Energy & Resource Mapping of MSME Brick Sector: Brick Sector Report

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Bureau of Energy Efficiency

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EXECUTIVE SUMMARY

Introduction to the Brick Sector

India is the second largest producer of burnt clay bricks in the world producing around 250 billion bricks annually. There are more than 100,000 micro and small enterprises involved in brick manufacturing employing more than 10 million workers. It is a seasonal industry, which operates for six to eight non-monsoon months of a year only (generally from November to June). Firing in medium and large capacity enterprises (production capacity > 2 million bricks/ year) is usually done in continuous kilns like Fixed Chimney Bull's Trench Kilns or zig-zag kilns, while for small-scale production (production capacity of < 2 million bricks/year) a variety of batch kilns, like clamps and downdraft kilns are used. Brick manufacturing is one of the largest energy consuming MSME sector in the country. It is estimated that 35-45 million tons/year of coal and biomass fuels are used for firing of bricks.

Brick making process in India

Brick making process includes clay mixing, moulding, drying, firing and cooling. 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 and 98% of the brick production through hand moulding in the country. 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 under sun. As bricks cannot be dried during the rainy season, the industry is seasonal. It operates for six to eight dry months of a year only (generally from November to June). Firing in medium and large enterprises (production capacity > 2 million bricks/ year) is usually done in continuous kilns like Bull's Trench Kilns (mostly fixed chimney) or zig-zag kilns, while for small-scale production (production capacity of < 2 million bricks/year) a variety of clamps and intermittent kilns are used.

Fuel (mainly coal) and clay are the two most important raw materials for clay brick manufacturing. The brick industry is facing problems in procuring clay and the cost of both coal and clay has increased significantly in recent years. The brick industry is also one of the larger polluters in terms of emission of particulate matter and carbon (both gaseous – CO_2 and solid form- Black Carbon) amongst MSMEs. Thus adopting resource efficiency measures is becoming critically important for the industry. However, lack of awareness, necessary institutional structures and capacities, and finance are acting as barriers in the adoption of cleaner production technologies by the brick industry.

Initiatives through various programs

In the recent past, there has been growing awareness on the issues related with environment protection and resource conservation leading to formulation of policies by various departments of the State and Central Governments. MoEFCC has formulated the emission standards. State governments have formulated siting criteria for brick industries. **Bureau of Energy Efficiency** has initiated programs on energy conservation in MSME clusters through pilot technology implementation; under this initiative Zig-zag technology has been implemented in the brick cluster at Varanasi, UP. Recently, BEE has introduced Energy Efficient Enterprise (E3) certification scheme for the brick sector to promote energy and resource efficiency in brick industry. Promotional and financial incentives have been introduced by Ministry of MSME to adopt cleaner production technologies in various MSMEs industries.

Objective of the Study

The objective of the study was to gather information and data on the brick kiln technologies and energy use, and then suggest technical and policy measures for energy conservation. Detailed energy audits were carried out in five clusters i.e. Begusarai, Nagpur, Tripura, Indore and Bengaluru, covering wide diversity of kiln technologies, fuels, raw materials and production processes. Information was also gathered from nine other clusters i.e. Gautam Buddh Nagar, Bagpat, Faridabad, Aligarh, Mathura, Tirupati, Ludhiana, Coimbatore and Varanasi through on-site interviews with brick kiln owners and industry association representatives.

National SEC Benchmarks for Brick Industry

The results of the monitoring, combined with the past data has resulted in developing national benchmarks for Specific Energy Consumption for different kiln types as given in the table below.

S. No	Kiln Technology	Average SEC national benchmark (MJ/kg)
1	Zigzag kiln	1.11
2	Hybrid Hoffmann kiln (HHK)	1.11
3	Fixed Chimney Bull's Trench Kiln (FCBTK)	1.34
4	Tunnel kiln	1.42
5	Hoffmann kiln	1.63
6	Clamp	1.79
7	Downdraft kiln	2.94

Energy Conservation Measures and technology options

Brick industries need to adopt energy efficient technology to become more efficient and economically competitive. There are instances of improved technologies being promoted and practiced in India. Instances of fly ash technologies (using waste materials), zigzag kiln technology, use of internal fuel (being practiced in Central India) are increasingly being adopted driven mainly by the economic reasons.

Apart from adopting better operation practices in the existing kilns, the key technical measures which can help in improving energy efficiency of the brick industry and in reducing air pollution from the industry can be categorized under three categories:

- Adoption of efficient kiln technologies like induced and natural draught zigzag, hybrid Hoffmann and tunnel kiln technologies
- Fuel switching: Use of gaseous fuels instead of solid fuels as well as promoting use of internal fuels
- Promoting the production of resource efficient bricks i.e. perforated, hollow and porous bricks

The study also resulted in the identification of the energy conservation measures. These are listed in the Table below.

S. No	Energy Conservation Measure	Remarks
Low-cost measure (<Rs 50 lakh investment)		
1	Improvement in operational practices in clamps, FCBTK and zigzag kilns	10-15% energy savings; improvement in percentage of class I bricks; reduction in air pollution
2	Conversion of FCBTK into zigzag kiln	15-20% energy savings; improvement in percentage of class I bricks; Reduction in air pollution
Medium to high-cost measure (Rs 50 lakh – 50 crore investment)		
3	Adoption of Hybrid Hoffmann Kiln	15-20% energy savings compared to FCBTK; increased production due to year-round operation; improvement in percentage of class I bricks; Reduction in air pollution
4	Adoption of tunnel kiln technology	Possibility of mass manufacturing of hollow and perforated bricks; if used for production of hollow blocks, then 30-40% energy savings compared to FCBTK; increased production due to year-round operation; improvement in percentage of class I bricks; Reduction in air pollution
5	Production of resource efficient bricks (hollow and perforated bricks)	Up to 50% reduction in clay and fuel consumption compared to solid bricks; lighter bricks with better insulation properties which helps in lowering energy for air-conditioning of buildings
6	Shift from solid to gaseous fuels	Reduction in air pollution; improvement in percentage of Class I bricks; gas based zigzag/ FCBTK technology yet to be demonstrated.

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Chapter 1. Introduction

1.1 Background

The Bureau of Energy Efficiency, Ministry of Power has undertaken an exercise to carry out Energy and Resource Mapping of MSME Sector in India. The MSME (micro, small and medium enterprises) sector accounts for about 33% of India's manufacturing output and around 28% contribution in the GDP. There are around sixty-three million MSMEs in India and a majority of them continue to depend on obsolete, low efficiency technologies. This has an adverse impact on the profitability and competitiveness of the MSMEs sector in India. It also puts a question mark on the sustainability of several MSMEs sector due to growing environmental concerns. Brick industry is one of the largest energy consuming MSME industry sector in the country. The objective of this project is to map energy use in the selected brick clusters in India and come up with technological and policy actions to improve energy efficiency in the sector.

1.2 Methodology

The various steps involved in the energy resource mapping exercise (Figure 1) for the brick sector were:

1. Energy Audit Studies in 5 Clusters: Conducting field studies and energy auditing for estimating the current status of the production, technology used and energy consumption in selected brick clusters. Five clusters located in 5 states were selected. The clusters were selected to cover the wide diversity of brick firing technologies in use in India, which include Clamp, Down Draft, Fixed Chimney Bull's Trench Kiln (FCBTK), zig-zag natural draught, zig-zag induced draught, Tunnel kiln with dryer, Hoffman kiln and hybrid Hoffman kiln.
2. Energy Performance Benchmarking: Using the data of the energy audits to calculate the Specific Energy Consumption (SEC). Combining with past data, come up with technology wise national SEC benchmarks and carrying out a comparison with international benchmarks.
3. Evaluation of Energy Efficiency Measures: Evaluation of both incremental and transformational measures to improve energy efficiency in the sector.
4. Cluster Level Consultations: Organizing cluster level stakeholder consultations in the five clusters as well as several other clusters to discuss the energy efficiency measures as well as to get an overview of the brick production in the country.
5. Cluster, Sector and Policy Reports: Preparation of cluster, sector and policy reports.

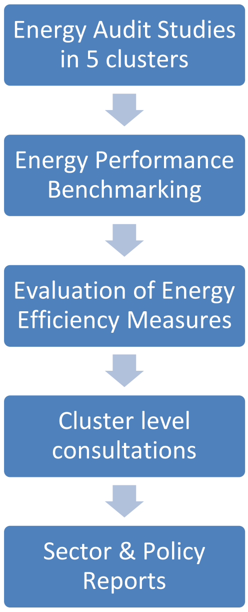


Figure 1 Methodology of the Sector Study

1.3 Organisation of the report

Chapter 2 of the report provides the status of brick industry in the country as well as provides key information and results of the cluster studies. Chapter 3 deals with international and national benchmarking of energy performance of brick kilns. Chapter 4 deals with the description of technical measures for reducing energy consumption in brick industry. Chapter 5 deals with the existing policies concerning the brick sector, while chapter 6 provides a brief information on the past initiatives and institutions involved in energy efficiency improvement work in the country. The last chapter (Chapter 7) provides key policy recommendations.

Chapter 2. Brick Sector Overview & Cluster Studies

2.1 Indian Brick Sector

India is the second largest producer of bricks in the world producing around 250 billion bricks annually1. There are around 140,000 brick kilns operating in India. 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 as open drying of bricks is not possible during the monsoon months, the industry is seasonal. In most places in India, brick kilns operate for six to eight non-monsoon months of a year (generally from November to June). Firing in large units is done in FCBTK and zigzag kilns while for small-scale production a variety of clamps and intermittent kilns are used. More than 10 million workers are estimated to be employed in the Indian brick industry.

2.1.1 Regional Diversity

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. Brick kilns, generally of medium and large production capacities (3–10 million bricks per year), are located in clusters around major towns and cities. 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 cities.

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.

2.1.2 Manufacturing Technology

Except for the use of mechanical excavators for mining, most of the other operations in brick kilns in India are non-mechanized. Use of roller crushers (for clay preparation) and extruders (for brick shaping) has been prevalent in Kerala and Karnataka, only recently a few industries in other parts of the country have started using extruders or soft mud moulding machines. In recent years, the use of mechanized pug-mills has become prevalent in north and east India. The indigenous capacity to produce machinery for semi-mechanized brick production is limited and is mostly confined to small industries and local workshops making pug mills, soft-mud moulding machines and extruders. In recent years, the import of Chinese extruders and clay preparation machinery is on increase.

[1] Market Transformation towards Energy Efficiency in Brick Sector - a strategic blueprint, from vision to mission, BEE & GIZ, December 2019

Drying of green bricks is mostly done in the open, except parts of South India where bricks are dried under drying sheds. Some of the brick kilns that use tunnel or Hoffman kiln also practice artificial drying using hot air.

Table 1 below provides the details about the various types of firing technology currently prevalent in India. Fixed Chimney Bull's Trench Kiln (FCBTK) is the leading technology for firing bricks. FCBTK accounts for around 45-50% of the total brick production in India and is prevalent in the Indo-Gangetic plains, as well as in some pockets in peninsular India. In recent years, FCBTKs are being converted into more efficient zig-zag kilns in the Indo-Gangetic plains and contribute to around 15-20% of the production. Clamps are used widely all-over peninsular India and contribute to 25-30% of the production. Remaining (< 5%) production is contributed by Down-draught, Vertical Shaft Brick Kilns (VSBK), Tunnel Kiln, Hybrid-Hoffmann and Hoffmann kilns.

Table 1 Types of brick firing technology in India (Estimates for 2021)

Kiln Type	Regional spread	Estimated contribution in brick production
Clamps	Central, West and Southern India	~25-30%
Fixed chimney BTK	Indo-Gangetic plains (North and East India) and some clusters in South and West India	~45-50%
Zig-zag	Bihar, West Bengal, Punjab, Haryana, National Capital Region, etc	~15-20 %
Hoffman Kiln	Mainly Kerala & Karnataka	< 5 %
Down-draught	Mainly in Karnataka	
VSBK	~ 100 kilns constructed in Central and East India. Only few operational	
Hybrid Hoffmann kiln	~5 kilns around the country	
Tunnel kiln	~ 10 kilns around the country	

2.1.3 Raw Materials

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 raw material for brick making, except West Bengal where silt deposited/harvested by rivers is also used. 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. In peninsular India, clay deposits from dams, percolation tanks as well as surface soil excavated from both agriculture and barren lands form the main sources of clay supplies. The Peninsular soils have varying colours and qualities and broadly, they are grouped under black cotton, red or lateritic soils. They are termed difficult for brick making.

Owing to these differences in the nature and quantity of available soils, the brick industry in the Gangetic Plain is dominated by FCBTK and zigzag (where large-scale concentrated production is practiced), while the Peninsula is dominated by open clamps (where small-scale scattered production is practiced).

Different types of bituminous coal, lignite and biomass are the main fuel used in brick kilns. Various types of Indian coals are used, prominent among them are those sourced from Jharia, Raniganj, Chandrapur, Meghalaya, etc. In recent years imported coal from USA, South Africa and Indonesia is also widely used. Some industries also use lignite and petroleum coke. Among biomass fuels, firewood is used as a supplementary fuel (mostly for initial firing); use of mustard stalk is common in Rajasthan and Haryana; rice husk is used both as internal as well as external fuel in peninsular region. Various types of boiler ash, fly ash and powdered coal is also used as internal fuel in the peninsular region. Recently, India's largest brick making factory located at Kunigal (Karnataka) has shifted to natural gas.

2.1.4 Economic condition

Fuel, clay and labour accounts for 85-90% of the cost of production. Fuel cost alone accounts for 25-35% of the cost of production. Management of fuel cost is an important consideration for brick makers, resulting in shifts to cheaper fuels. The selling price of fired bricks vary greatly across the country, the highest price of Rs 8-12/ brick is realized in West Bengal, Tripura and some of the Southern States. In the remaining regions of the country the brick prices vary from Rs 4-8/brick. The brick size and weight show significant variations. The weight of the fired brick could vary from anywhere from around 2.5 kg/brick (Andhra Pradesh) to 3.5 kg/brick (West Bengal), in most of the northern India, the weight of fired brick is around 3 kg/brick.

Brick industry plays an important role in the rural economy in terms of providing employment as well as money paid for purchase of clay and biomass fuels. It also supports several rural industries and workshops involved in making moulds, fuel feed hole covers, clay mixers, fans, etc. However, owing to their temporary existing, low use of technology, polluting nature and absence of professional management, production of bricks is generally not thought of as an "industrial" activity. A small fraction of the brick enterprises are registered with the Minister of MSME. 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. The plant has chamber dryer and a tunnel kiln based on natural gas. 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).

