thus, key research questions of the current study are:

1. What are the key gaps and challenges in existing smog mitigation, adaptation and resilience policies?
2. What are the potential environmental, economic, and social impacts of adopting carbon credit-based mechanisms to combat smog?

In summary, the study involved three key dimensions: (a) Analysis of existing policies and initiatives related to smog mitigation, adaptation and resilience and its cross validation through relevant officials in all listed major contributors including transport, agriculture and industry (b) The study developed Individual Planning-Based Emissions Reduction Model (IPERM) for assessing the feasibility in terms of affordability and willingness. This model involved quantifying the impacts on carbon emission and adoption rates. (c) The study also includes public engagement with the help of public/Social outreach.

## **LITERATURE REVIEW**

### **2.1. Overview in the Global and Regional Context**

Smog and air pollution, a global crisis intensified by industrial emissions, urbanization, and agricultural practices, pose serious health, economic, and environmental challenges, particularly in South and Southeast Asia due to rapid urban growth, transboundary pollution, and dependence on fossil fuels (Grote et al., 2016). Almost the entire global population (99 percent) is exposed to air quality that surpasses World Health Organization (WHO) health-based limits (WHO, 2021). The WHO estimates that air pollution causes 9 million premature deaths annually worldwide (Khan & Li, 2025). According to the World Bank and the Institute for Health Metrics and Evaluation (IHME), the global health burden from PM<sub>2.5</sub> pollution exposure, encompassing mortality, morbidity, and lost productivity, cost an estimated US 8.1 trillion dollars in 2019, equivalent to 6.1 percent of global gross domestic product (GDP) (Wagner, et al., 2023).

Over the past decade, smog-related issues have intensified across South Asia for decades. Although, it gained significant attention as a major public health and environmental issue in the mid-2010s (Abbasi & Mukhtar, 2023), particularly following severe smog episodes in cities like Delhi and Lahore in November 2016 (Majeed et al., 2024). Thus, this review synthesizes studies from 2016 to 2025, a period chosen to capture the emergence and escalation of smog as a critical issue, evaluating mitigation, adaptation, and resilience policies in South Asia.

### **2.2. Smog Mitigation Policies and Initiatives**

Mitigation policies in South Asia address greenhouse gases (GHGs) including CO<sub>2</sub> (carbon dioxide), CH<sub>4</sub> (methane), and NO<sub>2</sub> (nitrous oxide), pollutants like PM<sub>2.5</sub> and PM<sub>10</sub> (particulate matter), NO<sub>x</sub> (nitrogen oxides), SO<sub>x</sub> (Sulphur oxides), CO (carbon monoxide), and black carbon (BC), through regulatory, technological, and sectoral interventions (Meo et al., 2024).

According to world bank report, South Asian countries are unleashing solutions to fight air pollution and accelerate action to achieve National Ambient Air Quality Standards and are considering an aspirational goal of <35 µg/m<sup>3</sup> for annual PM<sub>2.5</sub> concentrations by 2035 (Mega, 2022).

As a part of South Asia, Pakistan faces a severe air pollution crisis, with smog becoming a current issue, particularly in urban centers like Lahore, where PM<sub>2.5</sub> levels have surged due to vehicular emissions, industrial activities, conventional agricultural practices as well as transboundary crop burning (Iram et al., 2025). The Smog Commission Report 2018 and Punjab Clean Air Action Plan 2019 reveal that Punjab experiences low visibility from smog, fog, and mist for 10-25 days annually between November and February, worsened by a regional phenomenon affecting South Asia from Delhi to Faisalabad (Government of Punjab, 2019). The Punjab Clean Air Action Plan 2019 also highlights the significant contribution of burning rice stubble in Punjab and Indian Punjab to regional smog in 2016. The NCAP 2023 highlights agricultural waste burning as a significant contributor to high PM<sub>2.5</sub> concentrations in Lahore, 24 times higher than the WHO guidelines in 2019 (Saqlain et al., 2025). The Roadmap for Smog Mitigation in Punjab 2024-2025 reveals that smog has become Punjab's "fifth season" from October to January, causing severe air pollution (AQI 300–400) in urban

centres like Lahore due to climate-induced weather patterns and agricultural stubble burning (Business Recorder, 2024).

The country has introduced multiple policies to mitigate smog, targeting pollutants such as PM<sub>2.5</sub>, PM<sub>10</sub>, NO<sub>x</sub>, SO<sub>x</sub>, CO<sub>2</sub>, CH<sub>4</sub>, NO<sub>2</sub>, and BC. These efforts include Renewable Energy Policy (2006) (Yazdanie & Rutherford, 2010), National Climate Change Policy (2012) (Mumtaz, 2018), Pakistan Clean Air Program (Slater, et al., 2024) climate policies aligned with Sustainable Development Goals (SDG 13), public awareness campaigns using willingness-to-pay (WTP) for smog reduction, clean energy promotion with AQI monitoring, and environmental education initiatives in South Punjab (Ahmad, , et al., 2025). Despite these measures, challenges such as weak enforcement, outdated technologies, poor monitoring infrastructure, limited investment in clean energy, high vehicle and industrial emissions, and a claim about transboundary pollution from India continue to hinder progress. This subsequent section details each policy, explores local initiatives, and evaluates impacts and challenges at macro and micro levels throughout the country in three major reported contributors including transport, agriculture and industry.

***Pakistan Environmental Protection Act (1997)*** was the first comprehensive law designed to protect, conserve, rehabilitate, and improve Pakistan's environment. According to PEPA 1997, air pollutants mean any substance that causes pollution of air and includes soot, smoke, dust particles, odor, light, electro-magnetic, radiation, heat, fumes, combustion exhaust, exhaust gases, noxious gases, hazardous substances and radioactive substances. However, PEPA ACT 1997, only address transportation sector i.e. installation of devices in, use of fuels by, and maintenance and testing of motor vehicles for control of air and noise pollution are mentioned under Power to Make Regulations. The PEPA 1997 also laid the foundation for industrial emission control by establishing National Environmental Quality Standards (NEQS) and mandating Initial Environmental Examinations (IEE) or Environmental Impact Assessments (EIA) for industrial projects, with penalties of up to PKR 1 million for non-compliance. It requires licensing for hazardous substances and empowers Environmental Protection Orders to enforce emission controls (Sial et al., 2018)

Afterward, the measures outlined in the ***National Environment Policy 2005*** predominantly focus on the transportation sector, with approximately 60% of the actions directly targeting vehicular emissions, fuel quality, vehicle manufacturing standards, and the promotion of cleaner and non-motorized modes of transport such as cycling and mass transit systems. Around 20% of the measures address industrial pollution through the enforcement of environmental quality standards, cleaner production technologies, and the phasing out of high-Sulphur fuels used in industrial processes. Notably, this policy advocates sustainable agricultural practices to prevent soil degradation and minimize the environmental impact of agrochemicals and waste. However, agricultural burning is not explicitly mentioned in the list of actions, indicating a gap in addressing this significant source of air pollution. For industrial emission, the NEP 2005 promoted National Clean Air Act, ambient air quality standards, and cleaner production technologies, supported by financial incentives like tax concessions and low-interest loans to encourage industries to adopt sustainable practices (GOP, 2005).

***Pakistan National Climate change policy 2012*** also aim to reduce greenhouse gas emissions while also addressing air pollutants like methane, ammonia, nitrogen oxides, and particulate matter through better fertilizer use, manure management, biogas production, improved livestock feeding, and sustainable farming practices. Supporting actions like integrating indigenous knowledge and capacity building further enhance air quality and promote sustainable agriculture. Similarly, to curtail the emissions from transport sectors, several policy measures were mentioned including maintenance for fuel efficiency enhancement, establishing and enforcement of vehicle emission standards and encouragement of non-motorized modes of travel, such as bicycle as well as walking for shorter distances. This policy also mentioned that an institutionalized system will be developed to measure and monitor GHG emissions from various sectors including trans-boundary pollution and maintain a database (Khan, 2014).

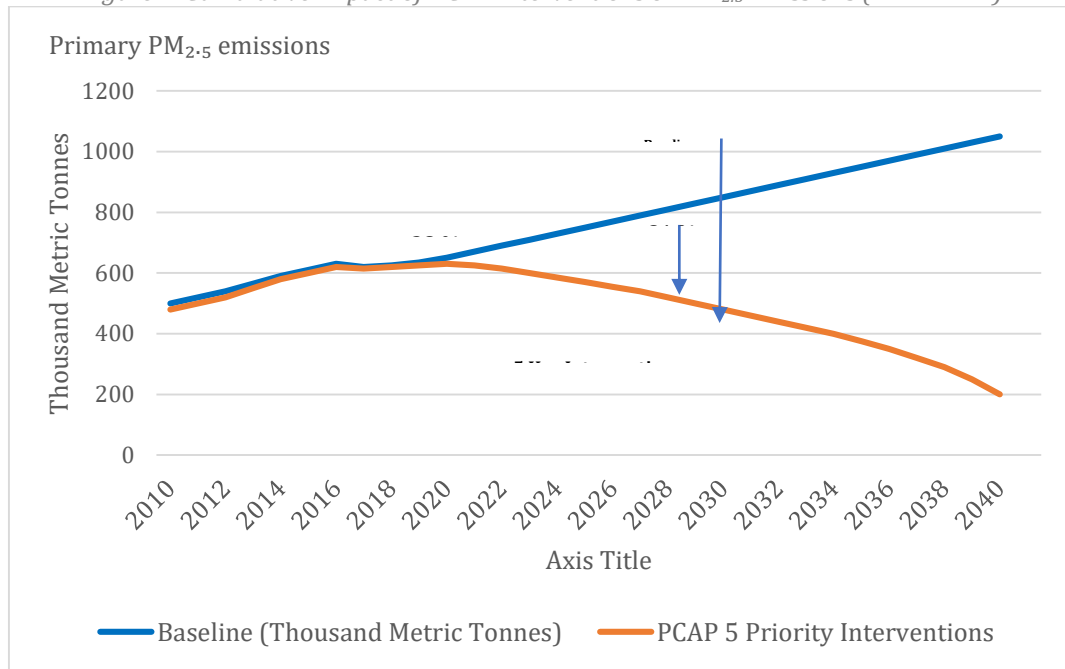
After onset of smog in November 2016, first committee was constituted to examine extreme weather of dense smog in Punjab. In 2017 a comprehensive **Policy on Controlling Smog** was published. In this policy, first time agriculture Department is directed to prepare and execute plan(s) for disposal of crop residue in an environmentally friendly manner. It was further directed by government to Agriculture Department to carry out vigorous campaign for educating farmers on fertility losses suffered due to burning of crop residues and at the same time introduce alternative technologies for quick and environmentally safe disposal of crop residue such as converting it into mulch. Likewise, Additional IG Traffic, C&W Department, Transport Department and LG & CD Department were responsible for implementing measures to reduce PM emissions from vehicles. These included controlling and managing traffic flow, restricting the circulation of private cars during high pollution episodes, and improving road infrastructure. Efforts such as coordinating traffic signals through 'green wave' systems and enhancing road conditions aimed to ensure smoother traffic movement. Additionally, these departments were tasked with organizing continuous public awareness campaigns to promote alternatives to motor vehicle use, such as bicycling and walking for short distances. They were also responsible for developing supportive infrastructure, including pedestrian walkways and dedicated bicycle lanes, to encourage eco-friendly transportation habits among the public. In conclusion, approximately 33% of the measures focus on the transport sector, addressing issues such as traffic management, adoption of Euro-II vehicle standards, installation of catalytic converters, and improvement of road infrastructure to reduce vehicular emissions. Around 27% of the actions target the industrial sector, including the shutdown of major smoke-emitting industries, introduction of low-Sulphur fuels, greening of industrial processes, and ensuring planned urban and industrial development to control pollution sources. About 13% of the actions focus on agriculture, primarily aiming to eliminate the burning of crop residues and promote alternative methods for waste disposal. The remaining 27% of the plan covers activities related to public health advisories, air quality monitoring, creation of woodlands, and fostering regional environmental cooperation to tackle transboundary pollution. Furthermore, it was mentioned that smog being a regional problem cannot be effectively controlled by eliminating local sources of pollution alone. Therefore, Agreement on "Transboundary Haze Pollution" set as a base example between ten ASEAN countries in 2002 with this consideration that bilateral and multilateral dialogues between India and Pakistan can be slow and difficult process (Rafiq-uz-Zaman, et al., 2024).

In subsequent year, **Smog commission report in 2018** declared to enhance capacity of EPA for ambient air quality monitoring as per “Punjab Environmental Quality Standards for Ambient Air” by purchasing and installing 30 ambient air quality monitoring stations (AAQMS) at the following locations all over the province including Lahore, Sheikhupura, Faisalabad, Rawalpindi, Multan, Gujranwala, Sialkot, Bahawalpur, D.G Khan, Sargodha, and 5 Mobile AQMS. It also mentioned that EPD introduced an environment friendly and cost-effective technology of brick kilns, Draught Zig Zag Brick Kiln in collaboration with All Pakistan Brick Kiln Owners Association, this technology was developed by International Centre for Integrated Mountain Development (ICIMOD) while working in Nepal. Under this policy measure, 200 brick kilns will be upgraded to more efficient Induced Draft Zig Zag Brick Kiln technology. In October 2016, the Environmental Protection Department (EPD) approached the World Bank for technical and financial assistance to develop a medium-term plan for improving air quality in Punjab. After extensive consultations, the World Bank approved a five-year Punjab Green Development Program (PGDP) on May 25, 2018, with a total outlay of US\$ 273 million, including US\$ 73 million from the Government of Punjab. The PGDP focuses on two key strategies: strengthening regulatory enforcement capacities in EPA and related agencies and promoting technology adoption in high-pollution sectors like brick kilns, steel furnaces, rice mills, and transport. The program aims to improve environmental quality by combining enforcement with incentives. Additionally, PGDP establishes a structured environmental governance framework in Punjab, dividing powers into Legislative, Executive, and Judiciary branches, with clear roles in regulation, enforcement, monitoring, and advisory support. For industrial emissions from the industrial estates in and around Lahore, such as Kot-Lakhpat, Kala Shah Kaku, Sundar was prioritized, along with highly polluting sectors, such as steel smelting furnaces and brick-kilns. Likewise, 02 specific actions have been proposed to address the issue of rice stubble burning. In the short term, it is planned to arrange a workshop with rice exporters to promote the adoption of the principles of the Sustainable Rice Global Initiative, which strictly prohibits the burning of rice stubble by farmers. For the medium term, the plan focuses on encouraging the use of sustainable farming methods and agricultural technologies, such as the “Happy Seeder”, which enable farmers to manage crop residues without resorting to burning (Fazal et al., 2024).

**Punjab Clean Air Policy 2019** provided timebound implementation plan of the Punjab Smog and Clean Air Policy in all three important contributors of SMOG in urban areas of Punjab (Slater et al., 2024).

Furthermore, the **National Climate Action Policy (NCAP) 2023** aims to reduce PM<sub>2.5</sub> emissions by 38% by 2030 and 81% by 2040 by preventing agricultural residue burning as one of five key interventions (Kamran et al., 2024), as shown in **Figure 5**. The Punjab Clean Air Policy, Punjab Environmental Protection Rules 2023, Smog Control Strategy 2024-25, Climate Resilient Punjab Vision & Action Plan 2024, and Roadmap for Smog Mitigation in Punjab 2024-2025 are implemented to enhance efforts through legislative enforcement, technological interventions (Super Seeders, Rice Straw Shredders), and extensive awareness campaigns.

Figure 5. Cumulative Impact of NCAP Interventions on PM<sub>2.5</sub> Emissions (2020-2040)



Source: Butt & Dahiya (2023).

