Greentech Knowledge Solutions Pvt. Ltd.

BIHAR

SHAKTI SUSTAINABLE ENERGY FOUNDATION

Learnings from Bihar's Experience of Implementing Cleaner Brick Kiln Directive: A Case Study

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An initiative supported by Shakti Sustainable Energy Foundation.

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Prof. Ashok Kumar Ghosh
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Chairman

BIHAR

Bihar State Pollution Control Board

Message

Air pollution has emerged as a serious challenge for the state of Bihar in the recent years. The State' is developing in various sectors such as infrastructure and buildings, power generation, transportation, *etc.* which may cause severe impacts on climate change, agriculture and human health.

The Brick Kilns in the State are identified as one of the important sources of air pollution. The kilns operating with inefficient technologies result in emission of high level of particulate matter and greenhouse gases. The large clusters of brick kilns especially located around the urban area add to worsen the urban air quality .

The Bihar State Pollution Control Board has been taking initiatives to control air pollution in Brick Sector since 2011. Several seminars and training programs involving technical experts have been organised for sensitisation and awareness generation for the entrepreneurs. An inter departmental task force for development of a low carbon pathway in production of building construction material was also constituted by the State Government in 2012 which has been advising on policy, regulations and its implementation in the Brick Sector.

The Boa rd had decided in February 2016 for the brick kilns located in five blocks in and around Patna to upgrade to cleaner brick kiln technologies by August 2016. Adoption of cleaner brick kiln technologies does not only bring in substantial environmental benefits but is also financially beneficial for the entrepreneurs because of reduction in fuel consumption and improvement in product quality. A technical support program of one-year duration was also put in place to help the brick kiln entrepreneurs in technology upgradation. Now the Board has directed all the brick kilns of the State to shift to cleaner technologies.

The initiatives taken by the Board in the Brick Sector, the approach and process of implementation of the directive in Patna region, and the outcomes and learnings are discussed in this case study. I hope that this case study will be immensely beneficial for the policy makers, regulators and other important stakeholders related to the brick sector in India and other South-Asian countries. I would also like to thank Shakti Sustainable Energy Foundation and Greentech Knowledge Solutions for their continued support in these initiatives of the Board.

Ashok Ghosh 02/08/18

(Ashok Kumar Ghosh)
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Foreword

India's rapidly growing construction sector will fuel the demand for various building materials. Solid burnt clay bricks are the dominant type of building material used for construction. The majority of clay brick production takes place in the Indo-Gangetic plains, a region grappling with high air pollution levels. Further, most of the kilns rely on the inefficient and fuel intensive Fixed Chimney Bull's Trench Kiln technology for brick production,making them a significant source of greenhouse gas {GHG) and black carbon emissions.

Facilitating the adoption of cleaner and more resource efficient brick production technologies is one of Shakti's flagship initiatives. We have engaged with key stakeholders to undertake the energy and environmental monitoring of brick kilns, design technical training programmes for brick makers for conversion to zig-zag kilns, complete kiln retrofit pilots to establish the economic case for the adoption of cleaner brick production technologies and provide capacity building support to government agencies and entrepreneurs.

Our work in Bihar has informed a series of policy measures to control air pollution from brick kilns and promote cleaner brick production in the state. In 2016, the Bihar State Pollution Control Board (BSPCB) implemented a pioneering policy decision that required all brick kilns in the Patna region to upgrade to cleaner brick production technologies. Since then, similar directives have been issued elsewhere,for example,in other regions in Bihar and the National Capital Region.

The key experiences and learnings of the BSPCB's policy experiment narrated in this document will be useful for policy makers and implementing agencies involved in promoting cleaner brick production technologies elsewhere in India.

I congratulate Dr Sameer Maithel and the team at Greentech Knowledge Solutions Pvt. Ltd. for their continued efforts on these important policy developments. I wish them success in their future endeavours.

Krishan Dhawan
Chief Executive Officer
Shakti Sustainable Energy Foundation

PREFACE

Brick kilns are among the major sources of air pollution in the state of Bihar, particularly in the cities and towns around which a large number of brick kilns are located. Since 2011, the Bihar State Pollution Control Board (BSPCB) has been promoting cleaner brick kiln technologies through awareness seminars, trainings, etc. In February 2016, BSPCB has issued a directive to all brick kiln enterprises located in five blocks of Patna district to shift to cleaner brick kiln technologies within a year's time. To assist the brick makers in transition to cleaner technologies, a one-year technical support programme was put in place with the support from Shakti Sustainable Energy Foundation. Greentech Knowledge Solutions was entrusted with the responsibility of implementing the technical support programme,which involved awareness generation campaign, and advising entrepreneurs on technology selection, construction, operation and troubleshooting of kilns, among other activities. This approach – a directive in combination with awareness campaign and provision of technical assistance – has helped in convincing the brick makers about the environmental and economic benefits of technology upgradation and in encouraging them for the transition.

This publication, a case study, documents the strategy and process of implementation of this technical assistance programme and its outcomes, and draws important learnings from it. This case study starts with discussing the context and background of this directive. It then discusses the approach adopted for implementation of the directive, key activities undertaken under the technical assistance programme and its implementation process, and outcomes of this effort in the form of number and quality of kiln upgrades and associated environmental and economic gains. At the end, it presents important learnings from this effort.

Greentech Knowledge Solutions Pvt. Ltd (GKSPL) was involved in providing technical assistance in the implementation of the Bihar's Cleaner Brick Directive, and in the process, received continued support and guidance from various organizations and individuals. First, the team would like to acknowledge the strategic guidance and support received from the Bihar State Pollution Control Board (BSPCB). We would like to thank Shakti Sustainable Energy Foundation for supporting the initiative with a special mention to Mr Kunal Sharma and Ms Arshpreet Kalsi for providing useful inputs throughout the assignment period. We would also like to thank Mascot Foundation who has worked with GKSPL as a team and supported during the entire process. The response from brick kiln entrepreneurs was positive and welcoming, and they also whole heartedly supported the team in organizing technical camps and meetings at their kiln sites. The team would like to thank these entrepreneurs for their support. We would also like to thank Mr K P Eashwar of Academic and Development Communication Services (ADCS) who helped in editing and publishing this document.

