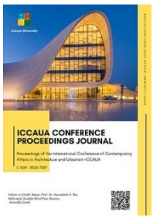

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Towards Eco-Friendly Brick Production in Rajshahi: Overcoming Barriers to Transition from Traditional Practices

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Abstract

Traditional clay bricks are the most used construction material in Bangladesh, yet its manufacture pose considerable environmental and health problems. Pollution from energy-intensive processes has led to calls for a switch to automated, cleaner manufacturing. The transition to automation is being pushed by governments and other organizations. This study investigates the obstacles of the shift from traditional to automated brick manufacture in Rajshahi, Bangladesh's third-largest metropolitan area, using surveys and interviews with kiln owners and operators at the root level. The findings show that approximately 90% of kilns still utilize polluting Fixed Chimney Kilns (FCKs), with little awareness of sustainable alternatives. Excessive investment, lack of experience, limited access to subsidies, qualified personnel, and equipment are all significant impediments. This paper identifies policy and technology options that will enable this transformation. The findings give a framework for policymakers to promote environmentally friendly brick production throughout Bangladesh.

Keywords: Clay Brick Industry; Sustainable Brick Manufacturing; Environmental Challenges; Policy Frameworks.

1. Introduction

The construction sector in Bangladesh has experienced rapid growth in recent decades, driven by fast-paced urbanization, population expansion, and infrastructural development. Among the fundamental materials supporting this growth, bricks hold a central role, largely due to the unavailability of naturally occurring stone in the country's deltaic landscape. Traditionally, bricks in Bangladesh are produced by heating clay blocks in coal-fired kilns—a practice that has become deeply embedded in both rural and peri-urban economies. However, this widespread practice comes at a substantial environmental and socio-economic cost. With over 7,800 kilns in operation and an annual production of approximately 34 billion bricks, the sector is not only one of the most labor-intensive but also one of the most environmentally damaging industrial processes in Bangladesh (World Bank, 2020).

1.1. Background and Context

Bangladesh is currently the fourth-largest producer and consumer of bricks globally, following China, India, and Pakistan. The country's brick industry plays a vital role in supporting national construction efforts, which are expanding rapidly due to sustained urban growth and rising housing demands. With an annual growth rate of approximately 8–10%, the sector continues to scale in response to infrastructural development and demographic pressure. The population, currently nearing 160 million, creates an estimated demand for around 4 million new housing units each year. This growing demand highlights the strategic importance of brick production as a pillar of national development. However, as the industry expands, ensuring its environmental and economic sustainability becomes increasingly urgent (Department of Environment [DoE], 2024; World Bank, 2020).

Conventional brick kilns, particularly Fixed Chimney Kilns (FCKs), have long been recognized as major contributors to greenhouse gas emissions and air pollution. These kilns are often inefficient, relying heavily on the combustion of coal and the extraction of fertile topsoil from agricultural lands. The sector emits over 21 million tons of CO_2 annually and consumes approximately 3.4 billion cubic feet of clay, much of which is extracted from productive agricultural land (Hasan et al., 2022). A significant portion of clay comes from valuable agricultural topsoil. These emissions contribute substantially to air quality degradation, particularly in the dry season when brick production peaks. Urban areas experience PM2.5 levels that frequently exceed World Health Organization (WHO) guidelines by a factor of eight, exposing millions of people to hazardous air pollution levels (Alam & Hossain, 2017).

Figure Error! No text of specified style in document.**:** Types of Kilns Used in Bangladesh and their corresponding CO2 and air pollution (ie., particulate matter, or PM2.5 for short) emissions. (Source: Author).

Despite increasing awareness of the environmental impacts, the adoption of sustainable and energy-efficient alternatives in the brick sector remains minimal. The current market is still dominated by traditional methods, with Zig-Zag kilns accounting for 66% of the production and FCKs contributing another 27%, while energy-efficient kilns such as Tunnel Kilns and Hybrid Hoffman Kilns collectively contribute less than 6%. Non-fired technologies—such as compressed stabilized earth blocks (CSEB) and autoclaved aerated concrete (AAC)—contribute only 0.45% to total production (World Bank, 2020). The adoption of such alternatives remains low due to limited awareness, high investment costs, and inadequate policy enforcement (Hossain, 2019). This sharp imbalance indicates a slow rate of innovation diffusion and highlights deep-rooted structural and institutional barriers that inhibit the transformation of the sector.

