

Final Report

Evaluating Energy Conservation Potential of Brick Production in India

A Report Prepared for the SAARC Energy Centre, Islamabad



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Executive Summary

With estimated annual production of 250 billion bricks a year, India is the second largest brick producer globally. There are more than 100,000 brick kilns in the country producing bricks. Fixed Chimney Bull's Trench Kiln (FCBTK) is the main brick kiln technology accounting for 70% of the production. Brick kilns consume about 35 million tonnes (MT) of coal a year, making them the second largest industrial consumer of coal after the steel industry. Inefficient combustion of coal and heat losses in brick kilns not results in a large loss of energy.

Adoption of energy conservation measures in brick kilns will not only result in very large fuel savings (20-60%) but also in reductions in SPM, Black Carbon and CO₂ emissions, improvements in the incomes and working conditions of workers, and production of better quality building material.

A variety of proven technical options exists for energy conservation in fired clay brick making. These consist of:

- a) Adoption of efficient kiln technologies, primarily retrofitting of FCBTKs into zigzag kilns
- b) Promotion of internal fuel in brick making
- c) Promotion of mechanized coal stoking/ burner systems
- d) Promotion of manufacturing of hollow and perforated bricks

Some of the key elements of the strategy to disseminate energy conservation measures in the Indian brick industry are:

- a) Introduction of regulation and policies that encourage adoption of energy-efficient/cleaner brick-firing technologies
- b) Putting in place an effective technology and knowledge delivery system
- c) Developing financial instruments specifically for upgradation of the brick industry

1. Introduction and Background

1.1 Historical Context

Clay fired bricks are the preferred walling material in India. India has a long and rich history of production and use of clay fired bricks dating back to the Indus valley civilization (2500-1500 BC). Historical monuments at Sarnath (3rd century BC – 11th century AD), Nalanda (4th -12 th century AD), Qutab Minar (12th -13th century AD) are some of the prominent examples of use of clay fired bricks. During Mughal period also brick making was widespread; the bricks were generally thin (2 inch thickness). The arrival of Europeans in India had an influence on Indian brick making. German missionaries introduced state-of- the- art clay roofing tiles manufacturing facilities on the Malabar coast in the 18th century which consisted of mechanised clay preparation and extrusion machinery for shaping and Hoffmann kiln for firing of tiles and bricks. The British introduced large size bricks (10 inches X 5 inches X 3 inches) bricks. They also established large clay brick production facilities near big cities. One of the largest factories was established at 1881 at Akra near Kolkatta for producing 20-30 million bricks/year. The British also introduced continuous brick firing technology called Bull's trench Kiln – a simpler form of the oval-shaped Hoffmann kiln – in the year 1873. The recent history of brick production in 19th and 20th century in India is that of stagnation in technology and enterprise management. Present socio-economic conditions in the Indian brick industry may be likened to the ones that existed in England and most parts of Europe during the period 1850 to 1900. After independence, there have been attempts to introduce improved technologies, but the rate of change has been slow. The environmental regulations (air pollution) introduced in 1990's have led to some incremental improvements in brick kiln technology.

1.2 Overview of Brick Making

India is the second largest producer of bricks in the world producing around 240 billion bricks annually¹. There are around 140,000 brick kilns operating in India which contribute more than 10% to the total brick production of the world. Indian brick industry is mainly unorganized and non-mechanized. Except some mechanized/ semi-mechanized units (mostly in south India), the industry employs mainly hand-moulding methods for shaping green bricks. Surface soil excavated from agriculture fields and silt deposited from river and tanks are the main sources of clay supplies. Drying is mostly done in the open and bricks cannot be dried during the rainy season. Therefore, the industry is seasonal. It operates for six to eight dry months of a year only (generally from November to June). Firing in large units is done in Bull's Trench Kilns (mostly fixed chimney) while for small-scale production a variety of clamps and intermittent kilns are

¹ Pritpal Singh: Presentation at the seminar on cleaner brick production held at Patna on 06th December 2012 organised by Bihar Pollution Control Board and Development Alternatives

used. More than 10 million workers are estimated to be employed with the Indian brick industry.

1.3 Brick demand in India

The Indian economy has been growing at an average annual rate of 5-8% since 2001. For the 12th five year plan (2012-13 to 2016-17), the target has been set to achieve an average annual growth rate of 9%². The rate of urbanization in India has also been rapid with a decadal growth rate of 31.3% between 1991 and 2001 and 31.8% between 2001 and 2011. The overall urban population has increased from 217.17 million to 377.10 million during 1991 to 2011. The numbers of towns and cities have also increased from 3,768 to 7,951 during this period³.

The growth in the economy and population coupled with urbanization has resulted in an increasing demand for residential, commercial, industrial and public buildings as well as other physical infrastructure. Various studies indicate that, out of the total constructed area existing in India in 2030, about 70% would have been constructed between 2010 and 2030. Building construction in India is estimated to grow at a rate of 6.6% per year during the period 2005 to 2030⁴. The building stock is expected to multiply five times during this period (Figure 1), resulting in a continuous increase in demand for building materials.

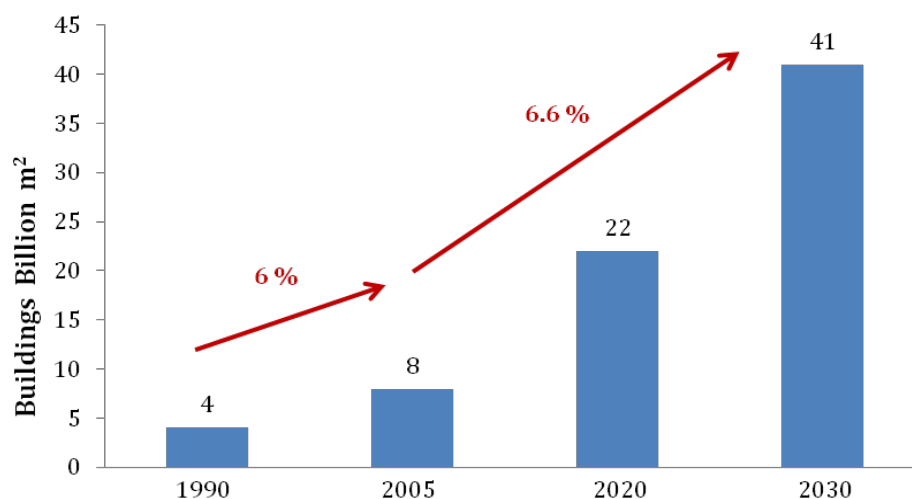


Figure 1: Projected Increase in Building Area in India⁵

² Faster, Sustainable and More Inclusive Growth – An Approach to the 12th Five Year Plan (2012-13 to 2016-17), Planning Commission of India, 2011.

³ Census of India, 1991; 2001; 2011.

⁴ Environmental and Energy Sustainability: An Approach for India, McKinsey & Co, August 2009

⁵ Ibid. 4

Bricks are one of the most important walling materials used in India. A 6.6% annual growth rate in construction activity would increase the annual demand for walling material to around 500 billion brick equivalent masonry units by 2030.

It is quite evident that India requires massive quantities of construction material over the next two decades. The bulk of building material is presently derived from locally available clay, soil, sand and gravel. Solid fired clay bricks are the most widely-used walling materials in the country. However, over the past few decades, the development of other materials such as solid/hollow concrete blocks, fly-ash bricks, Cement Stabilized Soil Blocks (CSSB), Fly Ash-Lime-Gypsum (FaL-G) blocks, Autoclaved Aerated Concrete (AAC) blocks, etc., has created viable alternatives to bricks and have also penetrated the market.

2. Scope of Work

This report has been prepared as a part of the study undertaken by SAARC Energy Centre (SEC) for “Evaluating Energy Conservation Potential of Brick Production in SAARC Region” in major brick producing SAARC Member countries namely Bangladesh, India, Nepal and Pakistan. The purpose of this assignment is to contribute & further understanding of the energy efficient techniques in order to reduce the cost of production, efficient utilization of fuel and market in the region, as a result assisting in the development and expansion of the market through the implementation of the report recommendations. This report deals with energy conservation potential in brick making in India. The scope of the study includes development of strategy for efficient use of coal in brick industry; outline the objectives, priority areas, best practices, countries technologies, for improvement of the sustainable market.

3. Methodology

The report has been prepared based on a literature survey of reports, papers and newspaper article on brick industry in India; collection of information from the All India Bricks and Tiles Manufacturing Federation (AIBTMF), Punjab State Council for Science and Technology (PSCST) and other expert organisation and previous and on-going work of the author.

4. Economic and Industrial Condition

Indian brick industry is characterized as a small scale, traditional industry mostly clustered in the rural and peri-urban areas. It is common to find large brick making clusters located around the towns and cities, which are the large demand centres for bricks. Some of these clusters have up to several hundred kilns. Brick industry is mainly unorganized with only a small number of units registered with the Department of Micro, Small and Medium Industries (MSME) unit. Brick units are normally set up on leased-

out lands near clay sources. In most cases, temporary permissions for seasonal operation are obtained from local statutory bodies and these are renewed every year.

4.1 Indian brick industry –Regional differences

Stratigraphically, India is divided into 3 broad regions – northern mountainous region, Gangetic plain and peninsula (triangular plateau region).

The brick production in the northern mountainous region is very low and is limited to valleys e.g. Srinagar, Jammu and Dehradun.

The Gangetic plains of north India account for about 65% of total brick production. Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal are the major brick producing states in this region (Table 1). Brick kilns, generally of medium and large production capacities (2–10 million bricks per year), are located in clusters around major towns and cities. Figure 2 shows a Google Earth image of a large brick cluster on the outskirts of Delhi in the state of Haryana. The availability of fertile alluvium soils in the Gangetic plains has caused the fringe areas of cities in this region to be dotted with brick kilns and consequently is a significant force in bringing about land use/ land cover changes around cities⁶.

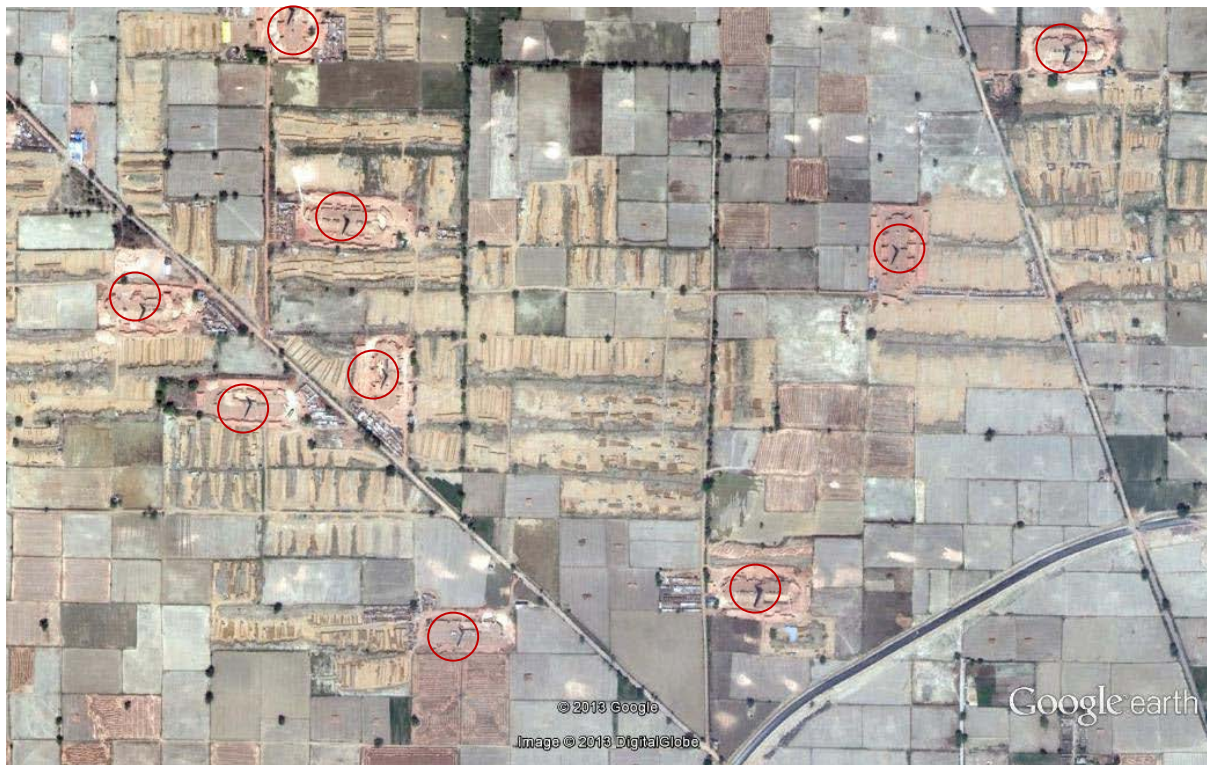


Figure 2: Google Earth image of a brick making cluster located outside Delhi in Haryana (9 FCBTKs can be seen in an area of 1.5 sq. km)