Furthermore, the 2023 Punjab Environmental Protection (Smog Prevention and Control) Rules enforce Provincial Environmental Quality Standards (PEQS), requiring emission control systems, CCTV monitoring, and banning tyre pyrolysis, with penalties ranging from Rs. 100,000 to Rs. 1,000,000 for violations (Malik, 2025). The Climate Resilient Punjab Vision & Action Plan 2024 advances industrial emission reduction through an Emission Trading System (ETS), annual emission caps, and mandatory continuous monitoring systems, while promoting biofuels and biomass to align with Pakistan’s Nationally Determined Contributions (NDCs) for a 50% greenhouse gas (GHG) reduction by 2030 (Moeen et al., 2025).

Recently, to control smog government has rolled out many policies in the transport sector i.e. deployment of 27 electric buses in Lahore Pakistan (Raees, 2025). Furthermore, Government has distributed 8000 EV bikes to students and planning to distribute 1000,000. Government also planned 20000 bikes through installments schemes (Saeed & Mahmood, 2024). Emission testing squads have been deployed which will ensure the vehicle emission quality. The government has amended the **Punjab Environmental Protection Act (2023)** to introduce stricter regulations (Malik, 2025). These include banning substandard fuels, imposing heavy fines on vehicles which exceed the emission levels this will also help to regulate the emissions.

### 2.3. Challenges in Policy Implementation

In Agricultural sector, some challenges include: **(a) Economic Barriers** which are mentioned in the Smog Control Strategy 2024-25. These barriers particularly include high equipment costs discourage adoption, despite subsidies being provided (Malik, 2025). Likewise, the Climate Resilient Punjab Vision & Action Plan 2024 aims to promote green financing for agricultural technologies (Ishaque et al., 2024). The Chief Minister's Initiative is being implemented to reduce costs in Punjab's Smog

Mitigation Roadmap 2024-2025 by offering subsidized Super Seeders and Rice Shredders; **(b) Teaching new technologies:** The Smog Control Strategy 2024-25 addresses uncertainty about new technologies through awareness campaigns, targeted training for farmers and mentioned training of 471,477 farmers and women. The Roadmap for Smog Mitigation in Punjab 2024-2025 focuses on youth engagement through the Mera Punjab Smog-Free Internship Program (Government of Punjab, 2025); **(c) Transboundary Pollution:** The Smog Commission Report 2018 and Punjab Clean Air Action Plan 2019 reveal that 32 million tons of rice stubble burned in 2016 in Indian Punjab contributed to Lahore's smog. Thus, the NCAP 2023 and Climate Resilient Punjab Vision & Action Plan 2024 emphasize the need for regional cooperation to address transboundary pollution, as emphasized in the Roadmap for Smog Mitigation in Punjab 2024-2025 (Malik, 2025); **(d) Infrastructure and Monitoring Gaps:** The Punjab Clean Air Action Plan 2019 addresses challenges in limited AQMS and monitoring capacity through proposed AQMS and EMC , while the NCAP 2023 promotes regular emission inventory updates. The Climate Resilient Punjab Vision & Action Plan 2024 establishes vigilance committees and regular reporting for monitoring, while the Roadmap for Smog Mitigation in Punjab 2024-2025 strengthens monitoring through SMU and "Smog Dashboard" with drone and thermal technologies.

Similarly, industrial smog control policies have weaknesses include funding shortages, weak coordination, and limited SME support, resulting in partial compliance and persistent smog challenges. Lastly, a key challenge in the transport sector is ensuring a reliable, renewable energy supply for EV charging, especially for electric buses. Without shifting to clean energy sources like solar, the benefits of EV adoption may be offset by continued reliance on fossil fuels (Rafiq-uz-Zaman et al., 2024).

## RESEARCH METHODOLOGY

This study adopted a mixed-method approach based on a combination of desk research, qualitative, and quantitative methods to evaluate the current landscape of smog-related environmental policies in Pakistan, with a particular focus on Punjab province. In the first phase, all selected policy documents were reviewed systematically, analysing 11 key policies mentioned in **Table 1**.

*Table 1: Selected Policies for Smog Mitigation, Adaptation and Resilience*

No.	Policy Name	Year	Issuing Authority
1	Pakistan Environmental Protection Act (1997)	1997	National Assembly of Pakistan
2	National Environment Policy (NEP) 2005	2005	Government of Punjab
3	National Climate Action policy	2012	Pakistani government
4	Policy on Controlling Smog	21-Oct-2017	Government of the Punjab Environment Protection Department
5	Smog Commission Report	28-May-2018	Government of the Punjab Environment Protection Department
6	Punjab Clean Air Action Plan	2019	Government of the Punjab Environment Protection Department
7	Punjab Clean Air Policy	17-Apr-2023	Government of the Punjab Environment Protection Department
8	National Clean Air Policy (NCAP)	02-May-2023	Ministry of Climate Change and Environmental Coordination
9	Punjab Environmental Protection Smog Prevention and Control Rules 2023	07-Jun-2023	Government of the Punjab Environment Protection Department
10	Climate Resilient Punjab Vision & Action Plan 2024	03-Sep-2024	Government of the Punjab Environment Protection Department
11	Roadmap for Smog Mitigation in Punjab (2024–2025)	02-Oct-2024	Government Of the Punjab Environment Protection Department

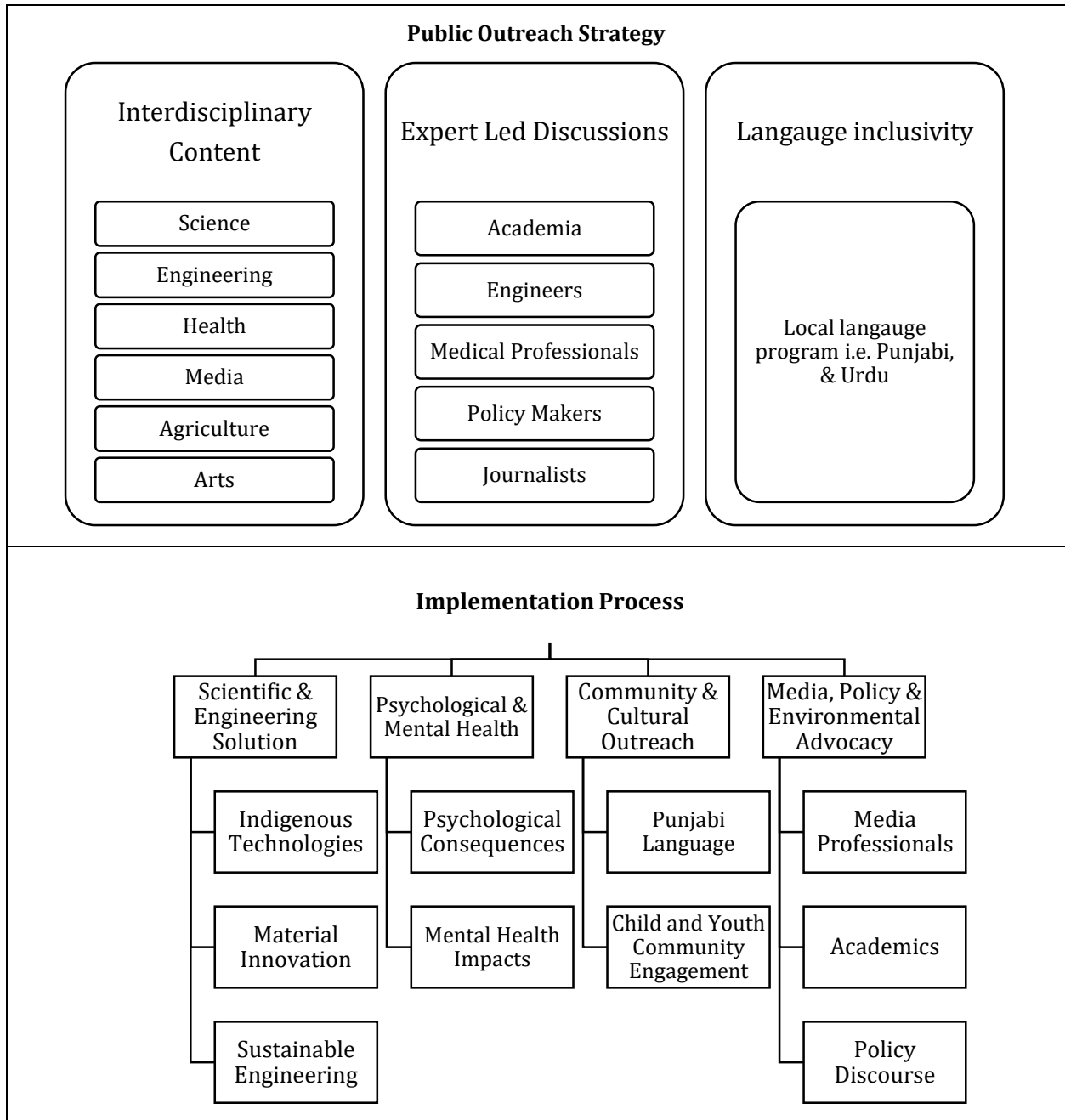
*Source: Authors' compilations.*

Selected policy documents and final reports related to air pollution/smog were analyzed to set the groundwork for interviews with farmers, transport operators, industries, and policymakers. This will be achieved through a detailed contextual analysis guided by a comprehensive framework encompassing ten evaluation dimensions: policy objectives, target population, geographic scope, type and design of the policy, policy implementation strategy, measures, stakeholder participation, cost and resources, evaluation methods, and media coverage.

While in Phase II, a mixed-methods research design is employed, combining quantitative and qualitative techniques to obtain a comprehensive understanding of the carbon credit feasibility, for this phase, a mixed-methods approach is employed, consisting of (i) in-depth interviews. (ii) a quantitative survey, (iii) a qualitative feasibility survey. This triangulation of methods enhanced the validity and robustness of the findings by capturing the phenomenon from multiple perspectives. The use of multiple data collection methods with different questionnaires was intentional, as the research objectives required both numerical measurement and contextual, exploratory insights. For example, quantitative data enabled statistical generalization, while qualitative methods facilitated a deeper understanding of feasibility, perceptions, and underlying factors that could not be captured through structured questionnaires alone.

In last phase of study, multi-seminar and interdisciplinary engagement strategy is opted to raise public and social awareness about air pollution and smog. The methodology of this phase was designed to engage diverse stakeholder groups, including scientists, students, policymakers, media professionals, and the public, using culturally responsive and evidence-based communication approaches.

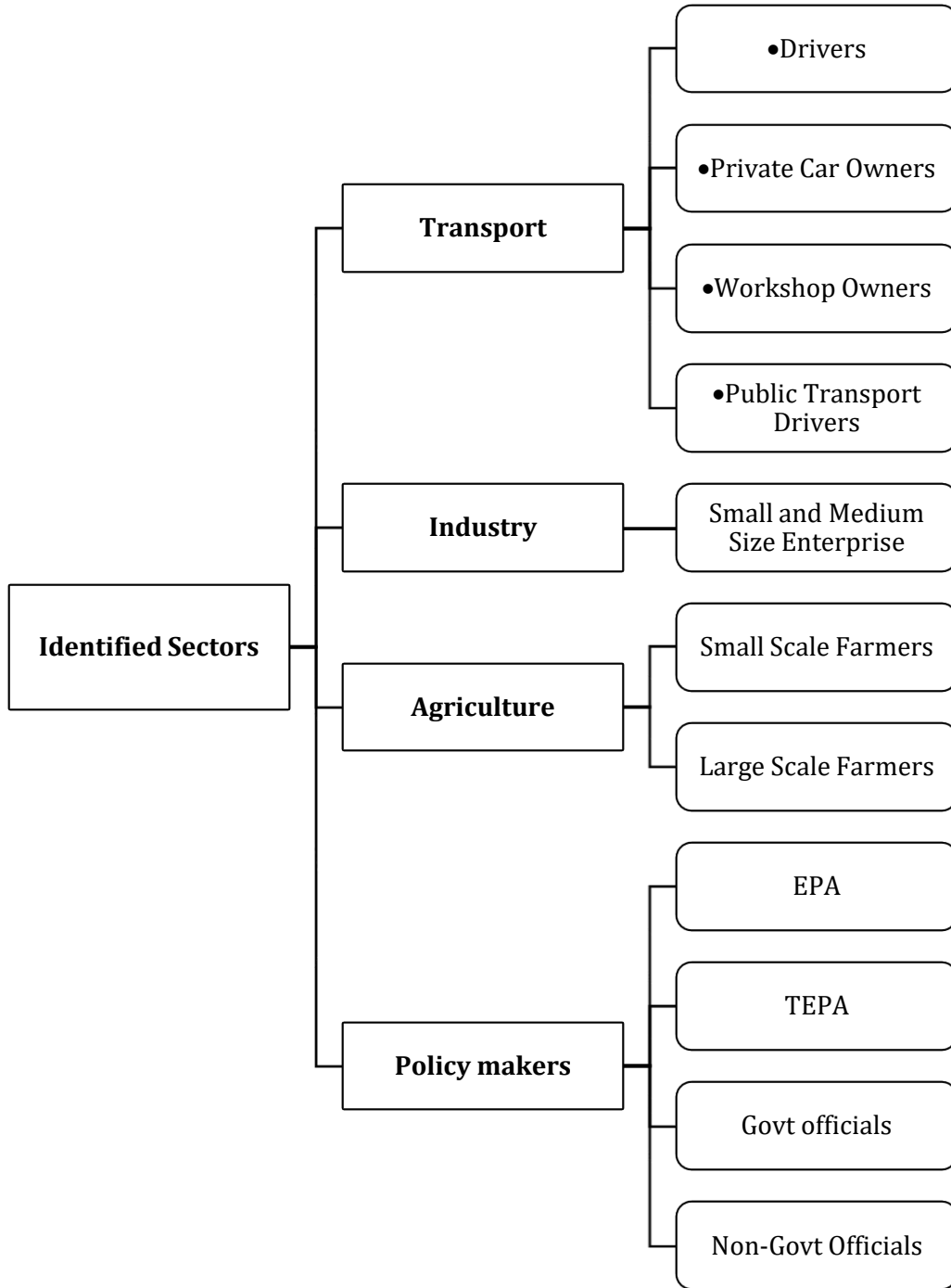
Figure 6. Public Outreach Strategy and Implementation Process for Smog Awareness



Source: Authors' compilations.

As part of qualitative research, section (i) in-depth interviews were carried out firstly using purposive sampling. The participants were selected from agriculture, industries, transport and policy makers (See Figure 7), and the sample size is determined based on theoretical saturation.

Figure 7. Interview Plan



Source: Authors' compilations.

## **Ethical Protocols and Questionnaire Design**

This work received full ethical approval before conducting and recording interviews. In qualitative research, all participants agreed. The study brief informed them that they were free to withdraw at any time, should they wish.

Given the diverse backgrounds of interviewees, including agriculture, transport, industry and sector-specific policy makers with tailored sets of questions were used for each group.

**Questionnaire Protocol for the Agricultural Sector:** For the study, farmers were categorized based on the size of their agricultural landholdings. Large-scale farmers were defined as those owning approximately three *kill* and more (roughly equivalent to 24 *Kanal*), whereas small-scale farmers were identified as those possessing comparatively limited landholdings, typically up to a few acres.

- 1) The Farmer's Background (Name, Residence, Farming Experience, Crops Grown)
- 2) Crop Residue Disposal Methods
- 3) Awareness of Smog
- 4) Government Efforts to Address Smog or Crop Burning
- 5) Alternatives to Burning Crop Residue
- 6) Government Support for Farmers to Avoid Burning

**Questionnaire Protocol for the Transport Sector:** It includes

- 1) What actions is the government taking to reduce smog at the individual and collective levels?
- 2) Have you fixed the vehicle inspection sticker on your car?
- 3) Is the government providing subsidies on electric bicycles?
- 4) Through which media platforms do you receive awareness about smog?