Table 1. Market share of different technologies in Bangladesh in FY 2023. (Source: Numbers of brick factories were collected from the DOE and the remaining data was estimated by the consultant)

Type of Kiln	Total Brick Factories FY 2023	Average Annual Production per Factory (Millions of Tons)	Total Annual Production (Millions of Tons)	FY 2023 Market Share by Total Production (Pcs of Bricks)
MCBTK (Drum Chimney)	0	3	-	0.00%
FCK	2235	4	8,940	26.85%
Zig-Zag Kiln	5524	4	22,096	66.35%
HHK (Gas)	6	15	90	0.27%
HHK (Coal)	36	9	324	0.97%
Tunnel Kiln	81	21	1,701	5.11%
Sub Total - Fired Clay Brick	**7882**	**4.21**	**33,151**	**99.55%**
Non-Fired Bricks	20	7.5	150	0.45%
Total	**7902**	**4.21**	**33,301**	**100%**

In response to growing environmental concerns, the Government of Bangladesh has initiated policy interventions aimed at reforming the sector. The Brick Manufacturing and Brick Kiln Establishment (Control) Act 2013 sought to regulate kiln siting and encourage modern technologies. Further, a November, 2019 directive mandates the exclusive use of non-fired blocks in all public construction (excluding roads and highways) by FY2024–25 (MoHPW, 2019). International collaborations such as the Climate and Clean Air Coalition (2019) have also offered roadmaps for technology transition. These policy presents an important opportunity to catalyze transformation within the sector. However, implementation has been sluggish, and the readiness of local industries to adopt such technologies remains uncertain.

1.2. Problem Statement and Research Gap

While national-level policy directives and international guidance have laid the foundation for a greener brick industry, local realities reflect a slower pace of transformation. In regions like Rajshahi—Bangladesh's third-largest metropolitan area—traditional practices persist. The district hosts 137 kilns—roughly 15% of the country's total—and is characterized by the continued dominance of highly polluting FCKs. Despite growing national and international pressure to adopt cleaner technologies, Rajshahi's brick industry remains largely conventional. This scenario makes Rajshahi an ideal microcosm to examine the key barriers, both systemic and operational, that hinder the adoption of eco-friendly alternatives in the broader national context.

The literature to date has thoroughly addressed the environmental and health impacts of traditional brick production (Begum, Biswas, & Hopke, 2011; Guttikunda & Khaliquzzaman, 2014; UNDP, 2020). However, there is a noticeable gap in region-specific studies that consider local dynamics such as resource availability, stakeholder perceptions, policy enforcement, and socio-economic variability. As Rahman et al. (2020) argue, national policy needs to be complemented by granular, localized research to be truly effective. Hence, this study addresses the need for empirical insights rooted in Rajshahi's context—a region that can serve as a microcosm for the broader national transition.

1.3. Objectives and Hypotheses

The primary objective of this study is to investigate the practical, financial, institutional, and technological challenges that impede the transition from traditional brick production to non-fired and environmentally sustainable alternatives in the Rajshahi district. Through field surveys, stakeholder interviews, and quantitative data analysis, the study aims to map out the level of technological readiness, awareness, and willingness among kiln owners to adopt alternative methods. A total of 40 kilns across two upazilas—Paba and Godagari—were surveyed to gather both qualitative and quantitative insights into existing practices, fuel consumption, raw material sourcing, production capacity, and employment patterns. This localized approach provides a grounded understanding of the brick sector's operational realities and informs scalable solutions that can be replicated in other parts of the country.

Beyond identifying barriers, the study also aims to support policy formulation by proposing targeted interventions. These include recommendations for public-private partnerships, financial incentives, training and capacity-building initiatives, and policy reforms that align local practices with national sustainability goals. By analyzing both the limitations and potential of existing brick-making technologies, this research contributes to the broader discourse on industrial ecology and climate resilience in the global South. The specific objectives are:

- To evaluate the level of technological readiness and awareness among kiln owners regarding non-fired and energy-efficient technologies.
- To identify key barriers—financial, operational, and institutional—that hinder the transition to cleaner brick production methods.
- To assess stakeholder expectations related to policy support, incentives, and market readiness for eco-friendly products.
- To propose strategic recommendations tailored to the Rajshahi region, drawing on global best practices and local insights.

