Alliance for an Energy Efficient Economy™

Survey Report on

Technology Adoption and Baseline Operational

Practices of Brick Kilns in East UP Clusters

August 2025

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Acknowledgements

This is a draft of the Survey Technology Adoption and Baseline Operational Survey Report on Practices of Brick Kilns in East UP Clusters prepared by Alliance for an Energy Efficient Economy (AEEE). This document is undergoing peer review and will be finalised through further consultation with Brick Kiln Associations, Brick kiln owners, Experts and Govt officials before being officially published. Full list of reviewer and contributors will be provided at that time.

Alliance for an Energy Efficient Economy (AEEE) supports policy implementation and enables the energy efficiency market with a not-for-profit motive. AEEE promotes energy efficiency as a resource and collaborates with industry and government to transform the market for energy-efficient products and services, thereby contributing toward meeting India's goals on energy security, clean energy, and climate change.

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Disclaimer: This report is based on the data collected during the survey conducted by AEEE team, suggestions from experts and best available information in the public domain. Every attempt has been made to ensure the correctness of the data. However, AEEE does not guarantee the accuracy of the data or accept responsibility for the consequences of the use of such data.

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Executive Summary

The brick-making industry is one of India's most energy-intensive and emission-intensive manufacturing sectors, with over 140,000 kilns nationwide producing roughly 250 billion bricks each year and employing more than 10 million people. Alongside cement and steel, brick ranks among the top three contributors to embodied carbon in construction, accounting for over 35 percent of material-related CO_2 emissions in many buildings. Uttar Pradesh is home for more than 19000 brick kilns and these kilns have been distributed across various districts. The traditional kilns in the state predominantly uses Fixed Chimney Bull's Trench Kilns (FCBTK) which consume large quantities of coal, biomass, or heavy oil at firing temperatures above 1,000 °C, releasing greenhouse gases (CO_2) and air pollutants (black carbon, particulate matter, SO_2, NO_x, and CO) through both combustion and the calcination of clay minerals. The other technology used for brick kilns are Zig Zag kilns which are capable of achieving up to 90% of Class I brick yield (High quality yield) and can provide energy saving up to 30% compared to FCBTK which in terms results in increased profitability and reduced carbon emissions. Govt of India has mandated all the brick kilns to adopt Zig Zag technology or vertical shaft kilns vide notification no GSR 143 (E) in 2023 in a time bound manner.

AEEE as part of their initiative to support low carbon transition in the MSME sector in UP, initiated a scoping study to identify high impact clusters and significant energy saving and emission reduction potential. Among the key findings, the East UP brick kiln sector including Varanasi, Lucknow and Gazipur, emerged as a critical area due to its high energy intensity, widespread use of outdated technologies, and limited availability of recent field-based data. AEEE convened a stakeholder consultation workshop involving policymakers, industry associations, and technical experts to validate the findings and identify next steps. The outcome emphasized the need for deeper, on-the-ground insights into the Zig Zag adoption status and operational practices of brick kilns. Guided by these recommendations and supported by Int Nirmata Parishad (Varanasi), Ghazipur Janpath Int Nirmata Samiti, the Lucknow Brick Kiln Association and subject matter experts in the brick sector, AEEE initiated this detailed field survey to assess existing gaps, understand operational challenges, and evaluate the sector's readiness for targeted energy efficiency interventions. The survey was also focussed on identifying the operational challenges faced by kilns who have adopted the Zig Zag technology but can't utilise its potential at full.

AEEE adopted a robust approach for conducting the survey. AEEE began the survey by designing a comprehensive survey questionnaire covering roughly eighty critical data points in close collaboration with sector experts. Once the form was finalized, we trained our field team on its use, ensuring everyone understood exactly what information to gather and how to verify it on site. Before launching the survey,

AEEE with support from associations, held awareness workshops in Varanasi, Lucknow and Ghazipur, introducing kiln owners to the project's goals and building trust. With this groundwork in place, our team conducted door-to-door visits across more than 150 kilns, interviewing owners, supervisors and operators and closely observing their operational practices to capture an accurate, on-the-ground picture of current technology use and challenges.

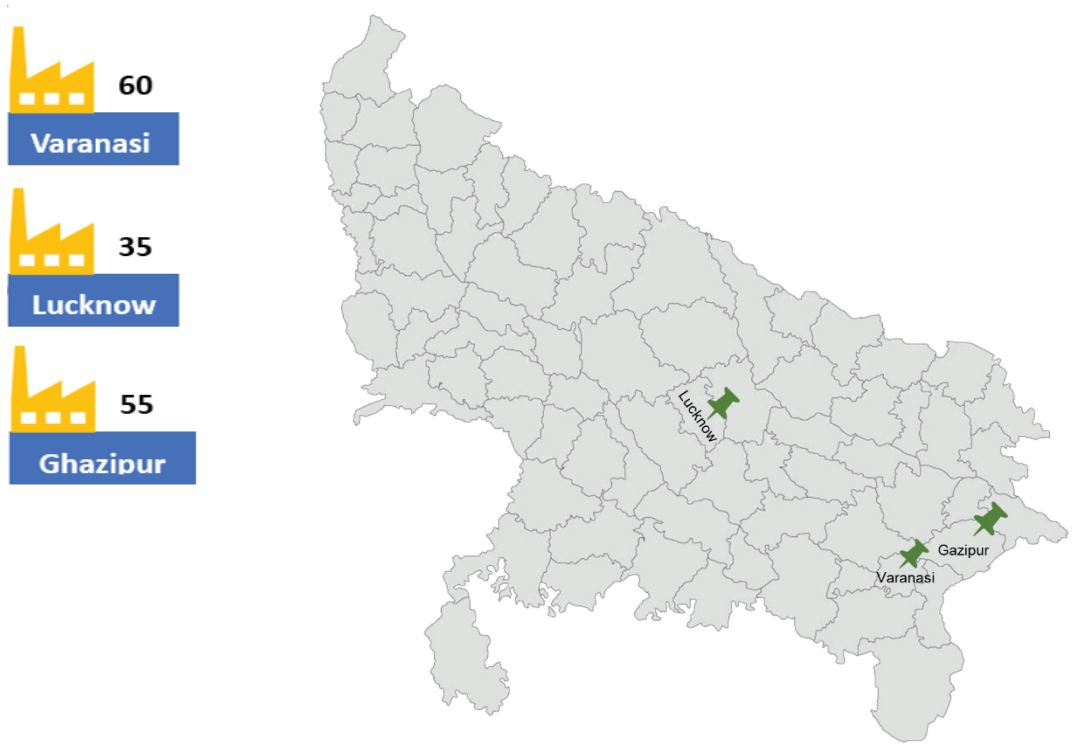


Figure 1: Number of brick kilns covered in the survey

Summary of key findings

Table 1: Comparison of key parameters

S. No.	Parameter	Ghazipur	Lucknow	Varanasi
1	Number of kilns surveyed	55	35	60
2	Zig Zag Adoption (%)	65%	91%	85%
3	% of Class 1 Bricks	67%	63%	67%
4	Fuel consumption from Zig Zag kilns (Ton/01 lakh)	14	15	14
5	Fuel consumption from FCBTK kilns (Ton/01 lakh)	20	13	17
6	Training & Awareness Need (%)	35%	85%	50%
7	Daily Production Capacity	20,800	32,500	20,000

Key Survey insights:

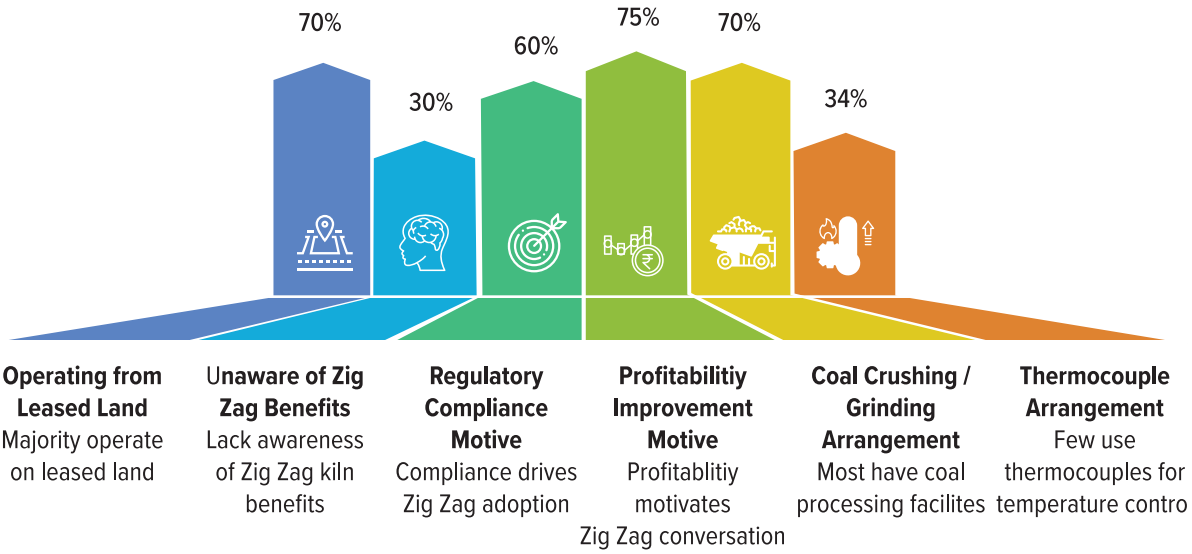


Figure 2: Key survey findings across three clusters

The survey findings reveal distinct trends and challenges across the brick clusters of Ghazipur, Lucknow, and Varanasi. Zig Zag technology adoption is highest in Lucknow (91%) and Varanasi (85%), while Ghazipur lags at 65%. Interestingly, Class 1 brick output is highest in Ghazipur and Varanasi (67%), suggesting better firing quality despite lower Zig Zag uptake in Ghazipur, a potential area for further investigation.

Fuel consumption is notably higher in Lucknow (15 tons per lakh bricks), hinting at operational inefficiencies despite its high Zig Zag coverage, while Ghazipur remains the most efficient at 13 tons of coal consumption per lakh of brick manufactured. The need for training and awareness is most pronounced in Varanasi (50%) and Ghazipur (36%), underlining the importance of capacity building to improve kiln performance and technology usage. In terms of production capacity, Lucknow leads significantly with 32,500 bricks/day, reflecting a higher degree of mechanization or larger kiln sizes, which could be leveraged for wider demonstration and replication of best practices.

It demands an integrated effort on technical, organizational, and policy fronts to rectify the gaps revealed by AEEE survey. Adopters of the Zig Zag technology first need focused, hands-on training to improve firing skills, maximize fuel efficiency, and regulate kiln parameters to achieve their maximum efficiency and quality potential of the technology. Non-adopters, alternatively, need to be approached through intensive knowledge-sharing workshops and peer-learning visits that demystify Zig Zag design, highlight cost-benefit trade-offs, and build operator confidence. Local brick-kiln associations in coordination with financing institutions and government bodies shall design large-scale awareness programs and design customized loan products or incentives that are designed to overcome initial barriers to the transition. To secure sustained gains, an ordered STIA framework (Survey → Training → Improvement → Assessment) needs to be institutionalized and scaled up in phases to other districts, thus evolving a self-sustaining ecosystem that promotes continuous learning and performance monitoring. Finally, enforcement and facilitation mechanisms of the Uttar Pradesh Brick Kilns (Siting Criteria for Establishment) Rules, 2012[1], and the Environment (Protection) Amendment Rules, 2022, will help the state and its brick sector to become a model of energy efficiency and low carbon growth.

1 https://upload.indiacode.nic.in/showfile?actid=AC_UP_88_464_00007_00007_1616154959565&type=rule&filename=final_bricklin_rules_pdf.pdf

CHAPTER

01

Background and Survey Framework

The brick sector in Eastern Uttar Pradesh particularly in the districts of Varanasi, Ghazipur, and Lucknow plays a vital role in the regional economy but continues to operate largely in an informal and energy-intensive manner. Recognizing the need for reliable, updated field-level data and a clear understanding of the current status of Zig Zag technology adoption, AEEE, with technical support from sector experts, initiated a detailed on-ground survey to assess existing practices, identify operational gaps, and evaluate the sector's readiness for clean energy interventions.

To ensure alignment with local stakeholders and facilitate smooth execution, AEEE organized roundtable meetings and consultation workshops within the targeted brick clusters. These engagements helped build trust among stakeholders, gather contextual insights, and secure access to kiln units. AEEE also partnered with key local associations like Int Nirmata Parishad (Varanasi), Ghazipur Janpath Int Nirmata Samiti (Ghazipur), and the Lucknow Brick Kiln Association (Lucknow), who played a critical role in mobilizing kiln owners, validating the survey approach, and strengthening outreach across the region. To maintain high standards of data quality, comprehensive training sessions were conducted for field teams, covering survey protocols, data entry processes, and engagement strategies to ensure accurate and consistent information collection throughout the exercise. This collaborative and systematic approach laid a strong foundation for the survey, which ultimately aimed to inform future interventions to scale up energy-efficient technologies in the brick sector. AEEE also prepared an exhaustive survey having more than 80 data points covering various profile of the kilns like details of operations, fuel consumption, firing practices, etc. and able to collect majority of the information from the kilns. Different teams were deployed at these three districts to collect the data and the team made visits to the kilns regularly to collect the data. To ensure high-quality data collection, comprehensive training programs were conducted for the field teams, including:

- **Mock Surveys:** Simulated field exercises to prepare teams for real-world challenges and accurate data capture.
- **Workshops and training on Zig Zag Technology:** Introducing technical concepts, energy benefits, and implementation nuances.

Figure 3: Onsite visit and training with the expert

CHAPTER

02

District-wise Analysis of Key Parameters

2.1 Gazipur District: Overview of Survey Findings

A total of 55 brick kilns were surveyed in Ghazipur district to assess the adoption of Zig Zag technology and understand ground-level practices. As shown in Figure 5, kilns are located around the city outskirts, in compliance with regulations prohibiting kiln operations within urban limits.

Most kilns were established between 2012 and 2022 (35%), with the earliest kiln in Rampur, dating back to 1972 and upgrading to Zig Zag in 2024. Adoption of Zig Zag technology in the district began in 2018. Of the surveyed kilns, 37 operate on leased land and 18 on owner-owned land.

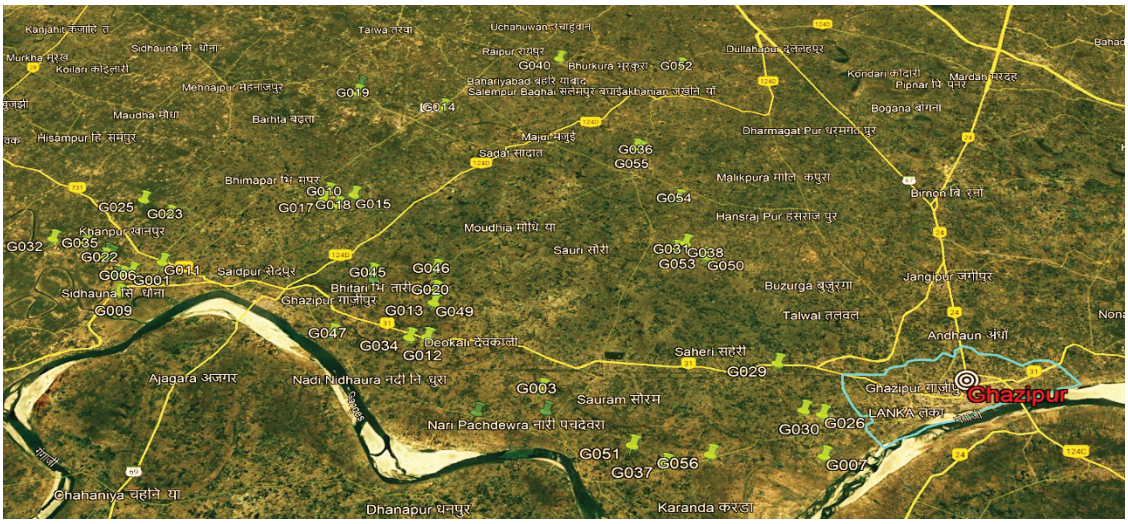
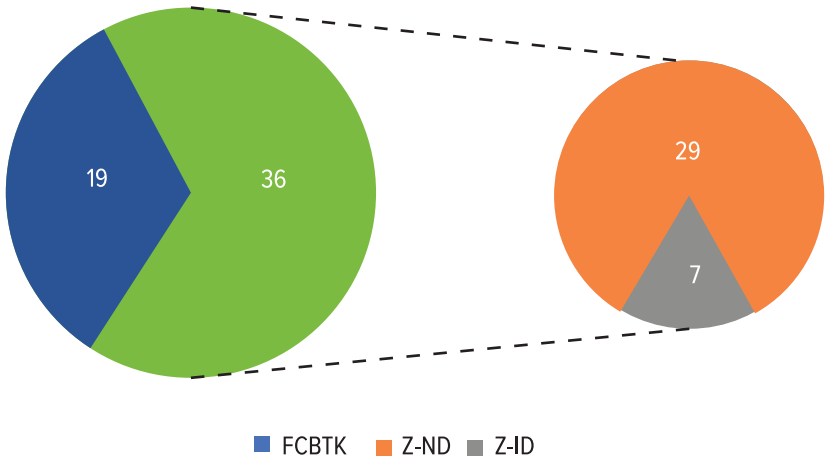