**Questionnaire Protocol for the Industrial Sector:** It includes

- 1) Do you think it is realistically possible to complete projects on time despite obstacles such as bureaucratic procedures?
- 2) Has your factory used any new technology or filtering system to reduce pollution and waste?
- 3) What steps have you taken to access the required resources (such as funding, consultancy, or skilled labour) to comply with environmental regulations?
- 4) Has the government enforced environmental laws strictly and effectively from your perspective?

Table 2: Mapping of Questions in Data Collection Instruments for Sector-Specific Policymakers

Category	Questions
Political Leaders, Industry & Business Stakeholders Agricultural Stakeholders	<ol style="list-style-type: none"> <li>1) Share the vision of the Punjab Government concerning climate action and sustainable solutions</li> <li>2) The government's role and efforts to control smog</li> <li>3) Regarding e-transport sustainability, i.e. 1100 buses' role in meeting the 30% target of NEV by 2030</li> <li>4) EPA sticker quantification of smog and its impact</li> <li>5) Upgrade to Euro 6 fuel</li> <li>6) Quality of the vehicle that is being produced</li> <li>7) CRS effectiveness</li> <li>8) Assuasive measure, i.e. social media and youth engagement effectiveness</li> </ol>

Source: Authors' compilations.

### 3.2. Data Review and Analysis

Data review and analysis are done in conjunction with data analysis. The following methodology is being adopted for data review and analysis.

**a. Data Familiarisation:** The in-depth interviews have been transcribed. The data has been thoroughly read and examined.

**b. Coding:** Important features of the data have been coded in a systematic manner across the entire dataset. Data has been collated for each code.

**c. Generating, Reviewing and Defining Themes:** Generating codes into potential themes, reviewing and analyzing and finalizing themes.

**d. Software-based Validation:** Use of R Studio for deriving themes and drawing conclusions

**e. Analysis and Report:** Research findings based on qualitative data analysis are compiled and finalized.

Furthermore, for section (ii), quantitative surveys were conducted to help understand the emission control. For this purpose, a stratified random sample (n = 385) was drawn from urban tehsils, ensuring representation across income, age, and gender. The survey was conducted to provide detailed data on the following: (i) demographic details (e.g. age, occupation, region of residence in Lahore); (ii) the current modes of transport, the distance of the trip, the distance traveled, the routes used, and the type of vehicle, fuel, and emissions; (iii) their awareness and preference in using low-emission transportation and their readiness to change, including their desired modes of transportation; (iv) incentive(s) that would make them adopt low-emissions transport, and (v) the factors that would influence their choice of the transport. The sample period was collected from January and April 2025 using both face-to-face and online questionnaires.

Likewise, another qualitative survey data was collected to evaluate key aspects such as awareness, knowledge, participation, perceived effectiveness, barriers, and incentives. The feasibility of CRS is evaluated whether the program is known, effective in perception, accessible, and appealing (e.g., via rewards like Green Credits). The data includes ~650 responses, with demographics, awareness metrics, ratings, and preferences.

Therefore, the integration of quantitative surveys, qualitative feasibility assessment, and in-depth interviews ensured methodological alignment with the study purpose and also strengthened the credibility and comprehensiveness of the study findings.

### 3.3. Secondary Data Source

**Active Fire Tracking as a Proxy for Stubble Burning:** The daily Suomi National Polar-Orbiting Partnership NASA Visible Infrared Imaging Radiometer Suite (VIIRS) Thermal Anomalies/Fire (VNP14A1) Version 1 data provides daily information about active fires and other thermal anomalies. The VNP14A1 data product is a global, 1km gridded composite of fire pixels detected from VIIRS 750m bands over a daily (24-hour) period. The VNP14 data products are designed after the Moderate Resolution Imaging Spectroradiometer (MODIS) Thermal Anomalies/Fire product suite. Dataset Availability is from 2012-01-19T00:00:00Z to 2025-08-31T00:00:00Z, and the dataset provider is NASA LP DAAC at the USGS EROS Center. The resolution is 1000 meters. The band used is MaxFRP in MW units by selecting Maximum Fire Radiative Power. These products are widely used to track agricultural burning in near-real time and to build multi-year trends by employing change detection analysis.

**EV Bus Routes Pre- and Post-Impact on Air Quality:** The methodology involved assessing pre- and post-implementation air quality conditions along the EV bus route in Lahore using satellite-based observations from Sentinel-5P (TROPOMI). Tropospheric column concentrations of key pollutants (CO, SO<sub>2</sub>, and NO<sub>2</sub>) were acquired for representative pre-launch (November 2018) and post-launch (November 2025) periods to minimize seasonal variability. The EV bus route alignment was overlaid on pollutant concentration maps using GIS techniques to examine spatial correspondence between the transport corridor and observed pollution patterns. Spatial interpolation and contour mapping were applied to highlight concentration gradients and hotspots along and around the route. A comparative pre-post analysis was then conducted to evaluate changes in pollutant intensity and spatial extent attributable to the introduction of electric buses, with emphasis on corridor-level impacts rather than citywide trends.

**Carbon Credit Reservation Scheme (CRS) Feasibility:** To assess the feasibility of the Punjab Green Credit Program (GCP), the survey data evaluates key aspects such as awareness and knowledge, participation, perceived effectiveness, barriers, and incentives. The term feasibility means whether the program is known, effective in perception, accessible, and appealing (e.g., via rewards like Green Credits as monetary benefits). See Table 3.

*Table 3: CRS Feasibility Indicators*

<b>Classifications</b>	<b>Relevant queries</b>
Public Awareness and Knowledge	Is the program reaching people?
Perceived Impact and Effectiveness	Do people see it working?
Barriers and Incentives	What hinders participation, and do credits motivate?
Demographic Variations	Does feasibility differ by age, income, gender, or education?
Overall Viability Metrics	Participation rates, willingness, and recommendations.

*Source: Authors' compilations.*

## FINDINGS AND DISCUSSION

### 4.1. Core Focus Areas in Policy Documents

The analysis identified six dominant common themes (**Table 4**) that consistently appeared across the reviewed policies. Foremost among these was environmental protection and pollution control, which emerged as the most consistent and central objective, underscoring the urgent need to reduce air pollution and improve environmental quality. Public health was another key priority, explicitly emphasized in several policies, including the *Punjab Clean Air Policy* and the *Clean Green Pakistan Initiative*, where air quality improvements were closely linked to health outcomes. Climate change adaptation and mitigation gained increased prominence in more recent policy documents, particularly those developed after 2018. These policies align with international commitments such as the Sustainable Development Goals (SDGs) and Pakistan's Nationally Determined Contributions (NDCs), reflecting a shift toward integrating air quality with broader climate resilience goals.

Additionally, sustainable development and economic growth emerged as important themes, with multiple policies promoting green jobs, clean industries, and eco-tourism as part of a transition to environmentally responsible economic planning. Institutional strengthening was also a recurring focus, particularly in strategic documents like the *National Clean Air Policy (NCAP)* and the *Smog Commission Report*, which emphasized legal reforms, enforcement mechanisms, and inter-agency coordination. Lastly, community engagement and behavior change strategies featured prominently in grassroots-oriented policies, especially the *Clean Green Pakistan Initiative*, which promoted awareness, education, and public participation as critical components for the success of environmental interventions.

Table 4: Common Themes in Current Policy Documentation

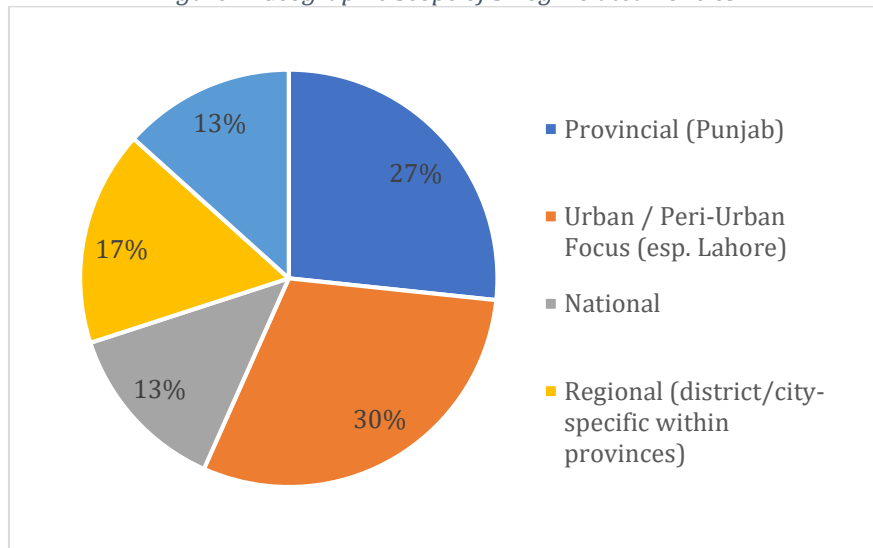
Theme	Key Policies
Environmental Protection	All (esp. NEP, EPA Act, Clean Air Action Plan, Smog Commission)
Public Health	Clean Air Policy, Smog Strategy, CGP, NEP, Smog Commission
Climate Change	Punjab Climate Plan, NCAP, Clean Air Policy, NEP, CGP
Sustainable/Green Economic Growth	NEP, EPA Act, CGP, Smog Commission, Clean Air Plan
Institutional Strengthening	NCAP, NEP, Clean Air Plan, Smog Commission
Community Engagement & Awareness	CGP, Smog Roadmap, NEP, Clean Air Plan

Source: Authors' compilations.

#### 4.1.1. Geographic Scope and Target Population

From a geographic perspective, the policies overwhelmingly focused on Punjab, especially urban centers like Lahore, which have been identified as a critical smog zone due to high population density and industrial activity (**Figure 8**).

Figure 8: Geographic Scope of Smog-Related Policies

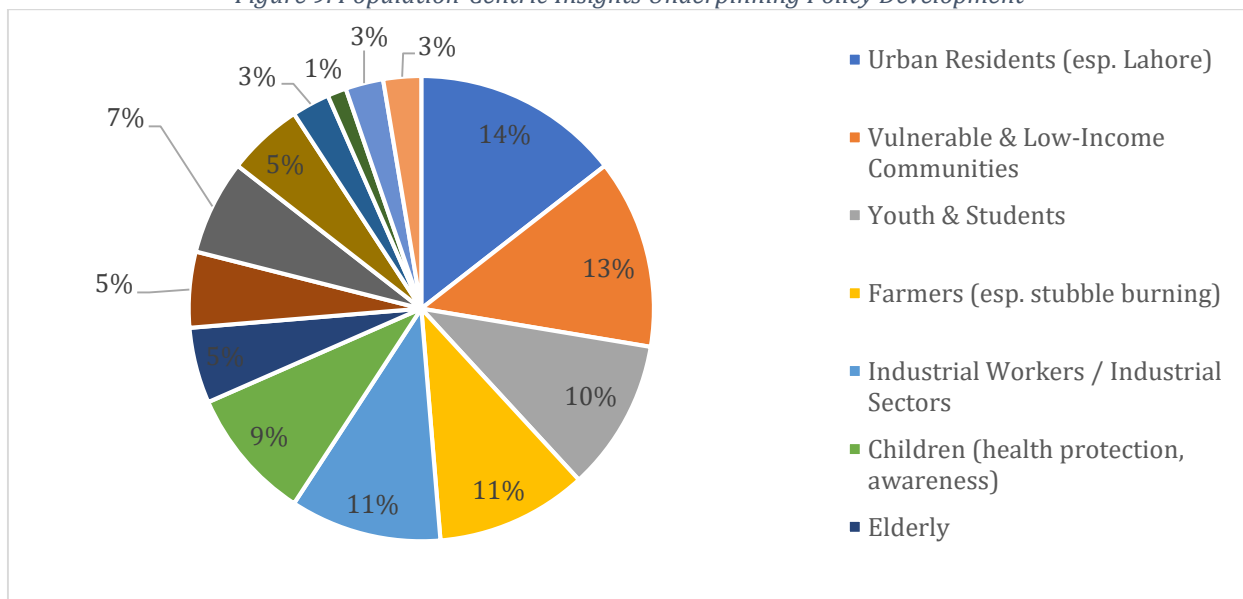


Source: Authors' compilations.

#### 4.1.2. Target Population

Target populations across these policies included urban dwellers, commuters, schoolchildren, farmers (particularly due to stubble burning), and industrial workers. Additionally, there was a growing recognition of gender-sensitive and inclusive planning, with increased references to youth, women, and vulnerable communities in post-2016 policy documents. **Figure 9** underscores that while smog impacts all social segments, effective policy must focus on transport, industry, and agriculture as priority intervention points.

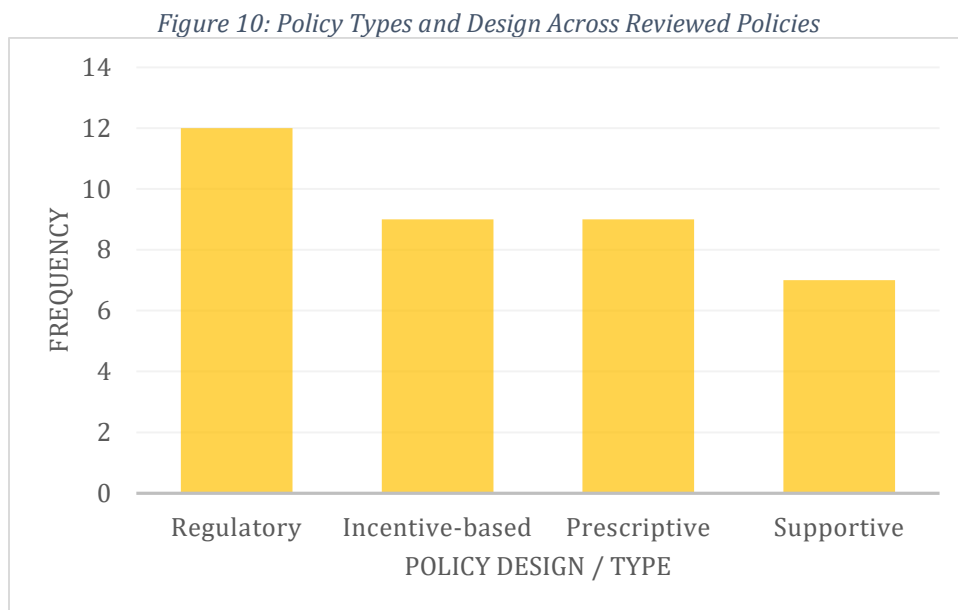
Figure 9. Population-Centric Insights Underpinning Policy Development



Source: Authors' compilations.

### 4.1.3. Policy Design and Type

The analysis of policy types and design revealed a strong reliance on regulatory mechanisms, which were present in all twelve reviewed policies. This indicates a predominant focus on enforcement-based approaches, where compliance with legal standards and environmental regulations forms the backbone of policy implementation. In addition to regulatory tools, incentive-based and prescriptive strategies were identified in nine policies, reflecting a hybrid approach that combines mandatory requirements with motivational measures aimed at encouraging voluntary compliance and proactive behavior. Furthermore, supportive mechanisms, including public awareness campaigns, educational initiatives, and financial assistance, were featured in seven policies (**Figure 10**). These elements suggest an effort to complement strict enforcement with tools that build public understanding, institutional capacity, and access to resources, thereby enhancing the overall effectiveness and acceptability of environmental interventions.