In summary, this paper positions the transition of Bangladesh's brick sector—especially in regions like Rajshahi—as a critical step toward meeting national and global sustainability targets. It underscores the urgency of replacing polluting kilns with non-fired technologies and stresses the need for a coordinated, multi-stakeholder approach that includes government agencies, industry actors, research institutions, and local communities. In doing so, it seeks not only to reduce the environmental footprint of brick production but also to support inclusive economic development and healthier living conditions for future generations.

1.5. Literature Review and Sectoral Overview

The brick manufacturing sector in Bangladesh has long been recognized for its critical contribution to the construction industry, yet its environmental and socio-economic implications remain significant concerns. Traditional brick production, particularly through coal-fired kilns such as Fixed Chimney Kilns (FCKs), is one of the largest sources of greenhouse gas (GHG) emissions in the country (World Bank, 2011). These kilns not only emit high levels of carbon dioxide and particulate matter but also depend heavily on fertile agricultural topsoil, contributing to land degradation and food insecurity (Guttikunda & Khaliquzzaman, 2014).

1.5.1. Environmental and Health Impacts

Multiple studies highlight that traditional brick kilns are major contributors to air pollution, particularly in the dry season when brick production peaks. According to Alam and Hossain (2017), PM2.5 concentrations in urban areas often exceed national standards by several fold during peak kiln operation periods. These emissions are linked to respiratory diseases, eye irritation, and chronic health issues, particularly among kiln workers and nearby residents (Begum, Biswas, & Hopke, 2011). Furthermore, the World Bank (2019) noted that emissions from brick kilns are a leading contributor to the worsening air quality in Dhaka and other urban centers.

1.5.2. Economic Significance and Sectoral Challenges

Despite the environmental costs, the brick sector remains economically vital. It contributes approximately 1% to Bangladesh's GDP and employs over 1.5 million people (DoE, 2022). However, the industry is largely informal, fragmented, and dominated by small-scale operators using outdated technologies. This poses a significant challenge for regulation, innovation diffusion, and large-scale adoption of cleaner alternatives (Chowdhury, Rasul, & Khan, 2021).

The dependency on clay sourced from fertile lands further aggravates environmental degradation. According to Hasan et al. (2022), approximately 3.4 billion cubic feet of clay is extracted annually from agricultural land, contributing to reduced crop yields and loss of livelihoods for farmers.

1.5.3. Technological Alternatives and Barriers to Adoption

Modern, energy-efficient technologies such as Zig-Zag kilns, Hybrid Hoffman kilns, and Tunnel kilns offer considerable improvements in fuel efficiency and emission reduction. Studies by the Global Alliance for Clean Cookstoves (2016) and the UNDP (2020) show that such kilns can reduce coal use by up to 30% and significantly cut PM and CO_2 emissions. Additionally, non-fired alternatives—such as compressed stabilized earth blocks (CSEB), concrete blocks, and autoclaved aerated concrete (AAC)—completely eliminate the need for coal combustion.

Despite their benefits, the adoption of cleaner technologies remains minimal in Bangladesh. Less than 10% of the country's brick production utilizes improved kiln technologies, and non-fired options account for less than 1% of total output (World Bank, 2020). Barriers to adoption include high initial capital costs, lack of technical knowledge, insufficient financial incentives, and policy gaps (Hossain, 2019; Akhter & Ahmed, 2021). Many kiln owners are hesitant to invest in unfamiliar technologies without assured market acceptance and regulatory support.