Figure 5: Geo-tagging of surveyed Kilns in Gazipur

2.1.1 Analyse the survey findings in the following parameters:

Technology Adoption Insights:

- Of the surveyed kilns, roughly 67 % reported their investment figures; among these, about 57 % indicated spending between INR 6–21 lakh, with an average outlay of INR 12.6 ± 4 lakh. Investment in Zig Zag adoption ranged from INR 1 lakh to INR 75 lakh, with an average of INR 14.65 lakh



[1]Figure 6: Distribution of Kilns in Gazipur

1 Z-ND= Zig Zag with Natural Draft; Z-ID= Zig Zag with induced draft

Of the 55 surveyed brick kilns in Ghazipur, 36 had adopted Zig Zag technology. Among these, 29 used Natural Draft systems, while 7 employed Induced Draft with diesel-powered fans. Natural Draft was the preferred choice due to its lower operational costs

- Voluntary adoption was the primary driver: 72% of kiln owners cited improved income and productivity as motivation, around 7% adopted solely to comply with regulations and about 21 % cited both voluntary and regulatory reasons for their decision.
- Further, 86% of the kiln owners reported tangible benefits from Zig Zag technology, including improved yield of Class 1 bricks, reduced fuel consumption, and increased production efficiency.

2.1.2 Kilns Performance Indicator on Operational Practices

The operational assessment of 36 Zig Zag kilns in Ghazipur revealed region-specific practices with moderate uniformity. The average trench width was 21.51 feet, with 30 kilns ranging between 18-24 feet. Single brick setting was dominant (69% of kilns), while 31% adopted multiple settings.

For firing operations, 44% of the kilns maintained four open chambers for fuel feeding, and 94% of the kilns completed two chambers every 24 hours, reflecting stable operations. Periodic fuel feeding was widely practiced (94% of the kilns), and alternative fuels like sawdust or powdery biomass were used in freshly opened chambers in 44% of the kilns.

Table -2: Setting of the Zig Zag kilns

S. N	Parameters	Details
1.	Average Trench Width	21.51ft (30 kilns used trench width in the range of 18 to 24 ft)
2.	Type of brick setting	Single (25) and Multiple (11)
3.	Number of chambers open for feeding fuel at any given time	4 Chambers (observed in 16 kilns)
4.	Number of chambers closed/completed every 24 hours	2 Chambers (Observed in 34 kilns), 3 Chambers (Observed in 2 kilns)
5.	Fuel Feeding (Periodic or Continuous)	Periodic fuel feeding observed in 34 kilns
6.	Sawdust or powdery biomass fed as fuel in freshly opened chambers	Observed in 16 kilns
7.	Average Thickness of ash layer on the top of the kiln	5.5 inches
8.	Method of closing the wicket gate: Single brick wall / Double brick wall	Double brick wall observed in 28 brick kilns.
9.	Fuel feed hole covers (tawa): Insulated/ Not Insulated	Observed insulated tawa in 34 brick kilns
10.	Number of shunts used at any given point of time	2 Shunts (observed in all kilns)
11.	Material of shunt: (Steel /Fibre/Iron)	Observed mostly steel shunts in 29 kilns
12	Insulated Shunts	34 kilns having insulated shunts
13.	Arrangement for coal crushing/grinding	32 kilns have arrangements for coal crushing
14.	Tools for temperature measurement	24 kilns have temperature measurement only by thermocouple device.

Based on the operational practices observed in the surveyed kilns in Gazipur, it is evident that several parameters are deviating from the recommended standards in various surveyed kilns. A uniform 9-inch ash layer on top of the kiln must be maintained to provide effective insulation, however, it was observed that kilns are maintaining an average thickness of 5.5 inch. Lesser thickness results in heat loss and lower system efficiency. It is also recommended to keep 2 to 6 chambers open at any given time for fuel feeding,

and closing 2 to 4 chambers every 24 hours, however this practice was adopted in only 45% of the kilns. Around 90% of the units have coal crushers but only 30% of the units are keeping the coal in powder form or up to 5mm in size. Keeping the coal in powder or up to 5 mm size will increase the combustion efficiency. Ensuring uniform temperature across the kiln cross-section will help in maximizing the proportion of Class I bricks. Additionally, the correct type and quantity of fuel/fuel mix must be evenly distributed across all six chambers for consistent combustion.

2.1.3 Class -1 brick production:

- The class I brick percentages is divided into three categories as per figure 7. The consideration is that the more percentage of fired class 1 bricks, the better performing brick kilns.
- The typical percentage distribution of fired class 1 bricks in "more than 70%" category was found in 7 Zig Zag kilns compared to 0 FCBTK kilns.

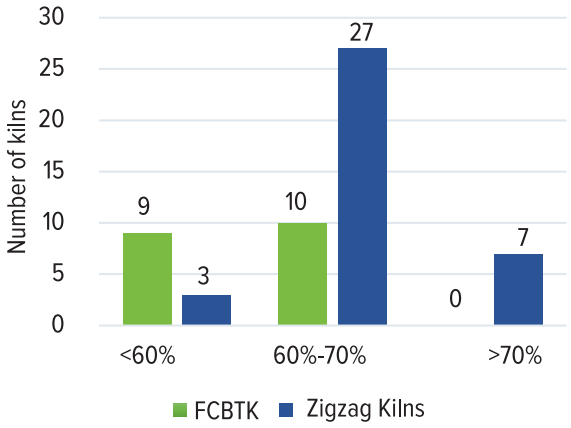


Figure 7: Distribution of Class I bricks in Gazipur

- Similarly, typical percentage distribution of fired class 1 bricks in "60% to 70%" category among bricks types was found in 27 Zig Zag kilns compared to 10 FCBTK.
- This observation indicating better performance of Zig Zag kilns over FCBTK but still typical percentage of class 1 brick is between 60-70% which shows there is potential to optimise the Zig Zag operation and increase the class I brick percentage up to 90%. The seven kilns which is having class I brick percentage over 70% still have potential for improving the operational efficiency of the Zig Zag kilns. This indicate a need for training to the operators and supervisors who are operating the Zig Zag kilns in this area.

2.1.4 Fuel Consumption Pattern:

- The comparison of fuel consumption and associated costs between FCBTK and Zig Zag kilns in Ghazipur district clearly highlights the operational efficiency of Zig Zag technology.
- FCBTKs consume approximately 20 tons of coal per lakh bricks, whereas Zig Zag kilns require only 13.5 tons for the same production, indicating a substantial reduction in coal use.

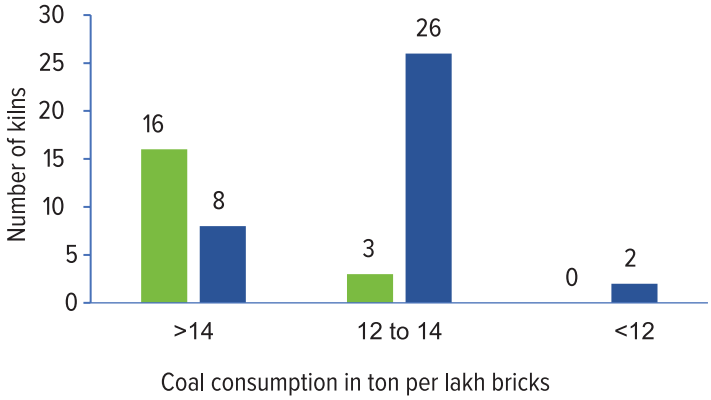


Figure 8: Comparative number of kilns with coal consumption

- Although the average coal landing price is slightly lower in Zig Zag kilns (INR 12,710 per ton) compared to FCBTKs (INR 13,450 per ton), the real saving comes from reduced consumption.
- As a result, the estimated coal cost per 1000 bricks is INR 2700 for FCBTKs and significantly lower at INR 1720 for Zig Zag kilns.
- A similar trend is observed in the use of sawdust and alternative fuels. Zig Zag kilns consume 5 tons per

lakh bricks, while FCBTKs use 7 tons.