1. BACKGROUND

India's building footprint is growing rapidly, fuelling the demand for various types of building materials. Construction of buildings using masonry bricks forms the dominant form in India. Solid burnt clay brick is the most widely used brick type. India produces about 250 billion burnt clay bricks per year, making it world's second largest producer. The production of burnt clay bricks has increased six times over the past 40 years and is expected to further triple in the next 20 years.[1]

About 70% of the burnt clay brick production in the country takes place in the Indo-Gangetic plains. Located in this region, Bihar is one of the largest burnt clay brick producing states in the country. Bihar is estimated to have 6000 brick kiln enterprises,[2] producing about 18 billion bricks per year. Most of the kilns employ Fixed Chimney Bull's Trench Kiln (FCBTK) technology and use coal as fuel. While in rural areas, kilns are located far off from one another, in urban areas, they are found in clusters around demand centres. Burning of large quantities of coal (about 3 million tonnes per year) results in the emission of carbon dioxide (CO_2), which makes brick industry an important source of greenhouse gas (GHG) emissions. Inefficient combustion of coal in FCBTK leads to emissions of particulate matter (PM), carbon monoxide, etc. Due to proximity of the brick kiln clusters to urban centres, such inefficient combustion contributes significantly to the urban air pollution. Recent studies on emission inventory of National Capital Region (NCR) in India[3] and Greater Dhaka

> *"Bihar is one of the largest brick producing states in the country. A large scope exists for saving coal and reducing air pollution by improving the brick kiln technologies."*

[1] Maithel S, Ananthakrishnan R, and Kumar S. 2017. Roadmap for Promoting Resource Efficient Bricks in India: A 2032 Strategy. New Delhi: Greentech Knowledge Solutions Pvt. Ltd and Shakti Sustainable Energy Foundation.

[2] Department of Mines and Geology, Government of Bihar. 2017. Information on number of brick kilns district-wise available at http://mines.bih.nic.in/ (last accessed on 11 April 2018).

[3] Guttikunda SK and Goel R. 2013. Health impacts of particulate pollution in a megacity—Delhi, India. *Environmental Development* 6: 8–20.

region in Bangladesh show that large brick kiln clusters around urban centres in the Indo-Gangetic plains may contribute up to 20% in spatial $PM_{2.5}$ concentrations, leading to significant health impacts on urban population.[4] A similar study on characterizing Patna's ambient air quality[5] conducted in 2014 estimates the contribution of brick kilns to spatial $PM_{2.5}$ concentration in some parts of the city of Patna at about 20%.

Recognizing the need to control air pollution from brick kilns and promote cleaner brick production in the state, the Government of Bihar has taken a series of policy measures. An interdepartmental task force for *Accelerating cleaner production systems in building material sector* was constituted in 2012 by the Department of Environment and Forests (DoEF), Government of Bihar, and the Bihar State Pollution Control Board (BSPCB). Since then a two-pronged policy approach has been adopted, which consists of (a) promoting adoption of cleaner brick firing technology by brick kilns in the state and (b) promoting fly ash brick production to partly replace the use of burnt clay bricks.

This case study describes the process of the implementation of the cleaner brick kiln directive, and the learnings thereof. The directive mandated replacement of existing FCBTKs with cleaner brick kiln technologies such as zigzag kilns and vertical shaft brick kilns (VSBKs) in brick clusters surrounding the city of Patna. This mandate was based on the results of previous studies,[6] which showed that shifting from FCBTK to cleaner technology like zigzag kiln leads to multiple benefits. The benefits include

[4] Guttikunda S, Begum B, and Wadud Z. 2012. Particulate pollution from brick kiln clusters in the Greater Dhaka region, Bangladesh. *Air Quality, Atmosphere & Health*(2013) 6:357–365.

[5] Guttikunda S. 2014.Characterizing Patna's Ambient Air Quality and Assessing Opportunities for Policy Intervention. Available at http://shaktifoundation.in /wp-content/uploads/2014/02/AQM-in-Patna-2014-07-15-Final-Report.pdf (last accessed on 11 April 2018).

[6] Lalchandani D andMaithel S. 2013. Towards Cleaner Brick Kilns in India. Greentech Knowledge Solutions Pvt. Ltd and Shakti Sustainable Energy Foundation.

(a) about 20% saving in coal consumption and CO_2 emissions, (b) upto 75% reduction in combustion-generated suspended particulate matter (SPM), and (c) improvement in the revenue of the brick enterprise because of better quality of bricks. Thus, this technology shift provides a win-win opportunity for both brick entrepreneurs and the society.

Box 1. Benefits of Upgradation to Zigzag Brick Kiln Technology: a case study

In 2012, Pawan Bricks of Patna demolished its oval-shaped FCBTK and constructed a new rectangular-shaped natural draught zigzag kiln. The capital cost involved in the technology upgradation was about ₹ 8.5 lakh. In addition to this, about 8.5 lakh bricks (about 1.5 lakh Class-I bricks and remaining Class-II and Class-III bricks) were also consumed in the construction of new kiln. The owner is happy with the performance of the new natural draught zigzag kiln.

Photograph of Natural draught zigzag kiln of Pawan Bricks, Patna

According to him, in FCBTK, the coal consumption was 18 tonnes per lakh of bricks. After kiln upgradation, the coal consumption came down to 14 tonnes per lakh of bricks. (This figure has been verified through an energy audit of the kiln.) There has been a significant increase in the share of Class-I bricks, from 60% in FCBTK to 90% in natural draught zigzag kiln. In its first year of operation, Pawan Bricks produced about 40 lakh bricks and saved about 160 tonnes of coal, resulting in monetary savings of ₹ 12.8 lakh. The increase in revenue due to higher percentage of Class-I bricks results in additional revenue of about ₹ 12 lakh. The measured average SPM emission from this kiln was 79 mg/Nm^3.

The Patna directive was the first such directive on replacing FCBTKs in the country. Since then, similar directives have been issued elsewhere, for example, in the NCR and remaining regions of Bihar. Shakti Sustainable Energy Foundation, through its technical partner Greentech Knowledge Solutions, has been collaborating with BSPCB in the implementation of the directive. The key experiences and learnings of the Patna experiment narrated in this booklet would serve a useful purpose for development agencies, policy makers, and implementing agencies involved in promoting cleaner brick production technologies elsewhere in India and other countries of South Asia.

"In February 2016, the Bihar State Pollution Control Board, through a directive, asked all brick kilns (about 200) located around Patna city to adopt cleaner brick kiln technologies by August 2016."

1.1 The Bihar State Pollution Control Board's Directive

On 18 February 2016, BSPCB published a directive in leading newspapers of Bihar asking all brick kilns located in the five administrative blocks of Patna district to adopt cleaner brick production technologies before 31 August 2016. The directive also stated that existing kilns that failed to do so by the specified date would not be provided Consent to Operate (CTO). It was also informed that the directive was being piloted in bricks kilns located near to the city of Patna first, and later would be extended to other parts of the state in the following year. Through this directive, BSPCB also committed to provide technical assistance to brick makers for this shift.