1.5.4. Government Policy and Legal Frameworks

The Government of Bangladesh has taken several steps to reform the brick sector. The Brick Manufacturing and Brick Kiln Establishment (Control) Act 2013 was a major legal initiative to regulate the location and technology of kilns. Later, a 2019 directive from the Ministry of Housing and Public Works mandated that 100% of all public construction by FY2024–25 use non-fired blocks (MoHPW, 2019). While these policies signal strong intent, implementation remains inconsistent due to institutional inertia, lack of enforcement mechanisms, and weak coordination among stakeholders (ADB, 2021).
International frameworks have also influenced national strategies. The Climate and Clean Air Coalition (2019) developed a roadmap for transitioning Bangladesh's brick sector toward cleaner technologies, highlighting the need for capacity-building, financial support, and updated regulatory standards. Although there is extensive literature on the brick sector's environmental impacts and technological solutions, fewer studies provide region-specific analyses, particularly in secondary urban centers like Rajshahi. Local factors such as raw material availability, land ownership patterns, and socio-economic conditions can significantly affect the feasibility of transitioning to eco-friendly practices (Rahman et al., 2020). Thus, empirical studies rooted in regional contexts are essential to develop actionable, localized solutions.

2. Methodology

This study adopted a mixed-methods approach, combining quantitative and qualitative data collection and analysis to examine the barriers to transitioning from traditional brick kilns to non-fired, eco-friendly alternatives in the Rajshahi district of Bangladesh. The methodological framework was designed to capture both the technical and socio-economic dimensions of kiln operations, owner perceptions, and policy awareness in a localized context.

2.1. Study Area Selection

Rajshahi was selected as the primary study area due to its strategic significance in the brick sector, hosting approximately 137 kilns—representing nearly 15% of Bangladesh's total. Two upazilas—Paba and Godagari—were identified as focal zones for investigation because of their high kiln density and operational diversity. These regions provided a representative cross-section of brick-making practices in northwestern Bangladesh.

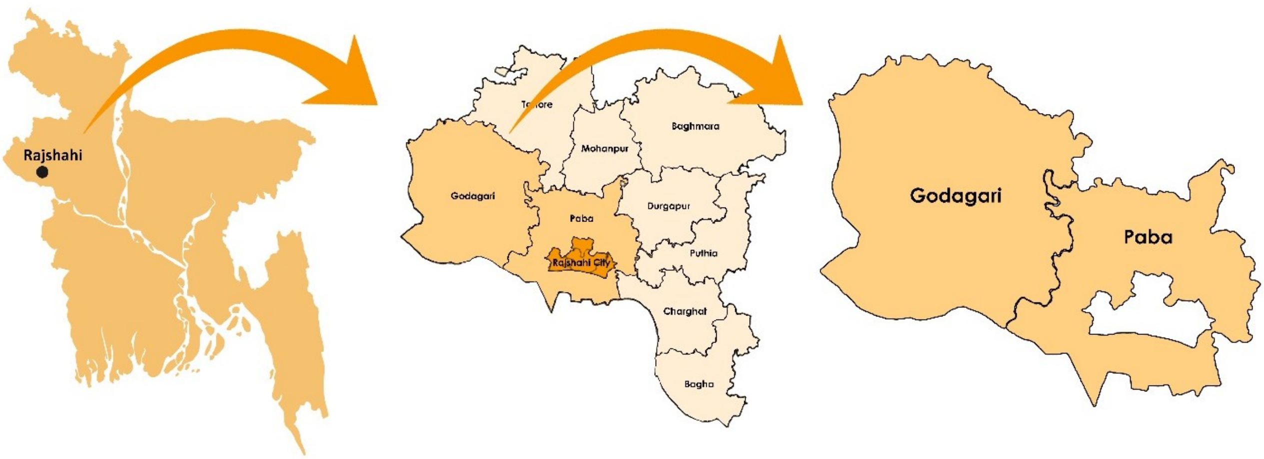

Figure 2: Location of Study Area- Paba and Godagari Upazilla in Rajshahi District. (Source: Author).

2.2. Sampling and Data Collection

A purposive sampling method was employed to select 40 brick kiln units—20 from each upazila. Data collection was carried out through a combination of reconnaissance surveys, structured questionnaires, and semi-structured interviews. The primary respondents included kiln owners, managers, and operational staff, supplemented by consultations with local authorities and stakeholders involved in construction and environmental regulation. Participation was voluntary, and informed verbal consent was obtained from all interviewees.
The questionnaire was designed to capture information across several key variables: kiln type and technology, production and employment capacity, sources of fuel and raw materials, environmental practices, awareness of non-fired technologies, and perceived barriers to adoption. Additionally, respondents were asked about their willingness to transition to cleaner technologies and the kind of support they expected from government or institutional actors.

