STRENGTHENING INDUSTRIAL EMISSION CONTROL IN PUNJAB'S BRICK KILNS: POLICY AND FINANCIAL PATHWAYS TO ADDRESS ECONOMIC AND TECHNOLOGICAL BARRIERS

A Thesis

Submitted to the Master's Study Program of Public Policy in Climate Change at the Faculty of Social Sciences in partial fulfillment of the requirements for the degree of

Master of Arts (M.A.)

by

Muhammad Qeyas

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UNIVERSITAS ISLAM INTERNASIONAL INDONESIA

DEPOK

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ABSTRACT

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Brick kilns in Punjab, Pakistan's largest province, face one of the highest levels of air pollution globally, with brick kilns identified as a major contributor to smog and particulate emissions. Despite the government's introduction of policies like the Punjab Smog Mitigation Roadmap (2024–2025) and the Clean Air Policy (2023), compliance across the brick kiln sector remains limited. This study investigates the economic, technological, and enforcement barriers hindering the adoption of cleaner kiln technologies, particularly Zigzag kilns, across Punjab's brick manufacturing industry. It examines the major reasons why many brick factories in Punjab are not adopting modern Zigzag kilns, including financial limits and other difficulties. The research draws on policy analysis, government reports, air quality data, and comparative case studies, most notably India's National Clean Air Programme (NCAP). According to the findings, high costs of capital, not being able to access green funding, low technical resources, and weak enforcement prevent many companies from complying with environmental requirements. Although switching to Zigzag kilns can cut down CO_2 by 30%, Black Carbon by 80%, and PM2.5 by 35%, not many areas outside Lahore and Kasur are using these kilns because of the challenges. The findings suggest that successfully introducing policies relies on using technology and ensuring sound institutions, accessible financial systems, and clear regulations. Considering this gap, it calls for subsidies that help make decisions, loan schemes, improved surveillance, and strong participation of communities. According to the study, a structured approach to govern and control air pollution in industrial regions of Pakistan is necessary.

Keywords: *Brick kiln industry, Punjab, air pollution, Zigzag kiln technology, smog mitigation, environmental policy, green financing, regulatory enforcement, industrial emissions, cleaner production, Punjab, sustainable development*

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CHAPTER I
INTRODUCTION

1.1 Problem Statement

Brick manufacturing dates back to approximately 5000 B.C., as archaeologists discovered bricks in the Indus Valley civilization while excavating for a railway track in the mid-19th century. Due to their increasing population, many third-world countries rely heavily on brick manufacturing, often employing Due to their increasing population, many third-world countries rely heavily on brick manufacturing, often employing centuries-old technologies that contribute to environmental deterioration and adverse social impacts. According to the World Bricks and Blocks Market report published by Zion Market Research in January 2021, the global bricks market was valued at approximately USD 140.43 billion in 2019 and is expected to generate revenue of around USD 200.51 billion by the end of 2026, growing at a CAGR of around 5.8% between 2020 and 2026 (Lee, J, 2020).

Four main types of brick kilns are operating in Punjab, Pakistan. These include Fixed Chimney Bull Trench Kilns (FCBTK); Moving Chimney Bull Trench Kilns (MCBTC); Vertical Shaft Brick kilns (VSBK); and ICIMOD-introduced Fixed Chimney Zig-Zag Bull Trench Kilns (zig–zag kilns). They differ in their firing and fuel feeding practices, and hence emit different amounts of emissions into the atmosphere. Among these types, zig-zag kilns emit the least amount of Black Carbon. Besides, a zig-zag kiln requires less upfront capital investment for its establishment, consumes less coal, and produces better quality bricks compared to FCBTK and MCBTK. ICIMOD and its partners have been advocating for zig-zag kilns in the South Asia region (Ahmad et al., 2022). With the increasing global warming and smog patterns during winters, there is a dire need to implement rigorous actions, including shifting the traditional brick kilns to new and cleaner technologies (Pervaiz et al., 2020).

Brick kilns in Punjab are scattered all over the province and are generally located in the suburbs of the towns. A total of 10,394 brick kilns are operating across Punjab; they make up 52% of the brick kilns operating in Pakistan. Smoke from brick kilns is the primary source of air pollution (Naureen et al., 2022). Lahore Division, a major contributor to air pollution, has a high concentration of coal-reliant industries. Lahore

houses the largest number of industrial units, followed by Sheikhupura and Kasur. Nankana Sahib hosts over 1,000 industries, and the division is known for its brick kilns (Hamid et al., 2023). Lahore, Pakistan's second-largest city, faces severe air pollution, with AQI levels frequently exceeding hazardous thresholds (300-400 AQI), well above PEQS and WHO standards. The city's population has surged to over 13 million, growing at 3.41% annually, increasing vehicular and industrial emissions (Government of Punjab, 2024). This rapid urbanization exacerbates the smog problem, with industrial emissions releasing over 154 Gg of pollutants annually (ICI&SDD, 2024). The city's economy also suffers, with sectors like healthcare, tourism, and overall productivity adversely affected by smog (Slater et al., 2024).

The lack of structured financial support mechanisms, such as low-interest loans or carbon credit incentives, further complicates this transition. Despite existing regulations like PEQS, enforcement remains inadequate due to technological and economic barriers. Many industries still rely on outdated technologies, like coal-fired boilers, which contribute significantly to SO2, NOx, and particulate matter emissions. The high costs of adopting cleaner production techniques deter industries, especially SMEs, from complying with regulations. The absence of incentives like tax exemptions or subsidies also limits the shift toward cleaner technologies (Ali et al., 2022).

On average, there are around 300,000 kilns worldwide. However, 75% of global brick production is concentrated mainly in four countries, namely China (54%), India (11%), Pakistan (8%), and Bangladesh (4%) (Abbas et al., 2021). Brick kilns in this region mainly rely on centuries-old brick-producing technology, which is not environmentally friendly and is notorious for unhealthy emissions (Skinder et al., 2014).

Transforming traditional kilns to zigzag kiln technology can yield substantial economic advantages, chiefly via fuel cost reductions and enhanced production. Zigzag kilns exhibit superior energy efficiency compared to traditional kilns, leading to considerable fuel cost reductions. Research conducted by the United Nations Development Program (UNDP) revealed that a zigzag kiln in Nepal decreased fuel usage by 35% relative to a conventional fixed chimney kiln. Research conducted by the International Centre for Integrated Mountain Development (ICIMOD) revealed that zigzag kilns in Bhutan decreased fuel usage by as much as 30%. These energy efficiencies can yield significant financial benefits for kiln operators, especially in regions

with elevated fuel expenses. Zigzag kilns are engineered to optimize fuel combustion and diminish the emission of pollutants, including particulate matter and carbon monoxide. This may yield environmental advantages, including enhanced air quality, and might potentially mitigate or decrease the expenses associated with compliance with emissions rules. Research by the IFC indicated that zigzag kilns in Bangladesh decreased particulate matter emissions by 45–50% and carbon monoxide emissions by 60–80% relative to traditional kilns. This may assist kiln operators in evading fines or penalties for non-compliance with emissions rules and may enable them to qualify for carbon credits or other incentives (Nations, 2019).