- Despite Zig Zag kilns reporting a marginally higher average price for sawdust (INR 6070 per ton compared to INR 5670 for FCBTKs), the lower consumption again leads to cost benefits. The estimated sawdust fuel cost per 1000 bricks stands at INR 305 for Zig Zag kilns and INR 380 for FCBTKs.
- Overall, the total estimated fuel cost per 1000 bricks is INR 2030 in Zig Zag kilns, significantly lower than INR 3080 in FCBTKs. This translates to a saving of over INR 1000 per 1000 bricks.

Table-3: Comparison of Fuel consumption in Zig Zag vs FCBTK

	FCBTK (Total 19 Kilns)			Zig Zag Kilns (Total 36 Kilns)		
Fuel Type	**Ton fuel /lakh bricks (average)**	**Average landing price**	**Estimated fuel cost per 1000 bricks**	**Ton fuel /lakh bricks (average)**	**Average landing price**	**Estimated fuel cost per 1000 bricks**
Coal	20	13450	2700	14	12710	1720
Sawdust and other alternatives	7	5670	380	5.0	6070	305
Total Estimated fuel cost per 1000 bricks			3080			2030

2.1.5 Training and Awareness Needs

- About 63 % of kiln owners having FCBTK expressed a need for support, including:
  - ~47 % calling for awareness programs
  - ~37 % requesting supervisor/operator training
  - ~58 % seeking access to skilled labour
  - ~32 % needing affordable loans or financial aid
- Among Zig Zag adopters, roughly 56 % welcomed further support:
  - 40 % asked for enhanced awareness and technology guidance
  - 25 % requested training for supervisors and workers
  - 35 % sought both awareness and training programs
- A small proportion of owners plan infrastructure upgrades: about 6 % intend to invest in improved moulding methods and roughly 14 % in shaded coverings for their kilns.

2.2 Lucknow District: Overview of Survey Findings:

A total of 35 brick kilns were surveyed, primarily located in the peri-urban areas surrounding the city of Lucknow, as brick kiln operations are not legally permitted within city limits. The study focuses on technological adoption, operational practices, existing challenges, and areas for potential improvement. Figure 8 shows the distribution of surveyed kilns across the Lucknow district, with the city boundary marked in blue.

The surveyed kilns have been established over several decades, with the earliest dating back to 1986 and the majority set up between 2006 and 2016 (40%). Notably, the oldest kiln was established in 1986 and adopted Zig Zag technology in 2024. The adoption of Zig Zag firing technology across the district began in 2018 and has gradually increased since then. Of the 35 kilns surveyed, 13 are operated on leased land,

while the remaining 22 are owner-operated.

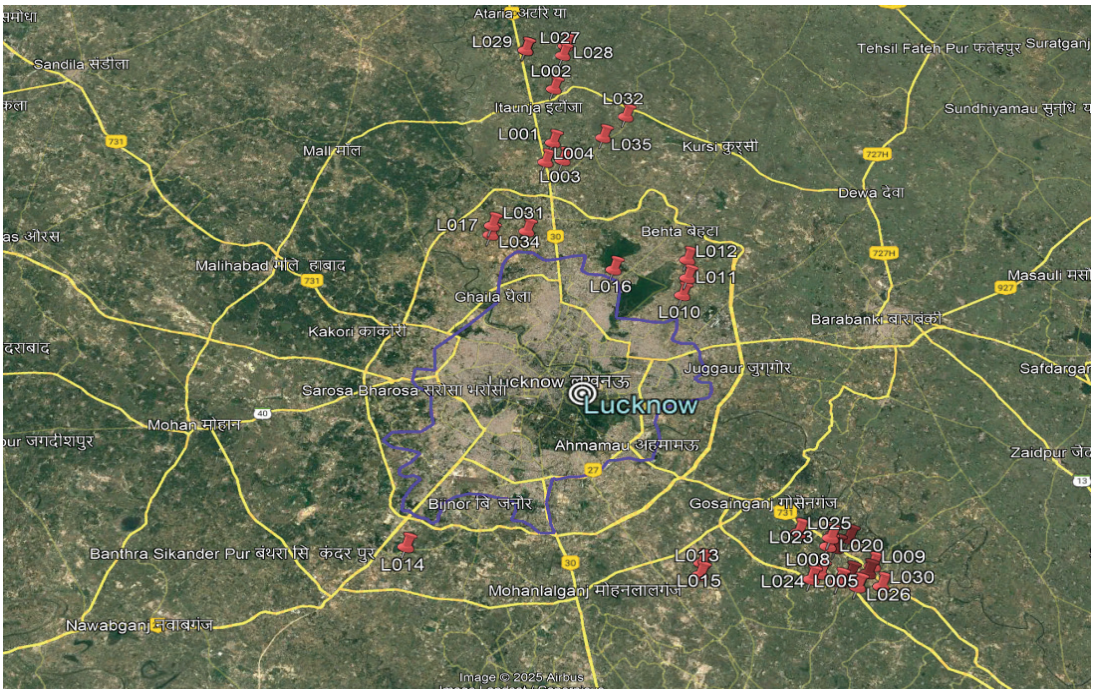


Figure 10: Geo-tagging of Kilns in Lucknow

2.2.1 Technology Adoption:

- Of the surveyed kilns, Investment in Zig Zag adoption ranged from INR 1 lakh to INR 70 lakh, averaging INR 28 lakh; over 60% of adopters invested less than INR 40 lakh, with an average outlay of INR 18 ± 2 lakh
- Of the brick kilns surveyed in Lucknow, approximately 90% have adopted Zig Zag technology; among these adopters, about 88% use Natural Draft systems, roughly 13% Induced Draft, and around 6% each rely on diesel-engine fans and grid-electricity setups.
- Natural Draft was preferred primarily due to its lower operational costs.
- Regarding the motivation for adoption, 40% of kiln owners cited both voluntary reasons such as improving the share of Class 1 brick production and the need to meet compliance mandates.
- Half of the adopters (50%) implemented Zig Zag technology solely to meet regulatory mandates, yet 88% of those subsequently reported benefits like higher Class I output and reduced fuel use.
- Just under 6% of adopters expressed dissatisfaction, noting no significant gains over their previous FCBTK operations.
- Around 9% of kiln owners adopted the technology entirely by choice and confirmed tangible performance improvements.