2.2 Key Growth drivers of the Brick sector

The construction industry contributes to about 10% of the Gross Domestic Product (GDP), registering an annual growth of about 9 %. Brick consumers are mainly government agencies, real estate developers, individuals constructing residential buildings, and contractors for road construction, etc. Majority bricks being the solid clay brick.

The major factor driving the growth of the brick market is the high demand from the building segment. Moreover, activities, such as urbanization, rapid industrial expansion, government infrastructure projects, are anticipated to escalate the product demand. The high consumption area for the brick market is the building segment. With urbanization, rapid industrialization, and focus on developing the infrastructure, the market is expected to propel in coming years. Moreover, India is continue to be one of the largest market, due to the large-scale production and consumption of brick products.

2.3 Key Challenges

One of the key issues about the manufacturing enterprises engaged in the production of different types of bricks is that >90% of the production is contributed from enterprises belonging to the unorganized sector. The common issues of these enterprises are listed below.

- Technology obsolescence: In the case of unorganized burnt clay brick manufacturing enterprises, the basic process of forming is manual and the brick kiln technologies in use are at least 100 years old.
- Problems in the supply/procurement of raw materials: Clay brick enterprises in most parts of the country are facing problems in getting access to brick earth for making bricks as the arrangements for providing environment clearance for the mining of brick earth is still not fully operational. The problem in clay procurement is particularly severe in states like Kerala.
- Poor product quality: In the absence of an effective quality control and assurance system, there is a large variation in quality of bricks available in the market Burnt clay bricks can have issues related to efflorescence, high water absorption, and large variation in product size and shape.
- Poor working conditions: Burnt clay brick production is a seasonal industrial activity and relies on migrant workers. Often the working and living conditions for workers are poor.
- Difficulty in understanding and complying with the complex environment regulations: Most of the owners of unorganized enterprises are not highly educated, also they do not have educated and professionally trained managers or supervisors. They find it difficult to understand complex environment regulations, e.g., environment clearance for the mining of brick earth. The opaqueness of the implementation process leads them into the hands of intermediaries to get necessary environment compliance. In recent years, the number of litigations related with brick industry has increased manifold and cases related with brick industry forms significant part of the ongoing cases in the National Green Tribunal.
- Overcapacity and low profitability: There is significant over capacity for manufacturing of bricks in certain regions. In states like Punjab, the installed burnt clay brick production capacity is way above the required capacity, resulting in severe pressure on profitability. The enterprises in the unorganized sector all over the country are under pressure to transform into the organized sector and to comply with regulations on environment, mining, taxation, transportation, workers, etc.

2.4 Environmental Challenges

In recent years, the brick industry is facing existential crisis due to a variety of environmental challenges. The environmental challenges facing the Indian brick industry can be broadly classified into three categories:

2.4.1 Air Pollution and health

There are several sources of air pollution in brick kilns. The combustion or burning of fuel (mostly coal and biomass fuels) for firing the bricks gives rise emission of particulate matter of various particle sizes ($PM_{2.5}$, PM_{10}), produced due to incomplete combustion (which gives black colour to the smoke) along with emission of gaseous pollutants, such as, Sulphur dioxide (SO_2), Carbon monoxide (CO), Hydrogen Fluoride (HF), etc. The combustion related pollution is often referred as stack emission or emissions discharged through the chimney or stack. In addition to the stack emission, dust pollution is also caused as the large amount of clay, ash, powdered fuel at the brick making site gets entrapped in the air or dust pollution caused by the movement of trucks, tractor trolleys etc. on the unpaved dusty roads around a brick kiln.

2.4.2 Emission of CO_2 and Global warming

Global warming is mainly being caused by the increasing concentration of carbon dioxide in the earth's atmosphere due to the burning of fossil fuels (coal, petroleum fuels). Fossil fuels contain carbon which on combustion gives rise to carbon dioxide. Coal is the main fuel in brick kilns in India and the brick industry in India is estimated to contribute 66–84 million tonnes of CO_2 emissions per year[2], which is about 2.5 % of the total CO_2 emissions of the country.

2.4.3 Use of clay from agricultural fields

Clay is generated from the decomposition of rocks and is one of the most abundant natural mineral materials on earth. The brick making clays are either surface clays or shales. Surface clays are found near to the surface of the earth. On the other hand, shales are clays that have been subjected to high pressures under the earth surface and must be mined. In India, brick production depends on surface clays e.g. clay obtained from agriculture fields, surface clay washed into water bodies (tanks, dams, etc.) and harnessed by desilting or clay harnessed from rivers in the river delta regions. For producing 250 billion solid bricks every year in India, approximately 750 million tons[3] of brick earth or clay is required and a significant part of it comes from agriculture fields and there are concerns related with loss in agricultural productivity and degradation of land due to unplanned mining.

2.5 Geographical Coverage of the Study

The brick cluster survey and audit exercise focused on mapping the current scenario of the energy consumption, production, technology aspects in each cluster. The objective of the exercise was to gather information on the technology used, energy consumption, identify energy conservation opportunities and enhance the awareness about energy efficiency and conservation measures among brick industries.

The cluster details are provided in the following sections. It is to be noted that while the information on five clusters i.e. Begusarai, Nagpur, Tripura, Indore and Bangalore is based on energy audits and extensive consultation carried out in the clusters; the information presented for remaining clusters i.e. Gautam Buddh Nagar, Baghpat,

[2] TERI. 2016 Report on Resource Audit of Brick Kilns New Delhi: The Energy and Resources Institute [Project Report No. 2015IE22]

[3] Assuming 3 kg of brick earth is required for the manufacturing of 1 solid clay brick.

Faridabad, Aligarh, Mathura, Tirupati, Ludhiana, Coimbatore and Varanasi is based mainly on on-site interviews conducted with selected brick kiln owners and industry association representatives. The clusters are marked on the map of India in Figure 2.

2.6 Audited Clusters

The details of the clusters in which energy audits were carried out are provided in this section.

2.6.1 Cluster – General Information

Five clusters located in 5 states were selected (Figure 2). The clusters were selected to cover the wide diversity of brick firing technologies used in India, which include Clamp, Down Draft, Fixed Chimney Bull's Trench Kiln (FCBTK), zig-zag natural draught, zig-zag induced draught, Tunnel kiln with dryer, Hoffman kiln and hybrid Hoffman kiln. The cluster-wise details of the number and types of kilns covered in the audited clusters is given in

Table 2. The photographs of the various types of kilns which were monitored during the study are given in Figure 3 and Figure 4.

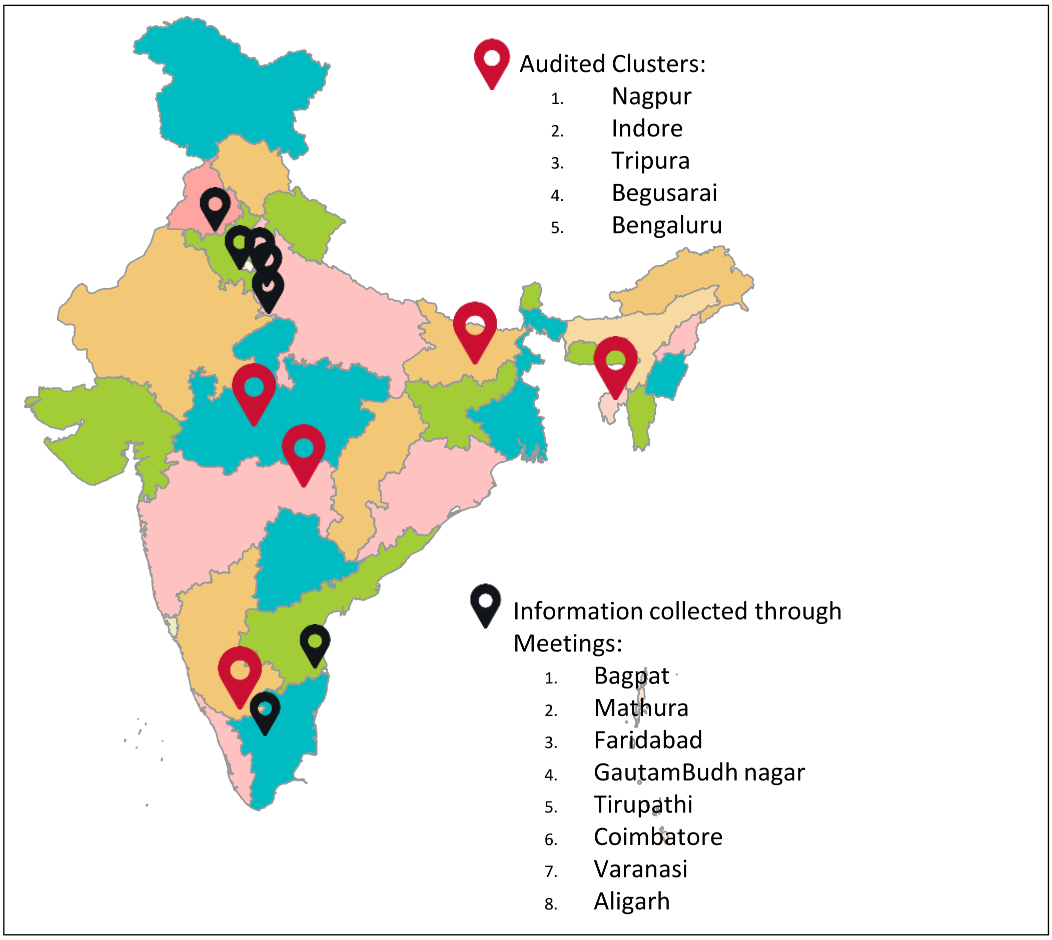


Figure 2 Brick kiln clusters covered in the study

Table 2 Cluster-wise details of the number and types of kilns in the audited clusters

Cluster	FCBTK	zigzag	Clamp	DDK	Hoffmann	Tunnel	Hybrid-Hoffmann	Total
Begusarai	0	150	0	0	0	0	0	150
Nagpur	150	0	50	0	0	0	0	200
Indore	0	0	400	0	0	0	0	400
Bengaluru	20	0	10	100	20	1	1	152
Tripura	178	7	0	0	0	0	0	185
Total	348	157	460	100	20	1	1	1087

Some other general information on the clusters are given in Table 3

Table 3: Raw material, fuel and selling price details of the audited clusters

Cluster	Raw material	Fuel	Selling price of Class I brick (Rs/brick)
Begusarai	Clay	Coal	Rs 8-10/brick
Nagpur	Clay and fly ash	Coal	Rs 5/brick
Indore	Clay and fly ash	Coal & internal fuel	Rs 6-10/brick
Bengaluru	Clay	Coal & biomass	Rs 6-12/ brick
Tripura	Clay	Coal	Rs 10-12/brick

a) Clamp -Indore

b) Covered Clamp – Bengaluru

c) Down Draught Kiln - Bengaluru

Figure 3 Intermittent kilns monitored during the study

 a) FCBTK – Nagpur	 b) FCBTK- Tripura
 c) zigzag – Begusarai	 d)FCBTK- Bengaluru
 e) zigzag- Tripura	 f) Hybrid Hoffmann Kiln - Bengaluru

Figure 4. Continuous kilns monitored during the study

2.6.2 Annual Brick Production & Fuel Consumption

The estimated annual production for the audited clusters is given in **Error! Reference ource not found.**. The production is influenced by the number of kilns, the average production capacity of the kilns and the length of the firing season. Amongst the audited clusters, the Nagpur cluster is estimated to have the largest production of around 9000-11250 lakh brick/year, while Bengaluru has the lowest production of around 1600-2500 lakh brick/year.

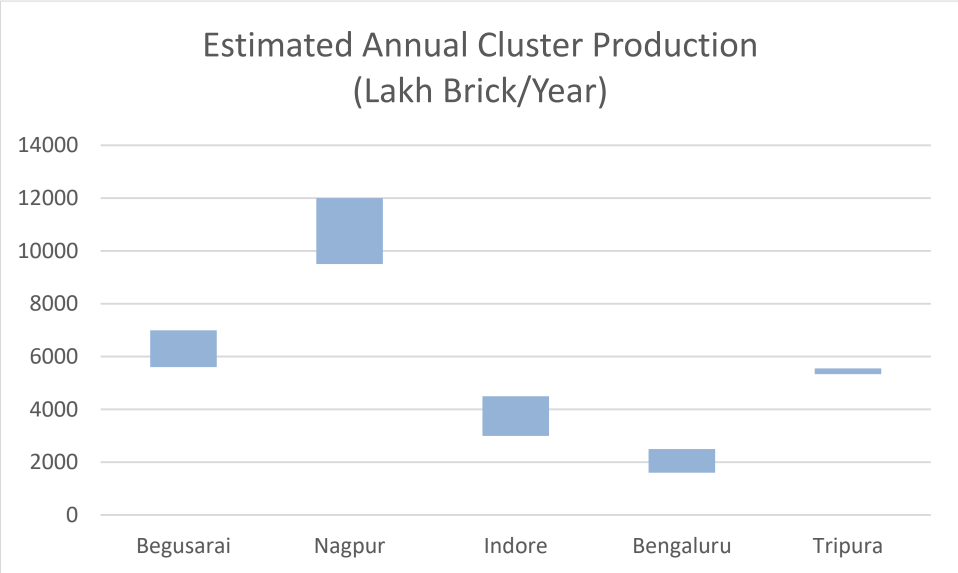


Figure 5 Estimated Annual Cluster Production (lakh brick/ year)

InTable 4 the kiln level estimated annual production is presented. A large variation was observed in the daily production capacity as well as the length of the firing season. While the brick manufacturing units based on intermittent kiln technologies like clamp were found to have smaller production capacities of 6 -15 lakh brick/year. The continuous kilns like Hoffmann, FCBTK and zigzag were found to have larger production capacities of 20-75 lakh brick/year. While Tripura had the shortest period of around 120 days in a year when brick kilns are operational, Bengaluru has the longest season of around 200 days in a year.

Table 4 Kiln Annual Production

Cluster name	Kiln Technology	Operating days of kiln per year	Estimated Annual Production/ Kiln (Lakh brick/year)	
			Min	Max
Begusarai	Zigzag	160	32	40
Nagpur	FCBTK	150	60	75
Nagpur	Clamp	180	10	15
Indore	Clamp	180	7.5	11.25
Bengaluru	FCBTK/Hoffman	200	20	30
Bengaluru	DDK	20	6	10
Tripura	FCBTK/Zigzag	120	28.8	30

2.6.3 Cluster Fuel Consumption

The estimated annual cluster level fuel consumption of the five audited clusters is provided in Table 5.