2.3. Secondary Data Sources

To complement the primary data, a review of secondary sources was conducted. Secondary data was collected through an extensive review of relevant literature, government policy documents, environmental reports, and industry statistics. These sources were used to contextualize the findings from Rajshahi within the broader national framework of brick sector operations and reforms.

2.4. Data Analysis

The collected data were organized and analyzed using descriptive statistics, frequency analysis, and thematic coding to identify patterns and recurring themes. Quantitative findings were visualized through bar charts and percentage distributions, while qualitative insights were synthesized to enrich interpretation and draw conclusions related to policy, technology adoption, and capacity-building needs.

This multi-tiered methodology allowed for a comprehensive understanding of both the operational realities and systemic challenges that define the brick sector's transition potential in Rajshahi.

3. Results

The field survey conducted across 40 kilns in Rajshahi district, covering Paba and Godagari upazilas, yielded revealing insights into the prevailing technologies, production capacities, material sourcing, and transition readiness in the local brick sector.

3.1. Kiln Technology and Environmental Readiness

Table 2. : Kiln Type and Technology. (Source: Field survey, 2025).

Sample Size	Clearance: Yes	Clearance: No	Fixed Chimney Kiln (80ft-120 ft)	Zig-Zag Kiln	Hybrid Hoffman Kiln	Automatic/ Tunnel Kiln	Alternative Tech	Total Environment Friendly Technology	Percentage
40	11	29	16	20	3	1	0	24	60%

Out of the 40 kilns surveyed, only 11 kilns have regulatory clearance, while 29 operate without it. This suggests serious gaps in monitoring and enforcement, which undermine national efforts to improve environmental compliance in the brick sector. Of the surveyed kilns, 40% were Fixed Chimney Kilns (FCKs), 50% were Zig-Zag Kilns, while only 10% operated using Hybrid Hoffman or Tunnel Kilns. None of the kilns used non-fired technologies.

Despite policy pressure, just 60% of kilns fall under the "Total Environment Friendly Technology" category—defined here to include Zig-Zag, Hoffman, and Tunnel kilns, but not non-fired types. This indicates that while some progress has been made, the overwhelming majority of kilns remain dependent on carbon-intensive processes.

3.2. Production and Employment Trends

Table 3. Responses from the respondents about production and employment capacity. (Source: Field survey, 2025).

Aspects of Enquiry	Frequency	% Responses
Production Capacity/Per Year (approximate number)		
1 Million Brick	4	10%
3 Million Brick	4	10%
4 Million Brick	8	20%
5 Million Brick	14	35%
7 Million Brick	6	15%
More than 7 Million Brick	4	10%
Employment Capacity/Per Year (approximate number)		
80-100 Person	6	15%
100-150 Person	14	35%
150-200 Person	9	22.5%
200-250 Person	4	10%
250-300 Person	7	17.5%

In terms of production capacity, the majority of kilns produce around 4 million bricks per year (35%), indicating a prevalence of medium-scale operations. Only 10% produce more than 7 million bricks annually, which aligns with the limited adoption of high-capacity, modern kiln types like Tunnel or Hybrid Hoffman kilns. Employment data mirrors this trend: the most common range is 100–150 workers (35%), followed by 150–200 workers (22.5%). These numbers are consistent with labor-intensive traditional technologies and show the sector's continued reliance on manual labor. This presents a social challenge—modernization could reduce pollution but may also displace unskilled workers if not managed with supportive retraining programs.

3.3. Raw Material and Fuel Dependency

Table 4. Responses from the respondents about raw material and fuel dependency. (Source: Field survey, 2025).