⁶ Lakshmi Singh, A. and Md. S. Asgher. 2005. "Impact of brick kilns on land use/land cover changes around Aligarh city, India." *Habitat International* 29 (2005) 591–602

Table1: Estimated numbers of kilns in major brick producing states in the Gangetic plains

	Typical production capacity of a kiln (number of bricks/year)	Total number of kilns
Punjab	4-8 million	3000-4000
Haryana	4-8 million	2000-3000
UP	2-8 million	15000-18000
Bihar	2-5 million	4000-6000
West Bengal	2-5 million	3000-5000

Note: Estimates based on interactions with brick industry

Peninsular and coastal India account for the remaining 35% of brick production. In this region, bricks are produced in numerous small units (production capacities generally range from 0.1 to 3 million bricks per year). Gujarat, Orissa, Madhya Pradesh, Maharashtra, Karnataka and Tamil Nadu are important brick producing states in the peninsular plateau and coastal India.

4.2 Technology

Most of the brick kilns in India are non-mechanised except few mechanized / semi-mechanized units contributing to less than 1% of the total production. They depend on piece-rate contract labours to carry out the clay winning, preparation, moulding, drying, firing and materials handling operations. In recent years use of mechanical excavators for clay winning is becoming common.

Use of roller crushers (for clay preparation) and extruders (for brick shaping) has been prevalent in the Malabar coast region, only recently a few industries in other parts of the country have started using extruders. Pug mills for mixing clay – both animal-driven and power-driven – have been in use in the states of West Bengal and Uttar Pradesh for a very long time. Some large mechanised pug mills are also in operation. The indigenous capacity to produce machinery for semi-mechanised brick production is limited. Though there are several small companies making soft-mud moulding machines and extruders, however, there are only a handful of established companies e.g. DeBoer-Damle, Vijaya Prakash Industries, producing reasonably good quality of machinery. In recent years, the import of Chinese extruders and clay preparation machinery is on increase and the number of such plants in operation or under commissioning is around 20.

Drying of green bricks is mostly done in the open, except parts of South India where bricks are dried under drying sheds.

Table 2 provides the details about the various types of firing technology currently prevalent in India. Currently, Fixed Chimney Bull's Trench Kiln (FCBTK) is the leading technology for firing bricks. FCBTK accounts for around 70% of the total brick production in India and is prevalent in the Indo-Gangetic plains, as well as in some

pockets in the rest of the country. Clamps are used widely all over peninsular India. Down-draught kilns, Vertical Shaft Brick Kilns (VSBK), Hoffmann kilns, and zig-zag fired kilns make up less than 5% of all kilns.

Table 2: Brick kiln technologies currently prevalent in India ⁷

Kiln Type	Regional spread	Approximate contribution in brick production
Clamps	Central, West and Southern India	25%
Fixed chimney BTK	Indo-Gangetic plains (North and East India) and several clusters in South and West India	70%
Zig-zag	West Bengal, a few clusters in North India	3-4%
VSBK	Central and East India	>1%

4.3 Raw material

Unlike developed countries, which utilize mined clay and shale for brick making, Indian brick manufacturers mostly use surface soil. In the Gangetic plains, surface soil from agriculture fields is the main source of clay. In the state of West Bengal, silt deposited by rivers is the main source of clay for making bricks. In South and West India clay from dams, percolation tanks as well as surface soil excavated from both agriculture as well as barren lands form the main sources of clay supplies.

The Gangetic plain is formed by the deposition of silt by the river Ganga and its tributaries and the soil is "alluvial" in nature. Its colour is faint yellow and it is a mixture of fine sand, silt, clay and organic matter. It is considered good for brick making. The Peninsular soils have varying colours and qualities and broadly, they are grouped under regur (black cotton), red or lateritic soils⁸. They are termed difficult for brick making. Owing to these differences in the nature of available soils, the brick industry in the Gangetic Plain is dominated by FCBTK (where large-scale concentrated production is practiced), while the Peninsula is dominated by open clamps (where small-scale scattered production is practiced).

4.4 Industrial and economic condition

Fuel and operation (mainly the labour cost) are the two most important cost components of brick production and together accounts for almost 70% of the cost of production (figure 3) . Management of fuel cost is an important consideration for brick

⁷ Brick Kilns Performance Assessment & a Roadmap for Cleaner Brick Production in India, Greentech Knowledge Solutions Pvt Ltd, February 2012.

⁸ Damle Anand, 2007, Present Status of the Brick Industry in India – Raw Materials, Process Technology and Market. Tile and Brick International

makers, resulting in shifts to cheaper fuels. In recent years, the cost of raw material (mainly brick earth or clay) has also increased and in certain areas of Western and Southern India can account for almost 25% of the cost of production. The selling price of fired bricks vary greatly across the country, the highest price of Rs 8-12/ brick is realized in West Bengal and some of the Southern States. In the remaining regions of the country the brick prices vary from Rs 4-8/bricks.

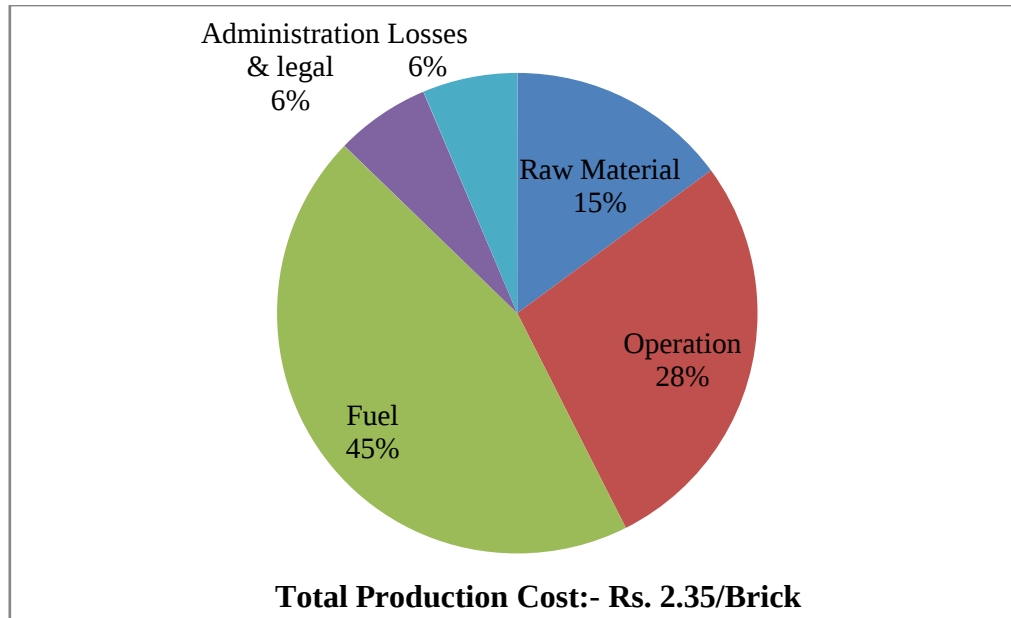


Figure 3: Average Production Cost Break-down Data for a FCBTKs in Indo-Gangetic Region⁹

Owing to their temporary, low technology and polluting nature and absence of professional management, production of bricks is generally not thought of as an "industrial" activity by the common man.

Only in South India, where roof tile plants are very common and the same setups are used to manufacture bricks, extruded or dust pressed bricks command reasonable consumer respect.

One of the new developments of note in Indian brick sector has been the entry of the largest brick manufacturing company in the world in the Indian market. Wienerberger (www.wienerberger.in) has set up a production facility near Bangalore. This is one of the most advanced Wienerberger plant in the world with Chamber dryer and a tunnel kiln based on pet coke and LPG. The plant has a production capacity of around 6600 tons per day (60,000 blocks/ day of hollow blocks of 200 x 200 x 400 mm dimensions and having a weight of 11 kg – Figure 4)¹⁰.

⁹ *Ibid.* 7

¹⁰ Personal Communication, Mr Kundan Dighe, Manager –Product Development, Wienerberger India Private Ltd.

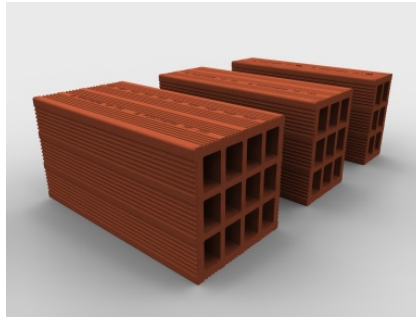


Figure 4: Hollow Blocks Produced by Weinerberger

5. Social and Environmental Impacts

5.1 Environmental Impacts

Brick firing is an energy intensive process. Coal, wood, and many agricultural wastes such as mustard stalk, rice husk etc. are used as fuels for firing bricks. Indian brick industry is one of the largest industrial consumers of coal in India (~ 35 million ton per annum)¹¹.

Combustion of coal and other biomass fuels in brick kilns results in the emissions of suspended particulate matter (SPM), including black carbon (BC), sulphur dioxide (SO₂), oxides of nitrogen (NO_x), and carbon monoxide (CO). Typical measured emissions from Fixed Chimney Bull's Trench Kiln (FCBTKs) are shown in Table 3. The emission of these pollutants has an adverse effect on the health of workers and vegetation around the kilns. In recent years, the higher cost and a shortage of good quality bituminous coal have resulted in an increased use of high-ash, high-sulphur coal, as well as in the use of industrial wastes and loose biomass fuels in brick kilns. All of these have resulted in new air emission challenges. The use of large quantities of coal in brick kilns contributes significantly to emissions of carbon dioxide (CO₂). Carbon dioxide emission along with emission of black carbon contributes to global warming.

Table 3: Measured Stack Emissions from Fixed Chimney Bull's Trench Kilns (FCBTK)¹²

	Kiln 1	Kiln 2	Kiln 3
SPM (mg/Nm ³)	766	143	370
PM _{2.5} (mg/Nm ³)	160	48	74
SO ₂ (mg/Nm ³)	610	29	326

¹¹ *Ibid.* 1

¹² *Ibid.* 7

Loss of topsoil from agriculture land is also an important environmental concern. Brick kilns are mostly situated on fertile agricultural land. The usual practice is to remove the topsoil for brick making (usually up to a depth of 1 m). Quite often soils used in brick-making have high fertility status and their opportunity cost is also high especially when the soil/brick-earth is removed from river basins with intensive agricultural production. The removal of topsoil has direct impact on agricultural crop production via reduced fertility status of soils. As the addition of organic matter in the forms of human and animal wastes and plant residues occurs only over the top layers of soil, removal of topsoil leads to loss of soil fertility¹³.