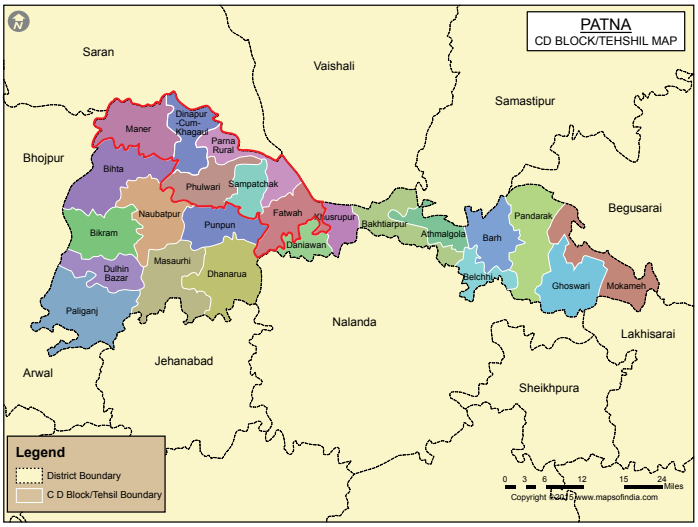


Figure 1. Map of Patna District showing the target clusters[7]

Figure 2. Smoke from a Fixed Chimney Bull's Trench Kiln

[7] The map has been taken from the website www.mapsofindia.com

2 STRATEGY TO IMPLEMENT THE DIRECTIVE

The DoEF and BSPCB's strategy for transition towards cleaner brick production for the brick industry makes for an interesting study. The strategy adopts a multi pronged and phased approach for implementation in which BSPCB's role was not merely that of a regulator but also that of a facilitator.

> *"BSPCB adopted a multi-pronged and phased approach for implementation, going beyond its role as a regulator."*

The strategy comprised these four key components.

a) **Pre-Directive Awareness Generation and Sensitization**

Though the directive was issued in February 2016, efforts towards sensitizing and building awareness amongst brick kiln owners had already begun by 2012.

- Several workshops and seminars were organized to motivate the brick makers towards technology upgradation.
- Officials from relevant government departments and agencies such as mining, labour, and commercial tax departments participated in these events to address concerns at a single platform.
- Technical experts were invited to all these events to explain the need and benefits of cleaner technology, and to address the technical queries.

During 2012–15, the government focused on mobilizing brick makers towards cleaner technology and upgradation was voluntary. By the end of 2015, only about 10 kilns had voluntarily made this shift.

b) **Directive for Technology Upgradation and Strict** Enforcement

The directive issued on 18 February 2016 made the transition to cleaner brick kiln technologies mandatory. The directive

was followed by enforcement in the form of non-renewal of CTO certificates and initiating legal action, such as registering FIRs, against brick kilns who did not comply with the directive.

c) **Clear and Continuous Government Communication during the Implementation Phase**

During the implementation phase (post February 2016), BSPCB and DoEF maintained continuous communication with brick makers through workshops, seminars, newspapers, and other channels. During these interactions, brick kiln owners were educated about the environmental and economic benefits of technology upgradation and the officials repeatedly drove home the fact that technology upgradation could not be sidelined and was mandatory.

d) **Technical Support to Brick Makers on Technology Upgradation during the Implementation Phase**

Lack of awareness about cleaner technologies, limited availability of trained technical personnel (masons/ contractors) to construct cleaner brick kilns, limited technical and managerial capacities of the existing brick kiln enterprises to adopt new kiln technologies, and lack of trained manpower (brick setters/firemen) to operate the new kilns were identified as important barriers in the implementation of the directive. To overcome these barriers, a technical support programme was devised. The technical support programme focused on awareness generation on cleaner kiln technologies, providing assistance to brick makers in technology selection, imparting technical knowledge to brick enterprises in best practices for the construction and operation of cleaner kilns.

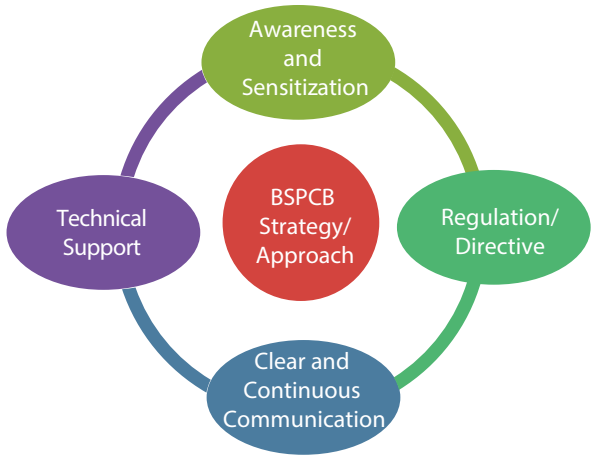


Figure 3. Approach adopted by the Bihar State Pollution Control Board (BSPCB) for implementation of its directive

Series of Events and Timeline:

Table 1. Series of events and timeline

2011 and 2012	▪ Recognition of the need to address the environmental issues related to brick sector and background work.
June 2012	▪ Constitution of inter-departmental task force to promote production and use of cleaner building materials.
December 2012	▪ Workshop on 'Cleaner Brick Production Technologies' organized with entrepreneurs, senior state government officials, technical experts. Deputy Chief Minister was the chief guest.
April 2013	▪ 2-day exposure and training programme conducted for a delegation of brick makers of Bihar and BSPCB officials at Varanasi.
2013–15	▪ Concept of a state-wide 'Cleaner Brick Production Programme' and Proposal seeking fund from the National Clean Energy Fund (NCEF). ▪ Study on characterizing the ambient air quality of Patna: brick kilns emerged as one of the main contributors to PM_{10} and $PM_{2.5}$ concentration in city's ambient air. ▪ Recommendations by the task force and by another inter-departmental meeting on improving air quality in the state, for technology upgradation of brick kilns.
October–December 2015	▪ Serious issue of poor ambient air quality noted in Patna city. ▪ Patna High Court held hearings on a PIL and sought response from the state on actions taken to reduce air pollution in Patna.
Feb 2016	▪ BSPCB directive to brick kilns located in five blocks of Patna district to shift to cleaner brick production technologies.

Contd....

February–May 2016	■ Awareness campaign rolled out by BSPCB.
May 2016–May 2017	■ Technical support programme to help brick makers in technology upgradation. ■ Enforcement actions by BSPCB.
August–October 2017	■ The directive for cleaner brick production was extended to the entire state. ■ Nine awareness workshops were organized, one in each divisional headquarters, attended by more than 2200 brick makers.
July–August 2018	■ Nine technical workshops on design and construction of zigzag kilns were organized for brick makers, kiln masons, and equipment suppliers,one in each divisional headquarters.