WHO estimations indicate that around 0.135 million individuals in Pakistan succumbed to harmful PM2.5 exposure in 2015 (HEI, 2017). This issue is especially acute in Bangladesh, India, Nepal, and Pakistan, where baked bricks are manufactured utilizing the traditional Fixed Chimney Bull's Trench Kiln (FCBTK) (S. Nasim and F. Sharif, 2020). In the Punjab region of Pakistan, there exist 10,394 operational brick kilns. Brick kilns in Pakistan, on average, utilize 3025.5 metric tons of coal (CEIC, 2020). Over 78% utilize such antiquated technologies. The zigzag kiln is a further improvement in technology aimed at mitigating the environmental impact of brick kilns. Zigzag kilns direct combustion gases through a zigzag configuration in the brick stack, leading to enhanced fuel efficiency and reduced emissions (Zavala, 2018). Zigzag brick kilns produce lower emissions of carbon monoxide and particulate matter compared to traditional brick kilns. The transition to cleaner industrial operations is economically challenging due to high capital investment requirements and limited access to green financing. SMEs, a significant portion of Lahore's industrial sector, struggle to secure funding for emission control technologies.

The combination of fast economic development with industrial growth produces 154 Gg of annual pollutants. Different technological and economic factors prevent the successful enforcement of modern regulations and policies. Small businesses and industries, and multiple industrial sectors, fail to acquire environmentally friendly technologies because both funding challenges and high financial hurdles prevent their expansion. Current regulations are becoming challenging to uphold since monitoring systems are insufficient for enforcement efforts. The research aims to analyze economic barriers that stop industrial facilities from fulfilling the pollution control requirements of

Punjab. The research provides essential knowledge to boost public health protection, together with economic production and sustainable industrial growth.

The severe air pollution emergency throughout Punjab Province demands immediate attention, where harmful AQI thresholds are regularly surpassed, leading to health and economic productivity hazards. The current air pollution reduction regulations remain ineffectual due to both technological hurdles alongside economic obstacles. SMEs, along with other industries, find it difficult to implement cleaner technologies, for instance, zigzag technology, because of expensive infrastructure requirements and limited available clean financing options. The situation demands immediate action because we are approaching key thresholds that will result in permanent health and environmental damage. My analysis investigates the economic challenges to industrial emission control through Punjab's smog mitigation policies (e.g., Roadmap for Smog Mitigation in Lahore 2024-2025, Lahore, National Clean Air Policy 2023, and Punjab Spatial Strategy 2047) and the National Clean Air Policy in India. The work remains essential to support sustainable industrial development. Lower energy consumption and savings on energy cost, one of the main advantages of a Zigzag kiln is its lower specific energy consumption (SEC) as compared to that of FCBTK. The Zigzag kilns use around 0.95–1.20 MJ of energy to make each kilogram of fired brick.

1.2 Research Questions

1. What economic, technological, and enforcement barriers prevent Lahore's brick kiln industry from complying with Punjab's smog mitigation policy?

2. How can financial and regulatory strategies from successful policies improve compliance and cleaner technology adoption in Lahore's brick kiln sector?

1.3 Hypothesis

1. High costs and limited financing hinder cleaner technology adoption in Lahore's brick kiln industry, making compliance unfeasible.

2. Weak emission monitoring and enforcement undermine compliance with Punjab's smog mitigation policy, but adopting best practices from effective global regulations can strengthen enforcement.

1.4 Significance of the study

The significance of this study lies in its potential to inform evidence-based policymaking aimed at strengthening air pollution control in South Asia's industrial sectors, particularly within the brick kiln industry. By identifying policy implementation gaps, looking at growing technology adoption, and understanding both economic and social reasons behind noncompliance, the research improves the development of more successful, inclusive, and science-based environmental governance policies. Expected policies, for example, a tiered approach to emissions standards, incentives, and AI-powered real-time monitoring, will address waste disposal issues in ways that are both effective and consistent with how best practices are handled worldwide. Like in Delhi and Bihar, and Pakistan’s similar industrial settings, these insights are essential, since strict regulation and advancing technology are important issues. Therefore, the study expands our understanding of industrial emissions rules in universities as well as supports actions for better environmental and health results.

CHAPTER II
LITERATURE REVIEW

2.1 Literature Review

The transition to cleaner industrial operations is economically challenging due to high capital investment requirements and limited access to green financing. SMEs, which make up a significant portion of Punjab's industrial sector, struggle to secure funding for emission control technologies. The lack of structured financial support mechanisms, such as low-interest loans or carbon credit incentives, further complicates this transition. Despite existing regulations like PEQS, enforcement remains. Smoke from brick kilns is the primary source of air pollution (Naureen et al., 2022). Lahore Division, a major contributor to air pollution, has a high concentration of coal-reliant industries. Lahore houses the largest number of industrial units, followed by Sheikhupura and Kasur. Nankana Sahib hosts over 1,000 industries, and the division is known for its brick kilns (Hamid et al., 2023). Lahore, Pakistan's second-largest city, faces severe air pollution, with AQI levels frequently exceeding hazardous thresholds (300-400 AQI) well above PEQS and WHO standards. The city's population has surged to over 13 million, growing at 3.41% annually, increasing vehicular and industrial emissions (Government of Punjab, 2024). This rapid urbanization exacerbates the smog problem, with industrial emissions releasing over 154 Gg of pollutants annually (ICI&SDD, 2024). The city's economy also suffers, with sectors like healthcare, tourism, and overall productivity adversely affected by smog (Slater et al., 2024).

According to a report from the Southern Africa Clay Brick Association (CBA), globally, 300,000 formal brick kilns produce approximately 1500 billion bricks every year. Worldwide, the construction industry uses 36% of all energy and accounts for significant greenhouse gas (GHG) emissions. Creating pollution with COx, NOx, Sox, and PM2.5 lowers the quality of the environment, and it also makes brick kilns unsafe for workers and nearby residents. This research did not include NOx emissions this time. Most of the air quality index readings for major cities exceed the levels set by the EMA, with readings typically around 100 or higher. In 2021, the global brick industry accounted for 2.7% of carbon emissions (Ncube, 2021). All in all, the main risks of making bricks include negative effects on health, the environment, climate change, and resources. The issue could be reduced a lot by adopting newer zigzag technologies and switching to fuels like paper sludge and biomass instead of coal (Kumbhar, 2014).