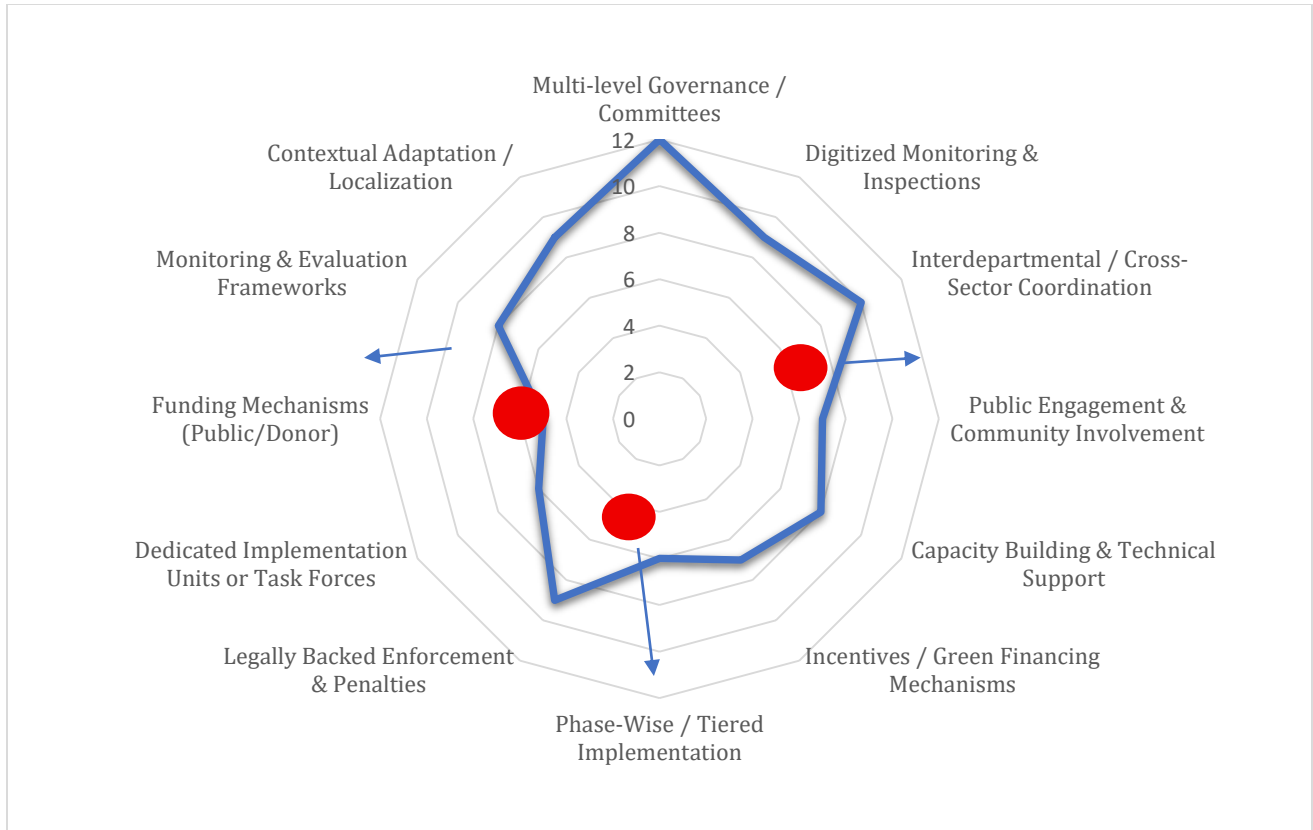


*Source: Authors' compilations.*

### 4.1.4. Implementation Strategies

- **Most Common Strategies** (noted in >8 policies): Use of environmental protection agencies, cross-sectoral coordination, and digitized monitoring systems.
- **Moderately Common Strategies** (5–8 policies): Capacity building, green financing, and M&E mechanisms were moderately integrated.
- **Less Common but Emerging:** Dedicated units (e.g., SMU), phase-wise implementation, and digital community engagement are signs of evolving practices. See **Figure 11**.

*Figure 11. Implementation Strategies Status*



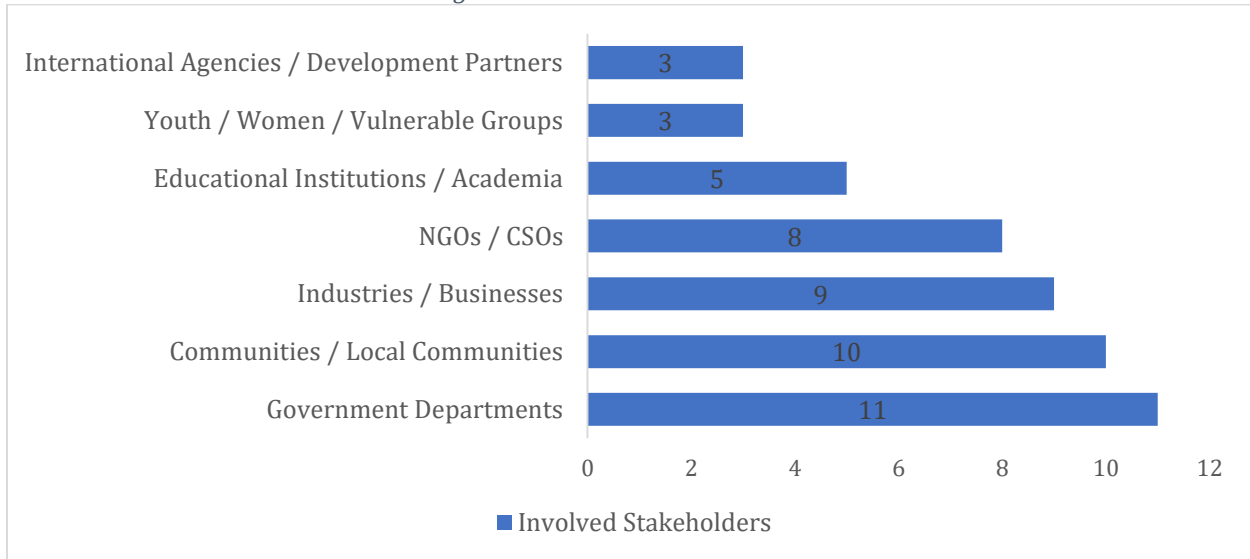
Source: Authors' compilations.

The findings reveal that Punjab's smog control measures are primarily based on command-and-control measures, including industrial inspections, emission caps, and bans on high-pollution practices. Economic measures, including targeted subsidies for cleaner agricultural machinery, electric vehicle instalment schemes, and initial proposals for an Emission Trading System, are emerging, but their scope is limited. Assuasive measures, which involve awareness campaigns and participatory tools, are underdeveloped, seasonal, and poorly integrated with enforcement and incentives. The absence of long-term environmental literacy programs and behavioral change initiatives hinders compliance with regulatory and market-based tools, thereby reducing the effectiveness of policy. The study concludes that Punjab's long-term smog reduction necessitates a balanced approach to policy, prioritizing continuous, well-funded assuasive measures alongside legal enforcement and economic instruments, to foster a lasting environmental responsibility culture and improve air quality outcomes.

#### 4.1.5. Stakeholders' Engagement

**Figure 12** illustrates the level of involvement or engagement of different stakeholder groups currently discussed in existing policies. While government bodies and local communities are highly engaged in addressing smog, there is comparatively lower involvement from vulnerable groups and international partners. This imbalance may highlight gaps in inclusivity and cross-border collaboration, which are critical for comprehensive and sustainable solutions.

Figure 12. Stakeholder Involvement



Source: Authors' compilations.

## 4.2. Awareness of Smog, Crop Residue Burning, and Alternatives among Farmers

### 4.2.1. Awareness Level of Farmers

Farmers were fully aware of smog situations, which appeared in the winter months. According to them, this phenomenon is harmful and harms their health, “like cancer”. They explained that crop residue is often burned because it is the cheapest, most convenient and fastest method, mostly opted for by large farm landlords. While small landowners save some residue for cattle. On the other hand, tractors with diesel costs, and labor are costly. In addition, sprays can help but cost PKR 3,500–4,000. Although the government claimed about provision of no one in their villages has received seeders or machinery. Farmers also shared that even cigarette butts along highways sometimes wipe out entire fields worth millions. Unknown sources of fire ignition on farms will not be effective for charging PKR 15000 per acre in case of stubble burning. As one of the farmers stated, “*We don’t set the fire ourselves, so if a fire breaks out, how is it our fault?*”. In this context, surveillance needs to be very effective and foremost not only on the highway but in all agricultural lands. They also revealed that small farmers usually save some residue for cattle and burn the rest, while large farmers burn everything.

Farmers agreed that that the residue forms thick clumps that are difficult to manage. According to them, stubble burning destroys soil fertility, hardens the land, and damages crops. Local practices by some farmers include, (a) use residue as cattle fodder, (b) watering residue so it decomposes into fertilizer, (c) mixes it back into the soil, which keeps land soft and fertile.

Farmers emphasized that the government and agriculture department rarely visit, have not provided guidance. Despite this fact, recent report smog strategy 2024-2025 claimed that approximately 40,000 training programs were launched, and 471,417 farmers are trained regarding smog. In case of creating awareness among farmers, the claims of mega gatherings, burjies (signboard), village mosques, literature distribution or drum beating found in effective till date. Words like “don’t know”, indicate lack of awareness of non-burning solutions. As one farmer stated that, “*We don’t know how*

else to manage residue.” The other stated that “I have only heard about machines but never seen them in my area.”

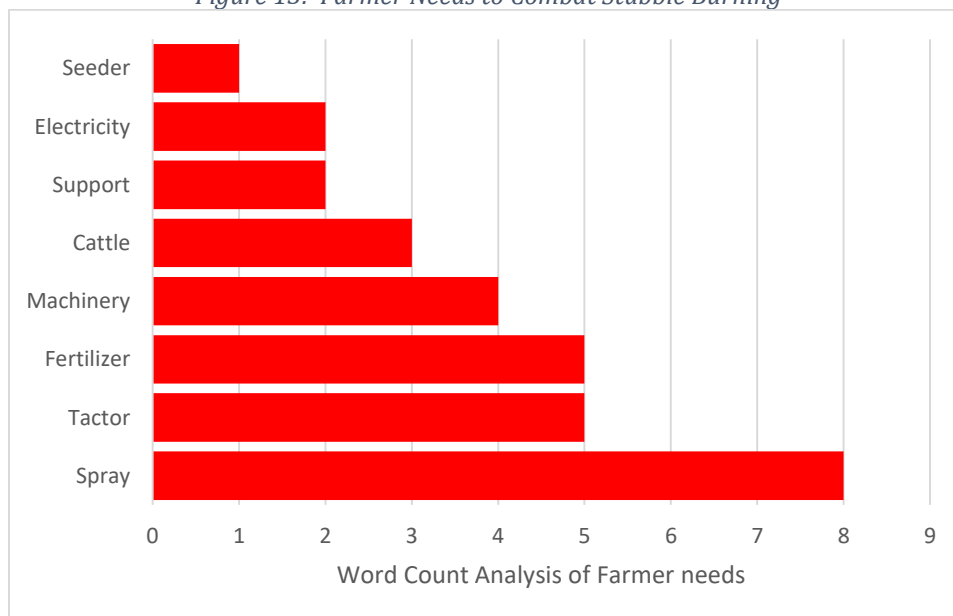
Referring to CM Smog Control Program that is launched in April 2024 with a vision to enhance Awareness, Facilitation and strict enforcement for farmers not to do stubble burning as stated by Iftikhar Ali Saho, Secretary Agriculture Punjab in an interview on a private news channel. Under the program, two programs were Announced including super seeder provisions (machinery for rice residue management) worth 5 billion project and Kisan card program that is interest free loan provision to small scale farmers. According to 1.28 million farmers registered and 0.35 million cards have been distributed in Punjab 2024. Furthermore, *Kisan* can obtain 30,000/- per acre for agricultural needs. It has also been shared that 80 percent of farmers who applied are owners of less than 5 acres and 70 percent of farmers who applied will be able to get loans for the first time from formal banking system. Awareness among farmers about the environmental and health impacts of burning was growing but not yet translating into widespread behavioral change, as alternatives were limited or costly.

The findings may indicate disparities in the distribution of incentives among small-scale and large-scale farmers. It may suggest that large-scale farmers are receiving greater benefits from government incentives.

Our results revealed that the small-scale farmers want support through reduced fertilizer and electricity prices, provision of affordable machinery or sprays, and direct outreach to guide farmers.

Some suggested keeping more cattle to consume residue, forming village committees, strict punishments for stubble burning, and growing greenery along roads to prevent fires spreading. Overall, farmers recognized that burning residue harms health and soil but reported they are helpless without affordable alternatives, government support, or effective enforcement **(Figure 13)**.

Figure 13: Farmer Needs to Combat Stubble Burning



Source: Authors' compilations.

Table 5. Development of Themes from Initial Codes in the Agricultural Sector

Main themes	Connecting themes/subthemes	Initial themes
Awareness about crop residue burning	Impacts of the crop residue burning	<ul style="list-style-type: none"> <li>• Air Pollution</li> <li>• Respiratory and skin diseases</li> <li>• Reduced soil fertility</li> <li>• Reduced cattle fodder</li> <li>• Make the soil hard, leading to difficulty in ploughing</li> </ul>
	Reasons for burning	<ul style="list-style-type: none"> <li>• Convenient solution</li> <li>• Community practice</li> <li>• Cheap</li> <li>• Negligence</li> <li>• Due to unknown reasons</li> </ul>
	Source of awareness	<ul style="list-style-type: none"> <li>• YouTube</li> <li>• TV</li> <li>• From other villagers</li> </ul>
	Government initiatives for smog mitigation	<ul style="list-style-type: none"> <li>• It's illegal to burn</li> <li>• Fine for burning the crop residue</li> <li>• Provision of technical support in terms of machines and expert suggestions for alternate solutions</li> </ul>
	Benefits of not burning the crop residue	<ul style="list-style-type: none"> <li>• Keep soil soft thus make it easy to plough</li> <li>• Environment cleanliness</li> </ul>
Current practices regarding crop residue removal	Legal	<ul style="list-style-type: none"> <li>• Increase fodder for cattle, thus can manage to raise more animals</li> <li>• Use of tractors for removing the crop residues</li> </ul>
	Illegal	<ul style="list-style-type: none"> <li>• Burning of the crop residue as its cheaper and convenient way</li> </ul>
Government initiatives	Awareness	<ul style="list-style-type: none"> <li>• Prohibit of burning as it causes smog and health issues for population across province of Punjab</li> <li>• Prescribed ways for safe removal of crop residues</li> </ul>
	Technical support	<ul style="list-style-type: none"> <li>• Provision of Super seeders in limited areas only</li> <li>• Lack of Expert advisory visits by Agriculture Department officials for technical help</li> </ul>
Enforcement and accountability	Government level	<ul style="list-style-type: none"> <li>• Lack of technical support from Agriculture Department officials.</li> <li>• no machinery provided</li> <li>• No fines or punishments were practiced till date</li> <li>• Police do not register FIR in case of reported burning of crops residues cases due to unidentified culprits.</li> <li>• nobody takes responsibility and is responsible for such incidents</li> </ul>
	Community level	<ul style="list-style-type: none"> <li>• negligence of individuals</li> <li>• carelessness of individuals burning residues cause burning of ready crops on large neighboring areas</li> </ul>

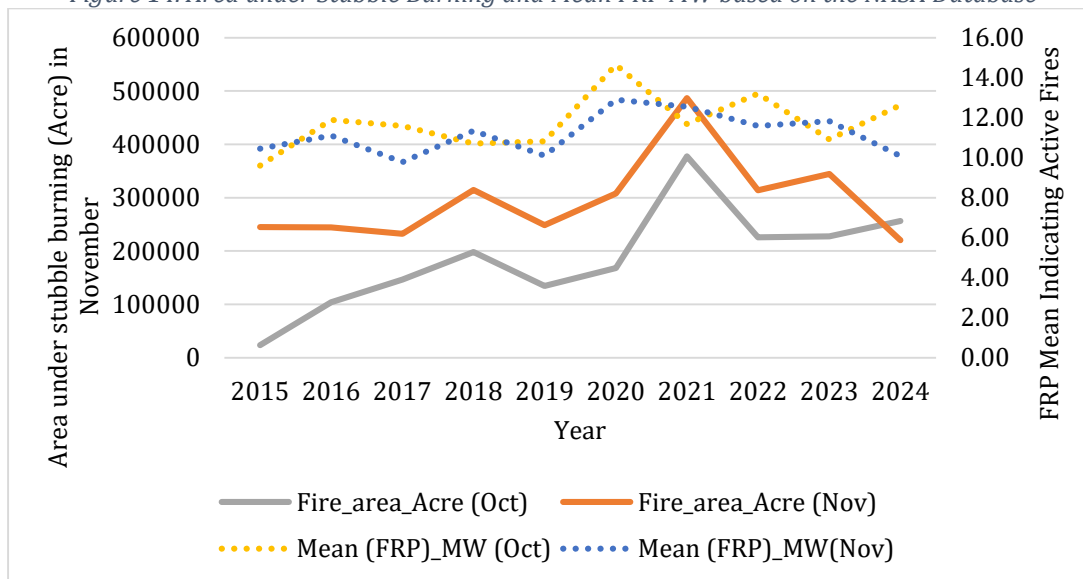
Source: Authors' compilations.