2.1 Technical Support Programme

To support the implementation of the Directive, a technical support programme was designed. The technical support programme was of one-year duration (May 2016 to May 2017). The programme was implemented by Greentech Knowledge Solutions Pvt. Ltd (GKSPL). GKSPL has extensive experience and expertise in the areas of brick kiln design, performance monitoring of brick kilns, and technical training. To implement the programme, GKSPL formed a two-tier team – an expert team and a local extension team.

"A comprehensive technical support programme consisting of awareness generation seminars, technical training programmes, and expert advice was put in place to facilitate the implementation of the directive."

The expert team consisted of engineers having expertise in brick kiln technology. The expert team was based at Delhi and a member of the expert team visited Patna on monthly basis. The main tasks assigned to the expert team were:

- Development of technical material in the form of technical presentations, brochures, posters, manuals on design and construction, operation and trouble-shooting of cleaner brick kiln technologies.
- Conducting awareness seminars, workshops, and training programmes for brick kiln owners.
- Carrying out periodic field visits,along with the local extension team, to interact with brick kiln owners and address technical queries.

- Compiling and analyzing the information sent by the local extension team and preparing periodic reports on the status of the implementation for BSPCB.

A 3-member local extension team was based at Patna. The extension team ensured permanent presence of the technical team at brick clusters and was the first point of contact for brick makers. Significant efforts were put in to train the extension team and develop standard reporting formats. The main tasks assigned to the local extension team were:

- Mapping and contacting all brick kilns in the region.
- Making periodic visits to the clusters, track the implementation of the directive, and provide monthly report.
- Maintaining regular communication and answering simple technical questions over phone. In case the questions were difficult, they were passed on to the expert team.
- Mobilizing brick makers for workshops, technical camps, and training programmes.

There were three phases in the technical support programme:

- **Phase I (May–July 2016):** Mobilization of brick makers and awareness generation about cleaner technology options
- **Phase II (August–December 2016):** Construction or upgradation of kilns to cleaner technologies
- **Phase III (January–May 2017):** Operation of the upgraded kilns

The team was able to reach out to each individual kiln in each phase through large-group meetings/workshops, small-group meetings, and visit to individual kilns.

Table 2. Summary of activities undertaken during technical support programme

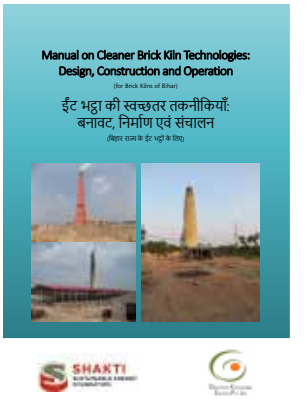
Timeline	Key Activities
May–July 2016 Mobilization and Awareness Generation Phase	■ Reaching out to individual kilns • Mobilization; information about technical support programme; database of brick kilns ■ Workshops for brick makers in larger groups • Awareness generation about BSPCB's directive, cleaner technology options, and technology selection; • Introduction to some technology providers ■ Visits to interested kilns by expert team and field team • Assistance in technology selection and cost estimation
August–December 2016 Kiln Construction Phase	■ Technical manual developed for brick makers and masons on 'Best Practices of Kiln Construction and Operation' ■ Technical camps organized for brick makers in groups of 15–20 at kiln sites • Guidance on design and construction of kilns ■ Individual guidance given to brick makers during kiln construction • Responding to their queries on phone calls; • Regular visits to kiln sites by field team; • Periodic visits by expert team ■ Tracking construction of each kiln and preparation of database
January–May 2017 Kiln Operation Phase	■ Individual guidance to brick makers during kiln operation • Responding to their queries on phone calls; • Regular visits to kiln sites by field team; • Periodic visits by expert team ■ Technical camps for brick makers in groups of 15–20 at kiln sites • Guidance on operation and troubleshooting of kilns ■ Instruction manual for BSPCB officials for field inspection.

Awareness seminars for brick kiln owners on Cleaner brick kiln technologies (July 2016)

Technical camps on kiln design and construstion at kiln sites (Aug-Sep, 2016)

Technical camps on kiln operation and troubleshooting at kiln sites (Apr-May, 2017)

Advising kiln owners on design and construction of kilns

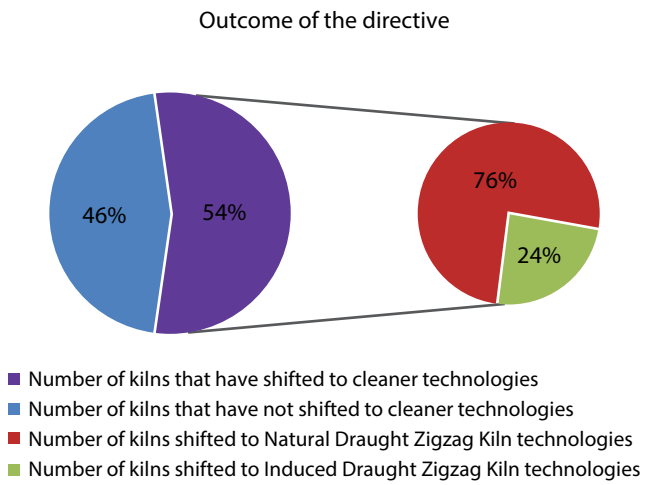


Manual on kiln design, construction and operation

Glimpses of the key activities in technical support programme

3 OUTCOME AND RESULTS

Out of the 190 brick kilns that were under the purview of the BSPCB's directive, 103 kilns upgraded their kiln technology by June 2017. All these brick kilns shifted either to natural draught zigzag kiln or induced draught zigzag kiln. A summary of the results is provided below.



Out of 190 kilns, 103 kilns (54% of the existing kilns) shifted to cleaner technologies. Many kilns decided not to shift to cleaner technologies because of the following reasons:

- Most brick kilns are located on leased land and the kilns whose lease agreements were close to expiry, decided not to shift.
- Some brick makers have shifted their kilns out of the five blocks of the Patna region.
- Some of them found it difficult to raise the required finance of about ₹ 20 lakh to undertake the conversion.
- Some of the brick kiln owners who had more than one kiln converted only one of them and decided to wait for a season before deciding to shift their other kiln(s).

Most of the kiln upgradations took place between July and December 2016 (which is the non-operational period for brick kilns) and the upgraded kilns became operational during the brick production season of January–June 2017. The construction and operation of all these kilns were tracked during this one-year period.