Table 5 Estimated Annual Fuel Consumption in Audited Clusters

Cluster name	Kiln Technology	Fuel Type	Estimated Cluster Fuel Consumption
			(Thousand Tons/ Year)
Begusarai	Zigzag	Coal	70-90
Nagpur	FCBTK & Clamp	Coal	130-160
Indore	Clamp	Coal Internal fuels (Rice husk, coal dust, saw dust, mustard, crop waste)	20-30 60-70
Bengaluru	FCBTK, Hoffman, DDK, Tunnel & HHK	Coal Wood, Eucalyptus leaves	60 – 100 20 - 30
Tripura	FCBTK &Zigzag	Coal	130-140

2.7 Information on Other Clusters

Apart from the five clusters where energy audits were carried out, information was collected for nine clusters i.e. Gautam Buddh Nagar, Baghpat, Faridabad, Aligarh, Mathura, Tirupati, Ludhiana, Coimbatore and Varanasi. The information on the type of brick kiln technology used, fuel consumption, quality and selling price of fired bricks was collected through interviews with selected brick kiln owners and industry association representatives done during the second half of 2021. The collected data along with some calculated data e.g. estimated Specific Energy Consumption is presented in Table 6.

Table 6 Salient information collected from nine other clusters

S No	Cluster	Type & No of Kilns	Production Capacity (brick/day)	Estimated Cluster Production (Lakh brick/year)	Fuel	Estimated Cluster Fuel Consumption (Thousand tons/year)	Estimated SEC (MJ/kg)	Class I brick (%)	Selling Price (Rs/brick)
1	Gautam Budh Nagar, UP	zigzag -70	30-40,000	3000	US coal	35	1-1.25	75-85	4-5
2	Faridabad, Haryana	zigzag -100	30-40,000	4200	US coal	45	1-1.25	75-85	4-5
3	Bagpat, UP	zigzag -450	30-40,000	19000	US coal	210	1-1.25	70-85	4-4.5
4	Aligarh, UP	Total-400, FCBTK-360, zigzag-40	25-30,000	16500	US coal	120	1-1.25	70-85	4-4.5
					Mustard Stalk	150	1.2 -1.5	50-70	4-4.5
5	Mathura, UP	Total - 200, FCBTK-170, zigzag-30	25-30,000	8250	US coal	65	1-1.25	70-85	4-4.5
					Mustard Stalk	70	1.2 -1.5	70-85	4-4.5

6	Tirupathi, AP	clamp-200	NA	2000	Coal	4	1.5-2.5	75	8-9
					Firewood	30			
7	Coimbatore, TN	FCBTK-150	20-25,000	5400	Coal	60	1.2-1.55	80-90	7-7.5
8	Ludhiana, Punjab	Total-330, zigzag-230, FCBTK-100	30-40,000	17000	Coal	180	1-1.25	70-85	4-4.5
9	Varanasi, UP	Total-300, zigzag - 270, FCBTK-30	25-40,000	15000	Coal	200	1.0-1.5	50-85	6-8

Following conclusions can be drawn:

1. The data shows that in the Indo-Gangetic plains, a majority of brick kilns have shifted from FCBTK to zigzag kiln technology in the National Capital Region districts as well as at Varanasi (Uttar Pradesh), Ludhiana (Punjab) and Begusarai (Bihar). In case of Mathura and Aligarh, the process of conversion has got initiated.
2. The two clusters in South India, presents a contrasting picture on technology front. Tirupati which is representative of brick industry in Andhra Pradesh and Telangana is using clamp technology. Coimbatore in Tamil Nadu is using FCBTK and zigzag technology has still not been introduced at Coimbatore.
3. The NCR districts – Gautam Budh Nagar, Faridabad and Bagpat has shorter brick firing season because of restrictions on kiln firing put by pollution control boards due to air pollution concerns.
4. The clusters in the Indo-Gangetic plains have much higher production capacities compared to the clusters in South India.
5. Coal is the main fuel. However, in some of the clusters, significant amount of biomass fuels are used e.g. firewood in Tirupati, mustard stalk at Mathura & Aligarh.

In large brick clusters in North India e.g. Bagpat, Ludhiana, Varanasi, etc, the annual coal consumption is of the order of 200 thousand tons/ year. For comparison, this consumption is of the same order as the annual coal consumption of a 50 MW coal based thermal power plant[4].

2.8 Brick sector level stakeholders

2.8.1 All India Brick and Tiles Manufactures Federation

All India Brick and Tiles Manufactures Federation (AIBTMF) has its office located at New Delhi and is currently headed by Mr Ashok Kumar Tiwari (President). It is the apex brick industry association. AIBTMF has representations from various state level Brick manufactures associations. Each state level association in turn is a federation of district/ cluster level brick kiln associations.

[4] https://cea.nic.in/old/reports/others/thermal/tppd/acq_norms.pdf

2.8.2 Begusarai Cluster

Begusari Brick manufactures Association is headed by Mr Murari kumar Manu and there are around 175 Zigzag Kilns operating in the Begusarai cluster. Begusarai Cluster brick manufactures produces solid clay bricks using clay.

2.8.3 Nagpur Cluster

Nagpur Brick manufactures Association headed by Mr Gopal Mehadia and there are around 150 FCBTK Kilns available in the Nagpur cluster. The clamp kilns are decreasing, and it is expected that all these clamp kilns are to be closed in due course.

2.8.4 Tripura Cluster

Tripura Brick manufactures Association coordinated with Mr Sanjith Choudhury and there are around 200 FCBTK Kilns and few Zigzag kilns available in the Tripura cluster. Tripura brick industries started to shift from FCBTK technology to Zigzag kiln technology to reduce the emissions. All the brick industries in the Tripura cluster uses clay as raw material which is from nearby agricultural paddy fields and ponds.

2.8.5 Indore Cluster

Indore Brick manufactures Association is headed by Mr Abhishek Purohit. There are around 400 Clamp Kilns and few FCBTK kilns available in the Indore cluster. Indore Cluster brick manufactures produces solid clay bricks using clay and Internal fuel. Most of the brick manufactures fall under the production capacities of around 5 to 25 lakh bricks per annum.

2.8.6 Bangalore Cluster

There are around 150 brick Kilns which includes Clamp, Hoffman, FCBTK and Down draught kilns and very few Tunnel kilns available in the Bengaluru cluster. All the brick industries in the Bengaluru cluster uses clay as raw material which is from nearby land and de-silting tanks. Bengaluru Cluster brick manufactures produces solid clay bricks using clay. Most of the brick manufactures fall under the production capacities of around 10 to 40 lakh bricks per season.

Chapter 3. Energy Benchmarking

3.1 Benchmarking energy consumption in brick sector

Brick sector energy consumption benchmarking is based on the energy use analysis carried out across five clusters in five states and through consolidation meeting/workshops conducted across the country covering remaining key clusters. The energy audit and survey covered all the brick sector technologies which includes Clamp, down draft kilns, FCBTK, Natural draught Zig-zag kilns, Induced draught Zig-zag kilns, Hoffman kilns, Hybrid Hoffman kilns, Tunnel kiln with dryers.

3.1.1 Need for Benchmarking in Brick sector

Benchmarking is used to compare the performance of individual kilns with the kiln of the same type or with other kiln types. Energy benchmarking is part of a much wider use of benchmarking as a management tool. The results of brick sectoral benchmark studies can be summarized in benchmark curves in which the energy use of individual kilns is plotted as a dependent variable from the most efficient to the least efficient kiln, either as function of cumulative production or of the number of kilns. The information from benchmark curves can be used to assess the relative performance of individual kilns. It can also, where sufficient specific information is available and the coverage of the benchmark curve is fairly comprehensive, be used to estimate the aggregate savings potential at the level of an individual cluster, a region, or state.

3.1.2 Factors influencing Energy benchmarking in Brick sector

Brick industry Energy intensities are expressed in terms of MJ/kg of fired brick. Specific energy consumption is a measure of energy used for firing one kg of green brick to fired brick in given conditions using specific type of kiln. A range of factors can play a role in making differences in Specific Energy Consumption, depending on the product, quality of clay, type of drying, period of drying, type of technology used for firing, climatic condition of the place, external/internal fuel applied status etc. Some of the factors influencing variation in specific energy consumption are described as below:

Type of clay used

Green bricks are fired in the kilns to convert a fairly loosely compacted blend of different minerals into a strong, hard, and stable product i.e. fired brick. The firing process determines the properties of the fired brick — strength, porosity, stability against moisture, hardness etc. Depending on nature of clay and quality of fired brick requirement, bricks are fired in a temperature range of 800–1100°C. Lower the firing zone temperature in the kiln the fuel consumption decreases. So, property of clay play vital role is deciding the fuel consumption and which in turn alter the specific energy consumption.

Type of fuel used

In brick kilns, generally solid fuels are used e.g. coal; wood; sawdust; agricultural residue like mustard stalk, rice husk, coffee husk; industrial waste and bye-products like used rubber tyres, pet-coke, etc. Apart from solid fuels, bricks can also be fired using natural gas, diesel, biogas, producer gas, etc. Majority of kilns are coal fired in the country. The calorific value and quality of the coal play a key role in producing better quality bricks. Many of the brick industries use imported coal having higher calorific value to get better quality bricks. The combustion characteristics as well as the method of addition of the fuel (as internal fuel mixed with clay or as external fuel fed in the kiln) has an impact on the SEC.

Kiln size and type of technology

Continuous kilns are more efficient and consume less fuel when compared to intermittent/batch kilns. In a continuous kiln fire is always burning and bricks are being warmed, fired and cooled simultaneously in different parts of the kiln. Fired bricks are continuously removed and replaced by green bricks in another part of the kiln which is then heated. Consequently, the rate of output is approximately constant. Heat in the flue gas is utilized for heating and drying of green bricks and the heat in the fired bricks is used for preheating air for combustion. Due to incorporation of heat recovery features, continuous kilns are more energy efficient. Whereas, in intermittent kilns, bricks are fired in batches; fire is allowed to die out and the bricks are allowed to cool after they have been fired. The kiln must be emptied, refilled and a new fire has to be started for each load/batch of bricks. In intermittent kilns, most of the heat contained in the hot flue gases, fired bricks and the kiln structure is thus lost. The specific energy of continuous kilns such as Zig-zag, Hoffman are less when compared to batch operated kilns such as Clamp and down draught kilns. So, the type of technology plays a key role in difference in specific energy consumption.

Type of green brick drying followed

The moisture percentage in the green brick immediately after moulding is around 20 to 25% based on the clay type and the method of moulding employed. During the drying process, this moisture should be reduced to as low as possible before loading the green brick for firing in the kiln. Higher the moisture in the loaded green bricks in the kiln, higher would be the fuel consumption to remove moisture in the kiln. There is a large variation in the moisture content of the dried green brick, and it can vary from 3% to 10% and it has a direct impact on the SEC. In case of natural drying, the moisture content of the dried green bricks depends on the duration of drying as well as on the ambient weather conditions. A lower moisture content is possible in brick kilns located in north and central India during dry summer season, on the other hand, the moisture content in green bricks is always higher in brick kilns located in the humid coastal areas. In case of tunnel kiln, as freshly loaded bricks (at 20-25% moisture content) are directly sent to a tunnel dryer, more energy is required for drying of bricks

3.2 Specific Energy Consumption (MJ/kg) – National Benchmarks

3.2.1 Specific Energy Consumption (MJ/kg brick) of Audited Kilns

Based on the energy audit data, the specific energy consumption in MJ/kg was calculated for 60 kilns. The cluster and kiln type wise distribution of these kilns is given Table 7. The three main kiln types i.e., FCBTK, clamp and zigzag forms the majority of the kilns which were audited.

Table 7 Distribution of 60 kilns for which energy audit was carried out

	Nagpur	Tripura	Bengaluru	Begusarai	Indore	Total
FCBTK	10	6	3			19
Clamp	1		2		11	14
zigzag		4		17		21
Hoffmann			3			3
Downdraught kiln			1			1
Hybrid Hoffmann Kiln			1			1
Tunnel Kiln			1			1
Total	11	10	11	17	11	60

The specific energy consumption of a brick kiln is impacted by the kiln type, fuel, the properties of the clay, weather conditions of the site, operational practices, etc.

A comparison of SEC of different clusters is shown in Figure 6. It is observed that Begusarai, where all the kilns were of zigzag type has the lowest average SEC of 1.05 MJ/kg. This is followed by Nagpur at 1.22 MJ/kg. Tripura, Bengaluru and Indore have average SEC of around 1.6 MJ/kg. However, given the large variety of kilns found in Bengaluru, there is a large variation in SEC of kilns.

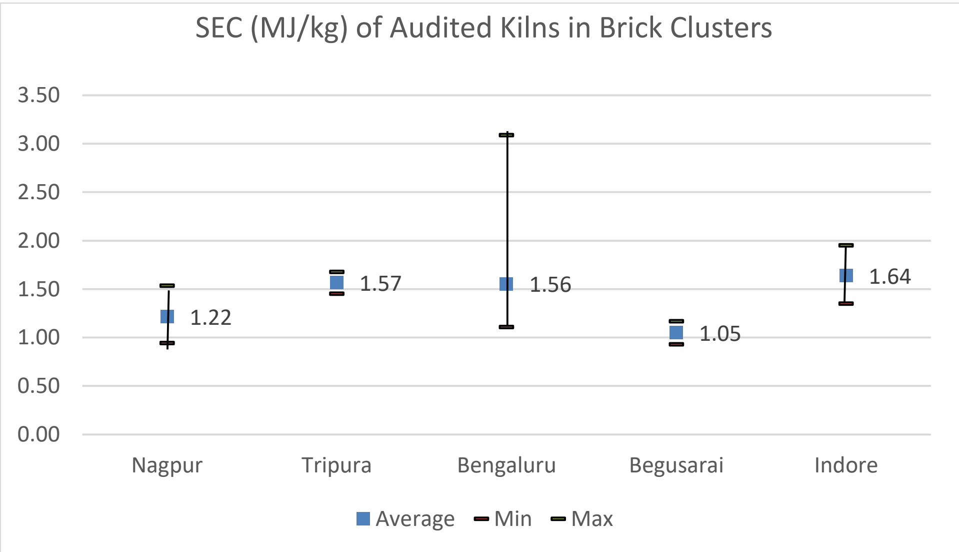


Figure 6 Cluster wise SEC of audited brick kilns

A comparison of SEC of different kiln types is shown in Figure 7. Following inferences can be made:

- The intermittent or batch kilns i.e., downdraft kiln and clamp have the highest SEC. In intermittent kilns, the extent of heat recovery from both hot fired bricks and hot flue gases is small, which is the primary reason for their high SEC. The lone biomass fired downdraft kiln has a very high SEC of 3.09 MJ/kg, while the coal fired clamps have SEC varying between 1.35 to 1.95 MJ/kg.
- The continuous kilns due to better heat recovery and continuous operation have lower SEC compared to intermittent kilns. Among the three traditional continuous kilns, the zigzag kilns, which are an improvement over FCBTK have around 15% lower average SEC of 1.16 MJ/kg compared to 1.33 MJ/kg for FCBTK. Traditional Hoffmann kiln with high thermal mass and low production rate show a high average SEC of 1.53 MJ/kg.
- Among the two advanced kiln options, the lone audited Hybrid Hoffmann Kiln has a low SEC of 1.11 MJ/kg , while the Tunnel Kiln has SEC of 1.45 MJ/kg. It is to be noted that in both the cases the SEC also include the energy used in the dryers. Also, the monitored Tunnel kiln is being used to produce resource efficient hollow clay blocks and have the lowest SEC if expressed in MJ/m^3 of bricks. Also due to uniformity in the temperatures, the wastage in the tunnel kiln is negligible.