#### 4.2.2. Stubble Burning Trends

Stubble burning trends have also been evaluated from surveillance perspective based on remotely sensed data. Stubble burning occurs mainly in October and November after rice harvest. Farmers traditionally burn crop residue as the cheapest and most convenient method as validated in previous section to quickly clear fields for the next sowing season for wheat. This practice contributes significantly to regional smog not only in Pakistan but also in India. However, the primary concern of

this section is to assess the extent of agricultural land under active fires indicative of stubble burning in Punjab, Pakistan, after multiple initiatives implemented by the Government of Punjab including awareness, facilitation and enforcement compliance on stubble burning under CM smog control program. Despite these efforts, remotely sensed data from sources like NASA satellites indicate persistent active fires in month of October, indicating a persistent reliance on burning. Whereas a slight decrease in month of November after 2023 is seen due to enhanced enforcement and technology adoption. This mixed trend suggests some success in reducing stubble burning, while the increase in October 2024 may reflect challenges or shifts in burning patterns (**Figure 14**).

Figure 14. Area under Stubble Burning and Mean FRP MW based on the NASA Database



Source: Authors' compilations.

Stubble-free days over the period show no change in the month of October. While, notable exception of improvement can be seen in November 2024, suggesting some recent success in reducing burning activity (**Table 6**).

Table 6. Post Harvesting Season FRP based Stubble Burning Situation

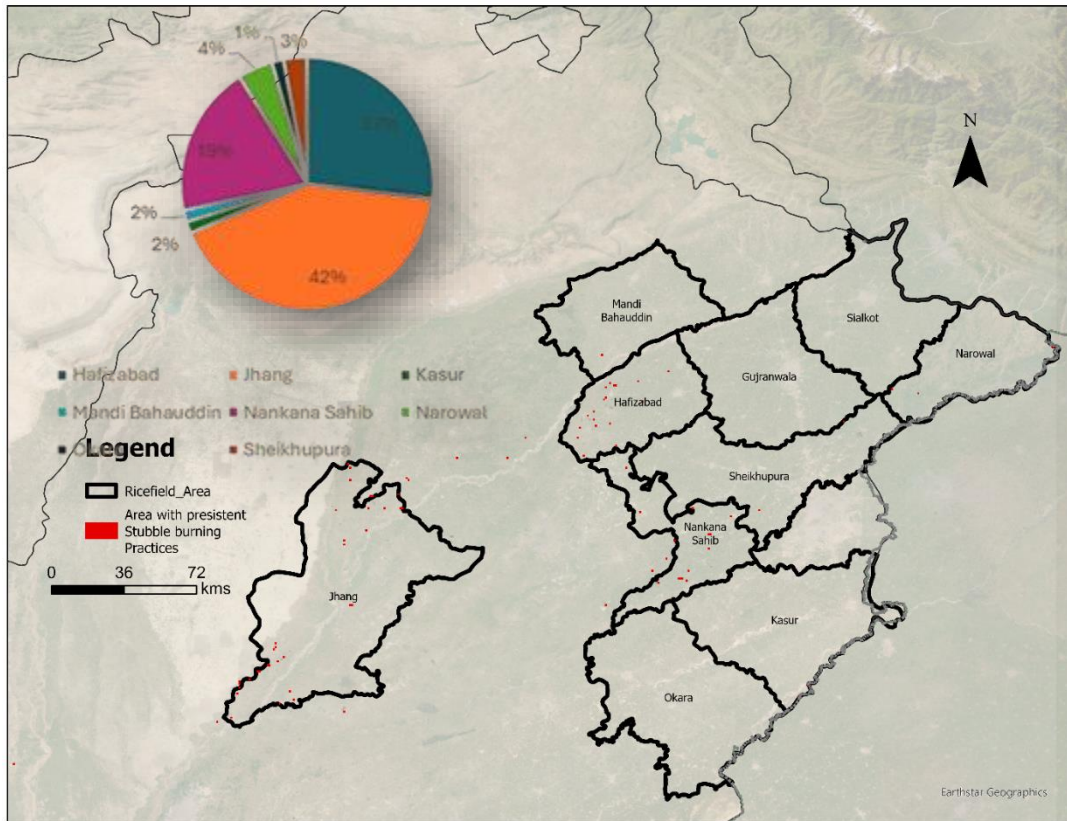
Year	Active Fire Area (Acre)	Mean (FRP) (MW)	No. days without stubble burning	Active Fire Area (Acre)	Mean FRP) (MW)	No. days without stubble burning
2015	23,215	9.60	20	245,128	10.45	2
2016	103,596	11.89	1	244,110	11.10	0
2017	146,212	11.59	0	232,236	9.78	3
2018	198,091	10.70	0	314,329	11.35	1
2019	134,301	10.81	3	248,262	10.10	3
2020	167,931	14.65	0	308,062	12.90	0
2021	377,302	11.68	0	486,723	12.55	0
2022	225,568	13.20	0	313,884	11.58	0
2023	227,472	10.92	0	344,745	11.82	2
2024	256,364	12.62	0	220,126	10.08	7

Source: Authors' compilations.

**Figure 15** illustrates the primary rice cultivation zones in Punjab province, Pakistan, with black outlines demarcating the rice field areas across various districts, including Jhang, Kasur, Okara, Sheikhpura, Nankana Sahib, Hafizabad, Gujranwala, Mandi Bahauddin, Sialkot, and Narowal. The red marks show persistent stubble burning practices at sites, identified through NASA's satellite. The results are based on change detection analysis of imagery from November 2023 and November 2024 to pinpoint areas with recurring active fires. Stubble burning, after rice harvest, remained unchanged in Jhang, followed by Hafizabad and Nankana Sahib.

Besides, the implementation of programs such as the Kisan Card in Punjab, Pakistan raises a critical question of the fungibility of financial support. Comparative evidence from neighbouring countries demonstrates that such programs intended for agricultural needs are often diverted to non-agricultural uses, including healthcare expenses, education of children, and even cultural practices such as dowry payments, etc. These practices could fade the program's original objective of promoting sustainable farming practices and reducing environmentally harmful behaviors such as stubble burning. In the case of Punjab's Kisan Card scheme, this introduces an enforcement and regulatory gap. Without regulatory mechanisms to track expenditure or conditionally link disbursements to verified agricultural uses, the program risks inefficiency in the coming years. In this scenario policy design must be carefully designed to distribute service vouchers redeemable only for approved agricultural needs.

*Figure 15 .Percentage of Ricefield Districts of Punjab Showing Persistent Stubble Burning Practices*



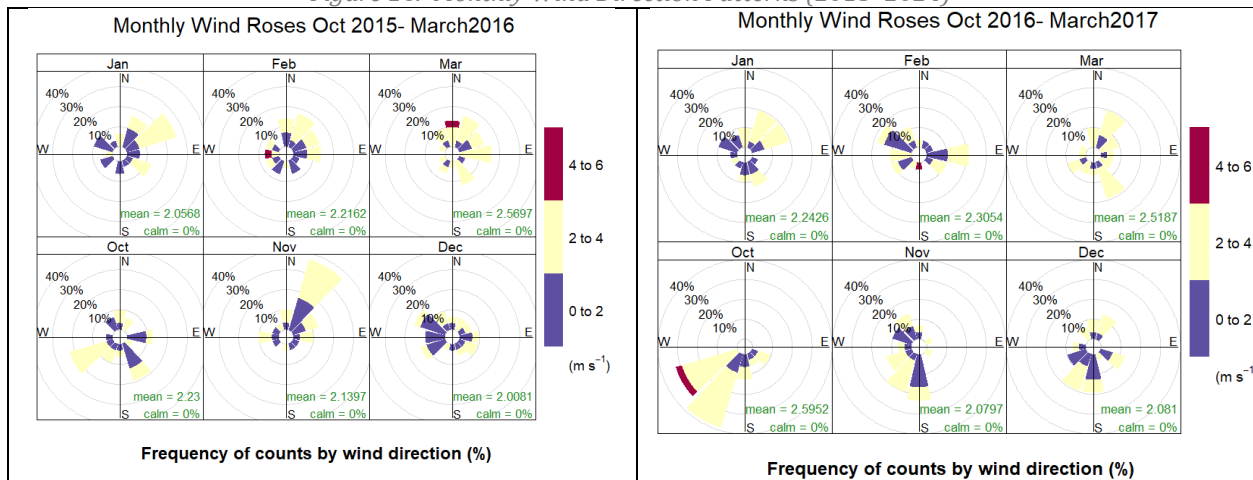
*Source: Authors' compilations.*

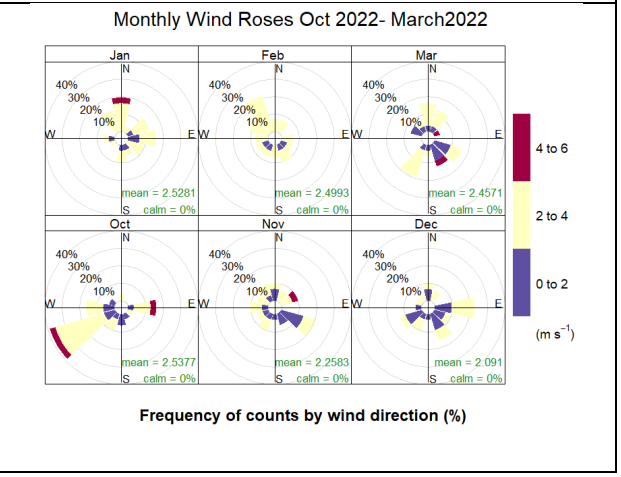
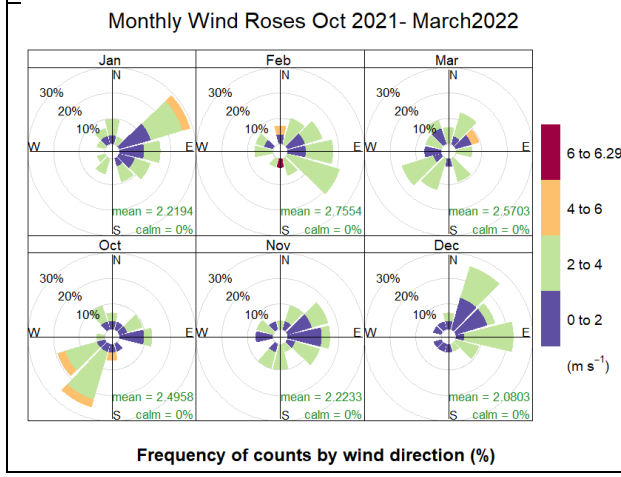
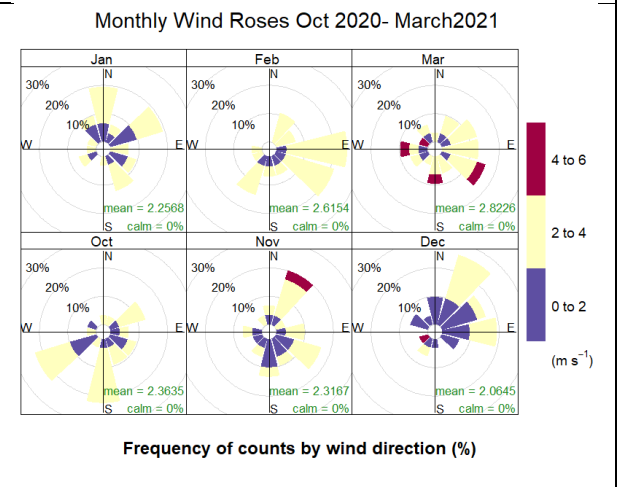
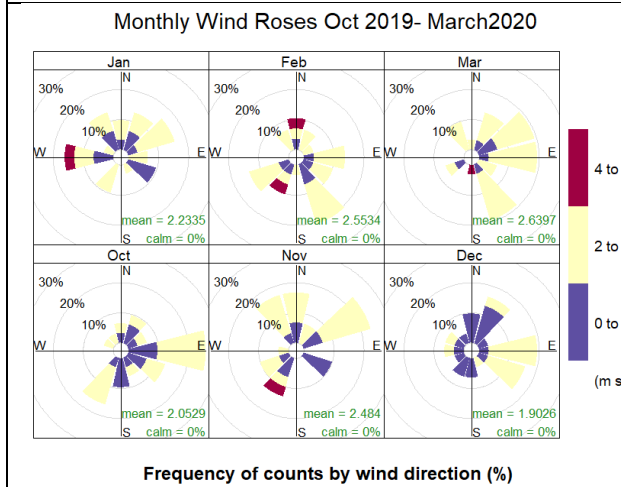
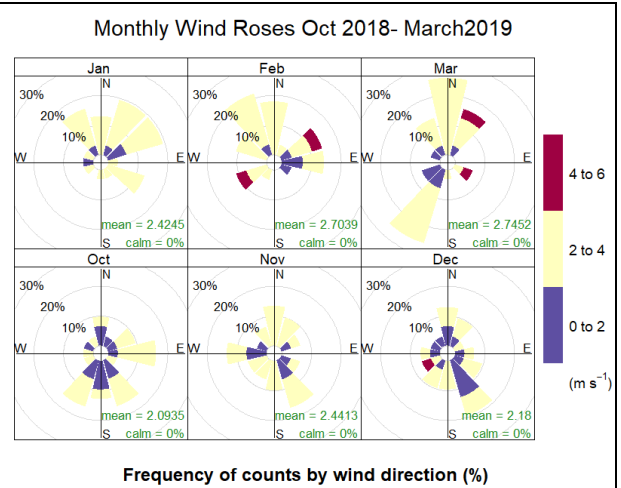
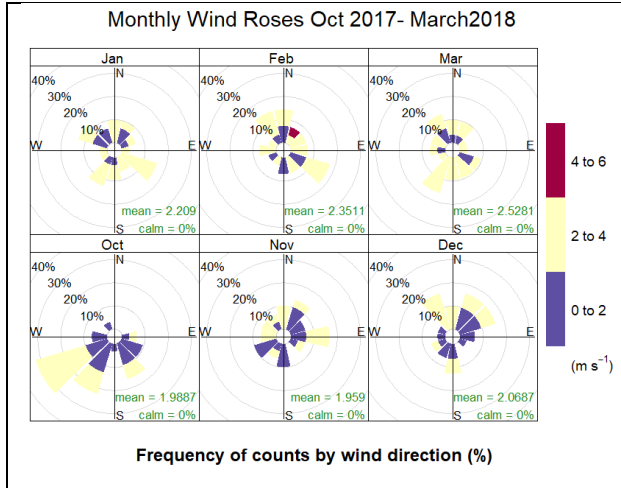
### 4.2.3. Wind Patterns and Transboundary Smog Effect of Stubble Burning