Most of these brick kilns in developing countries are not regulated, so there are no measures to address the emissions from these kilns (Adopt, 2019). Elsoragaby, 2020). Pakistan has over 20,000 brick kilns, and the majority are in Punjab. Out of all the coal used in the country, 20% to 30% goes to this industry (Government of Pakistan, 2020; Lin, 2020).

The most common types of brick kilns in Pakistan are Fixed Chimney Bull Trench Kilns (FCBTK), Moving Chimney Bull Trench Kilns (MCBTK), and Vertical Shaft Brick Kilns (VSBK). They use straight line firing when baking green bricks, which uses a lot of energy, effort, and fuel and causes dirtiness, hard work, and high costs (S. Nasim and F. Sharif, 2020; APN, 2016). They are also poorly built and tend to have too much air flow, which leads to heat being wasted, extra use of fuel, and increased air pollution.

Laws on air quality (e.g., Ambient Air Quality Law) require brick kilns in Pakistan to meet the standards set by each province. In Punjab province, certain air quality standards for smoke-emitting factories, including brick kilns, have been established by the provincial government. Specialized bodies in the judiciary made sure that the required laws and conditions were correctly implemented in the brick kiln sector in Pakistan. For instance, the Lahore High Court has taken steps to apply labour and environmental laws fairly in public interest lawsuits (Mohsin Raza Malik, 2020). Specifically, it instructed the provincial Labour and Human Resource Department to get all brick kilns in Punjab registered under the Factories Act, 1934. Informed the government of Punjab, Pakistan, to request the District Labour Committees (DLCs) state-wide to ensure the Punjab Prohibition of Child Labour at Brick Kilns Act, 2016, is properly implemented and supervised.

It is crucial to discuss the economic and technological barriers that inhibit the industry from using cleaner emission control technologies, which this study does for the brick kiln industry in Punjab. Despite rapid industrial growth, small and medium enterprises (SMEs) continue to face significant challenges due to high capital investment requirements and limited access to green financing. In addition to these economic challenges, the research investigates energy consumption in traditional methods and the efficiency of modern zigzag kilns, as well as the outcomes of today's legislation related to curbing industrial emissions. With the help of policy documents, data analysis, and

statistics on pollution levels, this research examines the differences between what the policies aim to do and what is achieved.

Therefore, this study intends to enhance academics by showing how economic constraints and slow technology uptake lead to ongoing air quality challenges in Punjab. It will analyze important factors such as industrial emissions, how well regulations are followed, investment levels, the effectiveness of law enforcement, and financing choices for green projects to produce a detailed comparison of policies. The research will both point out crucial problems with the present regulations, like off-target and costly monitoring systems for small businesses, and detail specific measures to combat pollution in certain areas. Learning from what has worked in the past and what is still a challenge, this research provides support for decisions that promote a thriving region economically and protect its population.

CHAPTER III
RESEARCH DESIGN

3.1 Methodology

This study uses a mixed method, combining qualitative and quantitative methods, to investigate barriers to emission control in different sectors. Data collection is primarily based on a thorough review of policy documents such as the Punjab Smog Mitigation Action Plan 2024–2025, Clean Air Policy (2023), and Climate Resilient Punjab Vision & Action Plan 2024. They help to explain the main regulations and the places where they are not fully implemented. In addition, secondary data are obtained from multiple sources: government and institutional reports from the Punjab Environmental Protection Department and the Urban Unit & Industries, Commerce, Investment, and Skills Development Department (ICI&SDD) are used to evaluate emission patterns and compliance records; air quality data (e.g., AQI, PM2.5, SO_2, NO_x levels) are collected from the Environmental Protection Agency (EPA) Punjab, Punjab Safe Cities Authority, and AirVisual; and industrial emission figures come from the Pakistan Bureau of Statistics (PBS) and additional records maintained by the Punjab Environmental Protection Department. Specific variables, such as technological barriers, industrial emission levels, compliance rates, capital investment in cleaner technologies, policy enforcement strength, green financing availability, technology adoption rates, and overall air quality trends, are operationally defined using metrics (e.g., concentration levels, frequency of inspections, and percentages of adoption on a monthly or annual basis). All the data in this study come from secondary sources that have already been shown to be available and reliable from government reports and policy documents.

3.2 Analysis

The analysis technique applied in this research is multi-pronged. First, the study looks at how India's industrial emission control approaches compare with benchmarked models. This analysis scrutinizes both the financial incentives (such as tax benefits and green financing mechanisms) and regulatory measures (including emission limits and technology upgrade requirements) enforced by these policies. The next step is to carry out a qualitative thematic analysis by examining documents, reports, and regulations to discover the significant challenges, like a lack of enforcement, high costs, and tough access to advanced technologies, affecting the implementation of pollution measures in the brick kiln industry. Next, the data from historical air quality and industrial emissions are studied

using statistical methods. This quantitative review focuses on trends in air quality (levels of PM2.5, PM10, SO_2, NO_x, and AQI), tracking changes over time, examining financial accessibility trends including tax incentives and capital investments in cleaner technologies, and assessing technology adoption indicators (e.g., the shift to zigzag kilns). Data visualization techniques (tables and charts) are utilized to illustrate the patterns observed and to facilitate a clear understanding of how policy enforcement translates into tangible environmental improvements. These methods are designed to look at how effective policies are at controlling industrial emissions and recommend ways to further improve regulations.

CHAPTER IV
FINDINGS AND DISCUSSION

4.1 Findings

Brick kilns are scattered across Punjab province and are concentrated in the suburbs of the towns. However, real-time data received from BKOAP shows that a total of 10,394 brick kilns are operating across 36 districts in Punjab province Table 1.

Table 1. Real-time brick kiln statistics received from BKOAP, November 2020.

No	District	Total Number of brick kilns	Total converted / being converted	Percent converted, being converted
	Attack	250	07	2.1%
	Rawalpindi	220	32	14.5%
	Jehlam	163	03	1.8%
	Chakwal	118	16	13.6%
	Sargodha	403	19	4.7%
	khushab	156	25	16.0%
	Mainwali	158	00	0.0%
	Chiniot	67	2	3.0%
	Gujrat	254	61	24.0%
	Mandi Bahauddin	245	75	30.6%
	Hafiz abad	93	62	66.7%
	narowal	205	105	51.2%
	Sialkot	265	60	22.6%
	Gujranwala	332	74	22.3%
	Sheikhupura	312	91	29.2%
	Nankana	107	35	32.7%
	Faisalabad	607	207	34.1%
	Toba Tek Singh	415	15	3.6%

Jhang	280	03	1.1%
Bhakar	198	01	0.5%
Layyah	254	01	0.4%
Muzaffargarh	426	07	1.6%
D.G. Khan	156	00	0.0%
Multan	614	12	2.0%
Rajanpur	162	01	o.6%
Rahim Yar khan	350	10	2.9%
Bahawalpur	450	25	5.6%
Lodhran	292	07	2.4%
Vehari	380	74	19.5%
Bahawalnagar	450	82	33.1%
Pakpattan	221	20	9.0%
Khanewal	320	24	7.5%
Sahiwal	230	59	25.7%
Okara	332	129	38.9%
Lahore	277	250	90.3%
Kasur	834	736	88.2%
Total:	**10,394**	**2330**	**22.4%**

Table. 2 Industry Department Action Plan (Sep 2024-Feb 2025).