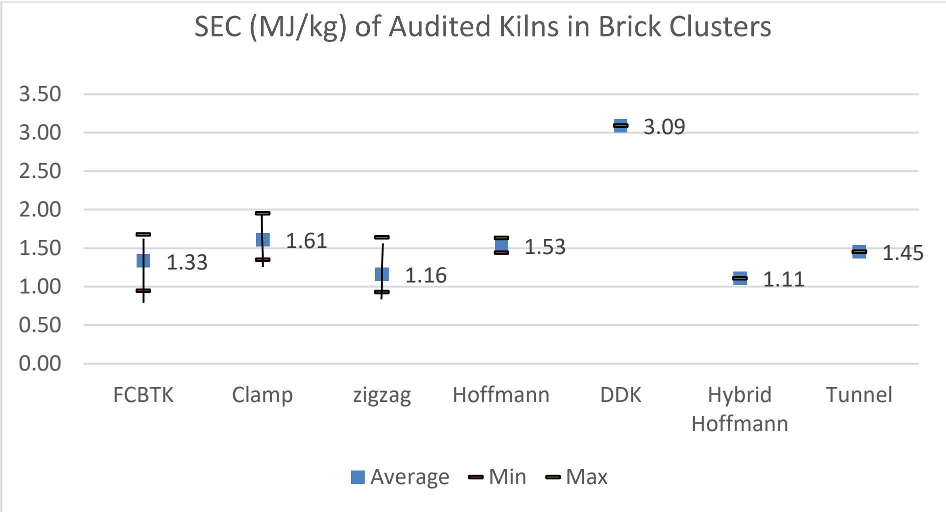


Figure 7 SEC of various kiln types of 60 audited kilns

3.3 Specific Energy Consumption (MJ/kg) – National Benchmarks

In 2020, while formulating the Energy Efficient Enterprise (E3) scheme for brick industry, the data collected through energy audits of brick kilns conducted by various organization was compiled and national benchmarks, based on the average SEC of the available dataset for various types of kilns were established. In Table 8, the results of the BEE E3 benchmarking study are presented along with the results of the present study. It is seen that there is a good agreement (within ±10%) for the various kilns, except clamps. In Table 8, a new set of benchmarks by merging the two datasets are also presented. The new benchmark SECs for different kilns, along with the SEC range, are presented in Figure 8.

Table 8 SEC benchmarks for Indian brick kilns

	BEE E3 Benchmarking Study (2019-20)		**BEE Energy & Resource Mapping Study (2020-21)**		**New BEE National Benchmark (2022)**	
	Number of Kilns	Average SEC (MJ/kg)	Number of Kilns	Average SEC (MJ/kg)	Number of Kilns	Average SEC (MJ/kg)
Intermittent Kilns						
Clamp	20	1.91	14	1.61	34	1.79
Downdraft Kiln	4	2.9	1	3.09	5	2.94
Continuous Kilns						
FCBTK	67	1.34	19	1.33	86	1.34
zigzag	16	1.06	18	1.16	34	1.11
Hoffmann Kiln	4	1.7	3	1.53	7	1.63
Hybrid Hoffmann Kiln	0	NA	1	1.11	1	1.11
Tunnel Kiln	2	1.4	1	1.45	3	1.42
Vertical Shaft Brick Kiln	13	0.91	0	NA	13	0.91

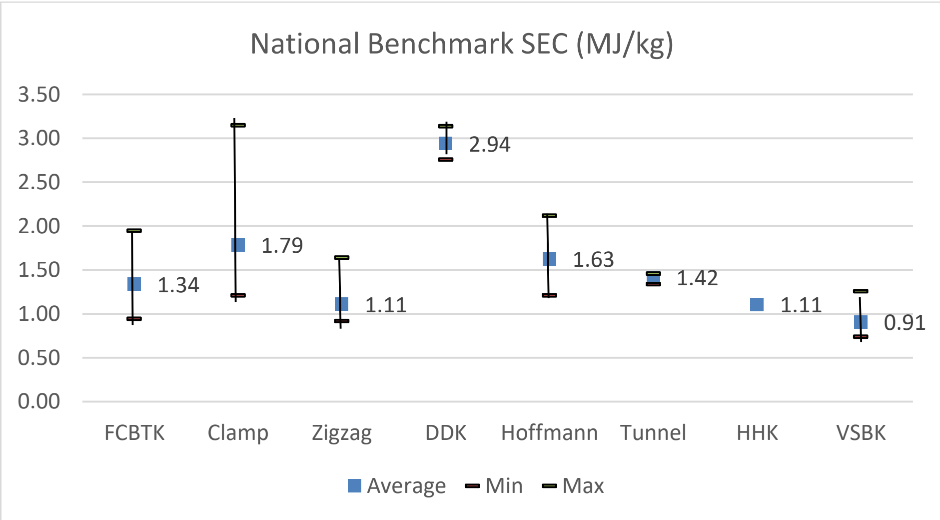


Figure 8 National benchmarks of SEC for various kiln types

3.4 Specific Energy Consumption (MJ/kg): International Benchmarks

Literature on energy performance of brick kilns in other countries was studied to look for SEC benchmarks in other countries.

3.4.1 Intermittent and Semi-continuous Kilns

The production details and specific energy consumption of intermittent and semi-continuous kilns are provided in Table 9. Internationally, intermittent and semi-continuous kilns are mostly used in developing countries of Asia, Africa and South America for small-scale production.

Table 9 SEC benchmarks for intermittent and semi-continuous kilns (International)[5]

Kiln	Type	Countries	Fuel	Capacity	Specific Energy Consumption (MJ/kg)
Circular domed downdraft kiln	Intermittent	Brazil, Colombia & Peru	Firewood	25,000 - 100,000 bricks per batch	3.5
Mobile kiln	Intermittent	Brazil, Colombia, Paraguay & Peru	Biomass briquettes, coal, gas	1,50,000 – 2,50,000 bricks per batch	1.80
Cedan kiln	Semi-continuous	Brazil	Firewood	200,000 bricks per week	1.85
Multi-chamber kiln	Semi-continuous	Colombia	Coal	1,20,000 per month	2.37

Among the intermittent kilns and semi-continuous kilns, the Mobile kiln, which is a new generation kiln with low SEC looks interesting for application in India. A brief description of the kiln is given below.

Mobile Kiln

Mobile kiln (Figure 9) has a light-weight structure made up of steel and insulated with ceramic fiber. The structure can be moved over a rail system. The batch of bricks to be fired are stacked, the structure is moved over the batch and doors are closed. There are burners or firing holes provided on the sides. The exhaust is carried through a chimney. Chopped firewood, briquettes, gas or oil are used as fuel. The kiln is widely used in South America.

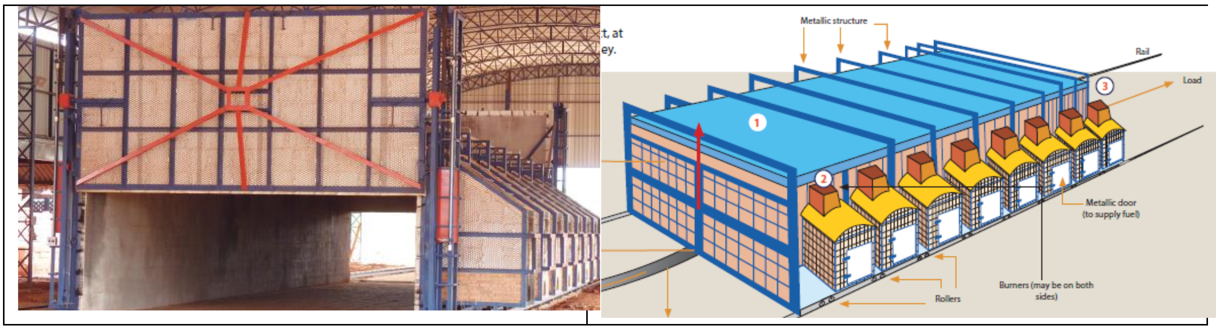


Figure 9 Mobile Kiln[6]

3.4.2 Continuous Kilns

Among the Continuous kilns, two kiln types that are becoming popular for large-scale production of bricks are Hybrid Hoffmann Kiln and Tunnel Kiln. Both these kilns generally have a dryer integrated with the kiln, in which the hot gases from the kiln are

[5] Source: CCAC factsheets on brick kilns in South America, 2013
[6] Source: CCAC factsheets on brick kilns in South America, 2013

used for drying the bricks. Thus, the SEC values for these kilns include both thermal energy used for both drying and firing of bricks. Tunnel kiln is a more versatile kiln and can be used to produce hollow clay blocks. In both China and Vietnam, a large part of the energy for firing comes from the internal fuel (powdered coal added to the clay during clay preparation) and helps in reducing the SEC.

Table 10 SEC benchmarks for Continuous kilns (International)[7]

Kiln	Type	Countries	Fuel	Capacity	Specific Energy Consumption (MJ/kg)
Hybrid Hoffmann Kiln	Continuous	China, Bangladesh	Coal	50,000 bricks per day	1.20
Tunnel kiln	Continuous	China, Bangladesh, Vietnam	Coal	50,000 - 100,000 bricks per day	1.3 -1.5 MJ/kg

Figure 10 Hybrid Hoffmann Kiln (China) & Tunnel Kiln (Vietnam)

3.5 Typical Heat Balance of Monitored Kilns

3.5.1 Intermittent Kiln

The main elements of heat balance of a typical downdraft kiln are shown in Table 11. As noticed earlier, downdraft kiln has the highest SEC amongst all the kiln types covered during the study. The four main heat losses that account for almost 55% of the energy are:

- Heat loss through exit flue gases, which is essentially the sensible heat in dry flue gases due to high exit flue gas temperatures and high quantity of excess air
- Surface heat losses are the radiation and convection heat losses taking place from outside surface of the kiln
- Heat loss through firing hole opening, which is unique to downdraft kiln as the Eucalyptus twigs and leaves are burned in external fireboxes, which are exposed to the ambient

[7] Source: CCAC factsheets on brick kilns in South Asia, 2013

- Heat used to evaporate the moisture in green bricks as the green bricks are not fully dried.

Table 11 Heat Balance of a Downdraft Kiln

Heat Balance Components	MJ/kg	%
Total Heat Input	3.09	100 %
Heat Output		
1) Heat loss through exit flue gases	0.53	17.2 %
2) Surface heat losses	0.39	12.8 %
3) Heat loss through firing hole openings	0.50	16.0 %
4) Heat used to evaporate the moisture in green brick	0.28	9.1 %
5) Useful energy, other accounted & unaccounted losses	1.39	45%

3.5.2 Continuous Kilns (without dryer)

Typical heat balance of a FCBTK, a zigzag and a Hoffmann kiln are shown in Table 12. All of these kilns are annular kilns and does not have a separate dryer attached to them. In these manufacturing units, natural brick drying under sun or under a shed is practised.

Table 12 Typical Heat Balance of FCBTK, zigzag and Hoffmann Kiln

Heat Balance Components	FCBTK		Zigzag		Hoffmann	
	MJ/kg	%	MJ/kg	%	MJ/kg	%
Total Heat Input	3.09	100 %	1.16	100%	1.53	100%
Heat Outputs						
1) Heat loss through exit flue gases	0.53	17.2 %	0.12	10.5%	0.36	23.3%
2) Surface heat losses	0.39	12.8 %	0.29	25%	0.18	11.6%
3) Heat used to evaporate the moisture in green brick	0.28	9.1 %	0.24	20.6%	0.23	15.3%
4) Useful energy, other accounted & unaccounted losses	1.39	45%	0.51	44%	0.76	49.7%

It can be noticed that the three main heat losses i.e a) heat loss through exit flue gases b) surface heat loss and c) heat used to evaporate the moisture in green bricks, combined together, accounts for around 50% of the energy. Hence, the energy conservation measures as explained in the next chapter revolve around reducing these three heat losses, apart from improving the combustion.

3.5.3 Continuous Kilns (with dryer)

Typical heat balance for a Hybrid Hoffmann Kiln and a Tunnel kiln are shown in Table 13. Both of these kilns have a separate dryer attached to the kiln and hot flue gases/air is extracted from the kiln and used in the dryer for drying of green bricks. It is observed that in both the cases around 33% of the energy is transferred from the kiln to the dryer, which also explains the higher SEC of Tunnel Kiln compared to zigzag kiln.

Table 13 Typical Heat Balance of a Hybrid Hoffmann Kiln and a Tunnel Kiln

Heat Balance Components	Hybrid Hoffmann Kiln		Tunnel Kiln	
	MJ/kg	%	MJ/kg	%
Total Heat Input	1.11	100 %	1.45	100%
Heat Outputs				
1) Heat loss through exit flue gases	NA	NA	0.09	6.2%
2) Surface heat losses	0.15	13.6 %	0.17	11.4%
3) Heat used to evaporate the moisture in green brick	0.01	1.3 %	0.14	9.7 %
4) Heat carried away in air/flue gas for heat recovery in dryer	0.38	33.9%	0.47	32.4%
4) Useful energy, other accounted & unaccounted losses	0.57	51.3%	0.58	40%

Chapter 4. Energy Conservation and Energy Efficiency Measures for the Brick Sector

The energy conservation and energy efficiency measures can be divided into two categories:

- Low-cost measures with short payback period
- Medium and high-cost measures with medium to high payback period

4.1 Low-cost and short payback EC measures

Low-cost measures (having investment of < Rs 50 lakhs) and short payback period of < 2 years.