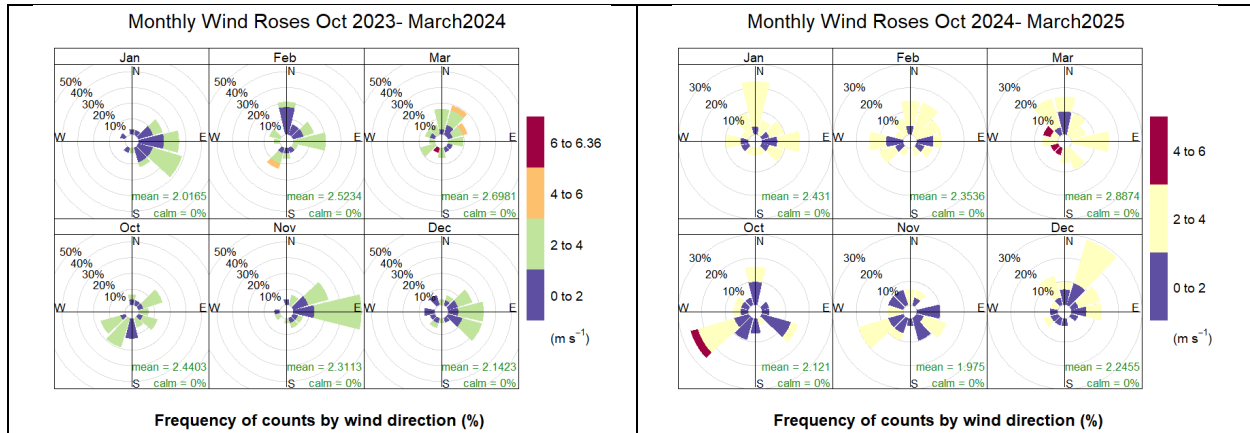
In central Punjab, particularly Lahore, Pakistan, the period from October to February marks a peak in smog intensity due to transboundary pollution as claimed by many sources. It has been reported that smoke and particulate matter from extensive crop stubble burning in neighboring Indian states like Punjab and Haryana across the border into Pakistan, contributing significantly to hazardous air quality levels.

The wind rose diagrams from 2015-2024 indicated that the predominant wind directions vary by month. This helps in assessing the potential for transboundary smog from India. In the month of October, winds are mostly from the west and southwest, suggesting minimal direct influence from India to the east. In November, winds shift toward the east and southeast which could allow some smoke from Indian Punjab or Haryana to drift into Pakistan. The wind patterns show strong easterly prevailing winds in December and onwards. The months of January and February maintain easterly and northeasterly winds, reinforcing the potential for Indian-sourced smog. By March, winds diversify but retain some easterly influence. In conclusion, stubble burning peaks in November and December, the easterly winds during these months are likely to contribute to transboundary smog, though temperature inversion, and local emissions also play significant role **(Figure 16)**.

Figure 16. Monthly Wind Direction Patterns (2015-2024)







Source: Authors' compilations.

### 4.3. Key Facts of Smog Control Measures & Planning in Transport Sector

The Urban Unit's claim that transport contributes approximately 83% of Lahore's smog. This fact is based on a sectoral emissions inventory that combines: (a) vehicle population data, (b) fuel consumption patterns, (c) emission factors, and (d) air quality modelling. Unlike other contributors mentioned, i.e. stubble burning or festival-related pollution with seasonal explanations, this approach captures continuous and year-round emission sources. Thus, it's concluded that transport emerged as the dominant contributor. Particularly, Lahore's land-use patterns, urban sprawl, citizen's behavior and limited mass-transit coverage have led to extreme dependence on private vehicles. Consequently, persistent traffic congestion, low average travel speeds, frequent stopping or stop-and-go conditions significantly increase emissions of PM<sub>2.5</sub>, NO<sub>x</sub>, CO, and VOCs, which are key precursors of smog.

Besides, Fugitive construction i.e. construction of elevated mass transit networks triggered the smog situation. This has been validated with data published through Excise and Transport Department. The facts show that Lahore has experienced a sharp rise in registered vehicles over the past few years. Registered vehicles increased from around 3.99 million in 2011 to well over 6 million by the mid-2020s, with motorcycles forming the bulk of this fleet.

Thus, critically reflecting on this, transport's dominance with 83 percent in Lahore's emissions is valid due to rapid urbanization, high vehicle density, and a modal mix heavily skewed toward private vehicles rather than cleaner mass transit. The qualitative conclusion that transport is the principal driver of Lahore's smog is supported both by emissions inventory findings and by sustained growth in vehicle registrations that elevate combustion emissions city-wide. For this purpose, current study proposed the following Individual Planning-Based Emissions Reduction Model (IPERM) that estimate emission reduction by analyzing the travel preferences.

#### 4.3.1. Individual Planning-based Emissions Reduction Model (IPERM)

Based on the statistical findings, the sample exhibited substantial potential for emission reduction through behavioral change. Of the 385 respondents, a majority (55.8%) reported plans to reduce emissions by shifting travel modes, with an average daily travel distance of 14.6 km (SD = 8.2), indicating moderate commuting intensity. Distance-stratified analysis revealed that the greatest

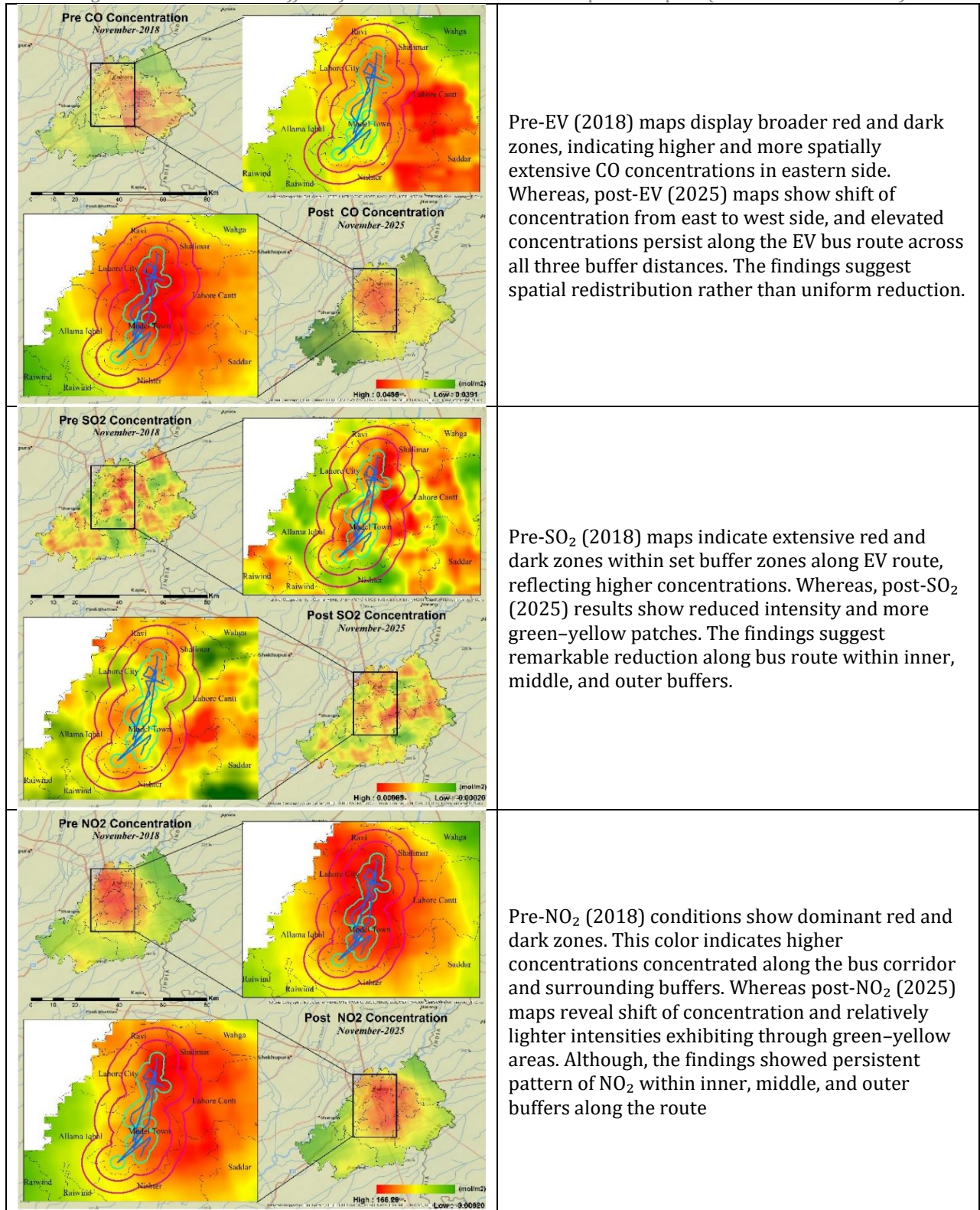
relative emission reductions were observed among respondents traveling 10–20 km daily, where projected emissions declined by 46.6%. In contrast, shorter-distance travel (<5 km) showed only marginal reductions (3.7%), suggesting limited scope for emission savings in already low-emission trips. Overall, average per-person emissions decreased from 34.98 kg CO<sub>2</sub>/day to 21.58 kg CO<sub>2</sub>/day, reflecting an aggregate reduction potential of 38.3%. Notably, over half of the respondents belonged to a critical population segment capable of achieving emission reductions exceeding 20%, translating to an estimated 3.91 million vehicles at scale.

Motivational and behavioral factors further contextualize these emission outcomes. Reduced public transport fares (68%) and fuel or maintenance discounts (62%) emerged as the most influential incentives for encouraging modal shift, while infrastructural and economic barriers, particularly inadequate public transport availability (71%) and the high cost of low-emission vehicles (59%)—significantly constrained adoption. Mode-choice decisions were primarily driven by practical considerations such as time efficiency (82%), cost (79%), and convenience (74%), with environmental impact ranking lowest (22%), underscoring a pragmatic rather than environmentally motivated travel behavior. This interpretation is statistically reinforced by chi-square results, which confirmed a strong association between cost sensitivity and willingness to switch modes ( $\chi^2(1)=14.2$ ,  $p<0.001$ ), highlighting the central role of economic incentives in shaping sustainable transport choices.

#### ***4.3.2. Pre and Post Air Pollutant Impact of Selected EV Route***

Table showed comparative assessment of the three pollutants CO, SO<sub>2</sub> and NO<sub>2</sub>. Figure 17 indicates distinct responses to the introduction of the EV bus system. Carbon monoxide (CO), primarily emitted from vehicular combustion, shows an overall weaker spatial response with an insignificant reduction after EV bus deployment, suggesting that residual traffic, mixed vehicle fleets, or background urban emissions continue to influence its concentration levels. In contrast, sulphur dioxide (SO<sub>2</sub>), mainly associated with fuel sulfur content and industrial activities, exhibits a significant reduction with a very clear spatial effect along the EV bus corridor, indicating that replacing conventional diesel buses has effectively reduced localized sulfur-related emissions. Nitrogen dioxide (NO<sub>2</sub>), a major pollutant originating from both vehicles and industrial sources, demonstrates a moderate reduction following the EV bus introduction, with spatial improvements present but weaker than those observed for SO<sub>2</sub>. Overall, the comparative behavior highlights that the air-quality benefits of EV buses vary by pollutant type, with the strongest localized impact observed for SO<sub>2</sub>, followed by NO<sub>2</sub>, while CO shows the least sensitivity to the intervention.

Figure 17. Pre and Post Effect of EV Buses on Air Pollutants Spatial Impact (Nov 2018 & Nov 2025)



Pre-EV (2018) maps display broader red and dark zones, indicating higher and more spatially extensive CO concentrations in eastern side. Whereas, post-EV (2025) maps show shift of concentration from east to west side, and elevated concentrations persist along the EV bus route across all three buffer distances. The findings suggest spatial redistribution rather than uniform reduction.

Pre-SO<sub>2</sub> (2018) maps indicate extensive red and dark zones within set buffer zones along EV route, reflecting higher concentrations. Whereas, post-SO<sub>2</sub> (2025) results show reduced intensity and more green-yellow patches. The findings suggest remarkable reduction along bus route within inner, middle, and outer buffers.

Pre-NO<sub>2</sub> (2018) conditions show dominant red and dark zones. This color indicates higher concentrations concentrated along the bus corridor and surrounding buffers. Whereas post-NO<sub>2</sub> (2025) maps reveal shift of concentration and relatively lighter intensities exhibiting through green-yellow areas. Although, the findings showed persistent pattern of NO<sub>2</sub> within inner, middle, and outer buffers along the route

Source: Authors' compilations.

Table 7. Comparative Assessment of the Three Pollutants CO, SO<sub>2</sub> and NO<sub>2</sub>

Aspect	CO	SO <sub>2</sub>	NO <sub>2</sub>
Main source	Vehicular emissions	Fuel sulfur + industry	Major pollutants from vehicles and industry
Response to EV buses	Insignificant reduction	Significant reduction	Moderate reduction
Spatial effect	Weaker	Very clear	Present but weaker

Source: Authors' compilations.

#### 4.4. Key Facts of Smog Control Measures & Planning in Industrial Sector

Modern emission control technologies are being adopted by industries to curb smoke and pollution. To manage hazardous particulates, high-energy consuming industries, such as drinks, manufacturing, and steel smelting, have been installing electrostatic precipitators, advanced monitoring systems, chimney-suction and filtration, wet and dry scrubbers, and air-lock technologies that trap the hazardous particulates, turn them into ash and emit clean air. In the lubricant industry, chimneys with heights of 80 feet with carbon traps known as Chhatri system are used to guarantee safe runaway smoke. Manufacturing industries of plastic products have already installed exhausts that are operated by operators during the times of fumigation.

The brick kiln industry has made a great accomplishment under shifting its fuel usage, tires and wood to the use of the zigzag kiln type, which interviews have indicated that workers and owners report a reduced smoke emission that is notable. Kilns are seasonally closed down when smog is high (November-December), whereby owners give their employees some financial help and minimal medical aid.

Many industries are moving to the use of cleaner energy. Historically, primarily the industries within the clothing/footwear and the lubricant industries have incorporated solar power into their production to reduce reliance on the traditional electricity. In-plant tree-plantation and green-cover programs are used to moderate climate of the environment and to capture CO<sub>2</sub>. The enhancement of energy efficiency and the reduction of waste are also done using process refinements including the deployment of Six Sigma practices.

Provisions in worker protection are highly highlighted in order to reduce health risks of smog. There is a mandatory use of masks during changes in shifts of operations with the support of annual full-body check-ups, healthcare visits, pharmaceutical supplies, first-aid kits, and in-house labs in such industries like clothing/footwear and steel. The training is focused on waste minimization, waste management and environmental awareness of the employees, which is often achieved by attending seminars at the national and global level.