September	October	November	December	January	February
• **Launch** awareness campaign for the industry. • **Initiate** plantation drives in PIEDMC, FIEDMC & PSIC. • **Implement** anti-smog measures in industrial estates. • **Form** inspection teams for monitoring emissions. • **Begin** inspection of Emission Control Systems (ECS) on boilers.	• **Continue** plantation drives in PIEDMC, FIEDMC & PSIC.	• **Conduct** ongoing ECS inspections on boilers. • **Alert** chambers of commerce and industrial associations on using clean fuel and avoiding emissions.	• **Monitor** industries and **issue** legal notices for corrective measures (e.g., lowering production, installing air pollution control devices).	• **Facilitate** cleaner production initiatives (solar, ETP, dry scrubbers, etc). *(to be continued till June 2025)*	• Continuous **monitoring** of industrial units followed by **punitive action.**

A. Institutional and Financial Framework

The Government of Punjab operationalized the Resource Efficiency and Cleaner Production (RECP) framework with a sectoral allocation of PKR 13.43 billion. To promote

green financing, two important financial measures were launched: the Environmental Endowment Fund and the Provincial Sustainable Development Fund, both supporting the use of clean technology.

B. Regulatory Action Against High-Pollution Sectors

The adoption of Zigzag technology was required by the government due to its ability to decrease particulate emissions. To enforce this transition: (I) All kilns were geo-tagged via e-mapping, and chimneys were assigned unique IDs. (ii) A one-month grace period was allowed for voluntary compliance. (iii) Enforcement efforts included collaboration with the Punjab Highways Patrol (PHP), supported by citizen reporting via the Punjab Green App. During October 2024, it was declared that 27 kilns in Layyah and 9 in Mianwali are being demolished, with only one in Mianwali verified to be compliant. C. Monitoring and Surveillance Technologies: a. Live Monitoring via Smog Cell: CCTV cameras and related equipment were used to create a live surveillance system in the Smog Monitoring Cell. This allowed for dynamic monitoring of industrial emissions and improved compliance with Punjab Environmental Quality Standards (PEQS) by enabling immediate identification of violations and deployment of regulatory response. b. Drone-Based Enforcement: The use of drones in industrial areas helps police increase both their field of view and the data they collect, especially for areas that are hard to reach or highly industrialized. c. Emission Control Systems (ECS) Emission Control Systems were introduced to industries, and they now have stack emission monitors that provide results in real time. The initial phase focused on the Lahore Division. Soon after a short period of voluntary compliance, officials began imposing fines, sealing buildings, registering FIRs, and demolishing non-compliant structures.

C. Supplementary Policy Tools and Legal Reforms

Various laws and organizations were established to back up the RECP framework. Environmental CSR Mandate: Legal provisions were drafted to require industries to implement Corporate Social Responsibility (CSR) initiatives focused on environmental sustainability. a. Location-Specific Industrial Regulation: The Chinese government made it a rule that no new industries could be launched outside of the areas assigned for heavy industry. b. Renewable Energy Promotion: The government offered tax incentives to motivate industries to switch to using renewable energy. Further legal developments included a ban on tire-derived fuels and amendments to the Punjab Boilers and Pressure

Vessels Safety Act (2024). The provincial government worked together with federal authorities to make sure fuel quality matched EURO-V standards.

While the ZZK system reduces pollution and helps to operate more efficiently, it has seen little use in Pakistan, particularly in Punjab, due to economic barriers. A significant barrier is that replacing a traditional FCBTK with a zigzag model is very costly. It is challenging for small and medium-sized kilns to follow these changes since they often lack the formal structure and access to resources that large companies have. Many brick kiln owners face this problem because they cannot access government support or loans from commercial banks given their often-unsuitable business profile (ICIMOD, 2021). In addition, not receiving income for a while during the retrofit process can discourage owners from transitioning to greener technologies. Maintaining and operating these kilns requires skilled workers and costs much more than traditional kilns, leading to further complications due to the added workload and responsibilities needed (Abbas et al., 2022). Due to the lack of formal regulations, tourism businesses generally miss out on public-sector support and benefits designed to upgrade them technology-wise. Therefore, using clean air technology on a large scale remains a struggle for the brick kiln industry in Pakistan.

Table 3. Sector Overview

Number of brick kilns (2018)	18,000-20,000
Annual brick production (2018)	82.5 billion bricks
Annual domestic consumption	90% of production bricks
Annual brick demand	112 billion bricks
Animals utilized (2017)	115,000 animals
Number employed (2018)	1.3 million people
Men employed	77% men
Women. Employed	23% women
Admin and others	60,000 people
Moulding	9,00,000 people
GB transport	150,000 people

Firing	1,00,000 people
Fired brick transport Sector investment (2018)	120,000 people PKRS 240 billion/USD 2 billion
Value of sales (2018)	PKRs 676.512 billion/USD 5.637 billion
GDP contribution	Not available
Tax contribution	No sales tax; taxation on coal and income
Estimated avg, coal consumption for firing bricks per annum (2018)	60-70% of total fuel consumption by brick sector
Annual coal expenses (2018)	PKRS 179 billion/USD 1.49 billion
Other fuel consumption	Common biomass fuel-rice husk, cotton stalk, sawdust, biomass residue, bagasse. About 30-40% of total fuel consumed by brick kilns. In some areas, bricks kilns exclusively. use biomass fuel. Cost of biomass fuel varies between PKRs 6-10 per kg.

Source: ICIMOD, 2019

Table 4. Brick Kiln Technologies: Kiln Count, Coal Consumption & Employment Metrics

Technology	Number (kilns with coal as the primary fuel)	Energy consumption (tons)	Number employed
Fixed Chimney Bull's Trench Kils (FCBTK) (natural draft)	15,000	13 million tons of coal (excluding biomass)	1.3 million
FCBTK (forced/induced draft)			
Zig-zag FCBTK (natural draft)	150	0.0945 million tons of coal	45,000
Zig-zag FCBTK (forced/induced draft)			
VSBK		N	
Hoffmann kiln		1	

Although brickmaking only contributes about 1.5% to the GDP, there are no official standards or records for how this work is carried out. In Punjab, there are around 10,000 brick kilns. Bricks are generally made by hand and then baked in local kilns. Different countries have introduced automatic plants for making bricks as well as a range of kilns such as the tunnel kiln, Hoffman kiln, modified FCBTK, and VSBKs. Making bricks with machines and baking them proved to be unsuccessful in the early days, as there were issues with both technology and the community. Zig Zag Kilns are claimed to reduce 70% Emissions are reduced by 40%, and fuel efficiency is increased by the same amount, compared to conventional brick kilns (PCAP,2023). A lack of proper training and advanced technologies makes it challenging to control environmental pollution in Pakistan. The creation of a Technology Transfer Centre within the Environment is a sound strategy.