4.1.1 Use of Internal Fuel

Internal fuel in the form of powdered coal, rice husk, bagasse, boiler ash, cow dung, etc can be added with clay at the time of preparation of clay-mix. Coal washery rejects and coal gangue can be utilised as internal fuels, particularly in brick kilns located near to the coal fields. Use of internal fuels helps in reducing the energy consumption, it also helps in reducing air pollution from brick kilns. Use of internal fuel, particularly biomass fuels can also help in reducing the density of bricks and thus improving the thermal insulation provided by them.

In addition to internal fuels, addition of fly ash and other industrial wastes like boiler ash in clay for making bricks is widespread in central, western and parts of southern India. The mixing is done as a part of clay mix preparation before moulding of bricks. The addition of fly ash and wastes with clay helps in reducing the amount of clay required for making bricks. In addition, addition of fly ash which also has some unburnt carbon in it also helps in reducing the amount of fuel required for baking the bricks. Addition of fly ash in black cotton soil (found widely in central and western India) is also beneficial in reducing the plasticity of the soil and hence reducing breakages taking place during drying and firing.

There are many ways in which mixing of internal fuel, fly ash or waste with clay is practised:

- Manual mixing
- Mixing using a tractor attachment
- Mixing using a mechanical mixer/pug mill

If the brick kiln is already using a pug-mill, then there is no additional investment required. Otherwise, depending upon the technology employed the investment can range from a few lakhs with maximum going up to Rs 10 lakhs.

Figure 11 Mixing of internal fuel and fly ash with clay (Maharashtra & Telangana)

Box 1: Mixing Fly Ash, other industrial wastes and internal fuel with Clay

Environmental Benefits:

- Utilisation of industrial and other wastes
- Reduction in clay consumption
- Reduction in fuel consumption
- Reduction in emission of particulate matter in stack gases
- Potential to produce porous bricks having better insulation properties

Investment requirement

- Up to Rs 10 lakhs/ kiln

Status & Potential

- Common practice to use coal gangue as internal fuel in China and Vietnam
- Common practice in parts of Central, Western & Southern India
- Potential to expand to around 60,000 FCBTKs/ zig-zag kilns located in the Indo-Gangetic plains

Action Points

- Testing of clays
- Mapping the availability of wastes and internal fuel
- Demonstrating viable clay-waste-internal fuel mix
- Adapting mixing technology as per the requirements of the Indo-Gangetic

4.1.2 Improvement in operating practices of clamps

Surface heat losses due to radiation and convection are one of the main heat losses taking place in clamps. Surface heat losses, depends both on the temperature of the surface as well as the surface area. Any strategy to reduce the surface temperature or the surface area would help in reducing the surface heat losses and saving of energy. The two suggested improvements are:

a) Improving the outer surface insulation through double wall and filling the cavity with ash helps in reducing the surface temperature and hence reduction in surface heat losses.

b) Increased size of the clamp to reduce the surface area to volume ratio which in turn helps in reducing the surface heat losses and better utilisation of the heat of flue gases within the clamp

4.1.3 Improvement in operating practices of zigzag kilns

Based on the study of the audited kilns, following improvement in operating practices to reduce energy consumption are suggested:

b) Improvements in FCBTK & zigzag

- Practising continuous feeding of fuel manually or use of continuous mechanical coal feeding system
- Using 10-inch ash layer to reduce heat loss and air leakage from the kiln surface
- Use of cavity wall filled with ash to close the wicket gates to reduce heat loss and air leakage

- Regular temperature and draught measurement of flue gases and temperature monitoring in the firing zone
- Using properly designed fans and use of VFD drive in case of induced draft zigzag kilns

4.1.4 FCBTK to zigzag conversion

The SEC of the zigzag kilns reported in the study as well as per the national benchmarking study is 15-25% lower compared to that of FCBTK.

Zig-zag kiln in the form of High Draught kiln was introduced in India around 50 years ago by the Central Building Research Institute (CBRI) as an alternative to the Bull's Trench Kiln. The main difference in the two kilns is regarding the brick setting and air flow. In a zig-zag kiln the bricks for firing are set/loaded in such a way that air in the kiln follows a zig-zag path, while in a BTK the air follows a straight line path. The introduction of a fan in the original design of the High Draught kiln also provided more air for combustion. The coal is crushed/powdered and is fed in small quantities. All of these changes help in more efficient heat transfer and better burning of the fuel. A zig-zag kiln saves around 15-25% fuel and results in up to 50% reduction in particulate matter emission as well as improvements in the percentage of good quality bricks. The initial investment for constructing a new good quality zig-zag kiln is estimated to be around Rs 40 lakhs.

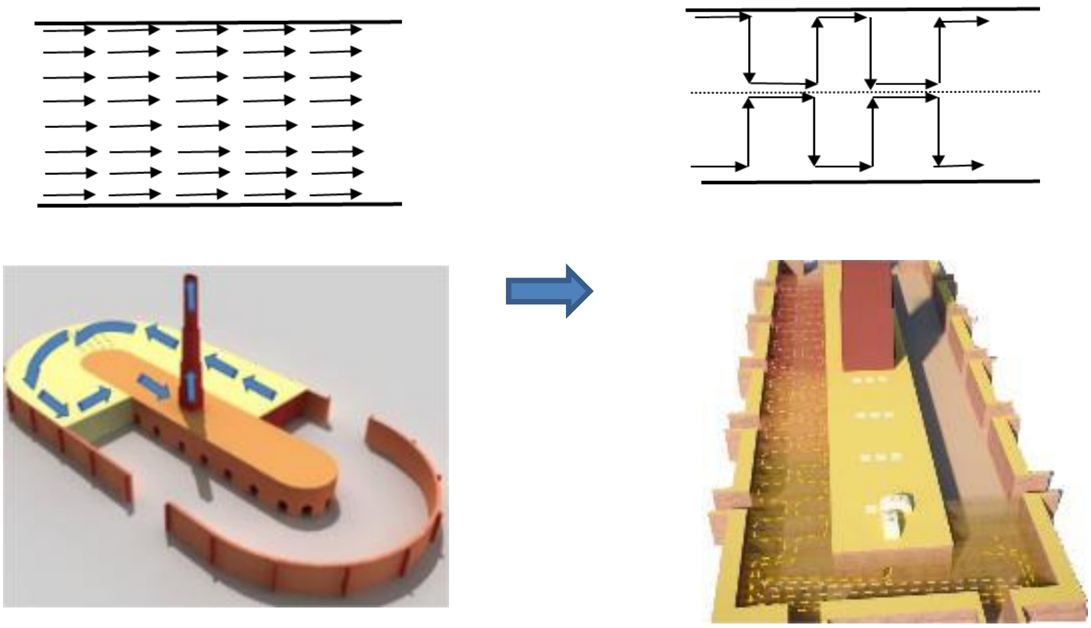


Figure 12 Conversion of FCBTK into zig-zag kiln

In addition, the collected data also shows that zigzag results in increasing the percentage of Class I bricks and hence in increasing the revenue and profitability. As per estimates based on discussion with brick industry associations, out of 50,00 -60,000 FCBTKs, which existed in the country in 2015, around 15,000 have changed over to zigzag technology. The state wise status of conversion is shown in Figure 13.

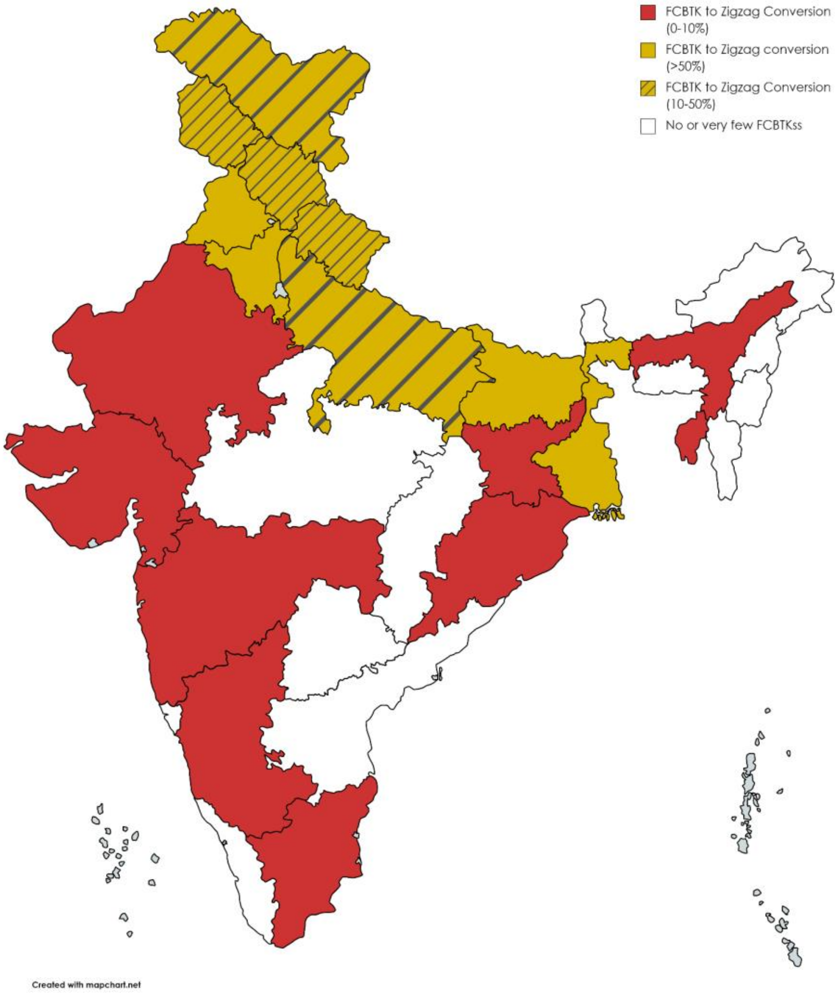


Figure 13 Status of FCBTK to Zigzag Conversion

During the cluster studies, it was found that a majority of FCBTKs at Begusarai (Bihar), NCR (Gautam Buddha Nagar, Bagpat & Faridabad), Varanasi (Uttar Pradesh) and Punjab (Ludhiana) have changed over from FCBTK to zigzag kiln technology. On the other hand, clusters, such as Nagpur (Maharashtra), Coimbatore (Tamil Nadu), Bengaluru (Karnataka) and Tripura have low or no penetration of zigzag kilns. Uttar Pradesh which has the largest number of FCBTKs in the country (around 20,000) shows a mixed situation. While some clusters in Uttar Pradesh such as those belonging to NCR, Varanasi show high conversion rate, others like Mathura and Aligarh show low level of conversion.

The initial investment in constructing a new zigzag kiln is estimated to be Rs 40-50 lakh and the retrofitting of an existing FCBTK to zigzag costs Rs 10-40 lakhs.

Box 2: Converting FCBTKs to zig-zag kiln technology

Environmental Benefits:

- Reduction in coal consumption (20-25%) and associated CO_2 emissions
- Reduction in emission of particulate matter (up to 50%)
- Reduction in wastage and improved quality

Investment requirement

- Rs 10 lakhs -40 lakhs/ kiln

Status & Potential

- Adopted by around 15,000 kilns till 2020
- 30,000 -40,000 FCBTKs yet to adopt; can result in savings of 5 to 7.5 million tons of coal/year

Action Points

- Intense awareness campaign amongst brick enterprises
- Making available standard designs
- Skill training of kiln masons
- Skill training of supervisors and workers involved in brick setting and fuel feeding

4.2 Medium to High Cost and Payback Period EC Measures

Medium and high-cost measures have investment of > Rs 50 lakhs and payback period of >2 years.

4.2.1 Shift to advanced brick firing technologies

a) Conversion from FCBTK/zigzag to Hybrid Hoffmann Kiln Technology

Hybrid Hoffman Kiln (HHK) technology is developed and widely used in China. It is a modified version of Hoffman kiln technology. The HHK combines use of green bricks produced by mixing powdered fuel with clay; and utilisation of waste heat by transferring the heat to an adjacent low-cost tunnel dryer to dry green bricks. These features lead to lower energy consumption and reduction of air pollution. In India there are a few (<5) HHK kilns, one of these located at Bengaluru was monitored and showed low SEC of 1.11 MJ/kg of fired brick.

In South Asia, the HHK technology was first introduced in Bangladesh in 2006 under an UNDP-GEF supported project and there were around 40 HHKs in Bangladesh in 2018. The production capacity of an HHK can vary from 50,000 to 100,000 bricks per day and the initial investment can vary from Rs 5-20 crore depending on the capacity and features.

b) Conversion from FCBTK/zigzag to Tunnel Kiln Technology

Tunnel kiln is a continuous moving ware kiln in which the clay products to be fired are passed on cars through a long horizontal tunnel. The firing of products occurs at the central part of the tunnel. The main advantages of tunnel kiln technology lie in its ability to fire a wide variety of clay products, better control over the firing process and high quality of the products.

The tunnel kiln technology was developed around mid-19th century in Germany. However, the application of the technology for brick firing took place in 20th century. After Second World War, the technology was widely adopted and lead to the transformation of European brick industry from several thousand small and scattered brick making units into few hundred large scale and highly mechanized tunnel kiln units. In Asia, China and Vietnam started adopting the technology during 1970's. Almost 75% of the brick production in China is accounted by Tunnel Kilns, while it is also the dominant technology in Vietnam with around 800 tunnel kilns in operation. In South Asia, Bangladesh has around 80 tunnel kilns, while India has around 10 tunnel kilns.

The production capacity of a Tunnel Kiln can vary from 50,000 to 400,000 bricks per day. The initial investment in a tunnel kiln producing 50,000 to 100,000 bricks per day is estimated to vary from Rs 10-30 crore depending on the capacity and features.

4.2.2 Production of Resource Efficient Bricks

Currently almost the entire brick production in the country is of the solid bricks, with less than 1% being that of hollow and perforated bricks. However, gradually a part of the demand for solid bricks can be replaced with that of hollow and perforated bricks. The production of hollow and perforated bricks can help in reducing the requirement of clay and energy by 10 to 55%. The large- format hollow blocks bring in advantage of better insulation and faster construction as well.