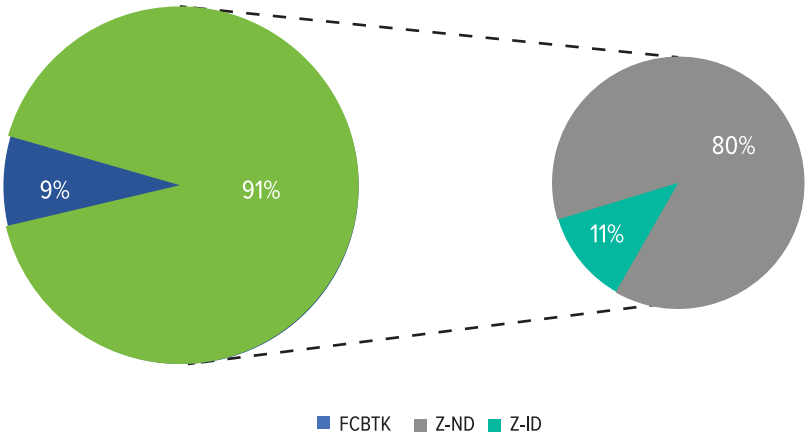


Figure 11: Distribution of Kilns in Lucknow

2.2.2 Kilns Performance Indicator on Operational Practices:

- The operational assessment of Zig Zag kilns in Lucknow indicates partial standardization with several localized adaptations. Among the kilns surveyed, 91% were Zig Zag kilns, while only 9% continued to operate as traditional FCBTKs.
- The average trench width across the Zig Zag kilns was 25.38 feet, with approximately 77% falling within the optimal range of 20–28 feet. Single-layer brick setting was predominant, practiced by around 83% of kilns, while only 11% employed multiple-layer settings.
- Periodic fuel feeding was followed by 91% of kilns, with about 40% typically opening three chambers and 29% opening two during feeding. Similarly, about 43% of kilns regularly closed three chambers per day, reflecting a relatively consistent firing cycle.
- Sawdust or powdery biomass was used as a supplementary fuel during initial combustion in roughly 80% of the kilns.
- An ash layer averaging 7.5 inches was commonly used to insulate kiln tops. Double brick walls were used to seal wicket gates in 83% of kilns, enhancing thermal efficiency. However, only 34% of kilns had insulated covers (tawas) over fuel feed holes.
- About 77% used two shunts, with 60% relying on iron-based versions and only 14% using insulated ones. While 77% of kilns had coal crushing infrastructure, none were equipped with temperature monitoring tools, pointing to a critical gap in scientific process control and thermal management.
- Overall, while many kilns have incorporated efficiency-enhancing practices, significant gaps remain in thermal insulation and process instrumentation, highlighting opportunities for targeted technical upgrades and operator training.

Table 4. Setting of Zig Zag kilns of Lucknow (Based on survey response from brick kilns)

SN	Parameters	Details
1.	Average Trench Width	25.38 ft (27 kilns used trench width in the range of 20 to 28 ft)
2.	Type of brick setting	Single (29) and Multiple (4)
3.	Number of chambers open for feeding fuel at any given time	3 Chambers (observed in 14 kilns) and 2 chambers (observed in 10 kilns)
4.	Number of chambers closed/completed every 24 hours	3 Chambers (Observed in 15 kilns) and 2 chambers (observed in 10 kilns)
5.	Fuel Feeding (Periodic or Continuous)	Periodic fuel feeding observed in 32 kilns
6.	Sawdust or powdery biomass fed as fuel in freshly opened chambers	Observed in 28 kilns
7.	Average Thickness of ash layer on the top of the kiln	7.51 inches
8.	Method of closing the wicket gate: Single brick wall / Double brick wall	Double brick wall observed in 29 brick kilns.
9.	Fuel feed hole covers (tawa): Insulated/ Not Insulated	Observed insulated tawa in 12 brick kilns
10.	Number of shunts used at any given point of time	2 Shunts (observed in 27 kilns)
11.	Material of shunt: (Steel /Fibre/Iron)	Observed mostly iron shunts in 21 kilns
12	Insulated Shunts	5 kilns having insulated shunts
13.	Arrangement for coal crushing/grinding	27 kilns have arrangements for coal crushing
14.	Tools for temperature measurement	No kilns have temperature measurement tools

Based on the operational practices observed in the surveyed kilns in Lucknow, it is evident that several parameters are deviating from the recommended standards in various surveyed kilns. The trench width shown that the kilns are of higher capacity as compared to the kilns in Gazipur. The ash layer thickness is higher than Gazipur but still not as per the standards which is 9-inch on top of the kiln. Only 34% of the kilns have insulated tawa for fuel feeding which shown a retrofitting option to improve the efficiency of the kilns. Around 77% of the units have coal crushers but only 25 % of the units are keeping the coal in powder form or up to 5mm in size. None of the kilns are using the temperature control device which are very important to monitor the heat and plan the fuel feeding to ensure uniform heating and improved class I brick percentage.

2.2.3 Class -1 brick production:

- A comparative analysis of brick type distribution and pricing between FCBTK and Zig Zag kilns in Lucknow highlights the economic superiority of Zig Zag technology.
- Zig Zag kilns produce a higher share of Class 1 bricks (63%) compared to FCBTKs (48%), with a significantly better average selling price of ₹6940 per 1000 bricks, against ₹5770 in FCBTKs. This leads to a higher revenue contribution of ₹4390 per 1000 bricks for Zig Zag kilns, versus ₹2770 for FCBTKs.
- Conversely, FCBTKs yield more lower-grade bricks Class 2 (21%) and Class 3 (18%) than Zig Zag kilns (15% and 12%, respectively), and at lower prices (₹4730 and ₹3170 for FCBTKs versus ₹6120 and ₹3970 for Zig Zag).
- Additionally, broken bricks form 10% of FCBTK output compared to only 6% in Zig Zag kilns, further diminishing overall profitability.

Table-5 Class -1 brick production

	FCBTK (Total 3 Kilns)			Zig Zag Kilns (Total 32 Kilns)		
Brick Type	**Typical Distribution of bricks (%)**	**Average Selling Price (INR/1000 Bricks)**	**Total Estimated selling price (INR/1000 Bricks)**	**Typical Distribution of bricks (%)**	**Average Selling Price (INR/1000 Bricks)**	**Total Estimated selling price (INR/1000 Bricks)**
Fired class 1 bricks	48	5770	2770	63	6940	4390
Fired class 2 bricks	21	4735	995	15	6120	915
Fired class 3 bricks	18	3170	570	12	3970	460
Broken bricks	10	2335	230	6	3085	200
Other Bricks	3	0	0	4	78	3
Estimated Revenue from 1000 fired bricks			4565			5970

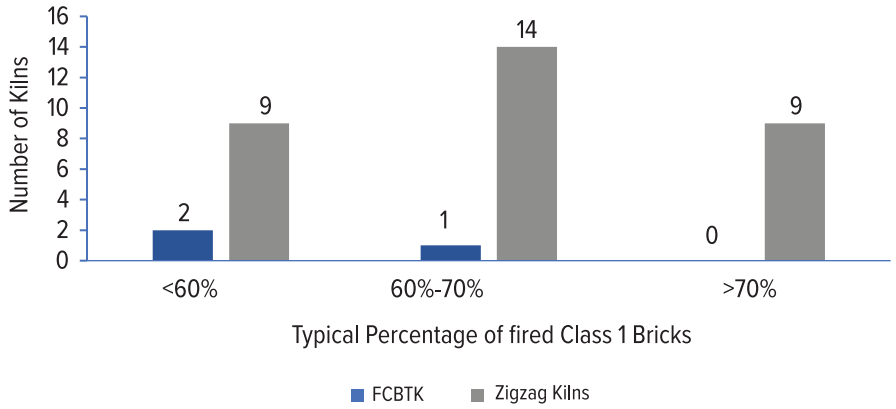


Figure-10 Percentage of fired Class 1 Bricks

- The typical percentage distribution of fired class 1 bricks in "more than 70%" category was found in 9 Zig Zag kilns compared to 0 FCBTK kilns.
- Similarly, typical percentage distribution of fired class 1 bricks in "60% to 70%" category among bricks types was found in 14 Zig Zag kilns compared to 1 FCBTK.
- This observation indicating better performance of Zig Zag kilns over FCBTK but still typical percentage of class 1 brick is between 60-70% which shows there is potential to optimise the Zig Zag operation and increase the class I brick percentage up to 90%. The nine kilns which is having class I brick percentage over 70% still have potential for improving the operational efficiency of the Zig Zag kilns. This indicate a need for training to the operators and supervisors who are operating the Zig Zag kilns in this area.

2.2.4 Fuel consumption:

- The analysis of fuel consumption and costs between FCBTK and Zig Zag kilns in Lucknow reveals a notable contrast. Despite the improved combustion efficiency of Zig Zag kilns, they exhibit higher average fuel consumption i.e. 15 tons of coal per lakh bricks compared to 13 tons in FCBTKs.
- Additionally, the average coal landing price is higher for Zig Zag kilns (₹12,515/ton) than for FCBTKs (₹11,500/ton), resulting in a higher coal cost of ₹1805 per 1000 bricks versus ₹1440 in FCBTKs.
- Zig Zag kilns also consume more alternative fuels, averaging 4.7 tons per lakh bricks, compared to 3.5 tons in FCBTKs. These fuels are also costlier for Zig Zag kilns (₹8125/ton) than FCBTKs (₹5875/ton), leading to a higher alternative fuel cost of ₹380 per 1000 bricks compared to ₹205.
- In total, the estimated fuel cost per 1000 bricks is ₹2190 for Zig Zag kilns substantially higher than ₹1640 for FCBTKs. However, this elevated cost is often balanced by the superior brick quality, higher selling prices, and reduced emissions offered by Zig Zag technology, making it a more sustainable and economically viable option in the long run.