Figure 4. Photograph of kiln construction

Figure 5. Photograph of kiln construction

Figure 6. Photograph of a newly constructed and operational natural draught zigzag kiln

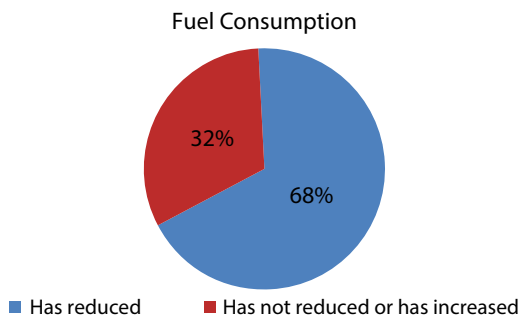
3.1 Survey of Brick Kilns Post Upgradation and Operation for One Year

A questionnaire survey of a random sample of 66 brick kilns, which had converted to cleaner technologies,was conducted during November–December 2017, after the completion of one season of operation of upgraded kilns. This was to gather feedback from these brick kiln owners on the performance of new technologies. The main parameters of this survey were as listed below.

1. Reduction in fuel consumption
2. Improvement in the product quality
3. Overall satisfaction level with the new technology

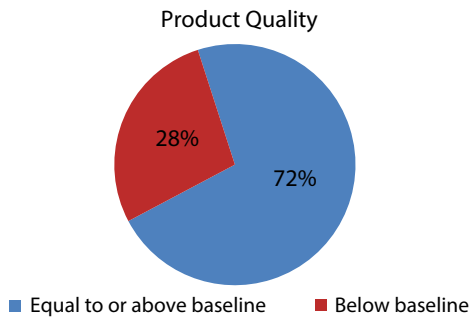
The results of the survey are presented below.

1. Fuel Consumption



Sixty-eight percent (68%) of the surveyed kilns reported a reduction in fuel consumption after adopting zigzag kilns. The remaining 32% either reported no savings and in a few cases reported increase in fuel consumption.

2. Product Quality



Seventy-two percent (72%) of the surveyed kilns reported an improvement in the percentage of Class I bricks after adopting zigzag kilns. The remaining 28% either reported no improvements or in a few cases reported decrease in the percentage of Class I bricks.

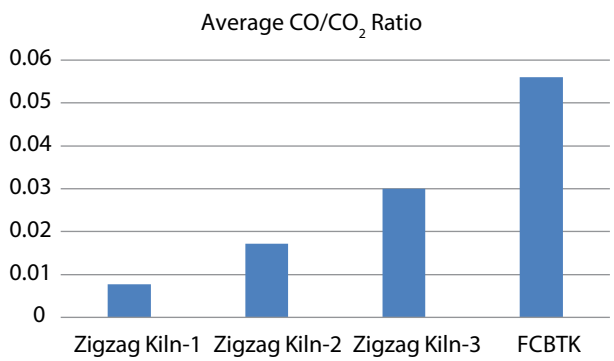
3. Overall Satisfaction Level

Fifty-seven percent (57%) of the surveyed kilns expressed satisfaction with the adoption of zigzag kilns. 29% felt that though the technology is good, but due to various reasons they have not been able to operate kilns satisfactorily. 14% were dissatisfied with the technology change.

3.2 Combustion Performance of Representative Kilns

A large part of particulate matter emission from brick kilns comes from incomplete combustion of fuel in the kiln. The ratio of carbon monoxide to carbon dioxide (i.e., the CO/CO_2 ratio) in flue gases is a good indication of the completeness of combustion of fuel. A lower CO/CO_2 ratio indicates better combustion and lower combustion related particulate matter emission.

Combustion performances (CO/CO_2 ratio) of three representative zigzag kilns were measured at Patna during May 2018. The measurement results of these zigzag kilns along with the CO/CO_2 ratio measured earlier for a typical FCBTK are shown below: [8]



The results show that:

- the CO/CO_2 ratio has reduced significantly after upgradation to zigzag kilns and
- within zigzag kilns, there is variation in the combustion performance and by adopting better operating practices, the performance of zigzag kilns can be improved further.

[8] Draft report prepared by Greentech Knowledge Solutions based on monitoring of brick kilns in Patna and Delhi-NCR in 2018 under a project supported by Swiss Agency for Development and Cooperation.

3.3 Summary of the analysis of the survey and monitoring results

Based on the analysis of the survey results, the bricks kilns that have shifted to cleaner technologies can be broadly categorized into three as described below.

Table 3. Categorization of brick kilns

Category	% number of kilns	Satisfaction level	Remarks
Category 1	50%–60%	Satisfied	▪ Experienced reduction in fuel consumption and improvement in product quality ▪ Kiln owners and workers have grasped the basics of operations of the new technology. Based on previous experience, it is expected that the performance of these kilns will improve further in next seasons with increase in experience. ▪ Significant improvement in the combustion performance as shown by reduction in the CO/CO_2 ratio.
Category 2	25%–30%	Technology change has not workedout for them consistently in the first season	▪ These enterprises have experienced improvement in the kiln performance at some points of time but have not been able to sustain continued good performance throughout the season. ▪ Are convinced about the technology but it has not worked as expected in the first season in their case. ▪ The combustion performance has improved as compared to conventional FCBTKs, but there is further scope for improvement, which can be achieved through improving the operating practices. ▪ In the coming one or two seasons, with more local experience with the new technology and some efforts, it is expected that the performance of these kilns will improve and stabilize.
Category 3	20%–25%	Not satisfied	▪ The kiln could not be operated properly because of various reasons such as poor quality of kiln construction; absence of experienced workers; and limited understanding of the new technology.

After the survey, on the request of BSPCB, field visits and interactions were organized with 11 brick kiln enterprises (during November/December 2017), with majority of the brick kilns belonging to categories 2 and 3, to look into the specific issues and problems faced by them. A technical expert visited these kilns and suggested corrective measures. Feedback from these kilns were again gathered in March 2018 through phone calls, and improvements in the performance of these kilns were observed. These findings indicate that these brick kilns need one or two seasons to adapt the new technologies. Availability of expert advice and knowledge sharing regarding best operating practices amongst brick kiln enterprises during one/two seasons is crucial for the success.

> *"Hand-holding support is required for one to two brick-making seasons so that the entrepreneurs are able to properly adopt the technologies."*

4 OVERALL ASSESSMENT AND LEARNINGS

Overall the response was positive from the brick makers towards the directive. It is estimated that the brick makers invested about ₹ 15–20 crore in upgrading to zigzag technology. A majority of the brick makers are convinced that in addition to reducing environmental pollution, the technology change is a win-win situation for them by way of economic benefits, in terms of savings in fuel cost and increased revenue due to improvement in the quality of Class I bricks.