There are two routes to make a shift towards the manufacturing of hollow and perforated bricks:

a) Upgradation of existing zig-zag kilns: In this case the existing brick kilns can mechanise their clay preparation process and install an extruder to manufacture green bricks having holes/hollows. The extruded bricks require controlled drying and hence drying under a shed or using an artificial dryer is required. The hollow and perforated bricks can be fired in the existing kilns. This upgradation has been operating in around 30 to 50 kilns in the country. The initial investment of upgrading the clay preparation, installing an extruder and putting up a drying shed can range anywhere between Rs 2 to 6 crores. This upgradation can help brick enterprises to enter the perforated and hollow brick market. However, in this case, the percentage of perforation is small, and it may not be possible to manufacture hollow blocks having ~ 50% perforation. Without having an artificial dryer the production volume remains small, and it is difficult to reduce the cost of production.

b) Setting up a mechanised tunnel kiln and artificial dryer plant for exclusive production of hollow and perforated products: In this case a dedicated plant consisting of clay preparation machinery, deairing extruder, artificial dryer, tunnel kiln and mechanised material handling systems is installed. Such a plant generally has capacity to produce minimum 1 lakh regular bricks per day. In these plants it is possible to bring down the cost of production and maintain consistent quality. The initial investment in plant and machinery is of the order of Rs 20-30 crores.

Shifting to hollow and perforated bricks requires careful testing of the clay as not all clays are suitable for extrusion. Thus, a suitable clay mix must be prepared. For running a mechanised brick plant, unhindered supply of electricity is needed. Shifting to hollow and perforated bricks production means a structured transformation of the brick industry and converting brick industry into an organised manufacturing industry. Such a transformation would require larger investments, access to credit and technology, technically skilled manpower for the operation of machinery, higher technical and managerial capacities, and year-round operations.

4.2.3 Shift to gaseous fuels

Gaseous fuels burn more cleanly and produce less particulate matter emissions compared to solid fuels like coal and biomass. The NGT in its recent orders has mentioned about exploring possibility of using gaseous fuels in brick kilns located in the NCR region. Gaseous fuels like piped natural gas, compressed natural gas or biogas are cleaner fuels which results in less air pollution as well as they also help in reducing CO_2 emissions. Wienerberger India (a large international company involved in manufacturing of bricks), has converted their factory at Kunigal, Karnataka to natural gas firing[8]. In neighboring Bangladesh, several Hoffmann kilns operated on natural gas (Figure 14).

Conversion of zig-zag kilns to gaseous fuels will require development of appropriate technology in the Indian context. The price of natural gas is almost three times that of coal that will increase the cost of firing the bricks. In addition, substantial investments would be required by the brick kiln owners in converting their kilns to gaseous fuels. Brick kilns are located amidst agricultural fields often in remote places, a suitable system of gas supply would have to be established. If we look at the example of Europe, the brick industry changed over from coal to natural gas over a 20 years period (1960 to 1980)[9]. This period was also characterised by mechanisation, a shift to tunnel kiln technology and the consolidation of brick industry.

[8] https://www.wienerberger.in/Press/News0.html
[9] https://www.brickguru.in/en/blog/moving-to-natural-gas-for-brick-firing-is-it-possible-in-india/

Figure 14 Use of Natural Gas in a Hoffmann Kiln in Bangladesh (Source: GKSPL)

4.3 Use of Renewable Energy

Traditional brick industry is using biomass, in the form of firewood, agricultural residue as fuel for firing bricks and solar energy for drying of bricks in the open sun drying. There are several possibilities of using modern renewable energy technologies in brick production, these are:

- Use of biomass briquettes and pellets as fuel.
- Use of biogas produced through bio methanation of waste or producer gas produced from biomass gasification as fuel for drying or firing of bricks.
- Use of solar photovoltaic technology to produce electricity and use it for operating the machinery used for brick manufacturing.

The details of renewable energy options are provided in Annexure 2.

Chapter 5. National Policies & Standards

This chapter provides a summary of the policies and standards pertaining to brick industry.

5.1 Technical Standards & Policies

5.1.1 Indian standards for bricks, technologies, processes

The Bureau of Indian Standards (BIS) has over the years developed around 20 number of standards laying down requirements for classification, general quality, dimensions and physical requirements for bricks as well as for the construction of brick kilns.

Impact: Several of these standards are followed in the organized construction sector. However, as a large part of the construction activity and brick manufacturing falls under the unorganized sector, overall, the adherence to standards is low.

5.1.2 Performance appraisal certificate scheme

A Performance Appraisal Certificate Scheme (PACS) is being implemented for the development and promotion of materials, products, and systems under the joint initiatives of Building Materials and Technology Promotion Council (BMPTC), Construction Industry Development Council, Bureau of Indian Standards (BIS) and other agencies. It covers intended use of new building materials, components, products, elements, construction systems and assemblies, not yet covered by the Indian Standards. Vertical Shaft Brick Kiln (VSBK) technology has been certified under PACS.

Impact: VSBK is the only brick kiln technology under PACS. The VSBK technology was introduced in India in mid 1990's under a bilateral project. Over the years more than 100 VSBKs were constructed, however, despite their superior energy performance, most of them are now not in use, hence this scheme has low relevance.

5.1.3 Technology up gradation support by DSIR

The Department of Scientific & Industrial Research (DSIR) provides catalytic support for development and demonstration of innovative product and process technologies, from proof of concept or laboratory stage to pilot stage, rendering them fit for commercialization. The Technology Promotion, Development and Utilization Programme (TPDU) of the department has the objective of Development and Demonstration of innovative need-based technologies for making the industry competitive.

Impact: There are a very few projects related with brick industry which have used this support, so overall impact is low. A targeted scheme of technology up gradation for brick industry is needed.

5.2 Environment Policies and Regulations

5.2.1 Emission standards for various brick technologies

The notification on emission standards for brick kilns was last revised by MoEFCC in February 2022. The emission standards provide the allowable particulate matter in stack (mg/Nm^3) and 'stack height '.

Table 14 Emission standards as per notification February 2022

Parameter	Standard
Particulate matter in stack emission	250 mg/Nm^3
Minimum stack height (Vertical Shaft Brick Kilns) a) Kiln capacity less than 30,000 bricks per day b) Kiln capacity equal or more than 30,000 bricks per day	a) 14 m (at least 7.5m from loading platform) b) 16 m (at least 8.5m from loading platform)
Minimum stack height (Other than Vertical Shaft Brick Kilns) a) Kiln capacity less than 30,000 bricks per day b) Kiln capacity equal or more than 30,000 bricks per day	a) 24 m b) 27 m

The Emission Standards further states that:

1. All new brick kilns shall be allowed only with zig-zag technology or vertical shaft or use of Piped Natural Gas as fuel in brick making and shall comply to these standards as stipulated in this notification.

2. The existing brick kilns which are not following zig-zag technology or vertical shaft or use Piped Natural Gas as fuel in brick making shall be converted to zig-zag technology or vertical shaft or use Piped Natural Gas as fuel in brick making within a period of (a) one year in case of kilns located within ten kilometre radius of non-attainment cities as defined by Central Pollution Control Board (b) two years for other areas. Further, in cases where Central Pollution Control Board/State Pollution Control Boards/Pollution Control Committees has separately laid down timelines for conversion, such orders shall prevail.

Impact: Though instances of pollution control board measuring the particulate matter emissions from brick kilns are rare, the emissions standards or the particulate matter concentrations in stack have been used as a basis to enforce changeover to less polluting kiln technologies. In late 1990s, the emission standards were successful in enforcing a transition from the Moving Chimney BTK to Fixed Chimney BTK. Since 2015, several state pollution control boards have mandated a changeover from Fixed chimney BTK to zigzag kiln technology. Each of these changeovers have resulted in 15-25% of savings in fuel as well.

5.2.2 Siting criteria for setting up brick production

An industry or an industrial area over a period of time could cause significant damage to the surrounding environment and ecological features due to the cumulative emissions or industrial waste generated in the zone. Industries are, therefore, required to be sited, striking a balance between economic and environmental considerations. Several states have come up with siting criteria.

Impact: Siting criteria have been used to give permission for siting of new kilns, generally they specify distance of the kiln from nearby habitation, kiln, plantations, water bodies etc. However, as over a period of time there are changes in the surrounding areas and these distances are not maintained, they also become a reason for litigation and conflict.

5.2.3 Fly Ash Regulations

Most of the electricity production in India is based on coal. During the year 2020-21, around 232 Million tonnes of fly ash[10] was generated. Safe disposal of this large amount of fly ash is a major environmental challenge. The Government has been promoting its use for various applications, including those for the manufacturing of cement and building materials. The first regulation for fly ash utilisation was notified in 1999, which have subsequently been revised in 2003, 2009, 2016 and 2021. As per the revised 2021 notification[11]:

- All building construction projects (Central, State and Local authorities, Govt. undertakings, other Govt. agencies and all private agencies) located within a radius of three hundred kilometres from a coal or lignite based thermal power plant shall use ash bricks, tiles, sintered ash aggregate or other ash based products, provided these are made available at prices not higher than the price of alternative products

Impact: Since 1999, the use of fly ash in brick making has increased. In the year 2020-21, around 30 Million tonnes of fly ash[12] was used for brick making. If we take 1.5 kg of fly ash utilization per brick this would translate into production of around 20 billion bricks per year, which is less than 10 % of the total annual brick production of the country. Analysis shows that utilization of all remaining annual fly ash generation if utilized for brick making, will be able to meet only a part of the total brick requirements of the country. During the cluster studies, it was found that fly ash was being mixed with clay in significant quantities at Nagpur and Indore clusters.

5.2.4 National Programme on Energy Efficiency and Technology Up gradation of MSMEs by BEE

In 2007, to recognize the importance of MSMEs in promoting energy efficiency, 'National Programme on Energy Efficiency and Technology Upgradation of MSMEs' was started by the Bureau of Energy Efficiency. Lack of access to finance for MSMEs is one of the stumbling blocks for implementing energy conservation measures and energy efficient technologies. With this cognizance, Bureau, under XII plan has implemented 21 pilot energy efficient technologies with financial assistance in 4 SME sectors including brick industries. To aid the replication of these technologies across the sectors, cluster level entities (i.e. local service providers, industrial associations etc.) were also strengthened. To effectively manage the experience so generated and spreading the same nationwide, knowledge management products like case studies, audio visuals were also developed.

Due to continuous efforts of Bureau, SDAs and its stakeholders, MSMEs in India have started to shift from a traditional strictly cost and quality approach to energy efficiency,

[10] https://cea.nic.in/wp-content/uploads/tcd/2021/09/Report_Ash_Yearly_2020_21.pdf
[11] Gazette of India, MoEFCC, dated 31st December 2021, PART II—Section 3—Sub-section (ii)
[12] https://cea.nic.in/wp-content/uploads/tcd/2021/09/Report_Ash_Yearly_2020_21.pdf

zero waste and reduced carbon emissions. Further, for bringing more competitiveness and making this sector more energy efficient, it is quintessential to understand the consumption of energy and its flow within the facility along with the classification of energy usage and its relationship to processes and production outputs in present scenario. Thus, Bureau is conducting energy mapping of 10 sectors including brick sector which will cover energy usage pattern, detailed analysis and technology gap analysis. Bureau has also developed more than fifty (50) multimedia tutorials on energy efficient technologies for more than twenty (20) sectors for knowledge transfer and thereby easy adoption of these technologies. Bureau has also signed a MoU for joint implementation of the programme titled "Promoting Energy Security of MSME sector" with the Office of DC, MSME.

Impact: BEE through the study of Varanasi cluster identified zigzag kiln technology as one of the energy efficient technologies. It also provided financial assistance to some of the kilns in the cluster to make a changeover from FCBTK to zigzag technology. Since then, under the influence of the air pollution regulations, the zigzag kiln technology has become mainstreamed in the country. Although the energy saving potential is immense in this sector which BEE intends to unlock, there are a number of barriers in achieving these aims. A discussion in these barriers is provided in Chapter 8.

5.3 Policies influencing the market for bricks

5.3.1 BEE's E3 certification program

Given the large potential for energy efficiency in clay brick manufacturing, the BEE is proposing a market transformation initiative for this sector, under which the end-customer market shift takes place towards bricks sourced from manufacturing units adopting lower specific energy for manufacturing and product innovation (viz. perforated and hollow bricks).

The market transformation strategy, on one hand, focuses on lowering the specific manufacturing energy through improvements in production technologies and promoting the production of energy efficient bricks (supply side measures), and on the other hand, creating market demand for such manufactured bricks (demand-side measures). The proposed strategy is dual-pronged. Firstly, it is proposed to develop a voluntary BEE accredited symbol/mark to convey the adoption of energy efficient manufacturing and develop the award process for "Energy Efficient Enterprise (E3)" symbol/mark to such manufacturers. Secondly, it is proposed to develop market demand (by E3 mark) in the eyes of the customer to source bricks from manufacturing units who manufacture energy efficiently.

The BEE accredited symbol shall be awarded to those brick manufacturers who meet the BEE proposed methodology to estimate the process SEC threshold. The Manufacturer SEC is calculated based on deemed specific manufacturing energy for different production processes (MJ/kg) and the product density (kg/m^3). A manufacturer will be awarded "E3" mark if the weighted average specific manufacturing energy of the manufacturing plant is below a certain threshold value. To begin with, it is proposed that the threshold value should be kept at 25% lower than the national baseline for specific manufacturing energy of clay bricks. This threshold shall be reviewed and revised every (say) two years.

The proposed supply side interventions are:

- Energy Efficient Enterprise (E3) Mark for manufacturers with energy efficient brick production
- Support package to manufacturers to facilitate a shift to E3 marked enterprises
    - ✓ Development of standard & affordable technology packages
    - ✓ Institutional capacity building and training
    - ✓ Catalyzing green finance (including for institutional customers as well)

The supply side interventions will be supplemented by simultaneous actions on the demand side such as:

- Increasing demand of Energy Efficient bricks by large institutional players such as government or private builders.
- Launching a targeted outreach and communication campaign for builders, architects, and other demand influencers.

The deemed energy-saving approach proposed for estimating energy efficiency savings to manufacturer and end-user of the E3 bricks would be useful to mobilise green finance towards sector modernization and builders/ developers sourcing bricks from E3 marked manufacturers.

Impact: The scheme was launched in March 2021 and applications have been received from the brick industries for its pilot implementation, though the actual award of certificates is yet to take place. The implementation of this proposed approach will require active involvement and concerted efforts of a wide range of stakeholders including various government ministries/departments.