5.2 Social Impacts^{14,15}

The brick industry employs in excess of 10 million workers. Majority of them are migratory workers belonging to most vulnerable and excluded community of Indian society i.e. Scheduled Castes and Scheduled Tribes and are mostly landless or having little amount of land that is insufficient to earn a sufficient livelihood. Due to the seasonal nature of brick industry, the workforce gets employment for a limited period of six months per annum. They are paid against completion of specific tasks such as moulding of 1000 bricks, transportation of 1000 green bricks etc. Brick making involves crude techniques causing considerable worker drudgery and brick workers are exposed to several occupational hazards. Brick workers, especially moulders are exposed to the sun for long hours. They are exposed to high concentration of dust. The firemen are exposed to high temperatures and have to walk on hot surface (top of the furnace) while monitoring and regulating the fire. They are also exposed to high concentrations of respirable suspended particulate matters (RSPM), during monitoring and regulating the fire, as the furnace chamber is covered with ash (ash acts as insulator). In several parts of the country, transportation of green and red bricks is done by head load. Generally 25-35 kg are carried at a time as head load. Carrying head loads on a regular basis causes health problems, especially in women. The living conditions of the workers at brick kiln sites are very poor; they live in temporary make-shift accommodation and generally do not have access to safe water and sanitation facilities.

¹³ Environmental cost of using top-soil for brick making – A case study from India. Accessed from www.webmeets.com/EAERE/2008/prog/getpdf.asp?pid...

¹⁴ Background Note on National Workshop on 'Livelihood and social security issues of brick kiln workers' held at Mahtama Gandhi Labour Institute, Ahmedabad on 25th August 2009.

¹⁵ Development Alternatives, 2005: Environmental and Social Report for VSBK - A Guidance document for Entrepreneurs and Project Auditors

6. Identification of relevant institution, activities for capacity building for promotion of energy efficiency in the sector

6.1 Institutions

Issues related to brick making has several dimensions such as energy, environment, social and economical. Many agencies including ministries in the state and central government, research institutes, Non Governmental Organizations (NGOs), multinational organizations and other donor agencies are likely to have an interest in addressing issues related to brick kiln.

Bureau of Energy Efficiency (BEE) is the nodal agency involved in developing and promoting strategies on energy efficiency in the country. BEE's activities on energy efficiency enhancement in brick and other small and medium enterprises include

- Analysis of technology and energy use
- Capacity building
- Implementation of energy efficiency (EE) measures and
- Facilitation of innovative financing mechanism for adoption of energy efficient technologies.

BEE has conducted an analysis of energy use in Varanasi brick cluster. However, at present, BEE is not very actively involved in undertaking energy efficiency activities in the brick industry.

Ministry of Environment & Forest (MoEF) is the nodal agency at the central government responsible for formulating and implementation of policies and regulations relating to conservation of environment. Three different departments at MOEF are working on issues directly or indirectly related to brick making in India.

- Control of pollution department at MoEF coordinates with Central Pollution Control Board in developing emission norms and guidelines for brick kilns. The existing emission standards for brick kilns cover – a) Bull's trench brick kilns notified by MoEF in 1996 b) Vertical shaft brick kilns notified by MoEF in 2006 c) down draught brick kilns. The department currently is engaged in the process of revising the standards for brick kilns.
- Climate Change Division deals with issues related to for climate change cooperation and global negotiations. It is also the nodal unit for coordinating the National Action Plan on Climate Change.
- Clean Technology department at MoEF support projects and initiatives to develop and promote clean technology and abatement of pollution through prevention strategies and waste minimization.

Central Pollution Control Board (CPCB) is statutory organization entrusted with power and functions to prevent and control pollution. They provide technical services to MoEF. The process of developing /revising emission norms for brick kilns is coordinated by CPCB while the Gazette notification is issued by MoEF. CPCB is currently involved in a study to revise the environment standards for the brick kilns.

Building Materials and Technology Promotion Council (BMTPC): BMTPC is an agency under the Ministry of Housing and Urban Poverty Alleviation and among other things is also responsible for promotion of alternate/new/sustainable building materials and construction technologies.

Punjab State Council of Science and Technology (PSCST): PSCST is the Science and Technology department of the Punjab Government. It provides technical and advisory services for promotion of cleaner technologies. PSCST is involved in the CPCB supported study on “Development of emission norms and best practice guidelines for Brick kilns”. The study is expected to result in the revision of the emission standards from brick kilns. In the past it has played an important role in dissemination of Fixed Chimney BTK in Punjab and Haryana.

The Energy and Resources Institute (TERI): TERI is an NGO and was one of the organization involved in transfer and promotion of Vertical Shaft Brick Kiln (VSBK) technology to India as a part of Swiss Agency for Development Cooperation (SDC) program. It also developed the emission norms for Vertical Shaft Brick kilns for CPCB and MoEF. TERI is currently the implementation organization for the UNDP-GEF project on resource efficiency in Indian brick industry.

Development Alternatives (DA): Development Alternatives (DA) an NGO and has a long history of working on alternate/eco- building materials in India as well as several other Asian and African countries. It has been involved in promotion of VSBK technology since 1996. In addition it also provides technology for industrial waste utilization in brick making as well as manufactures machinery for brick industry.

Greentech Knowledge Solutions Pvt Ltd (GKSPL): GKSPL carries out energy& environment monitoring of brick kilns and provides consulting and training services for cleaner brick production. Greentech is considered one of the premier consulting agency in this sector in the developing world and has been providing consulting and training in India, Nepal, Vietnam and South Africa under projects supported by UNDP, UNEP, Swiss Agency for Development and Cooperation, Shakti Sustainable Energy Foundation, etc.

Central Building Research Institute (CBRI): CBRI is the CSIR laboratory, responsible for promoting building science and technology. The institute carried out pioneering research work to develop technology for brick industry in 1960's and 1970's. It provides consultancy and design assistance to the industry primarily for High Draught Kiln.

All India Brick and Tiles Manufacturers Federation (AIBTMF): AIBTMF is the national federation of brick makers, with over 7000 members. The primary activity of AIBTMF is to lobby with the government to protect the interests of brick entrepreneurs.

State and Cluster level brick associations: Most of the states have state level associations of brick makers; there are several district/cluster level associations also. Like, AIBTMF, the primary activity of these organizations is to lobby with the government to protect the interests of their members.

Academic Institutes: Some of the Academic Institutes such as Indian Institute of Sciences (IISc), Bangalore and Indian Institute of Technology, Bombay are also involved in research aspects of brick making and building materials.

Multilateral and bi-lateral Funding Agencies Multilateral and bi-lateral Funding Agencies such as United Nation Development Program (UNDP), Swiss Development Cooperation (SDC) have been involved in brick kiln programmes in India. In recent years, Shakti Sustainable Energy Foundation has been supporting activities for cleaner brick production.

6.2 Activities for Promoting Energy Efficiency & Environment Performance of Brick Kilns

Despite its significance in the construction sector, its importance in the livelihoods of the poor, its large consumption of coal, and its impact on health and environment, the brick making sector has seen very few development interventions/programmes aimed at improving the industry. Initiatives that have been undertaken are listed in table 4. The most significant government interventions were the environmental regulations enacted in the 1990's, which resulted in upgradation in the firing technology from moving chimney bull trench kilns to fixed chimney bull trench kilns.

Table 4: Development Programmes/Initiatives in the Indian Brick Industry

	Agency/ Programme	Type of Intervention	Impact
1970's	Central Building Research Institute, Government of India	Technical: Introduction of zig-zag firing technology and semi-mechanization process	• Successful in seeding the technologies. • Adoption of technology only in certain states e.g. West Bengal
1990's	Central Pollution Control Board/ Ministry of Environment and Forest (MoEF)	Regulation: Air emission regulation for brick kilns	• Large-scale shift (around 30,000 kilns) from moving chimney Bull's Trench Kiln technology to more efficient and less polluting fixed chimney Bull's Trench Kiln technology.

1995-2004	Swiss Agency for Development and Cooperation	Technical: Introduction of Vertical Shaft Brick Kiln (VSBK) Technology	• Successful in seeding the technology. • No large-scale adoption.
2009-ongoing	United Nations Development Program - Global Environment Facility (UNDP-GEF)	Technical: Introduction of hollow bricks and other resource-efficient bricks.	• Increased awareness about resource-efficient bricks.
2010 - ongoing	Shakti Sustainable Energy Foundation	Assessment of technologies for brick making. Technology package and training programme on zigzag firing technology. Formation of a task force in the state of Bihar on cleaner brick production.	• Identification of possibility of retrofitting FCBTKs into natural draught zigzag firing • First active state level intervention (in the state of Bihar) to promote cleaner brick production

There have only been a few training initiatives to impart training on energy efficiency in brick industry, these are:

- Punjab State Council for Science and Technology in 2001 published a manual on “better feeding, firing and operating practices in Bull’s Trench Kilns”. This well-illustrated manual is available both in Hindi and English.
- The Energy and Resources Institute has conducted training programme on better operating practices for fire men and fire masters under a project supported by the Swiss Agency for Development and Cooperation.
- Development Alternatives offers training on Vertical Shaft Brick Kiln technology and fly-ash bricks.
- Greentech Knowledge Solutions along with Nextgen Brick Training Academy at Varanasi had recently developed a 5-days training programme on retrofitting FCBTKs into energy-efficient zigzag firing. This is the most comprehensive training programme designed so far and is targeted at brick kiln owners. The programme has been very well received and brief details of the training module are provided in box 1.
- Greentech Knowledge Solutions also offers training programmes on energy and environment performance monitoring/auditing of brick kilns for engineers.

Box 1: Training Module on Retrofitting FCBTKs to Energy Efficient Natural Draught Zigzag Firing

Greentech Knowledge Solutions in association with Nextgen Brick Training Academy has developed a technology knowledge package and training module on zigzag firing technology, with the help of support from Shakti Sustainable Energy Foundation. First training programme on zigzag firing technology for brick kiln owners was held on 20 – 26 June 2012 at Varanasi. Two more training programme are scheduled in March 2013 at Kathmandu (Nepal) & April 2013 at Varanasi for brick makers from Bihar.

The training programme is conducted through class-room lectures, field visits, tutorials and experiments and covers following modules:

- Basics of Firing & Combustion
- Fixed Chimney Bulls Trench Kiln & its shortcomings
- Introduction to natural draught Zigzag kilns & its brick setting
- Kiln & Fire management in a natural draught zig-zag kiln
- Construction of natural draught zig-zag kiln



7. Mapping of active stakeholders in the market, covering financiers/investors, technology providers

Active stakeholders in the market in the domain of energy efficiency of brick kilns are provided in the table 5.

Table 5 : Active Stakeholders in the domain of energy efficiency improvements of brick making

Name	Type of Activity
Technology Providers/ Consultants	
Punjab State Council of Science and Technology (PSCST), Chandigarh	• Technology provider of improved fixed chimney Bull's Trench Kiln Technology. • Training and consulting on production of hollow and perforated bricks. • Training on improved coal feeding and firing practices in FCBTKs
The Energy and Resources Institute (TERI), New Delhi	• Promotion of production of hollow and perforated bricks. • Training on improved coal feeding and firing practices in FCBTKs • Energy and environment monitoring of brick kilns
Development Alternatives (DA), New Delhi	• Technology provider of Vertical Shaft Brick Kiln technology and fly-ash bricks. • Training on clay fired brick and fly-ash brick making
Greentech Knowledge Solutions Pvt Ltd (GKSPL), New Delhi	• Training on improving energy performance of brick kilns and natural draught zigzag brick kiln • Energy auditing of brick kilns
Enzen Global Solutions Pvt Ltd, Bangalore	• Environment monitoring of brick kilns
Prayag Clay Products Pvt Ltd , Varanasi	• Technology provider of natural draught zigzag kiln technology. • Training on improving energy performance of brick kilns and natural draught zigzag brick kiln
Central Building Research Institute (CBRI), Roorkee	• Technology provider for High-Draught brick kiln technology and Fixed Chimney Bull's Trench Kiln
Eco Chimneys Pvt Ltd, Chennai	• Technology provider for Efficient Fixed Chimney Bull's Trench Kiln technology.
Institute for Solid Waste Research & Ecological Balance (INSWAREB), Vishakhapatnam	• Technology provider for fly-ash brick making (FaL-G technology)
Financial Institutions	
Small Industrial Development Bank of India (SIDBI)	• Financing of energy efficiency improvements in micro small and medium enterprises including brick kilns.
Khadi and Village Industries Commission (KVIC)	• Financing of brick making units

8. Identify and analyze barriers of the Private Sector for Investment

In case of FCBTKs, retrofitting of kilns and simple operational improvements can result in substantial energy savings. Typically the investment in these measures is up to US \$ 20,000. A large number of brick manufacturers have the capacity to mobilize finance through their own sources for undertaking these investments. However, measures such as construction of tunnel kiln, artificial driers, mechanization of the brick moulding process, mechanization of material handling, which will be necessary in the long run for modernizing the industry requires much larger investments, which are typically of the order of US \$ 200,000 to 2 million.