The Protection Department (EPD) would enable capacity development for transferring technology. The centre will look for the right technologies, experiment with innovative ideas at home, and recommend successful innovations to companies. This research will be focused on understanding what industry expects, so it remains current and meaningful. Its purpose is to make information more accessible so that more local groups can learn how to use environmental technologies properly. About Rs. 300 million has been allocated for the project, sourced from the World Bank.

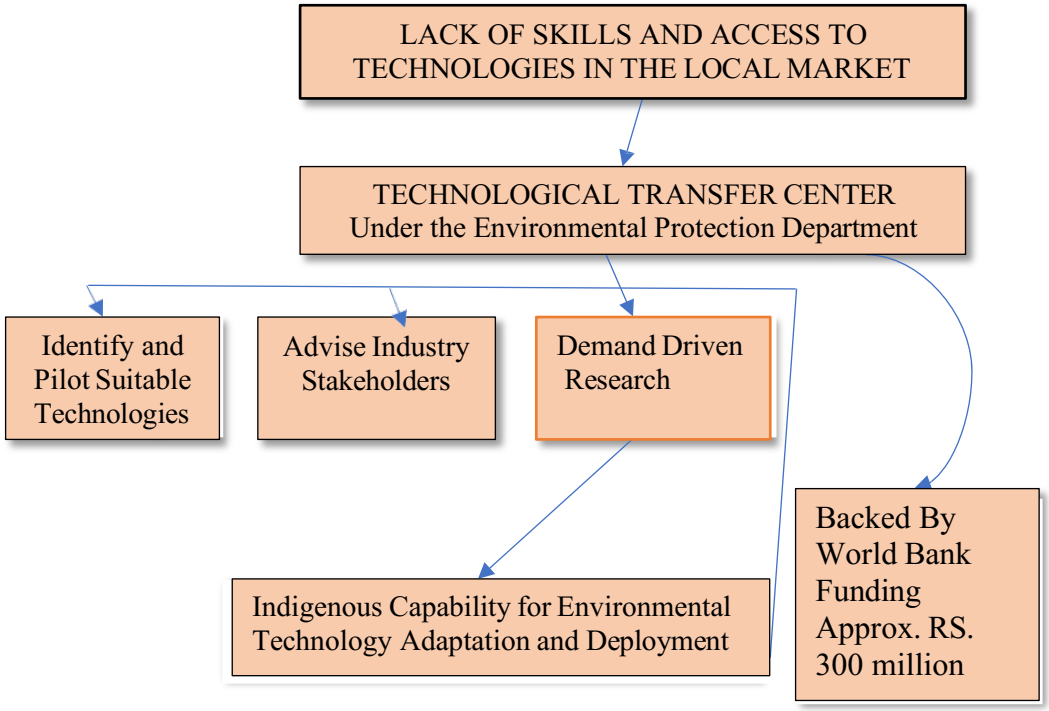

Fig 1. Strategic Policy Flow: Technology Transfer Centre Under EPD

Table 5. Upgrade Plan for 200 Brick Kilns

Proposed Action	Approx. Co	Timeline	Responsibility
200 brick kilns upgraded to more efficient induced draft Zigzag Brick kiln Technology	Rs. 800 m World Bank Funds	TBD	Lead: Environment Partner: Industry, Chambers of Commerce and Industry, respective industrial association

4.2 Technology diffusion through demonstration in most polluting sectors through matching grants

Brick kilns will be upgraded to Induced Draught Zig-Zag Brick Kiln technology, and new energy-saving and waste management plans will be implemented for the steel furnaces. The issue of dust and pollution from rice mills will be managed, while fly ash is also being addressed in boilers and power plants. Stone crushing plants will be required to improve dust control and processing. With support from a Rs. 1,200 million credit line arranged by the World Bank, the EPD will implement the successful pilots on a wider scale(PCAP,2023). The Technology Transfer Centre, as described in Policy Measure 12, will assist industries on essential matters by conducting local activities, performing research, advancing technologies, and supporting efforts to improve the use of advanced technologies among industries. As stated by SBP, the Refinance Facility allows SMEs to upgrade their existing kilns or build new ones with the zigzag technology. It leads to better air quality and improves how vehicles use fuel. SBP offers green bank funding for plant and machinery and also covers civil works, with a maximum of 20% for kilns and 50% for new zigzag kilns (SBP, 2019).

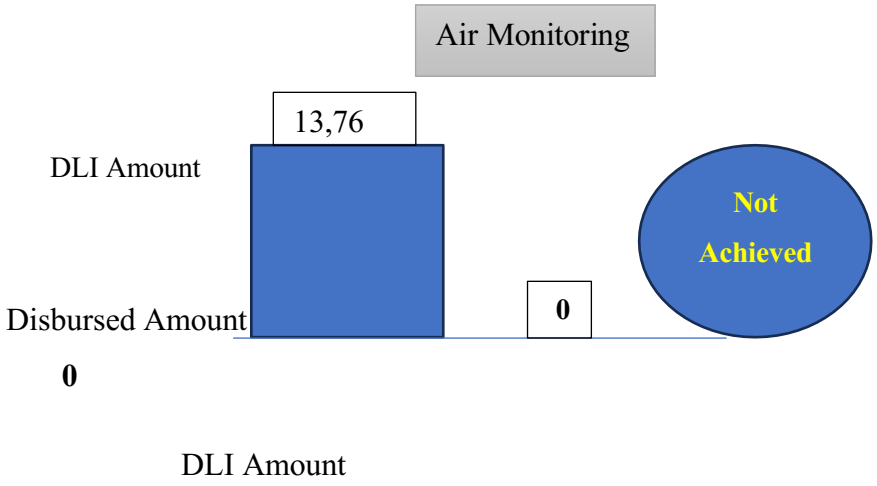

Fig 2. Challenges in Air Quality Monitoring DLI: Funding, Implementation, and Political Barriers

The consistent “Not Achieved” result shown for DLI in Air Quality Monitoring after XDR 13.76 million was allocated highlights the obstacles in tackling the environment in less-developed areas. A lack of disbursement suggests that both goals have not been met, and larger problems exist with the group and its systems. Three important factors are the necessary technology, inadequate monitoring structures, and exploiting the environment

for political reasons. Without proper air quality monitoring programmes, important data for policy creation and enforcement cannot be gathered. That's why the DLI is still labelled "Not Achieved," as no money from the disbursement has been made. Science and politics influence each other in ways that make this issue more complex. In many developing countries, air quality monitoring is not given as much importance as other forms of development because resources are often scarce. Also, when partners leave the finances and decisions to others, they end up with separate activities, and it can be hard to keep up. Environmental information manipulated or overlooked due to political interests usually leads to less reliable and less efficient environmental monitoring. It is necessary to address these challenges by working on capacity, offering more investment in infrastructure, and ensuring objectivity in environmental data so that air monitoring can achieve its aims(Redi, T. (2024), Andres, et al., 2023).