5.3.2 National Building Code

The National Building Code of India (NBC), a comprehensive building Code, is a national instrument providing guidelines for regulating the building construction activities across the country. It serves as a Model Code for adoption by all agencies involved in building construction activities be they Public Works Departments, other government construction departments, local bodies or private construction agencies. The Code mainly contains administrative provisions, development control rules and general building requirements; fire and life safety requirements; stipulations regarding building materials, structural design and construction (including safety); building and plumbing services; approach to sustainability; and asset and facility management. The Code was first published in 1970 at the instance of the then Planning Commissions and was subsequently revised in 1983 and 2005. The Code has now been revised again as NBC 2016 and formally released on 15 March 2017. NBC takes into account aspects of reduce, reuse, recycle, use of local materials and waste management and promotes the use of resource efficient building materials.

Impact: NBC is a guiding document that influences the building construction activities. Inclusion of a chapter on sustainability in the NBC, 2016 has increased awareness about resource-efficient building materials.

5.3.3 Energy Conservation Building Code

Bureau of Energy Efficiency had launched Energy Conservation Building Code (ECBC) 2007 to establish minimum energy performance standards for buildings in India. Buildings consume significant proportion of our energy resources and the ECBC is an essential regulatory tool to curb their energy footprint. Building energy codes are updated regularly to catch up with the curve of technology maturation and to set higher benchmarks for building energy efficiency. In alignment with current market scenario and advanced technologies ECBC has been taken for update also. Energy efficient technologies and materials that were aspirational in the years preceding launch of ECBC are now commonly available in Indian markets. Accordingly, ECBC 2017 has been revised to incorporate advanced technologies.

Additional parameters included are related to renewable energy integration, ease of compliance, inclusion of passive building design strategies and, flexibility for the designers. One of the major updates to the code is inclusion of incremental, voluntary energy efficiency performance levels. ECBC 2017 is one of the first building energy codes to recognize beyond code performance. There are now three levels of energy performance standards in the code. In ascending order of efficiency, these are ECBC, ECBC Plus and Super ECBC. The adherence to the minimum requirements stipulated for ECBC level of efficiency would demonstrate compliance with the code. Other two efficiency levels are of voluntary nature. This feature was added to prepare the building industry for meeting energy efficiency standards in coming years and give sufficient time to the market to adapt.

Impact: The building energy codes like ECBC promotes climate responsive buildings and has increased the awareness regarding the insulation properties of the walling materials.

5.3.4 Eco-Niwas Samhita 2018 (Part-I)

Eco Niwas Samhita, Part – I Building Envelope (Energy Conservation Building Code for Residential Sector) is developed and launched on 14th December, 2018. It been developed to set minimum building envelope performance standards to limit heat gains (for cooling dominated climates) and to limit heat loss (for heating dominated climate) as well as for ensuring adequate natural ventilation and day lighting. The code is applicable to residential use building projects built on plot area ≥ 500 m^2. The code has been developed with special consideration for its adoption by the Urban Local Bodies (ULBs) into building byelaws.

Impact: The building energy codes like ENS promotes climate responsive buildings and has increased the awareness regarding the insulation properties of the walling materials.

5.4 Financial Policies

5.4.1 Credit Linked Capital Subsidy Scheme (CLCSS)

The objective of the Scheme is to facilitate technology up-gradation in MSMEs by providing an upfront capital subsidy of 15 per cent (on institutional finance of upto Rs 1 crore availed by them) for induction of well-established and improved technology in the specified 51 sub-sectors/products approved. In other words, the major objective is to upgrade their plant & machinery with state-of-the-art technology, with or without expansion and also for new MSEs which have set up their facilities with appropriate eligible and proven technology duly approved under scheme guidelines.

5.4.2 Partial Risk Sharing Facility (PRSF) for Energy Efficiency

World Bank as implementing agency of each of the Global Environment Facility ("GEF") and the Clean Technology Fund ("CTF"), has provided support for a project titled "Partial Risk Sharing Facility for Energy Efficiency" ("PRSF"/Programme"). The objective of the Programme is to support the Government of India's efforts to transform energy efficiency market in India by promoting increased level of investments in energy efficient projects, particularly through energy service performance contracting delivered through energy service companies ("ESCOs"). The Programme will support the loans granted by various PFIs and by SIDBI as lender (in such capacity, "SIDBI as Lender"), who are empaneled with the PEA Division to either ESCOs or the Host who are implementing energy saving projects, by providing risk coverage for repayment of such loans. The Project has a total outlay of USD 43 million consisting of the "Partial Risk Sharing Facility for Energy Efficiency" component of USD 37 million and technical assistance component of USD 6 million. The entire "Risk Sharing Facility" component of USD 37 million is managed by SIDBI, under which partial credit guarantees are provided to cover a share of default risk faced by Participating Financial Institutions (PFI) in extending loans to eligible EE projects implemented through ESCOs.

Impact: There is no data available on the number of beneficiaries belonging to the brick sector of these financial schemes. However, discussion with the brick industry suggests that majority of the brick makers are not fully aware about these schemes and very few have taken benefits of these schemes.

Chapter 6. Past Initiatives & Institutions

6.1 Initiatives 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 **Error! eference source not found.** . The most significant government interventions related with air pollution, which resulted in up gradation in the firing technology from moving chimney bull trench kilns to fixed chimney bull trench kilns in 1990s and the ongoing transition of shifting from FCBTK to zigzag kiln technology. These two transitions combined together have resulted in around 40% reduction in SEC.

Table 23 Activities promoting Energy efficiency and environmental performance in brick kilns

Year	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 in certain states e.g. West Bengal
1990's	Central Pollution Control Board/ Ministry of Environment and Forest (MoEFCC)	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 and operational improvements in FCBTK.	• Successful in seeding the VSBK technology. • Building technical capacities to work in the brick sector.
2009-2015 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 - 2019 ongoing	Shakti Sustainable Energy Foundation	Technical: Assessment of brick kiln technologies. Policy: Policy advocacy and training on zigzag kiln technology. Technical support to Bihar for cleaner brick	• Identification of possibility of retrofitting FCBTKs into natural draughtzigzag firing • First active state level intervention (in the state of Bihar) to promote cleaner brick production • Large scale adoption of zigzag kiln technology in Bihar

		production.	• Significant increase in fly ash brick production in Bihar
2010 - ongoing	Bureau of Energy Efficiency Ministry of Power, Govt. of India	Technical: Energy mapping of Varanasi brick cluster; Promotion of zigzag kiln technology in Varanasi; Energy and Resources mapping for brick sector; E3 certification scheme for brick industry	• Mapping the brick industries across the country • Cluster wise energy audit and capacity building • Dissemination of information through workshops/webinars • Technology demonstration at key clusters and dissemination for scaling up to other clusters • Influencing to change the policies to support the brick industries to become energy efficient

6.2 Institutions

Issues related to brick making has several dimensions such as energy, environment, social and economic. 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. A list of some of the institutions involved with the energy and resource efficiency improvements in the brick sector along with their roles is given in Table 15

Table 15 Some institutions involved in energy/resource efficiency improvements in the brick sector

Organisation	Role
Government Ministries & Organisations	
Bureau of Energy Efficiency (BEE)	• Formulation and implementation of policies related with energy efficiency • Energy efficiency programme in brick clusters • Energy Efficient Enterprise (E3) scheme for brick industry
Ministry of Environment & Forest (MoEFCC)	• Formulating and implementation of policies and regulations relating to conservation of environment • Coordination of the national action plan for climate change and clean air programme. • Emission standards and fly-ash regulation
Central Pollution Control Board (CPCB)	• Development and revision of emissions standards and emission guidelines
State Pollution Control Board	• Implementation of emissions standards and environment guidelines
Building Materials and Technology Promotion Council (BMTPC)	• Under the Ministry of Housing and Urban Poverty Alleviation. Responsible for promotion of alternate/new/sustainable building materials and construction technologies
Industry Associations	
All India Brick & Tiles Manufacturers Federation (AIBTMF)	• Apex organization of the brick industry in India

State Level Brick Associations	• Important state associations of West Bengal, Bihar, Uttar Pradesh, Haryana. Punjab, Tamil Nadu, Rajasthan
District/cluster level brick Associations	• District and cluster associations of big brick clusters
Sector Expert organizations (Government, NGOs and private)	
Central Building Research Institute (CBRI)	• Technology development for energy efficient kiln technology, pollution control. brick production system, etc.
Punjab State Council for Science & Technology	• Technology dissemination of energy efficient kiln technologies, production of resource efficient bricks, capacity building and pollution control technologies
The Energy & Resources Institute (TERI)	• Energy and environment performance assessment • Technology dissemination and capacity building
Development Alternatives (DA)	• Technology dissemination of VSBK technology and capacity building
Greentech Knowledge Solutions Pvt Ltd (GKSPL)	• Energy and environment performance assessment • Technology dissemination and capacity building
Enzen Global Solutions Pvt Ltd	• Energy and environment performance assessment
Academic Institutions	
IIT, Bombay	• Environment impact of brick manufacturing
IISc, Bengaluru	• Alternate building materials
Foundations, Multilateral and bi-lateral Funding Agencies	
United Nation Development Program (UNDP)	• Implemented UNDP-GEF project on brick industry
Swiss Agency for Development & Cooperation (SDC)	• Supported projects on energy efficiency improvements in MSMEs including brick industry as well as on building energy efficiency
GIZ	• Supported projects on energy efficiency improvements including brick industry as well as on building energy efficiency
Shakti Sustainable Energy Foundation	• Supported projects on energy efficiency improvements, air pollution control and building energy efficiency
Climate and Clean Air Coalition (CCAC)	• Supporting projects on capacity building and skill training on zigzag kiln technology

Chapter 7. Policy Recommendations for Energy Conservation in Brick Industry

The study has resulted in the identification of the energy conservation measures. These measures are listed in Table 16 and their implementation can result in achieving 10-50% reduction in energy consumption in the sector.

Table 16 Energy Conservation Measures

S. No	Energy Conservation Measure	Benefits
Low-cost measure (<Rs 50 lakh investment)		
1	Improvement in operational practices in clamps, FCBTK and zigzag kilns	10-15% energy savings; improvement in percentage of class I bricks; reduction in air pollution
2	Conversion of FCBTK into zigzag kiln	15-20% energy savings; improvement in percentage of class I bricks; Reduction in air pollution
Medium to high-cost measure (Rs 50 lakh – 50 crore investment)		
3	Adoption of Hybrid Hoffmann Kiln	15-20% energy savings compared to FCBTK; increased production due to year-round operation; improvement in percentage of class I bricks; Reduction in air pollution
4	Adoption of tunnel kiln technology	Possibility of mass manufacturing of hollow and perforated bricks; if used for production of hollow blocks, then 30-40% energy savings compared to FCBTK; increased production due to year-round operation; improvement in percentage of class I bricks; Reduction in air pollution
5	Production of resource efficient bricks (hollow and perforated bricks)	Up to 50% reduction in clay and fuel consumption compared to solid bricks; lighter bricks with better insulation properties which helps in lowering energy for air-conditioning of buildings
6	Shift from solid to gaseous fuels	Reduction in air pollution; improvement in percentage of Class I bricks; gas based zigzag/ FCBTK technology yet to be demonstrated.

7.1 Barrier Analysis

During the interactions with the brick industry associations, several barriers which are hindering the adoption of resource efficiency measures to transform the sector were identified. The main barriers which need to be overcome for are described below:

Policy & Regulatory Barriers: One of the key barriers in the adoption of new energy and resource-efficient technologies and attracting new investment in the clay brick sector are the policy risks associated with lack of clarity and uncertainty regarding environment policies and regulations (refer section 6.2 on details of environment regulations). For example, while around 2500 brick kilns located in the NCR region have adopted zigzag technology as per CPCB instructions to reduce air pollution, by investing Rs 20-50 lakh/kiln, their working season has been restricted due to an NGT order, thus severely impacting the viability of these enterprises. This is having a negative impact on adoption of zigzag kiln technology in the neighbouring states. The latest amendment in the fly ash regulation puts uncertainty over the use of clay bricks for building construction in 300 km radius of coal/lignite based thermal power plants, which practically covers the entire country. This is even though the various studies have shown that even if all the remaining available fly ash is utilised for brick making, it will only meet a fraction of the demand for bricks. Large investments in technology upgradation would not materialise till the enterprises get assurance on their future operations. There is a need to have a holistic review of environment policies impacting the brick sector and bring synergies to promote resource efficient brick production in the country.

Technology Barriers: There are a variety of technical barriers impacting the transformation of Indian brick industry. For example, the use of extruders to produce resource efficient bricks require good quality lab testing facilities to test the clay and suggest the technical feasibility, similarly test lab facilities are required before taking a decision on adopting an advanced dryer or kiln technology. Such lab facilities are generally not available in India. Another example is regarding the access to technologies such as Hybrid Hoffmann Kiln, Tunnel Kiln, Tunnel and Chamber dryers, extruders, etc. Most of the suppliers of these technologies are from Europe or China, which makes both the cost and access to these technologies difficult. There is a large variation in the clay, climatic and market conditions across the country and as these technologies have yet not been tested under different conditions, the perceived technology failure risk is very high among the brick kiln owners.

Capacity & Knowledge Barriers: The exiting brick enterprises mostly belong to small-scale unorganised sector. Most of the brick kiln owners and supervisors come from rural background and with limited formal education. Their exposure and knowledge about energy-efficient technologies is low. There is no existing system for skill and vocational training for brick industry workers. Thus, the human resource capacity of the existing brick industry to absorb advanced technology is very limited. A programme to build the managerial and technical capacities including skill development programme for workers is essential for bringing a transformation in the brick industry.

Financial Barriers: The current brick industry enterprises mostly belong to small-scale unorganised sector. A discussion with brick kiln owners shows that the adoption of zigzag kiln by more than 15,000 enterprises in the country. The conversion involved an investment of Rs 10-50 lakh per kiln and this money was mostly raised through personal finance. The penetration of institutional finance (e.g. bank credit) to brick industry is very low. Also, as a large fraction of the brick enterprises belong to the unorganised sector, they do not have necessary financial documents and are not able to offer adequate collateral security (most of the kilns are located on leased lands and do not have much of fixed machinery) to avail credit from banks. It is shown that most of the measures required for bringing a transformation in the brick sector require investments ranging from Rs 2 to 50 crore. This level of investment requires access to finance from formal financial institutions. A better understanding of the financial needs of the brick industry and designing appropriate financial products is needed to improve access to finance to the sector.