> *About 7000 tonnes of coal saved and about 16000 tonnes of CO2 emission averted in Patna in the first year after technology upgradation. The benefits will increase in subsequent years as brick makers gain more experience and expertise.*

Based on the survey results, the reduction in the total coal consumption of these 103 brick kilns during their first year of operation, i.e. 2017, is estimated to be about 7000 tonnes. Assuming ₹ 7000/tonne as the price of coal, the monetary saving for brick makers in coal cost is estimated at about ₹ 5 crore in 2017. The associated reduction in CO_2 emission from these kilns is estimated to be about 16,000 tonnes. In addition, it is estimated that the revenue of the brick makers has increased by about ₹ 2 crore due to improvement in the product quality. It is expected that the annual savings in coal consumption and CO_2 emissions, and increase in revenue will rise further during 2018 as the brick enterprises gain more experience and expertise in the operation of zigzag kilns.

4.1 Factors Contributing to Positive Outcomes

The key factors that contributed to positive outcomes are listed below.

- Initiating awareness generation activities prior to issuing the directive (voluntary phase). Although the number of brick kiln owners that adopted cleaner technologies voluntarily were limited, awareness generation activities in the region helped the brick kiln owners understand what cleaner technologies

can fetch them in terms of benefits. The awareness generation activities and voluntary adoption of cleaner technologies by some brick makers also helped establish some level of experience on cleaner technologies even before the directive of change-over was made mandatory.

- The strategy of clear and direct communication with the brick industry by the BSPCB to communicate the directive and strictly enforcing the directive.
- Awareness generation campaigns that focused on the win-win aspects and benefits of technology upgradation contributed in overcoming the negative attitude of brick makers to technology change.
- Easy and timely access to technical information and guidance for the brick makers through the technical support programme that was run for a year (one complete cycle – kiln upgradation and operation for one season).

"Strict regulation along with provision of technical assistance has a positive impact, which encouraged the entrepreneurs for technology upgradation,."

4.2 Learnings and Recommendations

The BSPCB has announced that all brick kilns (about 6000) in Bihar should adopt cleaner brick kiln technologies by 30 August 2018. Similarly, all the brick kilns in the National Capital Region (about 4000) have been directed to change to zigzag technology by the end of 2018. The new draft environment regulation for brick kilns proposes changeover of all existing FCBTKs (about 40,000) to zigzag and other cleaner brick kiln technologies within a period of two years. The pilot initiative at Patna has thrown up several learnings, which would be useful during the scaling-up phase. The key learnings and the recommendations are discussed below.

1. Mounting effective awareness campaign

The Patna experience shows that an effective awareness generation campaign highlighting the win-win proposition, particularly the economic benefits, can play a key role in

gaining the confidence of brick makers and in developing a conducive environment for technology change. At Patna, as the geographical area was small, a combination of large seminars with smaller cluster-level meetings and one-to-one interactions proved to be instrumental in increasing the effectiveness of the awareness campaign. However, while scaling-up the initiative, use of internet, newspaper advertisements, telephone, videos and animation films,[9] and messaging applications like WhatsApp[10] should be used effectively for awareness generation.

> *"Developing capacities in kiln design, construction, and operation through training of masons, entrepreneurs, and workers will be crucial for technology upgradation in the sector."*

2. Developing capacities for the construction of the kilns

Good quality construction is crucial for good performance of the kilns. There are very few good quality technology providers for the construction of kilns. Construction of zigzag kilns largely involves masonry work. It is carried out by traditional masons/ contractors (different from masons involved in local building construction). They are not formally trained. At Patna, out of about 15 contractors involved in kiln construction, only a few met the minimum quality parameters. To construct 30,000 or 40,000 kilns over a short period of 1 to 2 years, hundreds of masons needs to be trained in kiln construction.

3. Making available standard kiln designs

At Patna, no standard design was available in the beginning. Later, a construction manual for a standard design of natural draught zigzag kiln was made available in Hindi. More than 200 copies of the manual were distributed. Several masons involved in the construction utilized the manual. Standard kiln designs for

[9] The importance of using internet can be gauged by the fact that an animation video (https://www.youtube.com/watch?v=WjjDhogWUW4), developed with support from Shakti Sustainable Energy Foundation, to explain the functioning of zigzag kiln has received more than 1 lakh views.

[10] There are a large number of WhatsApp group of brick kiln owners. In Bihar alone, there are 10 WhatsApp groups (having more than 1000 members) created to discuss technical and policy issues.

induced draught zigzag kilns have been developed for Punjab by the Punjab State Council for Science and Technology as well as in Nepal.[11] As different states/regions have different brick sizes, different kiln capacities, etc., there is a need to compile and supplement the information on standard zigzag kiln designs and make it available to brick makers and kiln contractors.

4. Developing capacities for the operation of kilns

Good skills for setting bricks and to carry out firing operations in zigzag or other cleaner kiln technologies are necessary for the success of the initiative. As there is no organized training set-up to train workers for the brick industry, a huge shortage of the trained workers was felt at Patna. One of the technology providers at Patna (himself a brick kiln owner), has put in place a system to train workers of the client kiln for two weeks, prior to the commissioning. This technology provider has constructed about 15 kilns and more than 90% of these kilns has achieved good performance in 2017. This experience shows that even a provision of 2-weeks formal training to the workers can greatly increase the success of the initiative. Standard training material on brick setting and firing of natural draught zigzag kilns is now available. Efforts are needed to develop a training network to impart the training.

> *"Developing affordable solutions for semi-mechanization of some of the processes such as fuel feeding, and its deployment will lead to increased environmental and social benefits."*

5. Semi-mechanization of the fuel feeding process

While analyzing the difference in performance of newly constructed zigzag kilns at Patna, it was found that the kilns that followed continuous and uniform feeding of fuel had better fuel savings (and hence possible better environment performance). Manual continuous fuel feeding is difficult to implement as the firemen must stay for longer duration on the top of the

[11] MinErgy, 2015, Design Manual – Improved Fixed Chimney Brick Kiln, http://www.gkspl.in/reports/energy_efficiency/design%20manual%20for%20improved%20fixed%20chimney%20brick%20kiln-%20nepal.pdf (last accessed on 30 April 2018).

kiln having surface temperature in excess of 100 °C. Semi-mechanization of the fuel feeding process using trickle feeders or pneumatic feeding systems can ensure better performance but very few such systems are available in India. There is a need to quickly develop and deploy affordable semi-mechanized fuel feeding systems.