4.3 Potential Policy Adaptation for Brick Kilns

The Punjab Green Development Programme (PGDP) and Green Development Loans have been instrumental in helping small and medium businesses in leather, steel, and textiles. The brick kilns remain excluded from these schemes. By granting more low-interest loans for Zigzag Kiln changes, scrubbers, or solar furnaces, the government might achieve its smog policy objectives more quickly. Little funding is currently used to shut down illegal kilns, but RECP finance could address this issue, just as it has in other sectors dealing with similar problems. (Sheikh et al., 2025) stated in their study that LCA assesses the impact of a product on the environment from start to finish. Evaluating these types of kilns using LCA reveals the environmental problems connected to brick production. ZZK shows superior performance in every area of botany. The energy used to make fired bricks in a ZZK is about 30% less than in an FCBTK. Consequently, less fuel is required for ZZKs. The emissions from the zigzag kilns in this study were found to be lower than those from the FCBTK version. If cleaner kilns are selected, GHGs will be cut by a large amount, specifically reducing CO2 emissions by 30%, BC emissions by 80%, and PM2.5 by 35%.

Table 6: Funding and Investment Overview for Brick Sector Green Transition Initiatives

Costs and Funding

Category	Details	Amount	Source
Sector Investment (2018)	Total investment in brick sector	PKR 240 billion (USD 2 billion)	ICIMOD, 2019
RECP Framework Allocation	Total green technology budget	PKR 13.43 billion	Govt of Punjab, 2024
ZZK Subsidies	State Bank refinance for conversions	20-50% of project cost	SBP, 2019
Technology Diffusion	Matching grants for 200 kiln upgrades	Rs. 1,200 million	PCAP, 2023
Tech Transfer Center	Capacity building initiative	Rs. 300 million	World Bank/EPD

4.4 India's National Clean Air Programme and Its Impact on the Brick Kiln Industry

In India, almost 70% of total brick production is done through the Fixed Chimney Bulls Trench Kiln (FCBTK). Towards Cleaner Brick Kilns in India. India, after China, produces the most bricks globally, running more than 100,000 kilns. These kilns emit 170 kt of PM2.5 (15% of the national total) and 120 Mt of CO2 (6% of the national total) annually, along with substantial SOx and NOx emissions. Transitioning from traditional Fixed Chimney Bull & Trench Kilns (FCBTKs) to cleaner technologies, such as Zigzag Kilns (ZZKs), has the potential to reduce coal consumption by 20% and particulate matter emissions by 70% (Goldmann et al., 2025).

The National Clean Air Programme (NCAP) was launched in 2019 to improve air quality in India by reducing particulate matter (PM) concentrations by 20-30% by 2024. It was later extended to 2026 with a revised target of a 40% reduction in PM10 levels compared to 2017 (NCAP, 2019). The National Clean Air Programme (NCAP) 2019 of India introduces a structured and time-bound framework for controlling industrial air pollution, particularly targeting the brick kiln sector, a major contributor to ambient air quality deterioration in several Indian states. The policy contains a set schedule of tasks with specified deadlines: take action against unapproved kilns within 30 days, see that all factories follow air quality standards within 60 days, require traditional kilns to be

upgraded within 90 days, and promote the use of natural gas within 120 days when possible. These actions demonstrate an integrated and phased approach aimed at immediate enforcement as well as medium-term technological shifts, reflecting the policy's commitment to both regulatory rigor and industrial modernization (NCAP, 2019). In the National Clean Air Programme, full enforcement of zigzag brick technology in brick kilns is a key action point. Furthermore, the authorities declared that none of the Brick Kilns in the Delhi area using old technology could continue on 30.06.2018. In Delhi's National Capital Region, a total of 4,247 Brick Kilns were operational in July 2017, of which 722 Brick Kilns converted to Zig-Zag technology (Guidance Document, 2023).

There are policies in place at the national level to address environmental problems caused by brick kilns. The Air (Prevention and Control of Pollution) Act, 1981, forms the legislative backbone, empowering the CPCB and State Pollution Control Boards (SPCBs) to regulate air emissions. Under this Act, kilns are categorized as red (high-pollution) industries, subject to stringent compliance. Furthermore, the Fly Ash Utilization Notification (2016), issued by the Ministry of Environment, Forest and Climate Change (MoEFCC), mandates kilns within a 300 km radius of thermal power plants to use at least 25% fly ash in brick production. They are intended to cut coal usage, increase recycling, and introduce cleaner ways to manufacture products. The cost of converting a traditional FCBTK to zigzag technology ranges between ₹10–15 lakh per kiln, depending on kiln size and location (CSE, 2020). Even though direct assistance is scarce, easier access to bank loans and soft credit lines has helped reduce the difficulties faced by kiln owners. In Bihar, over 80% of kilns had converted to zigzag design by 2023 following court mandates and proactive enforcement (Niazi, 2024). Delhi-NCR saw near-total conversion due to stringent regulatory pressure. In the country, close to half of kilns are using cleaner designs in 2024, still working towards meeting the requirements completely. Due to variations in how rules are enforced in rural areas and the issue of informal ownership, many do not adopt these standards. The emission standards provide the allowable particulate matter in the stack (mg/Nm3) and 'stack height.

Table 7. Shows Emission standards for various brick technologies in India

Parameters	Standards
Particulate matter in stack emission	250 mg/Nm3
Minimum stack height (Vertical Shaft Brick Kilns) a) Kiln capacity less than 30,000 bricks per day b) Kiln capacity equal or more than 30,000 bricks per day	a) 14 m (at least 7.5m from loading platform) b) 16 m (at least 8.5m from loading platform)
Minimum stack height (Other than Vertical Shaft Brick Kilns) a) Kiln capacity less than 30,000 bricks per day b) Kiln capacity equal or more than 30,000 bricks per day	a) 24 m b) 27 m

Source: *MoEFCC.*

New emission standards were tightened to 250 mg/Nm³ PM (from 750 mg), and the use of hazardous fuels (petcoke, waste plastic, etc.) was banned. Enforcement is uncompromising: e.g., the Commission for Air Quality Management (CAQM) has issued formal directions that "Brick kilns not converted to zig-zag technology are not permitted to operate in Delhi-NCR and the Supreme Court/EPCA similarly stipulated that only clean technology kilns may run after specified cut-off dates. In other states, rules were similarly strict; for example, Jammu & Kashmir mandated PNG fuel for new kilns, with existing units given a choice of PNG or approved biomass (Press Information Bureau, 2023).