There are several barriers in mobilizing private sector investments for modernization of brick industry.

The major barriers are:

- a) Absence of a government policy for energy/resource-efficient brick production: In the absence of a government policy that promotes and supports creation of a market for energy/resource efficient bricks, the manufacturers producing such bricks are at a price disadvantage compared to cheaper traditional bricks and this is a major barrier in mobilizing new investments for brick production modernization.
- b) Limited or no access to grid-electricity: Mechanization of the brick production process requires electricity. Most of the existing brick kilns either do not have access to grid electricity or are located on rural electricity feeders, which are prone to power outages and poor power quality. This is a significant barrier in adopting new technologies. Adopting new technologies requires investments in captive power generation facilities by brick makers.
- c) Land issue: The majority (>90%) of brick kilns in the Gangetic plains are located on leased land. Being located on leased land they hesitate in making investments in the construction of new facilities and machinery. A shift to new technologies would require them to first invest in land or renegotiate long-term lease agreements.
- d) Lack of off-the-shelf technology packages and technology providers: Standard technology packages are not available. The know-how of the zig-zag firing is limited to a handful of technology providers. For VSBK technology there is only one active technology provider. The manufacturing of machinery for brick making is concentrated in a few small-scale enterprises. Recently some European brick-making machinery manufacturers have entered the market and are involved in field trials on India-specific technology packages.
- e) Lack of trained manpower: Mechanization or shifting to any new technology requires trained manpower, which is in short supply. Currently, except for a new initiative by NextGen Brick Training Academy, there is no system in place to train manpower for the brick industry.

- f) Limited management capacity of brick enterprises: Most of the existing brick makers have limited education and lack in-house management capacity to undertake large-scale process modernization.
- g) Unfamiliarity of financial institutions with the sector: The financial institutions have very limited familiarity with the brick production sector and limited experience of lending to the brick producers. In general, brick producers are not positively looked for lending by financial institutions.

9. National Coal Policy and Present Situation of Coal Industry

The Indian coal industry is the fourth largest in terms of coal reserves and third largest in terms of coal production in the world. Exploration, development, and sale of coal and lignite resources in India are completely under the oversight of the Indian Government, through the Ministry of Coal. The Ministry is in administrative control of major coal-producing companies including Coal India Limited (CIL), Singareni Colliery Company Limited (SCCL), and Neyveli Lignite Corporation (NLC). More than 90% of coal and lignite produced in India is from the CIL, SCCL, and NLC mines, as only a small amount of captive coal mining is allowed for private steel, power and cement companies.

Brick kilns are estimated to consume roughly 35 million tonne of coal annually, which make them one of the largest industrial consumers of coal in the country (Figure 5)

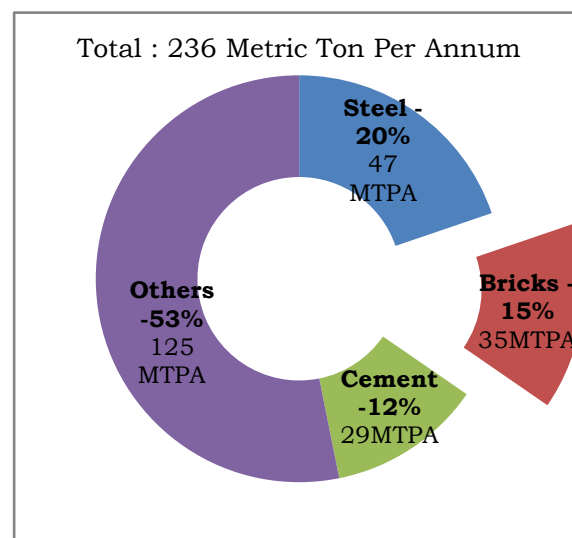


Figure 5: Major Industrial Consumers of Coal

Majority of the brick kilns, buy coal from open market and the coal prices fluctuate as per the demand and supply. The brick enterprises being small consumers of coal usually pay much higher price for coal compared to large industries and power plants. The retail price of coal sold to brick kilns can range anywhere between Rs 4000 - 15000/ ton depending on the quality of the coal and the distance from the coal mines. In some places, brick kiln associations buy coal directly from the public sector coal companies and the coal is delivered through railways. The price of such coal is lower.

Brick kilns can also purchase coal through e-auctions as proposed under the New Coal Distribution Policy of the government. A large number of kilns located in the southern and western India are now using imported coal from countries like Indonesia and South Africa. Use of petroleum coke (a waste product) of petroleum refining is also showing an increasing trend.

10. Environmental Policy and Regulations for Brick Industry

There is no comprehensive environmental policy for brick industry. However there are several environmental regulations applicable to brick production. The first environmental regulation dealing with emission standards for brick kilns dates back to 1996. Since then the regulation has been amended several times. There have also been regulations promoting the use of fly-ash in brick making. Various environmental regulations are listed in Table 6 below.

Table 6: Environmental regulations for brick kilns

Year	Notification/ Agency	Main Points
1996	Emission standards for brick kilns/ Ministry of Environment and Forests	- Existing moving chimney Bull's trench kilns shall be dispensed with by December 31, 1997 and no new moving chimney kilns shall be allowed to come up. - Considering the immediate need to protect the top soil and to find ways the safe disposal/utilisation of fly ash, it is provided that from the 1st January 1997, all brick manufacturing units within a radius of 50 km from any thermal power plant, shall utilise fly ash in optimal proportion for making bricks. - For Bull's Trench Kiln: SPM (Limiting concentration in mg/Nm³): Small – 1000; Medium – 750; Large – 750 Stack Height: Small – 22 m; Medium – 27 m; Large – 30 m, with gravity settling chamber
1999	Notification describing the fly ash utilization notification/ Regional Officer of the State Pollution Control Board or the Pollution Control Committee	Use of fly ash, bottom ash or pond ash in the manufacture of bricks and other construction activities- No person shall within a radius of 50 Km from coal or lignite based thermal power plants, manufacture clay bricks or tiles or blocks for use in construction activities without mixing at least 25% w/w of ash (fly ash, bottom ash or pond ash) In case of non-compliance, consent order issued to establish the brick kiln and the mining lease after approval can be cancelled

1999	Notification describing the utilisation of ash by Thermal Power Plants/ Central Pollution Control Board and concerned, State Pollution Control Board/ Committee and concerned regional office of the Ministry of Environment and Forests	Every coal or lignite based thermal power plant shall make available ash, for at least ten years from the date of publication of this notification, without any payment or any other consideration, for the purpose of manufacturing ash-based products such as cement, concrete blocks, bricks, panels Action plan provides for thirty per cent of the fly ash utilisation, within three years from the publication of this notification with further increase in utilisation by at least ten per cent points every year progressively for the next six years to enable utilisation of the entire fly ash generated in the power plant at least by the end of ninth year Action plan to be submitted to concerned authorities within a period of six months from the date of publication of this notification Annual implementation report providing information about the compliance of provisions in this notification shall be submitted by the 30th day of April every year to the concerned authorities
1999	Notification describing the specifications for use of ash-based products/ Bureau of Indian Standards, Central Building Research institute, Building Materials and Technology Promotion Council	Manufacture of ash-based products such as cement, concrete blocks, bricks, panels or any other material shall be carried out in accordance with specifications and guidelines laid down by the Bureau of Indian Standards; Central Building Research institute, Roorkee; Building Materials and Technology Promotion Council, New Delhi The Central Public Works Department, Public Works Departments in the State/Union Territory Governments, Development Authorities, Housing Boards, National Highway Authority of India and other construction agencies including those in the private sector shall also prescribe the use of ash and ash-based products in their respective schedules of specifications and construction applications, including appropriate standards and codes of practice, within a period of four months from the publication of this notification All local authorities shall specify in their respective building bye-laws and regulations the use of ash and ash-based products and construction techniques in building materials within a period of four months from the date of publication of this notification

2003	Notification amending the fly ash utilisation/ State Pollution Control Board or Pollution Control Committee	No person shall within a radius of 100 Km from coal or lignite based thermal power plants, manufacture clay bricks or tiles or blocks for use in construction activities without mixing at least 25% w/w of ash (fly ash, bottom ash or pond ash)
2008	Notification to amend the Utilization of flyash standards / State Pollution Control Board or Pollution Control Committee	Every construction agency engaged in the construction of buildings within a radius of 100 km (by road) from a coal or lignite based thermal power plant shall use only fly ash based products for construction. This will be applicable to all construction agencies of Central or State or Local Government and private or public sector. Annual returns need to be submitted to the concerned authorities.
2008	Notification amending Minimum fly ash content for building materials or products to qualify as “fly ash based products”	Fly ash bricks, blocks, tiles, etc. made with fly ash, lime, gypsum, sand, stone dust, cement, etc. (without clay) should have a minimum of 50% fly ash content on w/w basis of total raw material. Clay based building materials such as bricks, blocks, tiles, etc. should have a minimum of 25% fly ash content on w/w basis of total raw material.
2009	Amendment to emission standards for brick kilns/ Ministry of Environment and Forest, Government of India	For Fixed Chimney Bull's Trench Kiln: PM (Limiting conc. in mg/Nm³): Small – 1000; Medium – 750; Large – 750 Stack Height: Small – 22 m; Medium – 27 m; Large – 30 m For Down-Draft Kiln: SPM (Limiting concentration in mg/Nm³): Small/ Medium/ Large – 1200; Stack Height: Small – 12 m; Medium – 15 m; Large – 18 m For Vertical Shaft Kiln: SPM (Limiting concentration in mg/Nm³): Small/Medium/ Large – 250 Stack Height: Small – 11 m; Medium – 14 m; Large – 16 m

11. Experiences, expertise and the best available practices for sharing with other member states

A comparison of the energy performance of various brick kiln technologies is presented in Table 7.

Table 7: Comparison of energy performance of brick kilns

Type of Kiln	Specific Energy Consumption (SEC in MJ/kg of fired bricks)
VSBK	0.75-1.0
High draught	0.95 -1.1
Natural draught zigzag	1.0 -1.2
FCBTK	1.0 -1.4
Clamp	1.5-2.0
Downdraught	2.5-3.0

Source: Greentech Knowledge Solutions

In terms of SEC, VSBK is the most efficient kiln, followed by High Draught and Natural Draught zigzag kiln technologies. Adoption of these technologies can result in 20-60% energy savings compared to the traditional FCBTKs and clamps. Based on the experience in India, in this section four technological options for improving energy efficiency in brick firing have been presented. These are:

- a) best operating practices for FCBTK operation
- b) retrofitting FCBTKs into natural draught zigzag firing
- c) high-draught kiln
- d) vertical shaft brick kiln

11.1 Best operating practices for Fixed Chimney Bull's Trench Kiln

FCBTK is a continuous, cross-draught, annular, moving fire kiln operated under a natural draught, which is provided by a chimney. It is a moving fire kiln, in which the fire moves through the bricks, which are stacked in the annular space formed between the outer and the inner wall of the kiln. Green bricks are loaded in front of the firing zone, and cooled fired bricks are removed from behind. The kiln is generally of oval or circular shape.