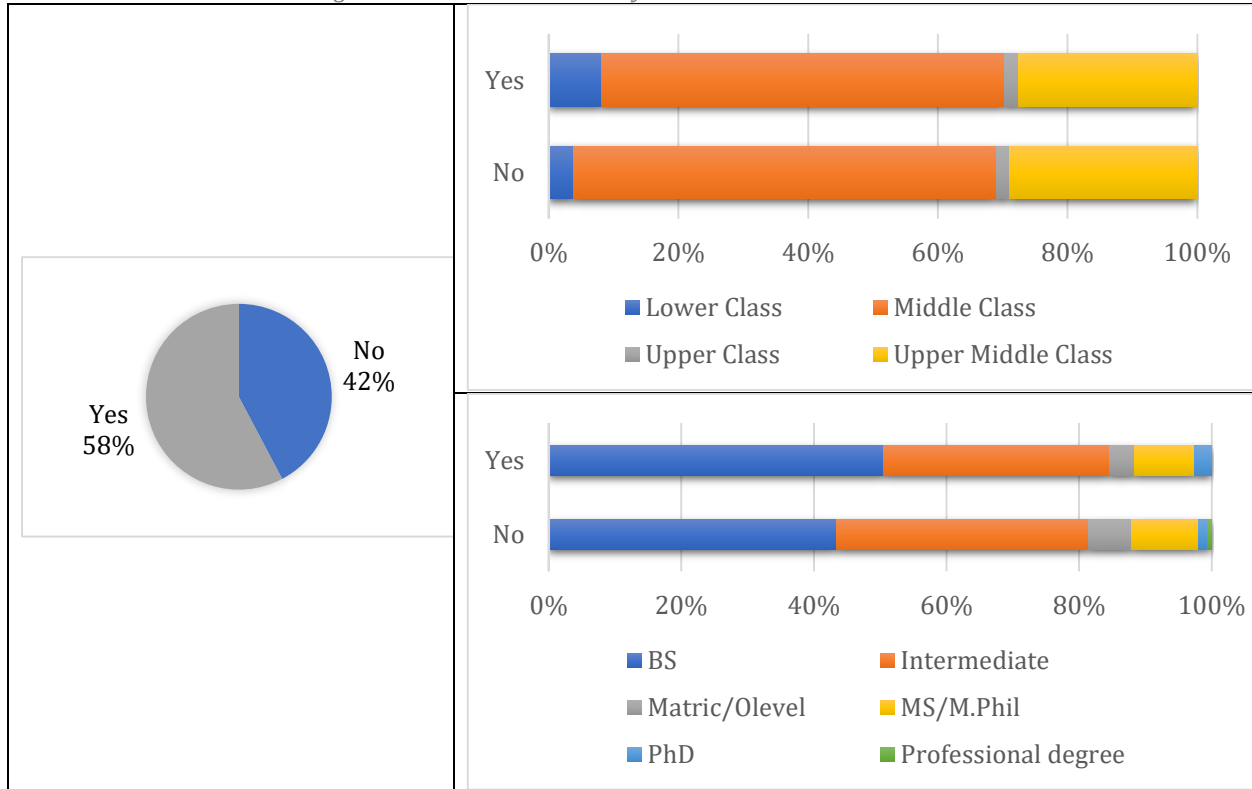
Regulatory compliance in industries occurs by the observed standards of national quality standards (NQS) and Punjab environmental regulations, collaborations with the Environmental Protection Agency (EPA) and external environmental consultants. Stricter emission-monitoring measures such as quarterly testing have been put forward. Interviewees across sectors stress that the collective responsibility is emphasized by stakeholders in different sectors, calling on the industry, government, individuals, and welfare organizations to collaborate. They constantly recall the need to

increase the government assistance, which includes subsidies, leasing schemes of small smoke-control equipment, technical expert tours, and training programs, so that more far-reaching and more effective smog reduction is achieved.

#### 4.5. CRS Feasibility from Citizen’s Perspective

##### 4.5.1. Awareness Level of Citizens

Figure 18. Awareness Level by Education and Social Class



Source: Authors’ compilations.

##### 4.5.2. Top Channels for Scaling Communication in Citizens Point of View

The findings indicate that social media was the primary discovery channel, cited most frequently by respondents, either alone or in combination with other sources. TV/News served as the leading mass-media entry point, especially when paired with social media, helping establish awareness and credibility. Schools and colleges were major institutional touch points, particularly for students and young adults, enabling structured exposure to the program. Friends and family played a supportive but important role, reinforcing awareness through trusted interpersonal networks. Additionally, Anti-Smog Champions and Government Officials contributed as credibility-driven sources, enhancing trust and validation, while community events functioned as localized discovery points with high engagement but limited reach. Overall, awareness of the program was driven by a multi-channel discovery pathway, led by digital platforms and reinforced by mass media, educational institutions, and trusted messengers.

### 4.5.3. Knowledge Accuracy of Citizens

Overall, responses show a clear consensus that reducing smog requires a combination of preventive and corrective actions, with tree plantation emerging as the most widely recognized and trusted solution. Respondents strongly associate smog reduction with controlling smoke-emitting vehicles, including vehicle emission testing, promoting public and electric transport, and discouraging excessive personal vehicle use. Regulation of brick kilns and industrial emissions and stopping open burning of municipal and agricultural waste are also repeatedly highlighted as critical measures. While anti-smog guns, artificial rain, and water spraying are frequently mentioned, many respondents view them as supportive or short-term measures rather than permanent solutions. Overall, public perception favors long-term, sustainable actions, cleaner transport, strict enforcement, and behavior change over temporary technological fixes. (See Table 8)

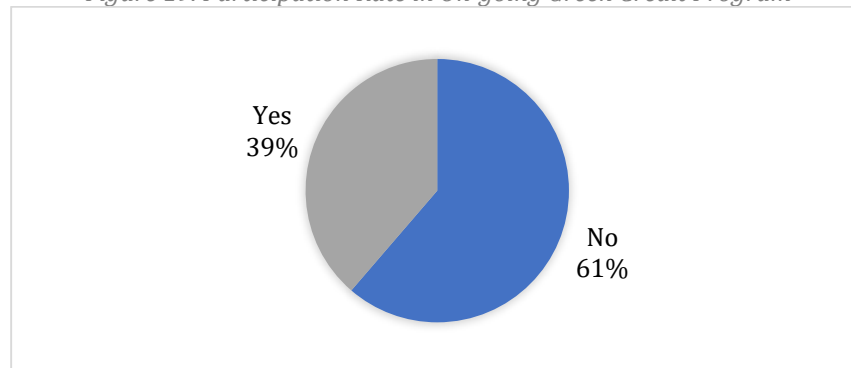
Table 8. key Insights of Knowledge Accuracy among Citizens

Category of SMOG Control Measure	Frequency (n) of terms used by citizens	Percentage (%)	Key Insight
Tree Plantation & Urban Greening	465	77.5%	Most widely recognized intervention; awareness largely symbolic
Vehicular Emission Control (smoke testing, checks)	382	63.7%	Strong recognition of transport as major pollution source
Electric Vehicles & Clean Transport	298	49.7%	Moderate awareness: feasibility constraints rarely mentioned
Municipal Waste / Open Burning Control	241	40.2%	Framed mainly as individual responsibility
Industrial Pollution & Brick Kilns	168	28.0%	Limited recognition beyond brick kilns
Anti-Smog Guns / Artificial Measures	214	35.7%	High recall but low perceived effectiveness
Awareness Campaigns / Anti-Smog Champions	119	19.8%	Weak visibility of public engagement initiatives
Rainwater Harvesting / Road Spraying	97	16.2%	Poorly understood and often confused
No Awareness / "Don't Know" Responses	143	23.8%	Indicates communication and outreach gap

Source: Authors' compilations.

### 4.5.4. Participation Rate in On-going Green Credit Program by Gender and Social Class

Figure 19. Participation Rate in On-going Green Credit Program



Source: Authors' compilations.

Participation in program-related activities was moderate, with 39 percent respondents reporting "Yes" compared to 61 percent reporting "No." This corresponds to an overall participation rate of

approximately 39%, which is well above the low-feasibility threshold of 20%. While most respondents have not yet participated, the results indicate a substantial base of active engagement, suggesting that participation is feasible but has clear room for improvement through increased outreach, accessibility, and motivation strategies as shown in **Figure 19**.

*Table 9. Participation in the Green Credit Program by gender and social class*

Social Classes	Participation					
	Yes		No		Maybe	
	Female	Male	Female	Male	Female	Male
Lower Class	9	13	2	3	10	6
Middle Class	149	106	11	17	102	50
Upper Class	2	2	4	0	6	1
Upper Middle Class	80	32	13	9	43	16
Grand Total	240	153	30	29	161	73

*Source: Authors' compilations.*

The data indicates that both gender and income (social class) appear to participate in a green credits system introduced by Govt of Punjab. Overall, affirmative responses (“Yes”) are substantially higher than “No” across all social classes, suggesting broad support for the initiative. Women consistently show greater willingness to participate than men in every income category, most notably within the middle class (149 females vs. 106 males) and upper middle class (80 females vs. 32 males), indicating a stronger pro-environmental inclination among female respondents (**See Table 9**).

Likewise, income also plays a significant role as participation increases markedly from the lower class to the middle and upper middle classes, implying that greater economic security may enhance readiness to engage in this program, possibly due to better awareness, resources, or perceived benefits. Lower-class respondents exhibit more uncertainty, as reflected in relatively higher “Maybe” responses, suggesting informational or financial barriers. Upper-class responses are few but still show a generally positive inclination. Taken together, the findings suggest that this program is more strongly favored by women and by respondents from middle and upper middle-income groups, while targeted awareness and support may be necessary to increase participation among men and lower-income groups while **Table 10** shows future willingness to participate in credit-based mechanism to combat smog.

*Table 10. Future Willingness to Participate in Credit Mechanism*

Willingness to Participate for Credit	Count
May be	234
No	59
Yes	393

*Source: Authors' compilations.*

#### **4.5.5. Variation in Perceived Air Quality Improvement**

**Table 11** showed that perceived effectiveness was skewed toward the higher end of the scale, with most responses clustering in the “moderately effective” to “very effective” categories (ratings 3–5), while relatively fewer respondents selected low effectiveness ratings (1–2), indicating broad confidence in the measures’ impact on air quality. Among the five measures, identifying and

controlling brick kilns and stopping open waste burning were most frequently rated as highly effective (ratings 4–5), followed closely by checking smoke-emitting vehicles, while promoting e-cars/e-rickshaws and the Anti-Smog Champions campaign showed relatively more mixed or moderate effectiveness ratings. Overall, the data suggest that respondents who assigned higher effectiveness ratings (4–5) generally reported greater perceived improvements in air quality, indicating a positive association between high ratings and perceived impact. Although some uncertainty (“don’t know”) remains, the pattern indicates that higher rates are more likely to perceive tangible air quality improvements.

*Table 11. Variation in Perceived Air Quality Improvement*

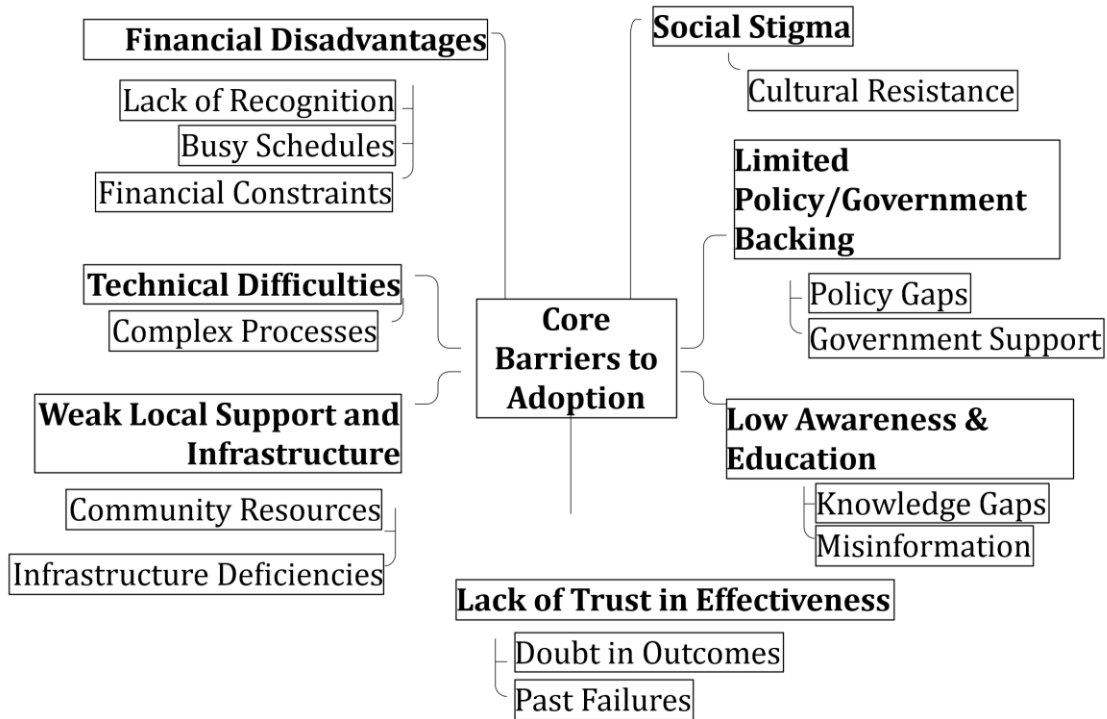
<b>Perceived Air Quality Improvement</b>	<b>Count</b>
No change	235
Worse	67
Yes, significant	73
Yes, slight	308

*Source: Authors' compilations.*

#### **4.5.6. Barriers to Launch CRS Alike Mechanism**

The findings reveal multiple, interrelated barriers to the adoption of a green credit system. Lack of awareness emerges as the most dominant challenge, often compounded by limited understanding and misinformation, leading to low trust in the system’s effectiveness. Economic factors, particularly the absence of clear incentives, significantly reduce motivation to participate. Additionally, time constraints and perceptions of complexity discourage engagement, especially among working populations. Structural issues such as inadequate local support and weak institutional presence further hinder implementation. Together, these barriers suggest that successful introduction of a green credit system requires simplified design, targeted awareness campaigns, incentive mechanisms, and strong community-level support **(Figure 20)**.

Figure 20. Core Barriers to Adoption



Source: Authors' compilations.

#### 4.5.7. CRS Feasibility Scoring

The composite feasibility scores for launching the CRS system show a mixed but cautiously promising outlook as shown in **Table 12**. A substantial share of observations falls above the 0.6 threshold, indicating that the system is largely feasible with minor challenges, with many scores clustering at 0.67, 0.83, and 1.00, reflecting strong institutional, technical, or stakeholder readiness in several cases. However, a non-trivial proportion of scores lie below 0.4 (including 0.33, 0.17, and 0.00), signaling major barriers such as low awareness, implementation capacity constraints, or governance challenges. Overall, while feasibility is achievable in many contexts, targeted interventions are required to address structural weaknesses before full-scale rollout.

Table 12. CRS Feasibility Scoring

FEASIBILITY SCORE	CATEGORY	INTERPRETATION FOR CRS LAUNCH
< 0.40	Major Barriers	Significant institutional, financial, or awareness-related challenges; CRS launch not advisable without major reforms
0.40 - 0.60	Moderate / Borderline Feasibility	Partial readiness: CRS could proceed only with targeted interventions and capacity building
> 0.60	Feasible with Tweaks	High readiness: CRS implementation is viable with minor operational or policy adjustments

Source: Authors' compilations.

#### ***4.5.8. Public Outreach Program***

Under Objective 4, four targeted seminars and two outreach short programs were organized to raise public and social awareness about air pollution and smog. These programs were designed to engage diverse audiences, including scientists, school and university students, policymakers, and the public, by using interdisciplinary approaches and culturally relevant communication.

The first seminar focused on scientific and engineering solutions to smog mitigation, emphasizing indigenous technologies and material innovations.

The second seminar highlighted the invisible psychological and mental health burdens of air pollution, expanding the narrative beyond physical health.