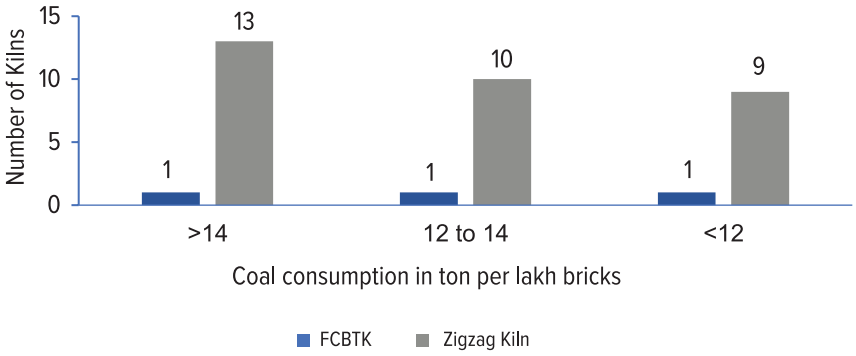


Figure-11 Fuel 1 (Coal) consumption in ton per lakh bricks

2.2.5 Training and Awareness Needs

- FCBTK kiln owners highlighted the need for awareness programs, technical training, access to skilled labour, and affordable financing options.
- Among the kilns that had adopted Zig Zag technology, approximately 69% expressed interest in further support. Specifically, around 31% sought help in improving awareness and technological know-how, 3% requested training support for supervisors and workers, and 34% expressed a need for both.
- Additionally, a small proportion of kiln owners indicated plans to invest in improved moulding methods (6%) and infrastructure upgrades such as shaded areas for kiln operations (14%).

2.3 Varanasi District: Overview of Survey Findings:

In Varanasi cluster, around 60 kilns have been surveyed and all the surveyed units were located on the outskirts of Varanasi, as illustrated in Figure 7. The surveyed kilns were established between 1985 and 2022, with the majority set up during 2005-2015 (40%). The oldest kiln surveyed was established in 1985, which had not adopted Zig Zag technology at the time of the survey. The earliest adopter of Zig Zag among the surveyed units was established in 1986 and upgraded in 2018. Of the 60 kilns, 41 were operating on leased land, 15 were owner-operated, and 4 had a mixed model of ownership and lease.

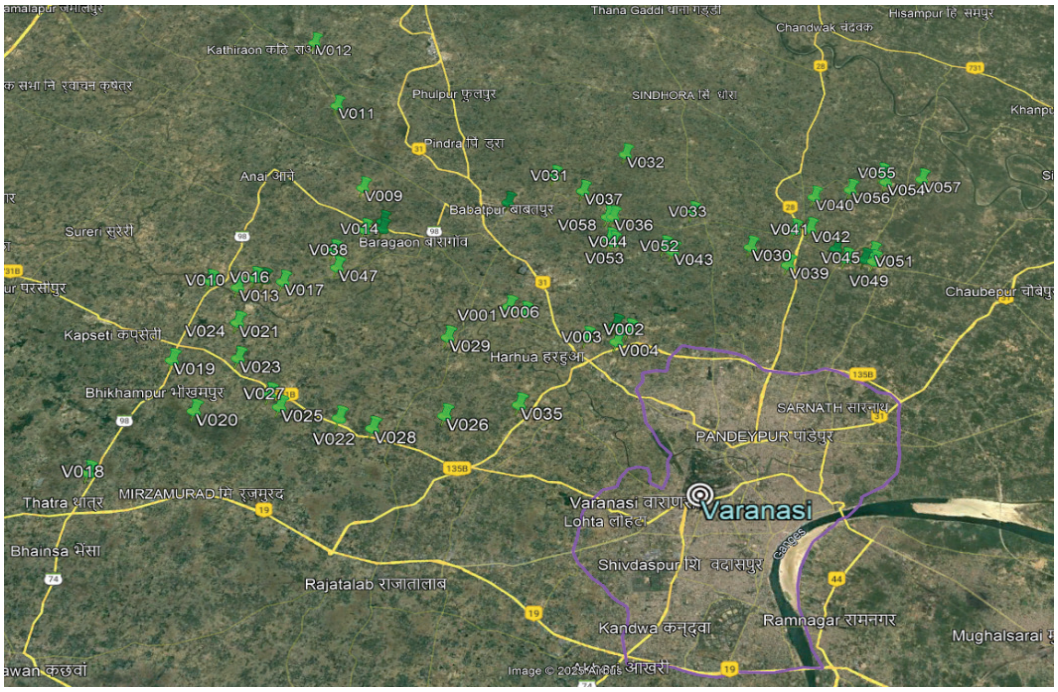


Figure 12: GPS tagging of surveyed brick kilns in Varanasi

3.3.1 Technology Adoption:

- The reported investment in technology adoption varied from INR 2 lakh to INR 80 lakh, averaging INR 16 lakhs. Approximately 58 % of surveyed kilns reported investing less than INR 40 lakh, with an average outlay of INR 15 ± 7 lakh.
- 50 brick kilns out of 60 surveyed kilns were found with Zig Zag technology in the Varanasi district.
- Out of 50 kilns, 42 kilns employed Natural Draft, while 8 kilns adopted Induced Draft with diesel engine-powered fans (4 kilns), diesel generator (1 kilns) and grid electricity (3 kilns).
- Natural Draft was preferred over induced draft mostly because of reducing cost of operation.
- About 60% of the kilns owner accepted for voluntarily adoption of Zig Zag technology for improved in percentage production of class 1 bricks and also to meet their compliance mandate.
- Around 30% of the kiln owners voluntarily adapted Zig Zag technology in their kilns to explore the technology benefit. Only 6% of the kilns owner accepted that adoption of Zig Zag technology was done because to meet their compliances mandate only.
- Though, mostly agreed they got benefits from it in the term of production of class 1 bricks and reduced fuel consumption but a few kiln owners disagree that there is any difference between FCBTK and Zig Zag Technology in terms of benefits.

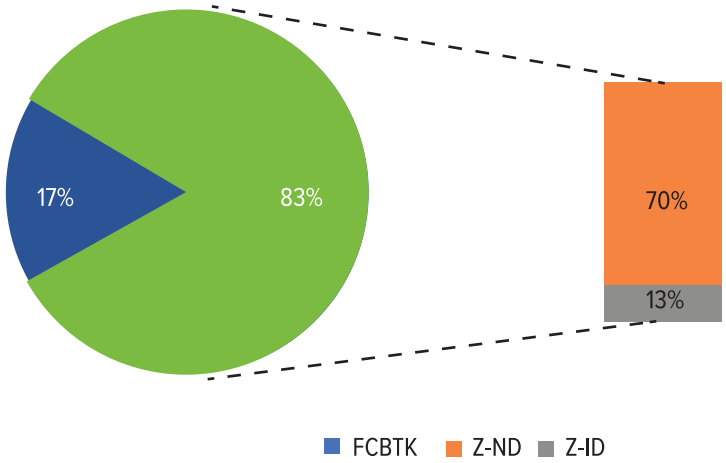


Figure -12 Zig Zag adoption in Varanasi District

2.3.2 Kilns Performance Indicator on Operational Practices:

- The assessment of operational features of Zig Zag brick kilns in Varanasi reveals a largely standardized adoption pattern with certain regional variations.
- The average trench width was 21.86 feet, with most kilns ranging between 18 to 28 feet. Multiple-layer brick settings were dominant, adopted by 84%of the kilns, while only 5% used single-layer arrangements.
- Periodic fuel feeding was practiced in 56% of the kilns, typically with 3 (19 kilns) or 4 (15 kilns) chambers open at a time, and 2 or 3 chambers closed every 24 hours in 50% and 26% of the kilns respectively. Supplementary use of sawdust or biomass in newly opened chambers was observed in 77% of the kilns.
- Insulation measures included an average ash layer of 7.7 inches and the use of insulated tawas in 77% of the kilns; however, 53% of the kilns still sealed their wicket gates with single brick walls, affecting heat retention.
- Most kilns (around 90%) operated with 2 shunts, predominantly made of steel while few only had insulated shunts.
- Coal crushing or grinding units were present in 73% of the kilns, indicating a focus on fuel preparation.
- Overall, the kilns exhibit a matured Zig Zag design, but critical gaps remain in insulation and temperature monitoring.