Pneumatic fuel-feeding system of a European company 'Beralmar' (manufacturing facility has recently been set up near Bangalore). One feeder can feed up to 10 feed holes and costs about ₹ 3–4 lakh.

Locally manufactured trickle fuel-feeding system being used in Hoffman kilns in Balaghat, Madhya Pradesh. One feeder being used to feed about 3–5 feed holes and costs about ₹ 50,000.

6. Strengthening the System for Monitoring, Compliance, and Enforcement

Brick kilns exist in large numbers and are dispersed widely across the country. Despite BSPCB's directive, some kilns continue to operate without upgrading their technology. The BSPCB has taken some legal action against such kilns within a small target region that were relatively easy to monitor. However, for a large-scale or state-level initiative, it is difficult to monitor each kiln on a regular basis for compliance, given the limited manpower resources of state pollution control boards. Digital record keeping and monitoring systems, use of GIS tools, and better coordination and synergies among different regulatory authorities such as mining department, pollution control board, district environment impact assessment authority, and commercial tax department will help in improved monitoring and enforcement of the compliance.

ANNEXURE 1: BRIEF DESCRIPTION OF CLEANER BRICK KILN TECHNOLOGIES

The main cleaner brick kiln technologies options considered under this program are

1. Zigzag brick kiln technology
2. Vertical Shaft Brick Kiln (VSBK) technology

1. Zigzag Brick Kiln Technology

Fixed Chimney Bull's Trench Kiln (FCBTK) is a continuous, moving fire kiln having oval or circular shape. The bricks are stacked in the kiln in a manner to allow air flow in straight paths along the kiln circuit.

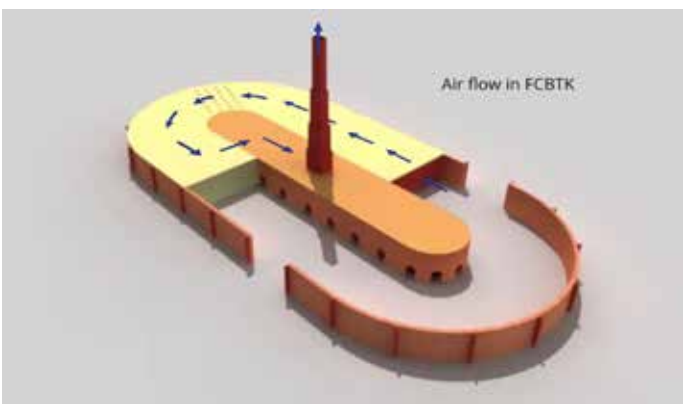


Figure 7. Schematic of FCBTK and air flow in FCBTK

The zigzag kilns are continuous, moving fire kiln having rectangular shape. In a zigzag kiln, the air follows a zigzag path instead of straight path followed in a FCBTK as shown in the figure below:

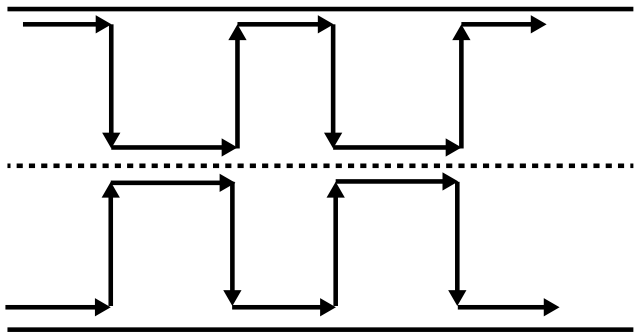


Figure 8. Air flow in zigzag kiln

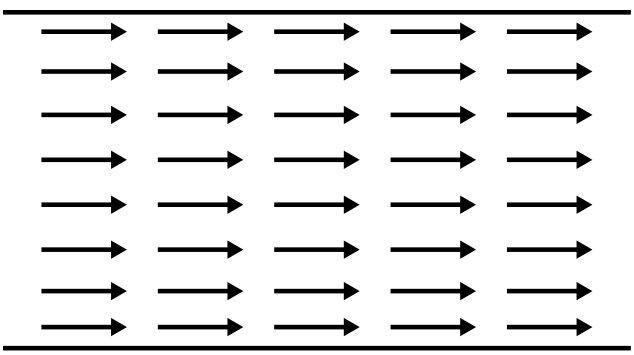


Figure 9. Air flow in FCBTK

The main differences in the operation of FCBTK and zigzag kilns lie in the brick setting pattern and the firing process, which results in better efficiency, better product quality and reduced emissions in case of zigzag kilns.

Types of Zigzag Kiln

There are two types of zigzag kilns prevalent in India. The difference lies in the way the required draught is created.

1. Induced Draught Zigzag Kiln (IDZK) in which the draught required for air flow in the kiln is created with the help of a fan.

2. Natural draught Zigzag Kiln (NDZK) in which the draught required for air flow in the kiln is created by the chimney itself.

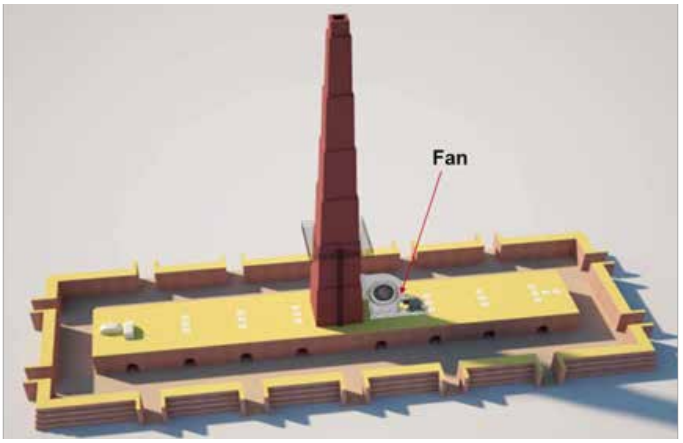


Figure 10. General design of induced draught zigzag kiln

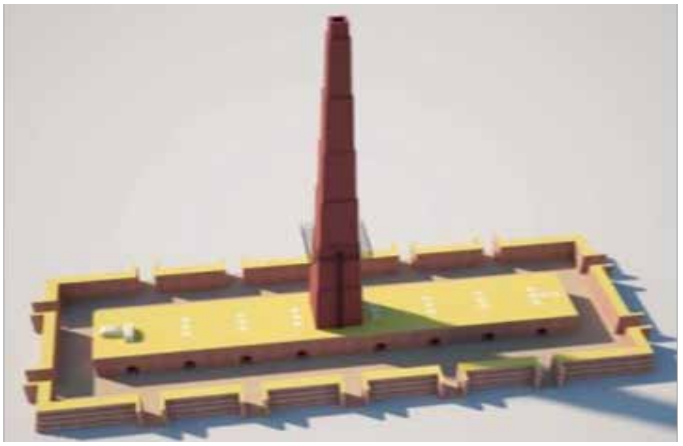


Figure 11. General design of natural draught zigzag kiln

Advantages of zigzag brick kiln technology over FCBTK:

1. Up to 25% reduction in fuel consumption and CO_2 emission
2. Production of more than 80% class-I bricks
3. Up to 75% reduction in PM emission
4. The existing FCBTKs can be easily retrofitted into zigzag kilns during the off-production season without impacting the annual production.