The third seminar, conducted in Punjabi, enabled effective public outreach by addressing smog through medical science, agriculture, civil engagement, and the arts. These seminars successfully communicated both the severity of the issue and actionable solutions, fostering informed discussion, awareness, and a sense of collective responsibility.

The fourth seminar highlighted key environmental challenges, especially smog, as part of an interdisciplinary research initiative promoting awareness and sustainability. It featured prominent media professionals and academics, including Senior Journalist and Columnist Wasif Nagi, Senior Investigative Journalist at PTV Dr. Huma Sadaf, and Dr. Naveed Iqbal, Assistant Professor in the Department of Mass Communication at LCWU. Chairperson Dr. Zaeem Yaseen emphasized the media's role in shaping public understanding, while Chief Guest Senator Bushra Anjum Butt stressed the need for collective climate action. Moreover, two social programs were also arranged with school and university students to sensitize the smog alert among future youth.

## CONCLUSION

The evaluation of smog mitigation policies and initiative of Government of Punjab Pakistan reveals minor gaps in implementation despite several policy and initiative frameworks. Desk reviews of provincial policies, such as the Punjab Clean Air Policy and Smog Control Strategy 2024–2025, highlight dominant themes including environmental protection, public health, and climate adaptation, with a geographic focus on urban centers like Lahore. This underscores inclusive and cross-border collaboration deficits.

Most of the policies are based on command-and-control manners, and few are climate finance or economic-based. While soft behavior program remained inactive before December 2024. KPIs of policies have also been set recently after 2023 prior to this no KPIs were set and targets were missing. Keeping all target sectors being the major culprits, Transport sector found most matured in terms of policy implementation, keeping Punjab air clean policy 2019 as base reference document.

The Urban Unit's claim is both logically constructed and empirically validated, reflecting a sound understanding of Lahore's emissions. In this context, the consistent identification of transport as the dominant smog source indicates that provincial transport-related policies are progressively improving in their focus and direction. For example, induction of electric vehicles was a significant step of government. It is scientifically proved that there is moderate SO<sub>2</sub> and NO<sub>2</sub> reductions along routes, but CO levels persist due to mixed fleets and background emissions with the help of pre-and post-EV bus deployment analysis (2018 vs. 2025). However, Electric automotives and energy department coordination for making this mean sustainable found missing. Furthermore, fuel quality assurance remained the biggest challenge and reported missing by stakeholders. In transport sector, carbon credit-based programs such as provision of monetary or non-monetary benefits have potential for emission reduction through behavioral shifts where travelers can be convinced to use public transport. Survey respondents of current study reveal 55% willingness to adopt cleaner modes, projecting up to 38% emission cuts if affordable, and convenient alternatives are provided. Therefore, policy makers must keep practical factors like time and cost in mind that outweigh environmental concerns in travel mode choices.

While numerous agricultural initiatives have been reported in official documents to combat smog by addressing stubble burning. But such initiatives were usually taken for large-scale farmers and small-scale farmers remained ignored. For instance, farmers exhibit high awareness of smog's health impacts. One farmer reported it as atmospheric cancer but continued stubble burning due to cost barriers and inaccessible alternatives like Happy Seeders. Besides, remote sensed data from NASA shows persistent burning in October-November after wheat harvesting period, with minimal reduction in active fire areas despite initiatives like the CM Smog Control Program. Wind pattern analysis (2015–2024) indicates slight transboundary influence from India in late December via easterly winds as mentioned in report in section 4.2.3, but local urban land-use changes and emissions drive 83% of local smog as reported by Urban Unit. Thus, it is challenging narratives blaming external factors like Diwali and stubble burning in neighboring countries. Furthermore, implementation of kissan card seems challenging to ensure that loans have been utilized for the

agricultural needs only rather any domestic/other non-agricultural purpose. This monitoring mechanism is not clearly defined for kisan card implementation.

In context of industry as another major contributor, reduced emissions by adoption of technologies e.g., zigzag kilns. Furthermore, seasonal closures/green lockdowns also help to tackle the smog situation. It is noteworthy to mention that brick kilns only contribute 15% of emissions. Thus, enforcement remains limited beyond kilns, neglecting broader high-emission industries.

For the Carbon Credit-based Reservation System (CRS), feasibility is moderate: 39% participation in the Green Credit Program, with higher rates among women and middle-class respondents. Barriers include low awareness (24% "don't know"), economic disincentives, and complexity. Knowledge accuracy is strong on preventive measures like tree planting (78%) but weak on temporary fixes. For example, citizens are well-informed about building a greener future but less equipped to handle the present smog crisis safely.

In conclusion, it is observed that despite the wide range of policies and programs, their overall impact is limited by weak enforcement mechanisms, weak interdepartmental coordination, and absence of incentive programs based on smallholder farmers and low-income beneficiaries. Empirical research indicates that the smog in Lahore can be mostly attributed to proximal factors related to accelerated urbanization, vehicular emissions, industrial development, and energy use; transboundary pollution plays a secondary, although compounding role. Under these circumstances, the Green Credit Program proves the breath of fresh air, as it would help decrease emissions by up to 38%, if there are credible alternatives which would be cheaper, more reliable and convenient to use, and offered to citizens. Enhancing institutional coordination, matching normative enforcement with incentive-based mechanisms, and putting citizen-centered solutions in the first place are likely to significantly increase policy effectiveness. Thus, these actions provide Pakistan with a viable chance of leaving the reactive smog control to the long-lasting enhancement in the air quality, thus alleviating the long-term health and economic costs in Lahore and similar urban areas with similar geographic and environmental factors.

## REFERENCES

- Abbasi, M., & Mukhtar, A. (2023). Analyzing the current state of coal consumption and combustion in Pakistan, including trends, patterns, and major sources of coal emissions. *Qlantic Journal of Social Sciences and Humanities*, 4(2), 6-20.
- Ahmad, R., Li, F., Hussain, I., & Hayat, A. (2025). Assessing the impact of public perception and willingness-to-pay on reducing smog in Pakistan: Evidence from Lahore City. *Heliyon*, 11(1).
- Arif, M. M., Bakar, M. A., & Ahmad, S. R. (2023). Impacts of air pollution on human health in Lahore city, Pakistan: A review. *Global Research Journal of Natural Science and Technology*, 1(2).
- Avis, R., & Richards, P. (2024). *Place-based solutions and air quality in the global South*. K4DD Rapid Evidence Review 177. Brighton, UK: Institute of Development Studies.
- Ayub, M., Mahmood, S., & Sarwar, M. (2024). Analyzing the contribution of transportation in formation of smog in district Lahore, Pakistan. *Int. J. of Inn. in Sci. & Tech*, 628-636.
- Bajwa, A. U., & Sheikh, H. A. (2023). Contribution of road transport to Pakistan's air pollution in the urban environment. *Air*, 1(4), 237-257.
- Business Recorder*. (2024, October 08). Roadmap for smog mitigation in Punjab 2024-2025. <https://www.brecorder.com/news/40326057>
- Butt, D., & Dahiya, S. (2023). *Air quality governance in Pakistan: A review of the new National Clean Air Policy (NCAP) and its limitations*. Centre for Research on Energy and Clean Air. <https://energyandcleanair.org/publication/air-quality-governance-in-pakistan-a-review/>
- Chanana, I., Sharma, A., Kumar, P., Kumar, L., Kulshreshtha, S., Kumar, S., & Patel, S. K. S. (2023). Combustion and stubble burning: a major concern for the environment and human health. *Fire*, 6(2), 79.
- Dutta, A., Singh, H., Qamar, M. Q., Kottuppalli, T. M., Upreti, F., Ghosh, S., ... & Kumar, A. (2024). Stubble burning and urban environmental pollution: Impacts and control measures. In H. Singh (Ed.), *Urban forests, climate change and environmental pollution: Physio-biochemical and molecular perspectives to enhance urban resilience* (pp. 507-529). Cham: Springer Nature Switzerland.
- Fazal, U. B., Mahmood, S., & Shahid, A. (2024). Analyzing government policies causing smog: An evaluation. *International Journal of Innovations in Science & Technology*, 6(6), 540-549.
- GOP (Government of Pakistan). (2005). *National Environmental Policy 2005*. Islamabad, GOP.
- Government of Punjab. (2019). *The Punjab Clean Air Action Plan*. Environment Protection Department. Government of Punjab. [https://epd.punjab.gov.pk/system/files/Annex%20D2%20Punjab%20Clean%20Air%20Action%20Plan\\_0.pdf](https://epd.punjab.gov.pk/system/files/Annex%20D2%20Punjab%20Clean%20Air%20Action%20Plan_0.pdf)
- Government of Punjab. (2020). *Sectoral Emission Inventory of Air Pollutants in Punjab, Pakistan (1990-2020)*. Environment Protection Department.

- Government of Punjab. (2023). *Sectoral Emission Inventory of Lahore*. Urban Unit.
- Government of Punjab. (2025). *The Smog Control Strategy 2024-25*. Lahore, Government of Punjab. [https://agripunjab.gov.pk/system/files/Smog%20Control%20Strategy%202024-25\\_0.pdf](https://agripunjab.gov.pk/system/files/Smog%20Control%20Strategy%202024-25_0.pdf)
- Grote, M., Williams, I., Preston, J., & Kemp, S. (2016). Including congestion effects in urban road traffic CO2 emissions modelling: Do Local Government Authorities have the right options?. *Transportation Research Part D: Transport and Environment*, 43, 95-106.
- IQAir (2025). IQAir Screenshot captured on 23/4/2025 showing Air quality records at different monitoring stations of Lahore. <https://www.iqair.com/au/air-quality-map/pakistan/punjab/lahore>
- Iram, S., Qaisar, I., Shabbir, R., Pomee, M. S., Schmidt, M., & Hertig, E. (2025). Impact of air pollution and smog on human health in Pakistan: A systematic review. *Environments*, 12(2), 46.
- Irfan, M., Riaz, M., Arif, M. S., Shahzad, S. M., Hussain, S., Akhtar, M. J., ... & Abbas, F. (2015). Spatial distribution of pollutant emissions from crop residue burning in the Punjab and Sindh provinces of Pakistan: uncertainties and challenges. *Environmental Science and Pollution Research*, 22(21), 16475-16491.
- Ishaque, M. A., Ullah, F., Afridi, M. A., Wazir, S., & Islam, M. U. (2024). Finance Minister's committee on carbon financing, carbon credits, and global climate resilience investments. *Khyber Journal of Public Policy*, 3(4), 122-133.
- Kamran, M., Aleem, M. F., & Raza, M. U. (2025). Towards sustainable development goal 7: Pakistan's commitment to accessible and green energy solutions. *Engineering Journal*, 29(11), 1-21.
- Khan, H. R. (2014). A review of Pakistan national climate change policy. In *Understanding Pakistan Volume II. Strengthening Participatory Organization*. [https://spopk.org/wp-content/uploads/2019/11/dp\\_volume\\_ii.pdf#page=57](https://spopk.org/wp-content/uploads/2019/11/dp_volume_ii.pdf#page=57)
- Khan, Y., & Li, X. (2025). The role of environmental mitigation technology and energy productivity in reducing air pollution-related premature deaths: insights from the top 20 polluted economies. *Air Quality, Atmosphere & Health*, 18(3), 755-773.
- Li, S., Xing, J., Yang, L., & Zhang, F. (2020). Transportation and the environment in developing countries. *Annual Review of Resource Economics*, 12(1), 389-409.
- Lin, M., & Begho, T. (2022). Crop residue burning in South Asia: A review of the scale, effect, and solutions with a focus on reducing reactive nitrogen losses. *Journal of Environmental Management*, 314, 115104.
- Majeed, R., Anjum, M. S., Imad-ud-din, M., Malik, S., Anwar, M. N., Anwar, B., & Khokhar, M. F. (2024). Solving the mysteries of Lahore smog: The fifth season in the country. *Frontiers in Sustainable Cities*, 5, 1314426.
- Malik, S. (2025). *Strategies for improvement of air quality in Punjab province of Pakistan* (Doctoral dissertation, Johns Hopkins University).

- Mega, V. (2022). *Human sustainable cities: Towards the SDGs and green, just, smart and inclusive transitions*. Springer Nature.
- Meo, S. A., Salih, M. A., Alkhalifah, J. M., Alsomali, A. H., & Almushawah, A. A. (2024). Environmental pollutants particulate matter (PM<sub>2.5</sub>, PM<sub>10</sub>), Carbon monoxide (CO), Nitrogen dioxide (NO<sub>2</sub>), Sulfur dioxide (SO<sub>2</sub>), and Ozone (O<sub>3</sub>) impact on lung functions. *Journal of King Saud University-Science*, 36(7), 103280.
- Moeen, M. S., Juepsta, J., & Hanaoka, T. (2025). Integrated energy planning: Review of global practices for energy security and Paris Agreement implementation in Pakistan. *Energy Nexus*, 18, 100413.
- Mumtaz, M. (2018). The national climate change policy of Pakistan: An evaluation of its impact on institutional change. *Earth Systems and Environment*, 2(3), 525-535.
- Nasar-u-Minallah, M., Jabbar, M., Zia, S., & Perveen, N. (2024). Assessing and anticipating environmental challenges in Lahore, Pakistan: future implications of air pollution on sustainable development and environmental governance. *Environmental Monitoring and Assessment*, 196(9), 865.
- Raees, M. (2025). Combating air pollution in Lahore: A critical analysis of the measures by the Punjab government. *Journal of Emerging Trends in Social Sciences and Humanities*, 2(3), 14-27.
- Rafiq-uz-Zaman, M., Faridi, M. Z., Khalid, N., & Khan, Z. A. (2024). Smog mitigation and climate resilience in Pakistan: A policy-centric review of strategies and challenges. *Social Sciences Spectrum*, 3(4), 302-317.
- Saeed, M. F., & Mahmood, S. (2024). Eco-Mobility in Lahore, Pakistan: Assessing the role of electric vehicles in air pollution mitigation. *International Journal of Innovations in Science & Technology*, 6(6), 527-539.
- Saqlain, M., Bilal, M., Hassan, M. M. U. U., & Riaz, M. Z. (2025). Analysis of air pollution: A comparative study of Pakistan, India and Singapore. *Research Consortium Archive*, 3(4), 1466-1486.
- Sial, S. A., Zaidi, S. M. A., & Taimour, S. (2018). *Review of existing environmental laws and regulations in Pakistan*. Punjab, Pakistan: WWF-Pakistan.
- Slater, J., Aftab, L., Jamshaid, H., Amjad, M., Bashir, S., Shafique, S., ... & Malley, C. S. (2024). Modeling air pollutant emission reductions from implementation of Pakistan's 2023 clean air policy. *ACS ES&T Air*, 1(8), 815-836.
- Wagner, F., Slater, J., Kiesewetter, G., & Klimont, Z. (2023). *Guide to assessing the costs of inaction of tackling air pollution*. Laxenburg, International Institute for Applied Systems Analysis.
- Waris, U., & Tariq, S. (2024). Temporal dynamics and forecasting of aerosol optical depth in megacities Lahore and Karachi: Insights from the Indo-Gangetic Basin and southern Pakistan, and implications for Sustainable development. *Atmospheric Pollution Research*, 15(7), 102146.

- WHO (World Health Organization). (2021). *WHO global air quality guidelines: Particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*. World Health Organization.
- Yazdanie, M., & Rutherford, T. (2010). Renewable energy in Pakistan: Policy strengths, challenges & the path forward. *ETH Zurich, 2*, 112-119.
- Zhang, J., Jiang, Y., & Zhang, Y. (2025). Transport-in-all-policies approach. In J. Zhang, Y. Jiang, & Y. Hayashi (Eds.), *Research handbook on transport and COVID-19* (pp. 469-490). Edward Elgar Publishing.