Aspects of Enquiry	Frequency	% Responses
Sources of Raw Material		
Clay of topsoil	16	40%

Clay of riverbed and banks	16	40%
Clay of barren/ fallen land	8	20%
Sources of Fuel		
Coal	36	90%
Jute Chalk	3	7.5%
Gas	1	2.5%

The survey reveals a critical concern regarding resource use. 40% of kilns still depend on topsoil clay, which exacerbates land degradation and threatens agricultural productivity. The same percentage of kilns use clay from riverbeds and banks, which poses risks of erosion and aquatic ecosystem disruption. Only 20% of kilns utilize clay from barren or fallow land, which would be the most sustainable source. This reliance on unsustainable raw materials highlights the urgent need for raw material mapping and strict sourcing regulations.

On the energy front, 90% of kilns rely on coal, with negligible adoption of cleaner alternatives—only 7.5% use jute chalk and a scant 2.5% use gas. This confirms that the environmental footprint of the brick sector remains substantial, and fuel diversification is virtually non-existent in Rajshahi's kiln operations.

3.4. Stakeholder Perspectives and Transition Challenges

Table 5. Responses from the respondents about transition challenges. (Source: Field survey, 2025).

Aspects of Enquiry	Frequency	% Responses
Interested in producing eco-friendly blocks.		
Yes	18	45%
No	22	55%
What are the key barriers preventing kiln owners from transitioning to eco-friendly brick technologies?		
High initial investment cost	40	100%
Limited access to finance and incentives	40	100%
Lack of technical knowledge	31	77.5%
Scarcity of skilled labor	29	72.5%
Policy and regularity gaps	34	85%
Low market acceptance of non-fired bricks	23	57.5%
Resource challanges	25	62.5%
What types of incentives or support do kiln owners expect to facilitate the transition?		
Declare 'Brick Sector' as an 'Industry'	40	100%
Access to finance or loan	40	100%
Tax rebate for non fired bricks	33	82.5%
Training and education	31	77.5%
Import duties brick machineries & equipment	25	62.5%
Review building code	27	67.5%
Promotion of non fired bricks	40	100%
What strategies do kiln owners suggest for increasing the market demand for eco-friendly bricks?		
Increasing business opportunity	40	100%
Reducing VAT on eco-friendly bricks	40	100%
Raw material mapping of eco-friendly bricks	29	72.5%
Promote energy efficiency measures	22	55%
Launching public awareness campaigns	19	47.5%
If assistance is provided, how many days will it take to shift?		
2 Years	3	7.5%
3 Years	5	12.5%
5 Years	16	40%
8 Years	5	12.5%
10 Years	9	22.5%

12 Years	2	5%

Survey findings reveal a divided but promising outlook among kiln owners regarding the adoption of eco-friendly brick technologies. While 45% of respondents showed interest in producing eco-friendly blocks, the remaining 55% were reluctant. The most frequently cited barriers were high investment costs and limited incentives or access to finance (100%), followed by lack of technical knowledge (77.5%), shortage of skilled labor (72.5%), and policy gaps (85%). Furthermore, about 60% of kiln owners viewed low market acceptance and shortage of resources as key obstacles.

Respondents overwhelmingly agreed on key enablers for this transition. All (100%) supported the promotion of non-fired bricks, formal recognition of the brick sector as an industry and access to finance or loan. A large majority also favored tax rebates (82.5%), training and education (77.5%), and building code revisions (67.5%). These results show that while technological awareness exists, systemic support remains inadequate.

To increase demand for non-fired bricks, 100% of respondents recommended business development initiatives and VAT reductions. Additionally, 72.5% suggested raw material mapping of eco-friendly bricks, while about 50% emphasized the promotion of energy efficiency programs and public awareness campaigns.

Among those interested, 40% believed they could shift within five years if proper support was provided, while others expected the transition to take 8–12 years, highlighting the need for time-bound, structured assistance.

In summary, while there is a willingness to transition, progress is hampered by financial, technical, and regulatory challenges. A holistic policy approach—encompassing incentives, training, financing, and awareness—is essential to unlock the sector's potential for sustainable transformation.

4. Discussions

Based on the key findings and analysis of the study, this chapter outlines a set of strategic recommendations to support the transition from traditional brick production to environmentally sustainable alternatives in Rajshahi and other similar regions. These recommendations reflect the perspectives of local stakeholders, align with national policy directives, and draw upon international best practices, including the roadmap developed by the Climate and Clean Air Coalition for Bangladesh's brick sector.