The FCBTKs are built above the ground, by constructing permanent sidewalls. Unlike the original form of BTK, which employed a moving metallic chimney, FCBTK has a fixed chimney at the centre of the kiln. Figure 6 below shows a sketch of a FCBTK.

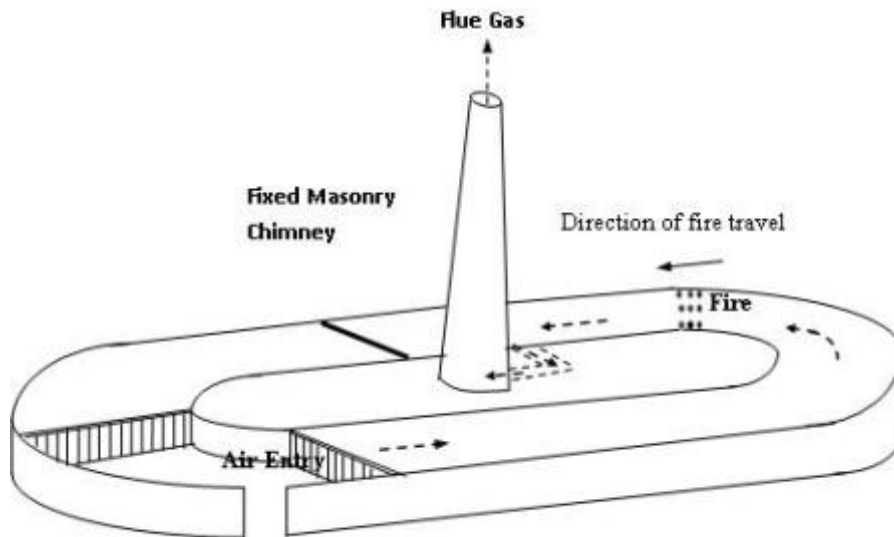


Figure 6: General Sketch of Fixed Chimney BTK

Green bricks to be fired are placed in the annular space and covered with a layer of partially fired or green bricks forming a temporary roof. A layer of ash and brick dust is spread over the top to seal the kiln and to provide thermal insulation. The bricks are stacked in a column and blade brick arrangement. The brick-unloading end is kept open for air entry into the kiln. The brick-loading end is sealed with a metal, cloth, paper or plastic damper.

At any given point of time, three distinct zones can be identified in a FCBTK. Proceeding from the brick-unloading end, the first zone is the brick cooling zone. In this zone, air entering from the unloading end picks up heat from fired bricks, resulting in heating of air and cooling of fired bricks.

The next zone is the fuel feeding zone (combustion zone), in which the fuel is fed from the feedholes provided on the roof of the kiln. Generally 2-3 rows are fed at a time. Some of the coal fed into the kiln accumulates on the ledges (provided at 5 levels) and the rest of the coal falls to the kiln floor (Figure 7). Coal comes in contact with hot gases, and combustion takes place in this zone. In general, in a FCBTK, coal is fed intermittently, with intervals between two successive feeding operation ranging from 20 minutes to 50 minutes. At any given time, coal is generally fed in 2 to 3 rows, and due to heavy charging of coal (10-15 kg/ min), black smoke can be observed coming out during and just after the coal feeding operation. When a fairly large charge of coal is fed, it creates a temporary deficiency of oxygen, the addition of cold fuel reduces the temperature of the fuel bed, some times below the ignition temperature of the fuel resulting in incomplete combustion.

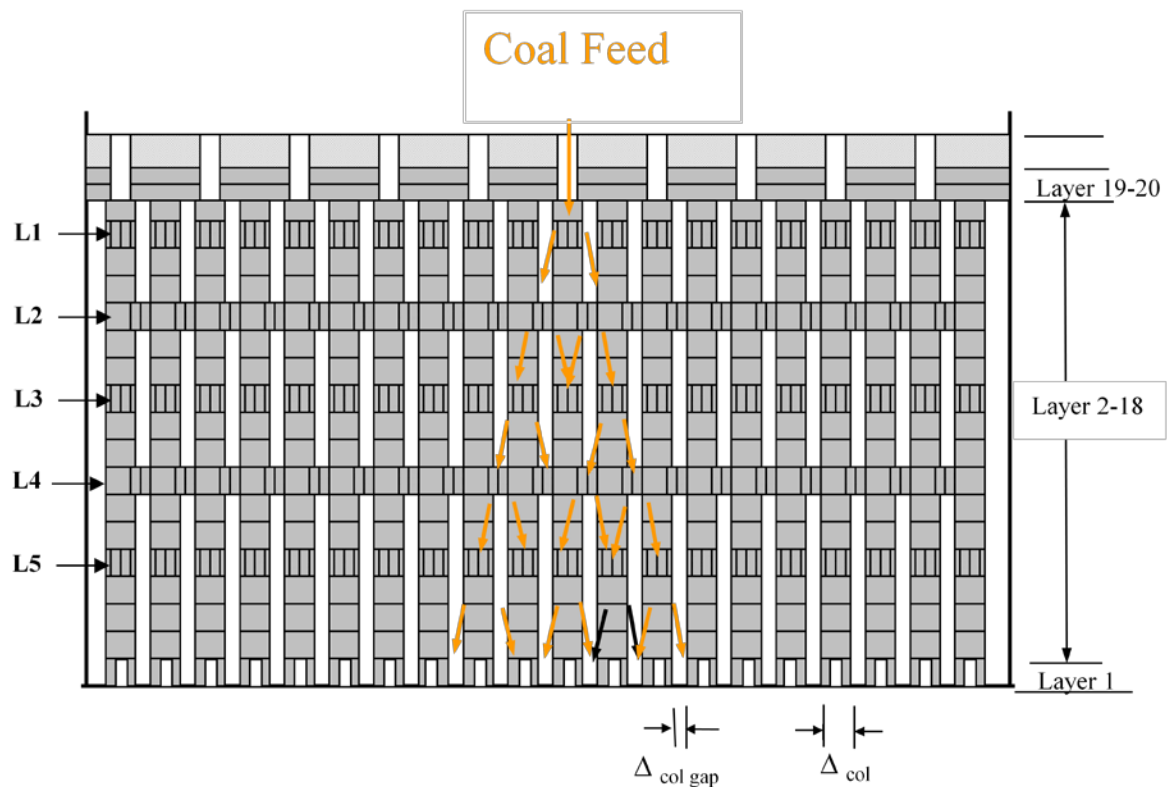


Figure 7: Brick setting in a FCBTK with details of ledges for coal combustion

The last zone is the brick-preheating zone; in this zone, heat available in the flue gases is utilized for preheating of green bricks. In the kiln, fire movement takes place in the direction of air travel. When the firing of a row is over, it is closed, and the next line is opened. The fire typically travels at a rate of 6-10 m/day. Once in 24 hours, the damper is shifted forward by the same distance (bringing in a new batch of green bricks in the kiln circuit), the next flue duct in the direction of fire travel is opened, and the previous one is closed. Once lit at the beginning of the brick making season, the kiln generally remains lit throughout the season (usually for 4-6 months).

Energy Performance of Fixed Chimney BTK: Various types of solid fuels like, bituminous coal, fire wood, agriculture residue, petroleum coke are used in FCBTKs. The fuel is fed for 5-10 minutes at an interval of 15-30 minutes. Various energy audits studies carried out on FCBTKs over last 15 years indicate that the specific energy consumption of FCBTKs varies from 1.0 to 1.4 MJ/kg of fired bricks. In terms of coal quantity, the consumption of coal varies from around 12 tons to 22 tons of coal/ 100000 bricks¹⁶. The typical energy balance for FCBTK kilns is shown in table 8.

¹⁶ Typical GCV of coal varying between 4000 -6000 kcal/ kg and fired brick weight varying between 2.5 to of 3.5 kg.

Table 8: Typical Energy Balance of FCBTK

Energy balance component	% of Energy
Irreversible chemical reactions	20-40
Removal of mechanical moisture in green bricks (drying of bricks in the kiln)	5-15
Sensible heat in flue gases	5-10
Sensible heat in fired bricks	5-10
Surface & Ground heat loss	25-35
Unburnt carbon and carbon monoxide loss	5-10
Total	100

Source: Energy Audits conducted by Greentech Knowledge Solutions

It is possible to save 15-25% energy in FCBTK's. The main areas where energy savings are possible are listed in Table 9.

Table 9: Operating Practices to Reduce Energy Consumption in FCBTKs¹⁷

Objective	Measures
1. Reduction of cold air leakage into the kiln <i>The entire kiln is under suction, thus the kiln is susceptible to leakage of cold air through any openings/ cracks. The cold air takes extra energy for heating and reduces the air flow through the kiln.</i>	a) The kiln structure and the chimney should be inspected regularly and repaired to plug any leakages. b) The leakage of air through wickets can be avoided by constructing double wall with ash filled between the two walls. c) By the use of "shunt" to connect the side ducts with the central duct (Figure 8).
2. Complete combustion of coal <i>Incomplete combustion of coal results in heat loss in the form of CO, black carbon and volatile matter emitted through the chimney as well as in the form of unburned fuel found in the ash at the kiln bottom.</i>	a) Increase in number of fuel feeding lines from 2-3 to 3-4 b) Continuous charging, instead of intermittent charging, which can be achieved either by the use of mechanical stoker or in case of manual operation by allowing only one person to charge at a time (Figure 9) c) Using small size spoons for fuel feeding to reduce the fuel feeding rate to around 5kg/min or lower d) The practice of feeding large sized fuel particles and lumps results in wastage. In general the particle size should be less than 20 mm for getting good efficiency. e) Forward row should be taken on coal feed only when a temperature of around 650 °C has been achieved. If the temperature is lower, the coal will not burn completely.
3. Maintaining sufficient air supply through the kiln <i>Air is the main heat transfer medium and</i>	a) The bricks should be stacked properly in columns. The columns should be in one line. b) The length of the cooling zone should be

¹⁷ Punjab State Council for Science and Technology (PSCST). Manual on better feeding, firing and operating practices in Bull's Trench Kilns. 2001

<i>sufficient amount of air is required for proper combustion.</i>	limited to around 50-60 m. Longer cooling zone results in additional pressure drop and lower air supply. c) The flues and chimney should be regularly inspected and cleaned. d) Avoiding leakages of cold air.
4. Reducing heat loss from kiln structure	a) The ash layer thickness on the top of the brick setting should be in excess of 20 cm. b) The coal feed hole covers should be double walled with ceramic wool insulation (Figure 10). c) The leakage of heat through wickets can be avoided by constructing double wall with ash filled between the two walls. d) Providing the floor level of the kiln 1 feet above the ground level for natural drainage