Table-6: Kilns Performance Indicator

SN	Parameters	Details
1.	Average Trench Width	21.86 ft (40 kilns used trench width in the range of 18 to 28 ft)
2.	Type of brick setting	Single (4) and Multiple (50)
3.	Number of chambers open for feeding fuel at any given time	3 Chambers (observed in 19 kilns) and 4 chambers (observed in 15 kilns)
4.	Number of chambers closed/completed every 24 hours	3 Chambers (Observed in 16 kilns) and 2 chambers (observed in 31 kilns)
5.	Fuel Feeding (Periodic or Continuous)	Periodic fuel feeding observed in 34 kilns
6.	Sawdust or powdery biomass fed as fuel in freshly opened chambers	Observed in 46 kilns

SN	Parameters	Details
7.	Average Thickness of ash layer on the top of the kiln	7.7 inches
8.	Method of closing the wicket gate: Single brick wall / Double brick wall	Single brick wall observed in 32 brick kilns.
9.	Fuel feed hole covers (tawa): Insulated/ Not Insulated	Observed insulated tawa in 46 brick kilns
10.	Number of shunts used at any given point of time	2 Shunts (observed in 50 kilns)
11.	Material of shunt: (Steel /Fibre/Iron)	Observed mostly steel shunts in 43 kilns
12	Insulated Shunts	5 kilns having insulated shunts
13.	Arrangement for coal crushing/grinding	44 kilns have arrangements for coal crushing
14.	Tools for temperature measurement	15 kilns have temperature measurement using thermocouples

Based on the operational practices observed in the surveyed kilns in Varanasi, it is evident that several parameters are deviating from the recommended standards in various surveyed kilns. A uniform 9-inch ash layer on top of the kiln must be maintained to provide effective insulation, however, it was observed that kilns are maintaining an average thickness of 7.7 inch. Lesser thickness results in heat loss and lower system efficiency. It is also recommended to keep 2 to 6 chambers open at any given time for fuel feeding, and closing 2 to 4 chambers every 24 hours, however this practice was adopted in only 50% of the kilns. Only 25% of the kilns had thermocouples or similar temperature monitoring tools, pointing to limited scientific process control. Ensuring uniform temperature across the kiln cross-section will help in maximizing the proportion of Class I bricks. Additionally, the correct type and quantity of fuel/fuel mix must be evenly distributed across all six chambers for consistent combustion

2.3.3 Class -1 brick production:

- The comparison of brick type distribution and pricing between FCBTKs and Zig Zag kilns in Varanasi underscores the economic advantage of Zig Zag technology.
- Zig Zag kilns produce a higher share of Class 1 bricks (67%) than FCBTKs (50%), resulting in greater revenue contribution of ₹4,250 per 1,000 bricks despite a marginally lower average selling price (₹6,370 vs. ₹6,600).
- Lower-grade bricks (Class 2 and 3) account for only 12% and 9% of Zig Zag output, compared to 22% and 11% in FCBTKs, indicating improved product quality.
- The share of broken and miscellaneous bricks is also lower in Zig Zag kilns, reducing material losses.
- Overall, the estimated revenue per 1,000 fired bricks is higher for Zig Zag kilns at ₹5,490, compared to ₹5,250 for FCBTKs, reflecting better quality distribution and enhanced profitability.

Table-7: Class -1 brick production

	FCBTK (Total 10 Kilns)			Zig Zag Kilns (Total 50 Kilns)		
Brick Type	Typical Distribution of bricks (%)	Average Selling Price (INR/1000 Bricks)	Total Estimated selling price (INR/1000 Bricks)	Typical Distribution of bricks (%)	Average Selling Price (INR/1000 Bricks)	Total Estimated selling price (INR/1000 Bricks)
Fired class 1 bricks	50	6600	3300	67	6370	4250
Fired class 2 bricks	22	5050	1110	12	5010	615

Fired class 3 bricks	11	3400	375	9	3380	295
Broken bricks	9	1550	140	7	1525	102
Other Bricks	8	4100	330	6	4100	230
Estimated Revenue from 1000 fired bricks (Rs)			5253			5491

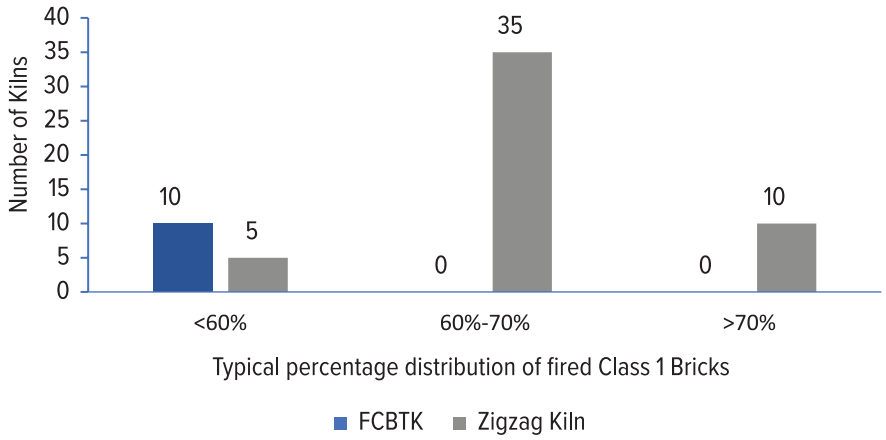


Figure -13: Comparative number of kilns with the percentage distribution of fired class 1 bricks

- The typical percentage distribution of fired class 1 bricks in "more than 70%" category was found in 10 Zig Zag kilns compared to 0 FCBTK kilns. Out of these only 3 kilns are having class I brick percentage of around 80%.
- Similarly, typical percentage distribution of fired class 1 bricks in "60% to 70%" category among bricks types was found in 35 Zig Zag kilns compared to 0 FCBTK.
- This observation indicating better performance of Zig Zag kilns over FCBTK but still typical percentage of class 1 brick is between 60-70% which shows there is potential to optimise the Zig Zag operation and increase the class I brick percentage up to 90%. The 10 kilns which is having class I brick percentage over 70% still have potential for improving the operational efficiency of the Zig Zag kilns. This indicate a need for training to the operators and supervisors who are operating the Zig Zag kilns in this area.

2.3.4 Fuel Consumption Pattern:

- The fuel usage and associated costs reveal the relative efficiency and cost-effectiveness of Zig Zag kilns compared to FCBTKs. On average, FCBTKs consume 17 tons of coal per lakh bricks, whereas Zig Zag kilns consume significantly less at 14 tons per lakh bricks, despite a slightly higher average landing price of ₹11,500 per ton in Zig Zag kilns compared to ₹11,300 in FCBTKs.
- This reduced coal consumption leads to a lower estimated coal cost per 1000 bricks ₹1660 for Zig Zag kilns versus ₹1940 for FCBTKs.
- In terms of alternative fuels like sawdust and other biomass options, Zig Zag kilns use slightly more (3.8 tons/lakh bricks) compared to FCBTKs (3.3 tons/lakh bricks), with a higher average landing price of ₹5875 per ton in Zig Zag kilns. As a result, the estimated cost of these alternatives per 1000 bricks is higher for Zig Zag kilns at ₹225 compared to ₹150 for FCBTKs.
- Despite the higher cost of alternative fuels, the total estimated fuel cost per 1000 bricks is lower in Zig Zag kilns (₹1885) than in FCBTKs (₹2080). This clearly reflects the improved fuel efficiency

and combustion control in Zig Zag kilns, leading to cost savings and a more sustainable fuel usage profile.