The proposed measures are grouped across key areas such as technology transition, policy reform, institutional capacity, and market development. Together, they aim to address existing barriers and guide policymakers, industry leaders, and development partners in implementing effective, scalable solutions for a cleaner and more resilient brick manufacturing industry.

4.1. Key Observation

This study explored the identification of key barriers to transitioning from traditional brick production methods to eco-friendly technologies in Rajshahi, Bangladesh. The results align with the original hypothesis that while awareness of sustainable alternatives exists among kiln operators, practical implementation remains low due to economic and institutional constraints. Despite policy directives encouraging modernization, such as the 2019 government mandate to adopt non-fired bricks in public construction (MoHPW 2019), 55% of kiln owners surveyed were still reluctant to shift. This hesitancy is attributed to high capital costs, lack of access to low-interest financing, insufficient technical knowledge, and weak market incentives.

Interestingly, about 50% of respondents expressed readiness to adopt eco-friendly technologies within a 3–5 year timeframe if adequate support mechanisms were in place. This suggests that the transition is not technically infeasible, but depends heavily on enabling conditions—a finding supported by Chowdhury, Rasul, and Khan (2021), who argue that institutional frameworks and incentives are critical for environmental innovation in the brick sector.

4.2. Contextualizing Findings within Existing Research

This study's findings are consistent with earlier national and international reports. For example, the World Bank (2020) and UNDP (2020) have identified Bangladesh's brick sector as a major contributor to urban air pollution, due to its heavy reliance on coal-fired technologies. Similarly, Guttikunda and Khaliquzzaman (2014) highlight that brick kilns account for significant PM2.5 emissions in South Asia's urban centers.

However, while national statistics often aggregate challenges, this study adds granularity by focusing on Rajshahi—a kiln-dense, yet under-researched region. In contrast to Hasan et al. (2022), who emphasize national production capacity and policy shifts, this study presents a localized account of the socio-economic and operational realities hindering green adoption. The high consensus on policy needs—especially regarding sector recognition and fiscal incentives—aligns with observations by Hossain (2019), who notes that ambiguity in regulation and enforcement often discourages innovation at the grassroots level.

4.3. Strengths and Limitations

One strength of this study is its grounded, field-based approach using both qualitative and quantitative methods. Data was collected from 40 kiln operators across two upazilas—Paba and Godagari—offering rich insights into technology use, production behavior, resource sourcing, and transition barriers. This localized lens addresses the call by Rahman et al. (2020) for region-specific sustainability analyses in Bangladesh's industrial sectors.

Nonetheless, limitations include the modest sample size, which may not fully represent the diversity of kiln operations across other districts. Additionally, the reliance on self-reported data may introduce response bias, particularly in questions addressing environmental responsibility or future intentions. Moreover, the study does not evaluate actual emission levels, energy use metrics, or lifecycle costs, which are crucial for comparative environmental assessments (ADB 2021).

4.4. Implications and Future Recommendation

The results have important implications for both policymakers and practitioners. The Climate and Clean Air Coalition's (CCAC 2019) roadmap for Bangladesh outlines a phased approach to cleaner brick production—moving from traditional kilns to energy-efficient models (Hybrid Hoffman and Tunnel kilns), and ultimately to non-fired alternatives like compressed stabilized earth blocks and autoclaved aerated concrete.