Financial support for this transition has been relatively modest. Under the National Clean Air Programme (NCAP), ~₹10,566.5 crore was earmarked for 2019–2024 across 131 cities, but a CSE analysis finds <1% of these funds went toward industrial emission controls (industries like brick kilns). Most expenditures from NCAP were for roads and general improvement, leaving brick manufacturers to make their upgrades. For instance, surveys indicate more than 15,000 brick enterprises retrofitted to zigzag on their own (at a cost of ~₹20–50 lakh per kiln). Commercial bank lending to kilns is limited by the unorganized nature of the sector (e.g., leased land, informal accounts. A few banks (e.g., Punjab & Sind Bank) do offer targeted MSME loan schemes for brick kiln owners, but uptake has been low. Analysts, therefore, advocate a dedicated Technology Upgradation Fund for brick kilns: subsidized loans (with interest/capital support) plus credit guarantees to waive collateral measures could bridge the finance gap highlighted by experts.

The NCR cities, including Delhi, have some of the most stringent regulations when it comes to brick kilns. A Supreme Court/EPCA order (2016) and subsequent CAQM rules required all kilns in NCR to convert to zigzag or be shut down. By mid-2018, roughly 1,000 of ~4,000 NCR kilns had adopted the zigzag design (each owner investing ≥₹10 lakh). Any kiln failing to convert faced closure. City authorities supplemented this with inspections and closures. Along with other pollution controls, these actions have helped make the air cleaner. For example, Delhi only experienced 110 days with a "Good/Moderate" AQI in 2016, but this number jumped to 209 in 2024. While there were several factors behind this, shutting down dirty kilns was crucial for the industry. (By law, only zigzag/VSBK/PNG kilns may now operate in NCR.

Table 8. Number of cities showing improvements in Air quality under NCAP

SI.No.	Improvements in PM10 levels in FY 2023-2024 as against FY 2017-18 (%)	No. of cities	(95) cities
1	>40	22	Varanasi, Bareily, Firozabad, Dehradun, Dhanbad, Tuticorin, Nalagarh, Moradabad, Khurja, Trichy, Kohima, Lucknow, Kanpur, Kadapa, Sivasagar, Sunder Nagar, Agra, Greater Mumbai, Rishikesh, Parwanoo, Jodhpur, Byrnihat
2	>30-40	13	Ahmedabad, Ghaziabad, Rajkot, Jalandhar, Raebareli, Amritsar, Kolkata, Jammu, Silchar, Vijayawada, Naya Nangal, Dimapur, Baddi
3	>20-30	16	Khanna, Durgapur, Kurnool, Dera Baba

			Nanak, Vadodara, Allahabad, Asansol, Hyderabad, Gorakhpur, Ranchi, Bengaluru, Akola, Ananthpur, Durg Bhilainagar, Surat, Noida
4	>10-20	21	Howrah, Thane, Latur, Nellore, Gajraula, Alwar, Chittur, Kala Amb, Mandi Gobindgarh, Amavati, Patiala, Jaipur, Ongole, Delhi, Chandrapur, Nashik, Jhansi, Sangli, Kota, Devanagere, Rajamuhndary
5	1-10	23	Hubli-Dharwad, Jabalpur, Ujjain, Guntur, Kalinga Nagar, Meerut, Nagpur, Eluru, Madurai, Damtal, Haldia, Anpara, Badlapur, Sangareddy. Udaipur, Chennai, Ludhiana, Pune, Jamshedpur, Kolhapur, Ulhasnagar. Srikakulam, Kashipur

Compliance with these directives has remained high, and many have followed the rules where vaccinations were required. In Bihar, ~85% of kilns are now zigzag; in the NCR, at least 25% had converted by 2018 (and non-converters closed). In Jammu & Kashmir, about 415 of 560 kilns applied for clearance, and ~48% had converted to zigzag by Jan 2024 (125 remaining units were ordered closed for violations). However, states that have not yet introduced mandates fall behind; about 10 percent, or 15,000 of the 150,000 kilns in India, have upgraded as of 2023. As a result, partial use of these policies decreases

pollution, for example, Bihar's fast adoption helps cut down coal use and PM in the area, and contributes to a decrease in national $PM_{2.5}$/PM_{10} levels. (Delhi's steady increase in "clean air" days – 209 in 2024 vs 110 in 2016 – reflects all interventions, including kiln controls.

4.5 Policies Implemented for Brick Kiln Modernization

A number of rules and guidelines have been established to promote environmentally sound methods of making bricks. i. Emission Standards: The Air (Prevention and Control of Pollution) Act, 1981, mandates emission limits for kilns. ii. Technology Upgradation: The Regulation for Fly Ash Utilization, 2016, encourages the use of other materials for cement. iii. Financial Incentives: The Energy Efficient Enterprise (E3) scheme and the Credit-Linked Capital Subsidy Scheme (CLCSS) provide funding for kiln owners transitioning to cleaner technologies (Bureau of Energy Efficiency, 2023).

4.6 Analysis and Discussion

ZZKs are recognized for being environmentally superior. ZZKs lower emissions of CO_2 by 30%, Black Carbon (BC) by 80%, and PM2.5 by 35% as well as being 30 percent more energy efficient than FCBTK (Bashir et al., 2023; PCAP, 2023). Yet, relying too much on technology dulls the main point: spreading new technologies in a complex, informal economy. The phased methods and clear rules in NCAP, along with assigned timelines and possible funds, make it a comparative model (NCAP, 2019; Goldmann et al., 2025). Most of the brick kilns in Bihar and Delhi-NCR have adopted ZZKs as a result of orders from courts, demands by buyers, and strong enforcement. By contrast, Pakistan's system fails to enforce its decisions, considers financial assistance without conditions, and lacks a single strong institution, resulting in weak and frequently insincere compliance.

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lacks a single strong institution, resulting in weak and frequently insincere compliance. Despite Punjab budgeting Rs. 1,200 million for 200 kiln improvements and planning a Rs. 300 million Technology Transfer Centre, the lack of effort and absence of regulation have always made these interventions visionary (World Bank/EPD; PCAP, 2023). The lack of a suitable governance plan prevents technology from bringing about major changes. Because much of the sector is not officially registered, using land without proper records, handling funds in cash, and owning property without being banked makes it hard for the sector to get finance.