Table-8: Fuel Consumption Pattern

	FCBTK (Total 10 Kilns)			Zig Zag Kilns (Total 50 Kilns)		
Fuel Type	**Ton fuel /lakh bricks (average)**	**Average landing price**	**Estimated fuel cost per 1000 bricks**	**Ton fuel /lakh bricks (average)**	**Average landing price**	**Estimated fuel cost per 1000 bricks**
Coal	17	11300	1935	14	11500	1660
Sawdust and other alternatives	3.3	4570	150	3.8	5875	225
Total Estimated fuel cost per 1000 bricks			2085			1885

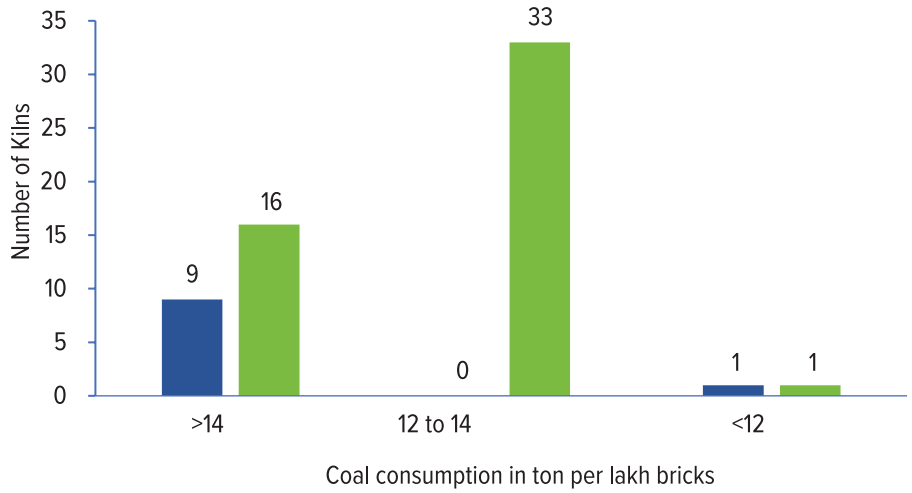


Figure -14 Coal consumption in ton per lakh bricks

3.3.5 Training and Awareness Needs

- All FCBTK Kiln owners expressed the need for awareness programs, training, access to skilled labour, and affordable loans or financial support.
- On the other hand, 64% of brick kilns with Zig Zag adoption requested support like: 6% sought increased awareness and technological knowledge, 20% needed training for supervisors and workers, and 38% required both types of support.
- A few bricks kilns owner expressed their planning to invest in moulding methods (15% of the kilns) and providing shades to kiln (5% of the kilns).

CHAPTER

03

Comparative Analysis

This comparative analysis of field survey report examines the adoption of Zig Zag Technology in brick kilns across three districts in Uttar Pradesh: **Ghazipur, Lucknow, and Varanasi**. The data is based on surveys conducted in each district, covering a representative sample of brick kilns.

3.1 Adoption of Zig Zag Technology

Table 09 District wise comparative table of targeted kilns and surveyed kilns.

District	Targeted number of kilns	Number of Kilns Using Zig Zag Tech	Number of kilns with Zig Zag (Natural Draft)	Number of kilns with Zig Zag (Induced Draft)
Ghazipur	55	36	29	7
Lucknow	35	32	28	4
Varanasi	60	51	43	8

3.2 Brick Production:

Table 10. District wise comparative table of production parameters of Zig Zag kilns

SN	Parameters	Zig Zag Kilns in Ghazipur (Total 36 Kilns)	Zig Zag Kilns in Lucknow (Total 32 Kilns)	Zig Zag Kilns in Varanasi (Total 50 Kilns)
1	Production Capacity: Daily brick firing capacity (bricks/day)	20,830	32,470	20,000
2	Starting month of brick kiln operation	Jan (22 kilns), Feb (13 kilns), other months (1 kilns)	Jan (15 kilns), Feb (13 kilns), other months (4 kilns)	Jan (25 kilns), Feb (15 kilns), other months (10 kilns)
3	Ending month of brick kiln operation	May (21 kilns), June (15 kilns), other months (0 kilns)	May (13 kilns), June (19 kilns), other months (0 kilns)	May (43 kilns), June (7 kilns), other months (0 kilns)
4	No. of Months of kiln operation	5.05 Months (Average)	5.34 Months (Average)	5.12 Months (Average)
5	No. of bricks fired in one season	26. lakh	60 lakh	28 lakh
6	Average weight of fired brick (kg/brick)	3	3	3

3.3 Estimations related to Class 1 bricks

Table 11. District wise comparative matrix of production and estimated selling price of Class 1 bricks of Zig Zag kilns

		Brick Type		Fired class 1 bricks	Fired class 2 bricks
Zig Zag Kilns in Ghazipur	(Total 36 Kilns)	Typical Distribution of bricks (%)		67	12
		Average Selling Price	(INR/1000 Bricks)	5890	4600
		Total Estimated selling price	(INR/1000 Bricks)	3950	570
Zig Zag Kilns in Lucknow	(Total 32 Kilns)	Typical Distribution of bricks (%)		63	15
		Average Selling Price	(INR/1000 Bricks)	6940	6120
		Total Estimated selling price	(INR/1000 Bricks)	4390	915
Zig Zag Kilns in Varanasi	(Total 50 Kilns)	Typical Distribution of bricks (%)		67	12
		Average Selling Price	(INR/1000 Bricks)	6370	5010
		Total Estimated selling price	(INR/1000 Bricks)	4250	615

3.4 Fuel Consumption & Cost Analysis:

Table 12. District wise fuel consumption matrix of Zig Zag kilns

	Fuel Type	Coal	Sawdust and other alternatives	Total Estimated fuel cost per 1000 bricks
Zig Zag Kilns in Ghazipur (Total 36 Kilns)	Ton fuel /lakh bricks (average)	14	5	
	Average landing price	12715	6070	
	Estimated fuel cost per 1000 bricks	1720	305	2025
Zig Zag Kilns in Lucknow (Total 32 Kilns)	Ton fuel /lakh bricks (average)	15	5	
	Average landing price	12515	8125	
	Estimated fuel cost per 1000 bricks	1805	380	2190
Zig Zag Kilns in Varanasi (Total 50 Kilns)	Ton fuel /lakh bricks (average)	14	4	
	Average landing price	11500	5875	
	Estimated fuel cost per 1000 bricks	1660	225	1885

3.5 Training & Awareness:

Table 13: Training and awareness need assessment

	Looking forward for support	Support as increasing awareness and technology knowledge	Support in training of Supervisor and workers	Both
Zig Zag kiln in Ghazipur (Total 36 kilns)	20	8	5	7
Zig Zag kiln in Lucknow (Total 32 kilns)	22	10	1	11
Zig Zag kiln in Varanasi (Total 50 kilns)	32	3	10	19

This pattern suggests that while awareness and technology dissemination is essential, there is a growing need for hands-on training and integrated capacity-building programs.

CHAPTER

04

Way Forward

Building on our findings of the survey and the phased action plan, it is proposed to adopt the following roadmap to drive a sustainable transformation of the brick-kiln sector in Uttar Pradesh:

1. Boost Technology Adoption in Ghazipur

- Launch targeted awareness campaigns and on-site technical support in low-performing areas.
- Organize peer-learning visits for Ghazipur kiln owners to high-performing sites in Lucknow and Varanasi.
- Facilitate access to affordable financing and logistical assistance for kiln upgrades.
- Involvement of state dept and scheme for financial and technical support to adopt the technology

2. Strengthen Operator Capacity and Certification

- Roll out a "Training of Trainers" (ToT) program to develop a network of master trainers
- Deliver localized, hands-on workshops covering fuel-efficient firing, Class I quality control, and routine maintenance to address operational challenges.
- Partner with technical institutes and district MSME offices to establish a formal skill-certification pathway for supervisors and operators.

3. Demonstrate Impact Through Pilot Kilns

- Retrofit one kiln each in Lucknow/Ghazipur as demonstration units with ESCO mode or support from FI.
- Track key performance indicators like coal use, Class I output and cost savings and document lessons learned.
- Share success stories broadly to build momentum for wider Zig Zag adoption.

4. Align Policy and Institutional Support

- Engage with MSME-DIC, the State Pollution Control Board and the Environment Department to finalize a state-level kiln modernization plan.
- Advocate for inclusion of Zig Zag technology in Uttar Pradesh's decarbonization and clean-air initiatives.
- Recommend fiscal incentives and the development of local manufacturing for Zig Zag components.

5. Scale Up and Sustain Long-Term Impact

- Extend outreach to all major brick-kiln districts across the state.
- Establish a permanent training and certification ecosystem in collaboration with UPSIDA and the State Skill Development Department.
- Forge multi-stakeholder partnerships with engineering colleges, technology providers and industry associations to support ongoing R&D, knowledge sharing and performance monitoring.

Key Targets

Zig Zag Adoption: Raise Ghazipur's rate to 90%.

Class I Output: Increase average production to above 75%.

Coal Consumption: Reduce fuel use to below 10 tons per 100,000 bricks.

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