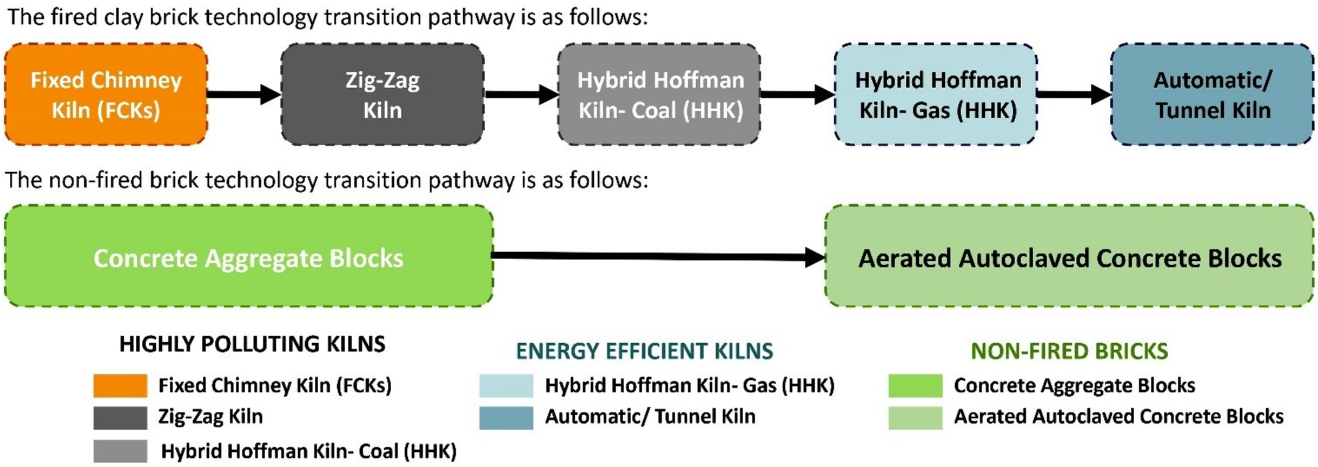

Figure 3: Technology Transition Pathways. (Source: Author).

To operationalize such a roadmap, the following policy actions are recommended:

- Formal recognition of the brick sector as an industry to facilitate access to institutional finance, tax credits, and subsidies (Chowdhury et al. 2021).
- Revision of building codes and procurement policies to mandate or incentivize the use of eco-friendly materials (Hossain 2019).
- Public-private partnerships for the development of demonstration projects showcasing non-fired brick technologies.
- Targeted capacity-building programs for kiln workers and owners to increase technical competency (UNDP 2020).

Table 6. Strategic Recommendations.

Strengthen the Policy Environment	Energy Efficiency and Resource Efficiency	Facilitate Access to Finance and Incentives	Capacity and Institutional Framework
Adoption of Brick Sector Policy and Roadmap	Traditional brick technology Phase out plan	Feasibility Study of Non-Fired Brick Technology	Training and Education
Amendment of 2013 Acts	Raw Material Mapping	Access to Finance	Public Awareness
Declare 'Brick Sector' as an 'Industry'	Standards for Building Materials	Traditional kilns phaseout fund	Raw material Test Laboratory
Review Building Code	Promote Energy Efficiency Measures	Reduce VAT for Hollow Bricks	
Improvement of Data Management System	Promotion of Hollow /Perforated Bricks	Import Duties Brick Machineries & Equipment	
	R&D of Alternative brick making technologies	Tax Rebate for non fired bricks	

Future research should explore the economic viability of eco-friendly kiln models in different regional contexts, possibly through cost-benefit and life cycle analysis. Additionally, longitudinal studies could assess how policy changes influence adoption over time, as suggested by Alam and Hossain (2017). Integrating geospatial mapping of kiln locations and resource use patterns would also aid in planning region-specific interventions.

5. Conclusions

This study set out to examine the barriers to transitioning from traditional brick manufacturing methods to eco-friendly alternatives in Rajshahi, Bangladesh. The findings reveal that while awareness of sustainable technologies exists among kiln operators, practical adoption is constrained by financial limitations, lack of technical knowledge, weak regulatory enforcement, and low market demand. These results confirm the initial hypothesis that systemic and institutional challenges hinder the adoption of cleaner technologies despite policy incentives. The study contributes to the growing body of literature on sustainable construction practices by offering a localized perspective from one of Bangladesh's kiln-dense regions, thus highlighting the need for region-specific interventions. While the sample size and self-reported nature of the data pose limitations, the insights gained are valuable for informing targeted policy, especially regarding access to finance, capacity-building, and industry formalization. Future research should explore the economic feasibility of non-fired technologies, assess long-term environmental impacts, and monitor the effectiveness of implemented policy reforms. Overall, this study underscores the importance of a multi-dimensional, collaborative approach to achieving sustainable transformation in the brick sector, aligning environmental priorities with socio-economic realities.

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Conflict of Interests

The Author(s) declare(s) that there is no conflict of interest.

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