Although the SBP has offered funding for green kilns through their Refinance Facility, not many kilns have opted for it as they do not meet credit requirements or know about the program (SBP, 2019). The approach is very different in India, where MSMEs obtain credit thanks you to government subsidies, special credit schemes, and guarantees (Bureau of Energy Efficiency, 2023). Besides, although there is a PKR 13.43 billion RECP spending plan for brick kilns, the money actually going to these kilns is very small. When budget and spending do not match, especially in the air quality monitoring DLI, it points to deeper issues of inertia in the system and how politics influences environmental management (Redi, 2024; Andres et al., 2023). A "Not Achieved" score from the DLI and a 0% payout on a large grant sum indicate the institution was more interested in policy ideas than in real results. Often, technological transition initiatives like those advocating ZZKs or VSBKs fail to recognize the cultural resistance involved and the problems of resource restraints. Pakistan's initial failures with mechanized brick production point to a broader issue: policy misalignment with community readiness (PCAP, 2023). In India, rural areas also struggle with compliance for similar reasons. The plans for a Technology Transfer Centre in Punjab's EPD are good, yet they lack definite timeframes, effective reach in villages, and uncertainty around support from select industries. Without localized training programs, pilot demonstrations, and industry co-ownership, the Centre risks becoming yet another underutilized node in Pakistan's policy landscape (World Bank/EPD, 2024).

The Chief Minister of Punjab's Roadmap for Smog Mitigation in Lahore (2024–2025) outlines a series of aggressive enforcement actions and regulatory reforms aimed at curbing air pollution, particularly from brick kilns and industrial emissions. On October 2, 2024, Punjab's government reported inspecting 38,528 brick kilns, issuing over 9,600 notices, sealing over 1,000 kilns, registering 1,217 FIRs, and collecting Rs. 89 million in

fines. The roadmap also highlights that more than 95% of brick kilns in Punjab are now using zigzag firing. Besides, the Indian government has forbidden pyrolysis plants and pyro-carbon fuel, turned to e-mapping and ID labels for brick kilns, and teamed up with Punjab Highways Patrol to find violators by using the Punjab Green App. The government is investing PKR 5 billion in the agricultural sector to help reduce stubble burning by making agricultural machinery accessible to farmers. Changes in legislation are being discussed to increase legal observance, such as banning tires as fuel and requiring companies to follow Corporate Social Responsibility and EURO-V fuel standards.

This roadmap might be ambitious and seem well-planned, but its actual achievements are still not clear. Even with most countries' high claims of compliance, studies show that turning to zigzag technology does not stop pollution unless it is cared for and properly monitored. According to a recent study by Zhang et al. (2023) in Environmental Science & Policy, "technological adoption without institutional oversight often leads to underperformance in emission control." Moreover, the Rs. 5 billion subsidy for stubble-burning alternatives, while commendable, remains "in progress," casting doubt on its immediate impact. Empirical observations in Lahore during past winters, such as those reported by IQAir (2023), continue to rank the city among the most polluted globally, suggesting a gap between official claims and on-ground realities. Also, when harsh actions are taken without fixing underlying flaws, businesses may only stick to the rules briefly and not become more ethical in the long run. Consequently, the pathway can only work well if supported by tougher organizational rules, healthy transparency in records, and combined with effective community efforts in managing the environment.

It appears that the biggest issue is the lack of consistent and reliable monitoring of air quality in zones where bricks are produced. If we do not have proper monitoring systems, it becomes difficult to apply rules and supply the small-scale emissions data needed for making effective policies for certain areas. This scientific vacuum allows political actors to manipulate or suppress environmental data, rendering policymaking reactive and opaque (Andres et al., 2023; Redi, 2024). Using remote sensing, tracking pollution live, and relying on CPCB help India improve its policies and enforce them with ease. Without thorough and accurate data, nobody in Pakistan can be held responsible or informed.

CHAPTER V
CONCLUSION

The industrial production of bricks in Lahore is a major reason for high air pollution in Punjab because the production process is outdated, and regulatory oversight is weak. While Zigzag kilns save lots of energy and emit less CO_2, black carbon, and PM2.5, there has been limited progress in upgrading to cleaner processes. Although the government of Punjab has brought in the Smog Mitigation Roadmap 2024–2025, Clean Air Policy 2023, and the RECP with an allocated PKR 13.43 billion, these actions have not consistently improved the environment across the province.

The biggest and most common barrier to technology use is insufficient funds. The high capital investment required to convert from traditional Fixed Chimney Bull's Trench Kilns (FCBTKs) to Zigzag technology discourages compliance, especially among small and medium-sized enterprises. It is also a challenge that the kiln owners work in the informal sector and do not have the necessary papers or credit rating to qualify for the green banking initiatives managed by the State Bank of Pakistan. Even if matching grants and subsidies are available, many GDPOs continue to avoid them because very few are aware of them, and the process is too complicated.

Technological challenges are also prominent. It takes skilled and technically trained workers to operate and maintain Zigzag kilns, but these skills are not present in the current workforce. Current training and capacity-building mechanisms, such as the Technology Transfer Centre in the Environmental Protection Department, have not taken hold, limiting efforts to scale up innovation. Another challenge is that the failure of existing mechanized models makes the sector slow to embrace new ideas.

In Punjab, applying environmental regulations is hindered by serious systemic issues. While using geo-tagging, CCTV, and drones to inspect kilns is a good sign, the methods are still used in a scattered and reactive way. Because of limited monitoring and political meddling, more kilns that are not following rules can continue working without being caught. The persistent failure of Disbursement-Linked Indicators (DLIs) in air quality monitoring despite allocated funding exemplifies the broader institutional inertia and lack of accountability in environmental governance.

In contrast, comparative policy analysis with India's National Clean Air Programme (NCAP) highlights the potential for a more effective and phased regulatory model. Because of IEPA-2015's rules, most of Delhi-NCR and Bihar use Zigzag kilns as their primary burning practice. Thanks to legislation, credit programs, and monitoring carried out by the CPCB, this progress has been made possible. Improvements in air pollution levels and more clean days in Indian cities are the result of clear enforcement and united efforts by stakeholders.

While the government says almost all kilns in Lahore and Kasur now use the Zigzag model, experts believe that just converting doesn't always reduce emissions. If both best practice procedures and regular, honest monitoring are not in place, even better kilns might still fail to benefit the environment. Additionally, creating a Rs. 5 billion fund for reducing the burning of crop waste in farming is a positive move, yet due to under-implementation, the benefit to air quality is limited.

The key to sustainable brick making in Lahore lies in combining financial approaches, organizational developments, community activity, and new technology. Appropriate support in the form of subsidized lines of credit, loans without collateral, and financing tied to specific results should be made available to the brick kiln sector. Likewise, agencies charged with enforcement should have access to sophisticated tracking devices and must not be controlled by politics to maintain fair and uniform regulation. To significantly lower air pollution and achieve aims in climate and public health, the Lahore brick kiln industry needs strong efforts from all three sectors: policy, finance, and technology.

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