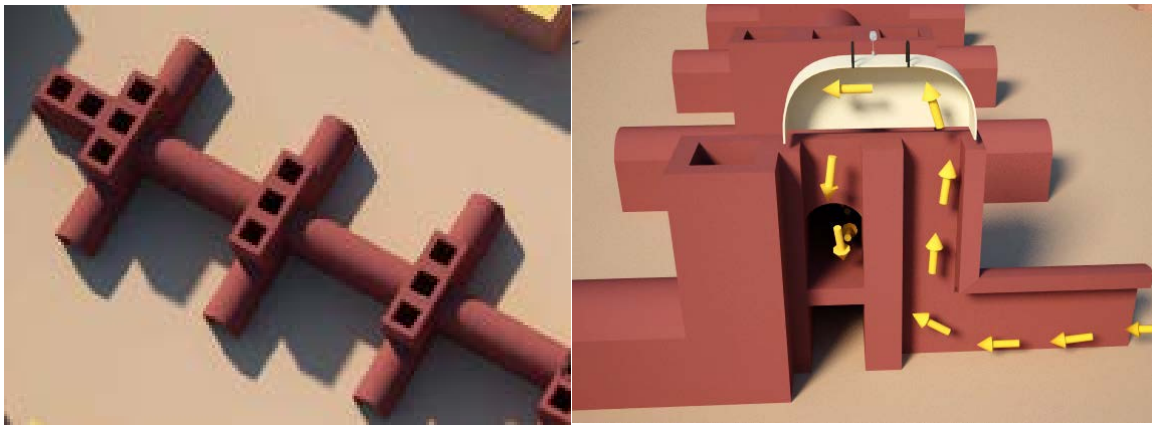


Figure 8: Details of “shunt” to connect side ducts with the central duct

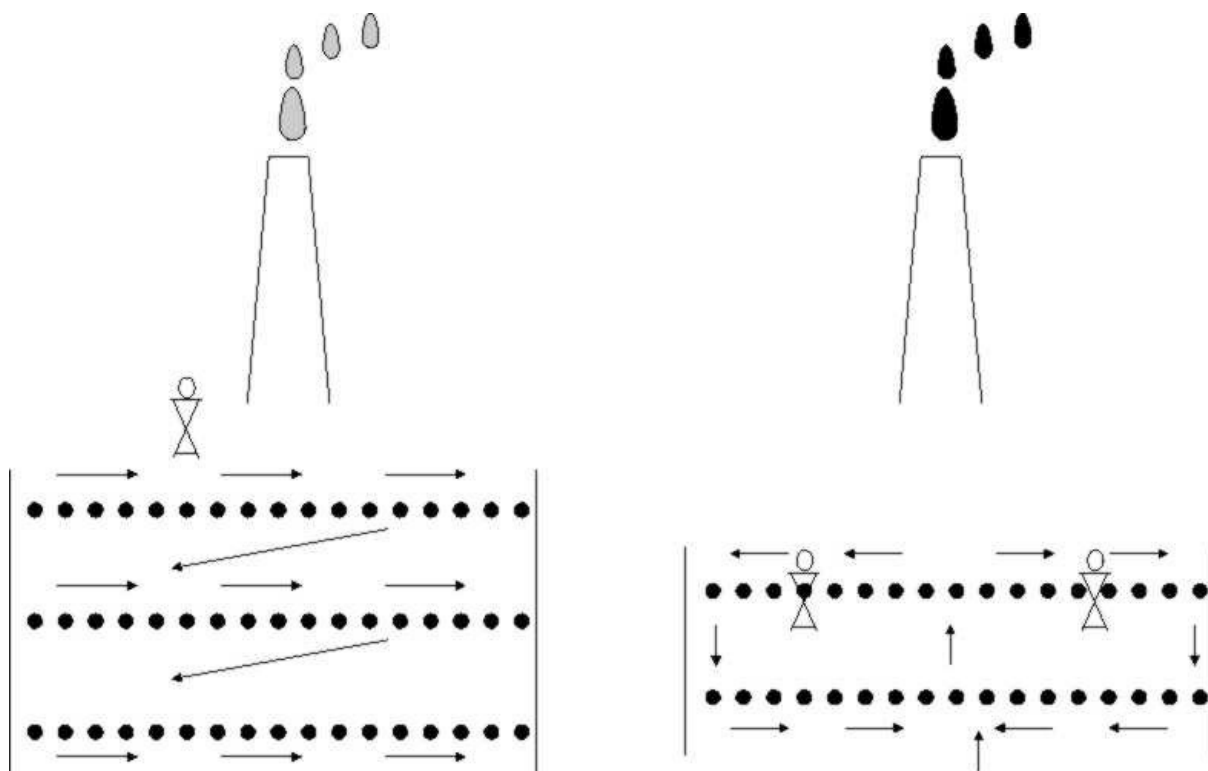


Figure 9: The sketch on the left shows the improved method of coal feeding with one firemen; the sketch on the right shows the traditional way of feeding coal in BTKs



Figure 10: The photo on left is of uninsulated coal feedhole covers used in BTKs; the photo on the right shows the improved insulated feedhole covers

11.2 High Draught Kiln

In a Zigzag kiln, the fire follows a zig-zag path instead of the straight path followed in a FCBTK. The Zigzag kiln is considered an improvement over the FCBTKs and results in:

- Higher heat transfer rates between the air and bricks due to higher velocities and turbulence caused by the frequent change in direction of air/flue gas.
- Improved combustion due to better mixing of air and fuel in the combustion zone and longer time available for volatiles in the combustion zone.
- Shorter length of the kiln and hence smaller footprint of the kiln.

The zig-zag firing concept was first used in the Buhrer Kiln (patented in 1868). The Buhrer kiln was similar to a Hoffmann kiln in construction. The main innovation was the zig-zag path to increase the length of the firing channel and accelerate the firing through a flue gas fan. Zigzag kilns were widely used in Germany between the first and Second World Wars. They were also popular in Australia. The Zigzag kiln was introduced in India by the Central Building Research Institute during the early 1970's in the form of a high draught kiln. Several hundred Zigzag kilns are believed to be operational, mostly in the eastern region of the country. In forty years since its introduction in India, many modifications have happened to the original design and several different variations of High Draught kiln can be found in the field. The original design consisted of a rectangular shaped annular kiln, having 24 chambers. Draught was created by an induced draught fan with a 15 hp motor. A photograph of a high draught kiln is shown in Figure 11 and a sketch of the original design is given in Figure 12.



Figure 11: A High Draught Zigzag kilns, Howrah, West Bengal

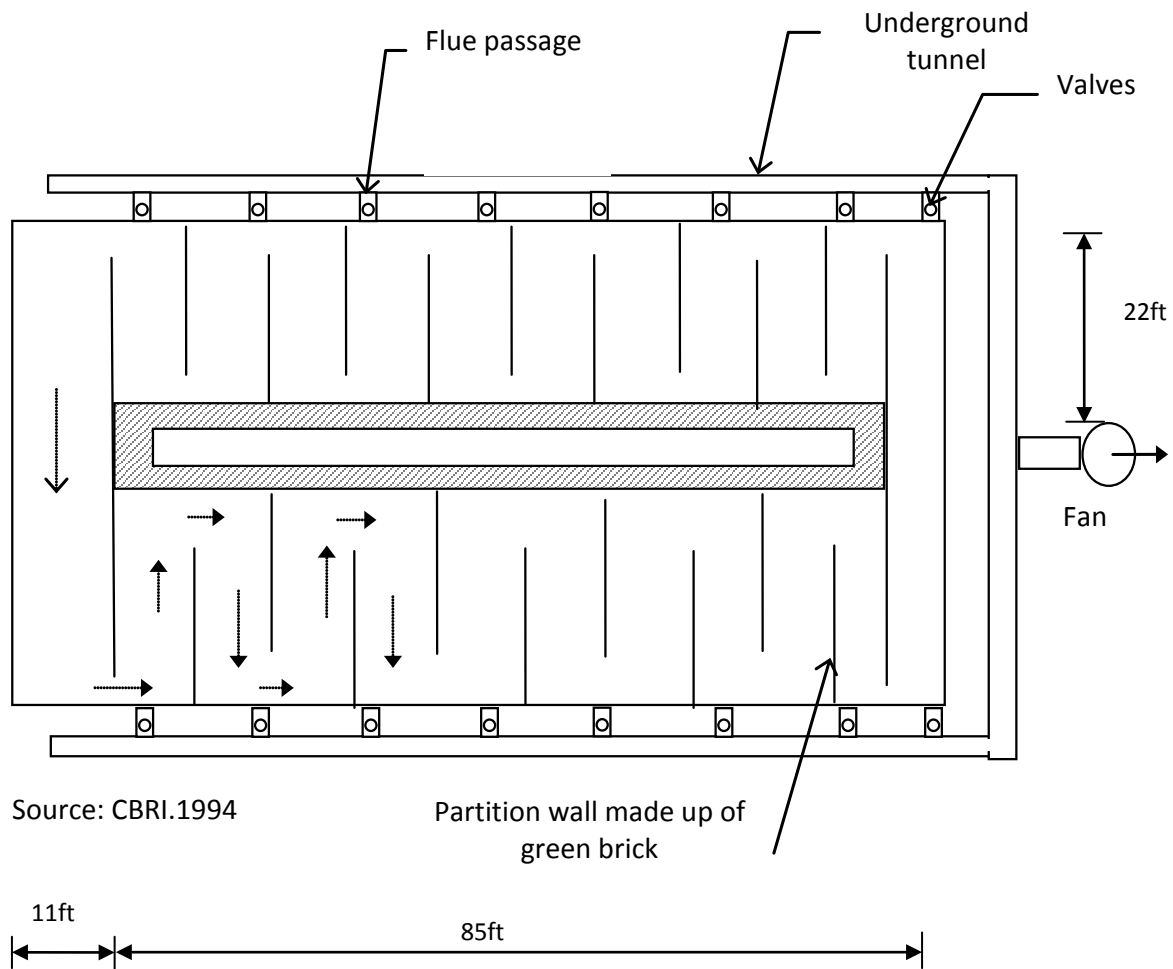


Figure 12: Original design of High draught Zigzag kiln, Source: CBRI

Energy Performance of High Draught Kiln : The performance of High Draught kilns measured in North and Eastern India using bituminous coal as the main fuel has been measured. The specific fuel consumption range from 12 -16 tons of fuel/100,000 brick. In terms of specific energy consumption this translates into specific energy consumption of 0.95 -1.1 MJ/ kg of fired bricks.

The main reasons for better energy performance of High Draught kiln over FCBTK are:

- Turbulence created by the zigzag air movement results in better mixing of air and fuel, resulting in complete combustion of fuel.
- Longer combustion zone results in six fold increase in retention time of volatile material in combustion zone, providing ample of time for complete combustion of volatile gases.
- Zigzag motion results in larger heat transfer area there by increasing the rate of heat transfer from cooling to preheating zone.

11.3 Natural Draught Zigzag Kiln¹⁸

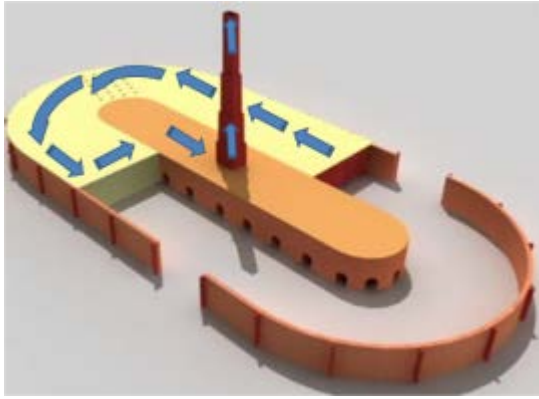
In a natural draught zigzag kiln, the draught is created by a chimney and no fan is used for creating the draught as is the case in a high draught kiln. The kiln works on the zigzag principle, but the brick setting is a bit different compared to a high draught kiln. The main difference being lower brick setting density compared to a high draught kiln.

Natural draught zigzag kiln is a relatively new concept. In 1997, an experienced Indian brickmaker -- Mr. Rajinder Singh of Priya bricks (located near Kolkata), modified his FCBTK to Zigzag kiln operating on natural draught of chimney by changing the brick stacking technique of FCBTK. From Mr Rajinder Singh, the concept was adopted by Mr O P Badlani of Prayag Clay Products, Varanasi, who played an important role in further development and dissemination of this technology. Mr Badlani, first converted his 3 FCBTKs into natural draught zigzag kilns. Armed with this practical experience, Mr Badlani started helping other brickmakers in retrofitting their FCBTKs into natural draught zigzag kiln. Till March 2013, there were around 50 operational natural draught zigzag kilns in India. The main attraction of the technology lies in the fact as most of the FCBTKs can be retrofitted into natural draught zigzag kilns.