2. Vertical Shaft Brick Kiln (VSBK) Technology

In a vertical shaft brick kiln (VSBK), the bricks are fired in a vertical shaft in which the fire is burning around the center of the shaft. The height of the shaft is around 6–10 m and cross-section of the shaft can range from 1.0 x 1.5 m to 1.75 x 3.75 m. Mostly, the kiln consists of two or more shafts. The green bricks are loaded from the top, gradually moved down, fired around the middle height of the shaft, and are unloaded from the bottom.

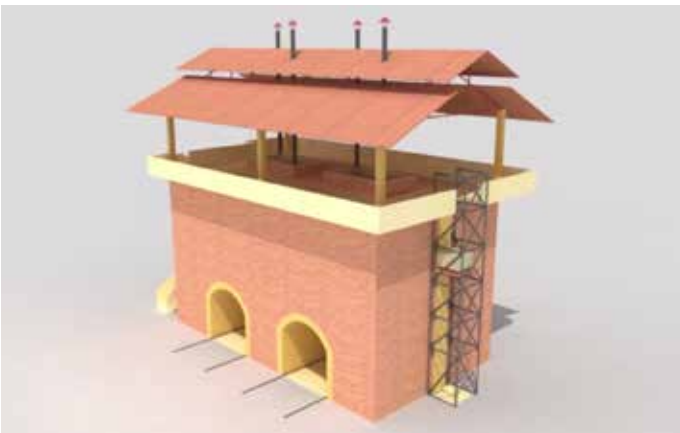


Figure 12. General design of a VSBK

Advantages of VSBK technology:

1. Up to 35% reduction in fuel consumption and CO_2 emission
2. Up to 75% reduction in PM emission

Limitations:

Soil of some of the regions is not suitable for fast firing as the case in a VSBK which results in fired bricks having poor quality ring sound (these are considered of inferior quality in the market). VSBK is more suitable for green bricks having better strength, i.e., brick produced through mechanical process (e.g., extrusion). Mechanical moulding requires additional investment and availability of electricity/ mechanical power.

ANNEXURE 2: SOME USEFUL RESOURCES AVAILABLE ON THE INTERNET

The list of some useful related resources available on the web is provided below:

1. Manual in Hindi on construction and operation of zigzag kilns prepared for Bihar titled "Manual on Cleaner Brick Kiln Technologies: Design, Construction and Operation" available at http://www.gkspl.in/reports/energy_efficiency/Manual_Kiln-Design-and-Construction-final.pdf
2. Policy brief titled "Towards Cleaner Brick Kilns in India – A win–win approach based on Zigzag firing technology" available at http://shaktifoundation.in/wp-content/uploads/2014/02/CATF-2013-Towards-Cleaner-Brick-Kilns-in-India.pdf
3. Fact sheets on brick kiln technologies being used in South Asia available at http://www.ccacoalition.org/en/resources/factsheets-about-brick-kilns-south-and-south-east-asia
4. Manual on design of zigzag kilns prepared for Nepal titled "Design Manual: Improved Fixed Chimney Brick Kilns" available at http://www.minergynepal.com/publications/Design%20Mannual%20-%20MinErgy.pdf
5. Animation film on natural draught zigzag kiln available at https://www.youtube.com/watch?v=WjjDhogWUW4
6. Policy brief titled "A Roadmap for promoting Resource Efficient Bricks in India: A 2032 strategy" available at http://shaktifoundation.in/report/roadmap-promoting-resource-efficient-bricks-india-summary/?psec=NQ==#NjY5OQ

About Bihar State Pollution Control Board

Bihar State Pollution Control Board (BSPCB) is a statutory body constituted in the year 1974 under the provisions of the Water (Prevention and Control of Pollution) Act, 1974. It is also mandated to ensure the provisions of the Air (Prevention and Control of Pollution) Act, 1981, the Environment (Protection) Act, 1986 and the various rules made thereunder. BSPCB is engaged in implementation of policies and regulations for prevention and control of pollution and environment protection. The Board is committed for a cleaner environment.

About Shakti Sustainable Energy Foundation

Shakti Sustainable Energy Foundation works to strengthen the energy security of the country by aiding the design and implementation of policies that encourage energy efficiency, renewable energy and sustainable transport solutions, with an emphasis on sub-sectors with the most energy saving potential. Working together with policy makers, civil society, academia, industry,and other partners, Shakti takes concerted action to help chart out a sustainable energy future for India. (www.shaktifoundation.in)

About Greentech Knowledge Solutions Pvt. Ltd (GKSPL)

Greentech Knowledge Solutions Pvt. Ltd (GKSPL) is a research-based advisory firm in the domains of clean energy and sustainable buildings. Key areas of expertise at GKSPL are: (a) reducing air pollution and improving energy efficiency in industrial processes to manufacture building materials such as bricks; (b) designing buildings that provide better thermal comfort to occupants and require less energy for air-conditioning; and (c) application of renewable energy technologies.

GKSPL provides technical services to develop and test technical solutions, undertakes policy studies and participates in policy advocacy, and disseminates knowledge through reports, website, and training programmes. (www.gkspl.in)

About the Study

Production of burnt clay bricks through FCBTK technology, the conventional and predominantly used brick kiln technology in the Indo-Gangetic region, has been identified as a key source of air pollution in the region. In the past few years, there has been strong advocacy for upgradation of brick kilns to cleaner and less polluting kiln technologies. The Government of Bihar, as a pilot initiative in this direction, issued a directive in the year 2016 asking all the brick kilns located around Patna city to shift to cleaner kiln technologies. Later on, this directive was extended to the entire state of Bihar. Similar directives have been issued by the authorities in other regions also such as the National Capital Region and Punjab.

This case study documents the strategy and process of implementation of the directive in the Patna region and draws important learnings from it. The experience and learnings discussed in this publication can be useful for policy makers, development agencies, and other key stakeholders in the implementation of similar initiatives in the brick sector in India and other South-Asian countries.

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