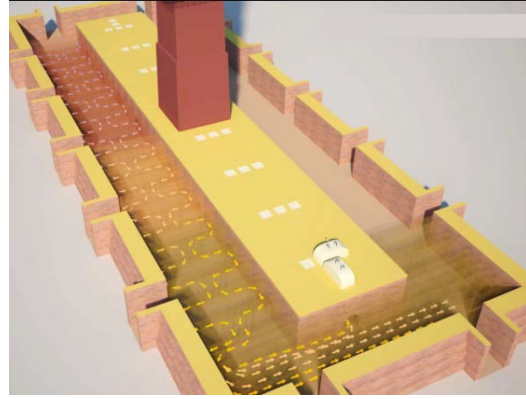
The natural draught Zigzag Kiln is an improvement over the FCBTK. The main innovation is in the arrangement of bricks in such a way so that the air is forced to follow a zigzag path. The main differences between the FCBTK and the Zigzag Kiln are listed below.

1. In a Zigzag Kiln, the air moves in a zigzag path whereas in an FCBTK, the movement of air is in a straight path (refer figure 13). The length of the zigzag air path is about three times longer than the straight-line air path. The increased air velocities in the kiln, the turbulence created due to the zigzag air movement, and the longer air path result in improved heat transfer between air/flue gases and bricks.
2. In a Zigzag Kiln, powdered coal is fed in small quantities; the fuel feeding zone is six times longer than the FCBTK (Figure 14). The longer fuel feeding zone, the smaller coal particle size, and the turbulence help in mixing the coal volatiles and air, resulting in more complete and cleaner combustion of coal.
3. The FCBTK is oval or circular in shape, while the Zigzag Kiln is rectangular in shape.

¹⁸ Greentech Knowledge Solutions. Towards Cleaner Brick Kilns in India - A win-win approach based on Zigzag firing technology. March 2013

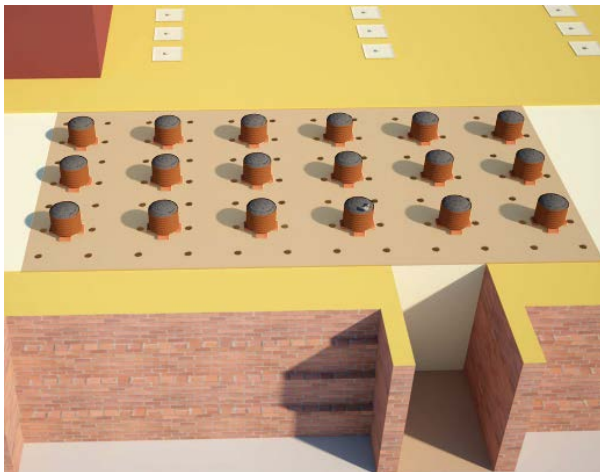


Straight air flow in FCBTK



Zigzag air flow in Zigzag kiln

Figure 13: Difference in airflow between FCBTK and Zigzag kiln



Sketch showing longer coal feeding zone



Photo showing longer coal feeding zone

Figure 14: Longer coal feeding zone in a natural draught zigzag kiln

FCBTKs can be retrofitted into efficient and cleaner zigzag firing. Detailed scientific measurements on brick kilns shows that conversion from FCBTK to zigzag firing results in:

- 20% savings in coal consumption and CO₂ emissions
- 75% reduction in SPM and Black Carbon emissions
- Doubling of profits for brick producers due to fuel savings and quality improvements

Most of the FCBTKs can be retrofitted into natural or high draught Zigzag Kiln. The cost of retrofitting varies from INR 10 lakh to INR 25 lakh (US \$ 20,000 to 50,000) depending

upon the condition of the existing kiln and the extent of retrofitting required. Retrofitting involves (a) partial reconstruction of the chimney and reconstruction of the flue-ducts and the outer wall of the kiln (Figure 15 a) and (b) change in brick setting from column blade setting in FCBTK to chamber wise setting for Zigzag (Figure 15 b).

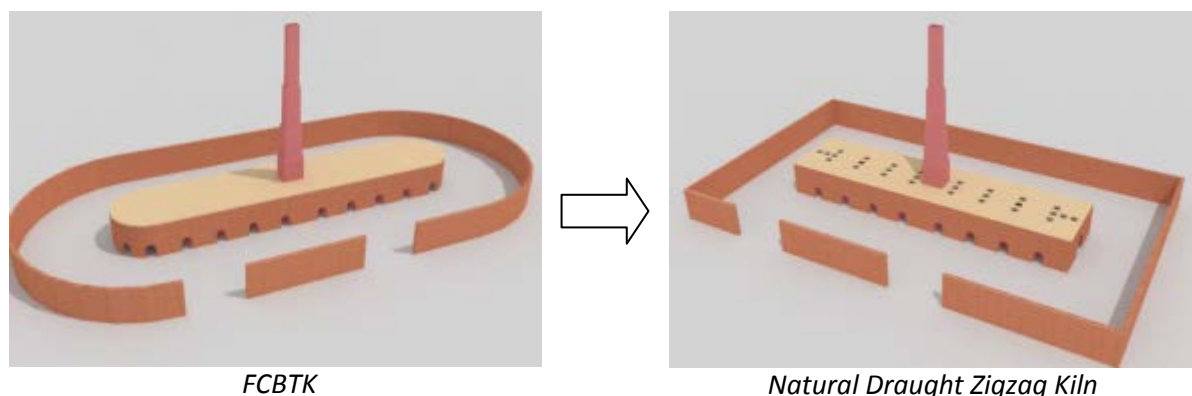


Figure 15a: Reconstruction of the kiln for switching from FCBTK to natural draught Zigzag kiln

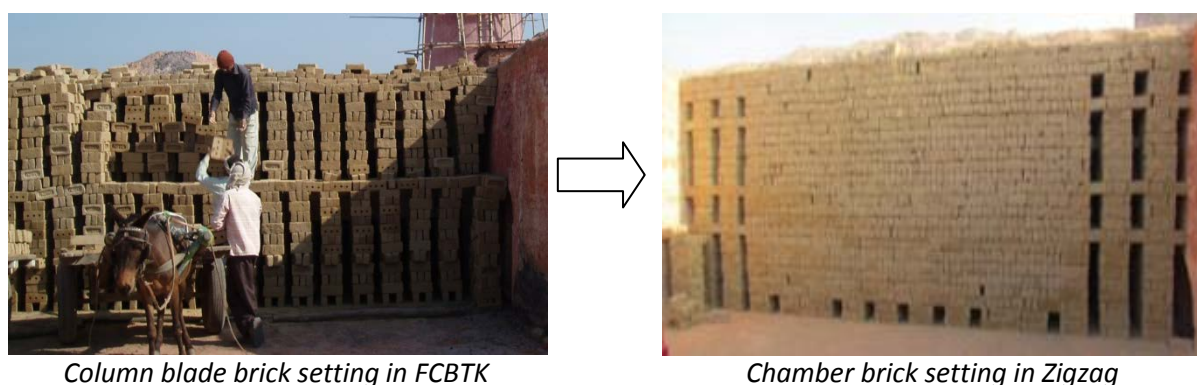


Figure 15b: Change in the brick setting for switching from FCBTK to natural draught Zigzag kiln

The conversion from FCBTK to Zigzag kilns benefits brick-kiln owners the most. The two-fold financial benefits firstly through savings from reduced fuel consumption and secondly by increase in revenue due to higher percentage of highest quality product makes it a financially attractive proposition. Clay-fired bricks are locally produced and locally consumed; therefore, the price of bricks as well as price differentiation between the quality grades of bricks varies across the regions. Hence the techno-economics of conversion will vary from one region to the other. If a typical FCBTK located in eastern UP, Bihar, or West Bengal get converted to Zigzag Kiln, it would result in doubling of the operating profit margin of the kiln. For a new construction, the capital cost of constructing a Zigzag Kiln is equivalent to or in some cases marginally higher than an FCBTK; however Zigzag Kiln yields higher profit margins. Box 2 provides a success story of a retrofitted FCBTK into a natural draught Zigzag Kiln.

Box 2. Success story of retrofitting of FCBTK to natural draught Zigzag

In 2011, Payal Bricks of Varanasi retrofitted its circular-shaped FCBTK into rectangular shaped natural draught Zigzag Kiln. The capital cost involved in retrofitting was about INR 2.5 million. The owner is happy with the performance of the retrofitted natural draught zigzag kiln. According to him, in FCBTK, the coal consumption was 18 tonne per lakh of bricks. After retrofitting, the coal consumption has come down to 13 tonne 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 55% in FCBTK to 80% in natural draught Zigzag kiln.

Today, Payal Bricks saves about 250 tonne of coal annually, resulting in monetary savings of INR 2 million. The increase in revenue due to higher percentage of class-I bricks results in additional revenue of about INR 3 million. Overall the capital cost of conversion (INR 2.5 million) was recovered in 6 months time.



Black smoke from a FCBTK during fuel charging



No visible black smoke from a natural draught kiln during fuel charging

Figure 16: Natural draught Zigzag kiln results in significant reduction in air pollution¹⁹

¹⁹ O P Badlani. A Case Study of Bull's Trench Kiln conversion into Natural Draught ZigZag Firing. UNEP Consultation on Soft Approaches for Achieving Co-benefits from Black Carbon Emissions Reduction, Kathmandu, March 21-23, 2011

11.4 Vertical Shaft Brick Kiln

The evolution and initial development of the Vertical Shaft Brick Kiln (VSBK) technology took place in rural China. In 1996, several hundred VSBKs were reported to be operating in China. Since then the technology has been transferred (under various development projects) to several countries, including India, Nepal, Afghanistan, Vietnam, Pakistan, Sudan, and South Africa. Among these countries the technology has gained wide-spread popularity in Vietnam only; in other countries the dissemination of the VSBK technology is still limited to a small number of enterprises. VSBK technology was transferred to India under a project supported by the Swiss Agency for Development and Cooperation (SDC).

VSBK has a vertical shaft of rectangular or square cross-section. The shaft is located inside a rectangular brick structure; the gap between the shaft wall and outer kiln wall is filled with insulating materials – clay, fly ash and rice husk. The kiln works as a counter current heat exchanger, with heat exchange taking place between the air moving up (continuous flow) and bricks moving down (intermittent movement). Green bricks are loaded from the top in batches; the bricks move down the shaft through brick pre-heating, firing and cooling zones, and are unloaded at the bottom (Figure 17). The combustion of powdered coal (put along with bricks at the top), takes place in the middle of the shaft. Air for combustion enters the shaft at the bottom, and gets preheated by the hot fired bricks in the lower portion of the shaft before reaching the combustion zone. Hot flue gases preheat the green bricks in the upper portion of the shaft before exiting from the kiln through the shaft or the chimney.

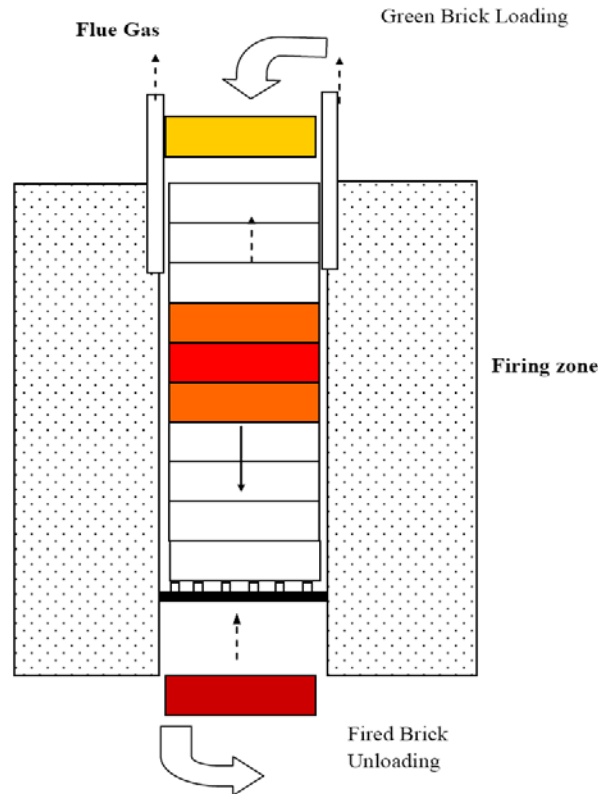


Figure 17: VSBK basic arrangement

The brick setting in the kiln is supported on bars at the bottom of the shaft. Brick unloading is carried out from the bottom of the shaft using a trolley. For unloading, the trolley is lifted (using a screw mechanism or chain pulley blocks) until the rectangular beams placed on the trolley touch the bottom of the brick setting, and the weight of bricks is transferred on to the trolley. The support bars, now freed of the weight of bricks, are removed. The trolley is then lowered by one batch (four layers of bricks). Support bars are again put in place through the holes provided in the brick setting for the purpose. With a slight downward movement, the weight of the brick setting is again transferred back on the support bars. The trolley (with one batch of fired bricks on it) is further lowered till it touches the ground and is pulled out of the kiln on a pair of rails. In traditional operations, every 2-3 hours one batch is unloaded at the bottom and a batch of fresh green bricks is loaded at the top. At any given time, there are typically 8 to 12 batches in the kiln.

Two chimneys located diagonally opposite to each other are provided for the removal of flue gases. Sometimes, a lid is also provided on the top opening of the shaft. The lid is kept closed during normal operation and hence flue gases do not pollute the working area on the top of the kiln.

The performance of VSBK have been measured in India. The specific energy consumption in VSBKs typically varies between 0.75-1.0 MJ/ kg of fired bricks.

The VSBK was first introduced in India in 1996, though 15 years have passed, the rate of dissemination of the technology still remains low. Though VSBK has the lowest SEC, there are several issues which need to be taken into account before adopting VSBK.

Experience in India shows that the quality of hand-moulded fired bricks in VSBK is generally inferior to that of FCBTKs, this may be due to factors, such as, a) poor quality of hand-moulded green bricks and damage/ crushing of green bricks during handling or in the kiln where it is subjected to high static and dynamic stresses b) the fast heating and cooling of bricks can induce cracks in bricks. In general, the quality of VSBK fired bricks has been found to be better when the bricks are machine-made and the thickness of the bricks is between 50 -70 mm (as is the case in China and Vietnam).

In terms of its operation, lifting of green bricks to the top of the shaft is often a problem. In India, in the absence of electricity at most of the kiln sites, often this task is done manually or using animals. Experience show that use of electricity/ mechanically driven lifts or conveyors for lifting the green bricks is a must for the success of VSBK.

Compared to traditional kilns and improved kilns like Zigzag kiln, the VSBK has a longer pay-back period, this is due to low production volume of a VSBK. The capital cost of a two shaft VSBK, which can produce around 10,000 bricks/ day is almost equal to the cost of a FCBTK or a new natural draught zigzag kiln, which can produce up to 40,000 bricks/ day. Experience in India shows that while energy costs in a VSBK are lower, its operational cost are higher (manpower cost for operating the kiln, operational cost of lift/ conveyor).

12. Economic and Cost Benefit Analysis

Typical financial analysis of three main types of brick kilns operating in North India is presented in Table 10. As can be seen, Zigzag kilns which are more efficient offers a better profit compared to FCBTK.

Table 10: Comparison of Kiln Technologies (Financial Performance)²⁰

Type of Kiln	FCBTK (Base Case)	Zigzag Natural Draught	Zigzag High Draught
Type of moulding	Hand	Hand	Hand
Type of brick	Solid	Solid	Solid
Annual Capacity (Million brick/year)	6	6	6
Total Land (Acres)	8	8	8
Capital Cost* (Million Rs)	4.5	4.5	5
Coal Consumption (ton/100,000 brick)	18	13	13
Price of coal @ year 2012 (Rs/ton)	8000	8000	8000
Diesel consumption (Liter/100,000 brick)	Nil	Nil	100
Price of diesel @ year 2012 (Rs/liter)	N/A	N/A	45
Operation Cost (Rs per 1000 bricks)			
Raw Material	400	400	400
Operation	1000	1000	1000
Fuel	1440	1040	1085
Administration & legal	250	250	275
Losses	250	250	250
Total cost/1000 brick	3340	2940	3010
Total operation cost Million Rs/year	20.04	17.64	18.06
Revenue Generated			
Class -I (%)	60%	80%	80%
Class -II (%)	15%	15%	10%
Class -III (%)	25%	5%	10%
Selling Price (as of March 2012)			
Class - I (Rs/brick)	5.0	5.0	5.0
Class - II (Rs/brick)	4.2	4.2	4.2
Class - III (Rs/brick)	2.5	2.5	2.5
Average Selling Price (Rs/brick)	4.26	4.76	4.76
Revenue through sales (Million Rs/year)	25.53	28.53	28.02
Losses and Pilferages (Million Rs/year)	1.5	1.5	1.5
Profit (Million Rs/year)	4.0	9.39	8.46
Operating Profit Margin %	16%	33%	30%

*excluding land cost & working capital

²⁰ Greentech Knowledge Solutions. Zigzag Kiln Performance Assessment – 2012. A report prepared for the Shakti Sustainable Energy Foundation. 2013.

13. Recommendations for Energy Conservation in Brick Industry

13.1 Technology options

A variety of options exists for energy conservation in fired clay brick making. These consists of

- e) Adoption of efficient kiln technologies
- f) Promotion of internal fuel in brick making
- g) Promotion of mechanized coal stoking/ burner systems
- h) Promotion of manufacturing of hollow and perforated bricks

Adoption of Efficient kiln technologies

An energy saving potential of 20-60% exists by replacing inefficient technologies like clamp, downdraught and FCBTK kilns with efficient technologies, such as, VSBK, High Draught and Natural Draught zigzag kiln technologies.

- Zigzag kilns appear to be the logical replacement for FCBTKs, because of low capital investment, easy integration with the existing production process, and the possibility of retrofitting FCBTKs into zigzag firing.
- VSBK appears to have a limited market, mainly because of its inability to produce good quality bricks from all types of clays and its low productivity under the Indian conditions. VSBK dissemination needs to be properly targeted.
- The tunnel kiln technology is capital intensive, and the current technological know-how and experience is limited in India. Adoption of the tunnel kiln also requires extensive modifications in brick moulding, drying and material handling. Widespread adoption of tunnel kiln technology is not foreseen in the immediate future.

Promotion of internal fuel in brick making by mechanizing the brick making process

Internal fuel addition significantly reduces fuel consumption and SPM emissions. Cheaper fuels, such as coal slurry, coal dust, charcoal dust, and sawdust can be used as internal fuels and can help reduce fuel cost. Management of internal fuel addition (Figure 18) is difficult in the manual molding process. Semi-mechanization of moulding needs to be promoted to support the use of internal fuels. Semi-mechanization of the brick moulding process would have other benefits, including an ability to use inferior clay resources and wastes, reduction in drudgery and better working conditions for workers, and the potential to produce hollow and perforated bricks.



Figure 18. Manual addition of internal fuel followed by mixing in a mechanized pug-mill ²¹

²¹ Suyesh Prajapati. Presentation for the defence of M Sc Renewable Energy thesis “Studies on the Application of Renewable Solid Fuel Alternative to the Imported Coal Fuel in VSBK”, Institute of Engineering, Tribhuvan University, Kathmandu, 2009.

Promotion of mechanized coal stoking/ burner systems

Continuous feeding of properly sized fuel in an FCBTK or a zig-zag kiln – through the use of mechanized coal stoking systems or solid fuel burners – can reduce both coal consumption as well as emissions by ensuring cleaner combustion. The solid fuel burner from Beralamar, Italy (Figure 19) includes a fuel crushing and distribution unit. It delivers solid fuel mixed with positive airflow ensuring perfect and consistent firing.



Figure 19. Solid fuel burners having a fuel crushing and distribution unit

(Source: <http://www.beralmar.com>)

Promotion of manufacturing of hollow and perforated bricks

Hollow and perforated bricks require less clay and hence fuel. They also provide better thermal insulation of walls. A variety of hollow and perforated bricks can be manufactured as shown in figure 20. The hollow or perforated bricks are manufactured using extruders (Figure 21).



Figure 20 A variety of perforated and hollow bricks produced in Vietnam



Figure21 An extruder for making perforated bricks near Chandigarh (India)

13.2 Strategy for Dissemination of Energy Conservation Measures

Transition to energy-efficient brick production offers immense potential for energy savings. In addition, there are reductions in SPM, Black Carbon and CO₂ emissions, improvements in the incomes and working conditions of workers, and production of better quality building material. Some of the key elements of the strategy are described below:

Introduction of regulation and policies that encourage adoption of energy-efficient/cleaner brick-firing technologies

The main central ministries that can play a role in the dissemination of energy conservation measures in the brick sector are:

- a) Ministry of Environment and Forests (MoEF) through stricter environment regulations
- b) Ministry of Power (MoP) through the Bureau of Energy Efficiency (BEE) by running cluster development programmes for brick industry in collaboration with the Ministry of Micro, Small and Medium Industries (MSME)
- c) Ministry of Urban Development (MoUD) through specifying norms that promote the market for energy-efficient/ cleaner bricks like hollow and perforated bricks.

Putting in place an effective technology and knowledge delivery system

Reaching out to more than 30,000 FCBTKs and overall more than 100,000 brick making units in orderly and accelerated manner would require efficient and reliable technology delivery mechanism coupled with training of the owner, as well as the supervising and operating staff. The local technology and knowledge delivery could be through a network of technical training institutions, brick industry associations, individual brick makers, engineering consultants, etc.

Financial instruments specifically for upgradation of the brick industry

Some relatively large brick-kiln owners may be in a position to self-finance kiln upgrades (e.g. retrofitting of FCBTKs into Zigzag kilns), but that is not the case universally. Small- and medium-size operators would need access to financial services for kiln retrofits. Further, entrepreneurs interested in setting up large modern brick manufacturing facilities would also need access to finance. At present, there are several constraints due to which conventional bank financing option is inaccessible to the brick-makers. Some of the main constraints are listed below.

- Most brick-kiln entrepreneurs operate on leased land and hence the land could not be used for providing collateral security for availing loans.
- A large part of brick trade takes place in cash, which means that tax compliance is poor and the profit and loss accounts and balance sheets of brick enterprises do not reflect the true picture of the trade and in establishing credit worthiness.
- Many brick-kiln entrepreneurs lack financial knowledge and the ability to prepare business plans and the documentation needed to apply for a loan.
- Commercial banks have limited experience lending to the brick sector and do not currently offer financial instruments tailored to this sector.

Thus, there are multiple barriers for both lenders and borrowers and hence a multipronged approach in the form of Special Technology Upgradation Fund (STUF) for

brick industry is needed. The characteristics of the proposed STUF for the brick industry should be as follows:

- Allocation of dedicated funds for lending to brick industry in the form of loans coupled with capital or interest subsidy.
- Elimination of collateral requirements by operating the scheme under Credit Guarantee Trust Fund Scheme for Micro and Small Enterprises (CGTMSE)

Setting up the proposed STUF would provide a direct line of credit and would address the issues of collateral securities required for availing finance. An awareness-cum-capacity building programme for preparing the brick-kiln owners for availing financial incentives from the lending institutions and orientation programmes for lending institutes providing the overview and characteristics of the brick industry would also be required.

Annexure 1. Useful Indian Websites on Brick Industry

<http://www.ecobrick.in>

www.resourceefficientbricks.org

<http://www.vsbkindia.com>

<http://www.brick-india.com>

<http://www.damleclaystructurals.com>

<http://www.indiamart.com/vpindustrials/>

www.gkspl.in