Market Barrier: Building construction industry is a very conservative sector, and the process of adoption of new building materials and construction technologies is long and slow. Green building rating systems as well as energy conservation building codes are trying to push resource efficiency in the building construction sector. However, the rate of adoption of resource efficient bricks like perforated and hollow bricks and blocks, is still low and restricted to a few regions. More focussed and multi-dimensional approach is required to overcome the market barrier.

The policy recommendations given later in the chapter touch upon some of the strategies to overcome these barriers.

7.2 International Experience of Brick Sector Transformation

7.2.1 Europe[13]

The European brick and tile industry consists of around 1300 kilns owned by 700 companies, from SMEs to large international groups, which employ around 50,000 people across Europe and generate a production value of around €5.5 billion (Around INR 44,000 crore).

Over the last decades, the sector has invested heavily in product and process innovations that have revolutionised the manufacturing process and delivered modern building solutions. This technological progress has profoundly modified the functioning of brick and roof tile plants. Today kilns are fully automated and heat recovery systems optimise the overall energy efficiency of the plant. Furthermore, modern process technology ensures that the environmental impact is minimal.

There is a long history of technology modernization and transformation of European brick industry:

- Bricks were made by hand until about 1885, before the brickmaking machinery was introduced. With the introduction of the machinery the number of clays that could be made into brick was greatly increased which influenced the production capacity.[14]
- Another major transformation took place after Second World War, when due to high demand and introduction of new labour laws, the focus was on mechanising the industry, during this time tunnel kiln technology was widely adopted, and the consolidation of the industry started taking place.
- Since 1960s, a shift from coal and liquid fuels to gaseous fuels started taking place and by 1990, natural gas became the dominant fuel, accounting for almost 80% of the total energy used in the European brick industry. In

[13] http://www.tiles-bricks.eu/industry
[14] https://brickarchitecture.com/about-brick/why-brick/the-history-of-bricks-brickmaking

recent years along with natural gas, use of renewable biomass as fuel has also increased (Figure 15)

- Introduction of building energy conservation codes and emphasis on energy efficiency in buildings which got introduced in 1970's and 1980's resulted in introduction of new hollow clay blocks (Figure 16) which also had profound impact on the manufacturing process.

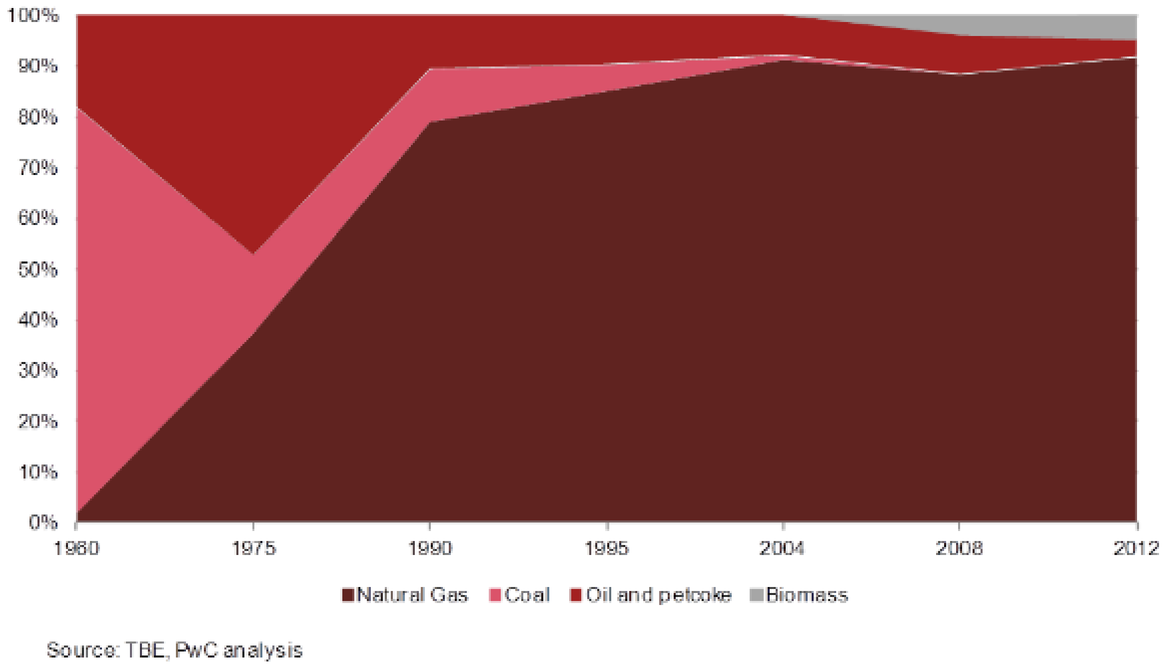


Figure 15 Fuel mix used by the tiles and brick industry in Europe, 1960 -2012

Figure 16 Examples of Hollow Clay Blocks made in Europe[15]

[15] http://www.tiles-bricks.eu/industry

7.2.2 China

In China, the work of introducing new technology in the brick industry started in 1960's. Xi'an Research and Design Institute of Wall and Roof Materials was set up in 1965. Extrusion and tunnel kiln technologies were introduced during 1970's and public sector enterprises for producing bricks were set up.

During 1980's Chinese brick industry expanded rapidly. In 1994, brick production in China stood at close to 800 billion bricks/year. The bricks were produced in more than 84,000 small brickworks in rural areas throughout the country and about 1,200 large and medium-sized ones in the vicinity of cities and towns[16]. Already most of the bricks were being produced through extrusion process. In terms of brick kiln technology, the Hoffmann Kiln was the most popular kiln, while a few of the large enterprises were also using Tunnel kiln technology. In the rural areas, intermittent "horse-foot" kiln and Vertical Shaft Brick Kiln (VSBK) were being used. The typical production capacity of the brick manufacturing units ranged from 5 to 65 lakhs bricks/year. Since then, the brick industry has undergone a transformation.

In 2018, the total production of bricks in China was estimated to be 980 billion bricks/ year[17]. This consisted of:

- Fired Clay brick - 830 billion bricks, produced in around 3800 brick manufacturing units
- AAC blocks – 130 billion blocks, produced in around 3000 AAC block plants
- Concrete blocks – 20 billion blocks produced in around 350 manufacturing units.

The main resource efficiency strategies being promoted in China during this time has been:

- Use of internal fuel in bricks, particularly the use of coal gangue for brick making. Coal-gangue is the rock-type waste left over from coal mining and contains a variety of rock-type materials – including coal particles.
- Utilization of waste heat from tunnel kilns to use in tunnel dryers for drying of bricks. In case of coal-gangue based tunnel kiln, waste heat recovery system to produce steam and generate electricity (Figure 17)
- Use of high efficiency motors and VFD drives to save electrical energy
- Using both process side measures and air pollution control device to reduce air pollution pf particulate matter, SO2, Nos, CO, HF, HCl, etc. As per the National Emission Standards for brick kilns (2016) the particulate matter in the chimney should not exceed 30 mg/Nm^3.
- Preferred use of tunnel kiln and dryer system for firing of bricks (Figure 18, Figure 19)

[16] Z Zhang: Energy Efficiency of Brick Making in China. https://www.aceee.org/files/proceedings/1995/data/papers/SS95_Panel2_Paper11.pdf

[17] Yu Xiaolin, The Fired Brick Industry in China, Policy & Advocacy Networking Meeting, June 20-21, 2019, Bangkok, Organised by CCAC & ICIMOD

- Promoting the production of perforated and hollow bricks

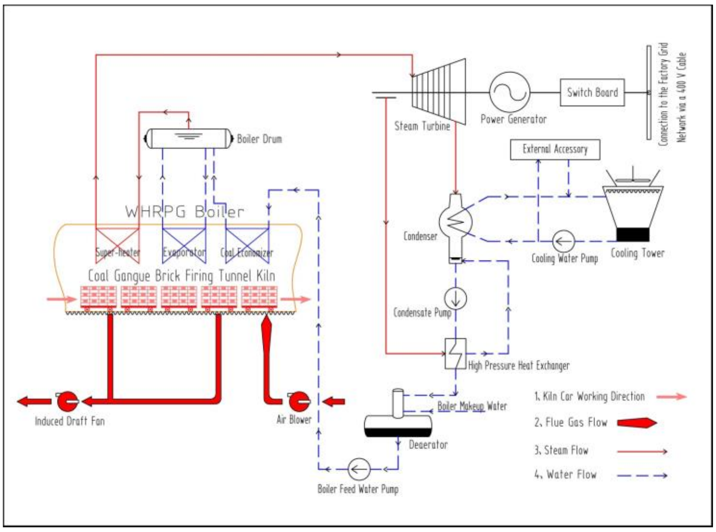


Figure 17 Schematic Diagram of a Waste Heat Recovery Power Generation Schemes for Tunnel Kilns[18]

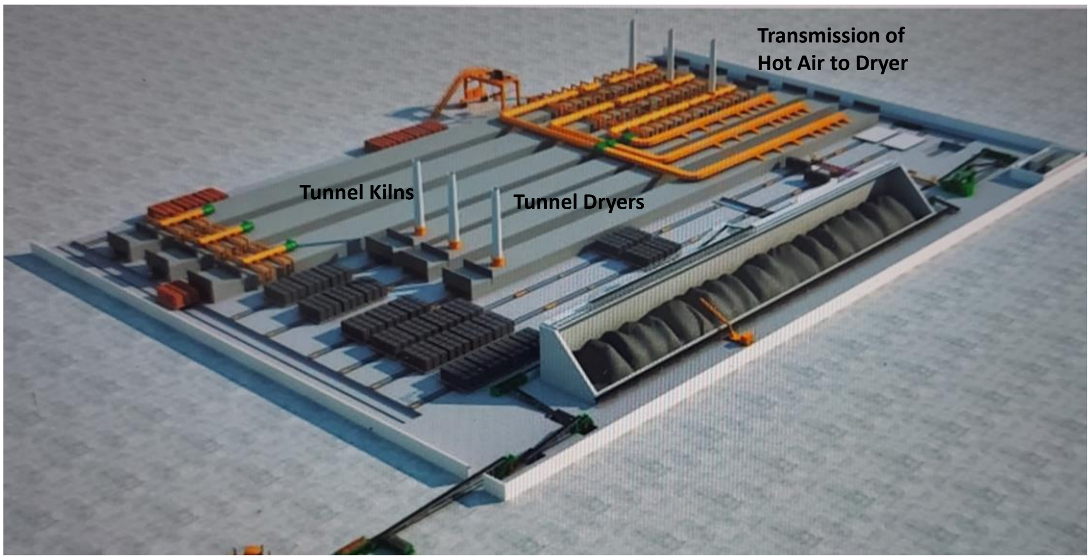


Figure 18 Typical Lay out of a Tunnel Kiln Plant (China)

[18] J New (2010) Promotion of small-scale and medium temperature waste heat recovery power generation – A case study of Chinese coal-gangue brick making sector, UNFCC Workshop, Tianjin, 09 October 2010.

Figure 19 A Tunnel Kiln and Dryer (China)

Over 30 years (1990-2020), some of the key trends which can be identified in China are:

- Despite the introduction of non-fired products, clay brick remains the preferred walling material with 85% market share. In absolute terms also, the clay brick production remains almost at the same level ~ 800 billion bricks/year.
- Consolidation of brick manufacturing: The average production capacity has increased to 200 lakh bricks/ year or more and the number of brick manufacturing industries have come down to 3800, compared to around 85,000 in 1994. It seems that the number of small rural brick enterprises has reduced significantly.
- Shift to modern firing technologies like Tunnel and Rotary Tunnel kiln and year round production of bricks instead of seasonal production.
- Instead of depending on clay from agriculture fields as the main raw material, new sources of clay have been identified (e.g. coal-gangue) and instead of solid brick now the product mix has larger share of perforated and hollow bricks.

7.2.3 Vietnam

Vietnam is another major clay brick producing country in Asia. Similar to China, Vietnam has a strong government supported institutional set-up in the form of the Ministry of Construction, Vietnam Institute of Building Materials, public sector manufacturing units involved in the production of bricks and almost 50 years history of government supported interventions to mechanise the brick industry.

In 2014, Government announced a master plan for development of construction materials in the country[19]. The main aim of the master plan was to improve environment sustainability of the brick sector. Air pollution, CO_2 emissions and use of clay from agricultural fields were identified as the main environmental concerns. Some of the major provisions of the master plan were:

- Ban on traditional kiln technologies: Due to air pollution concerns, government announced a ban on use of traditional intermittent kilns by 2016 and coal based VSBK and Hoffman kilns by 2018. After 2018, only Hoffmann kilns using biomass fuels, Tunnel kiln and Rotary Tunnel kilns were to be allowed.
- Increase market share of non-fired bricks to at least 30% by 2020. To increase the production of non-fired bricks several incentives were announced, which included:
    - Reduction in corporate income tax
    - Exemption on import duties for importing machinery
    - Exemption or reduction in land use tax and land rent.
    - Training support
    - Credit support
    - Support for technology transfer as well as research and development
    - Making use of non-fired bricks mandatory in government construction depending on the categorisation of cities as well as making their use mandatory (80% of the total brick use) in private construction having height of more than 9 storeys.

Due to the implementation of the master plan, by 2018 the Vietnam had 800 tunnel kilns, 10 rotary tunnel kilns and 350 Hoffmann kiln using rice husk and straw.

Figure 20 Rotary Tunnel Kiln (Vietnam)

[19] Nguyen Quang Hiep, Cleaner Brick Production in Vietnam, Policy & Advocacy Networking Meeting, June 20-21, 2019, Bangkok, Organised by CCAC & ICIMOD

Figure 21 Tunnel Kiln (Vietnam)

In 2019[20], the average Specific Energy Consumption in fired clay brick industry was estimated to be:

- Thermal Energy: 1.63 MJ/kg
- Electrical Energy: 0.036 MJ/kg

As per the Vietnam Institute of Building Materials, Ministry of Construction, the target is to reduce the Specific Energy Consumption to:

- Thermal Energy: 1.50 MJ/kg
- Electrical Energy: 0.022MJ/kg

7.2.4 Bangladesh[21]

Clay fired bricks are the main walling material in Bangladesh. In 2010, the Government of Bangladesh issued a circular that banned most polluting Fixed Chimney Kilns (FCKs) by 2012, to be replaced by more energy efficient and less polluting kilns, such as the Zig-Zag Kiln, Vertical Shaft Brick Kiln (VSBK), Hybrid-Hoffman Kiln (HHK) and Tunnel Kiln. The notification became an act in 2013 called the Brick Manufacturing and Kiln Establishment (Control) Act 2013. Bangladesh's brick sector consists of 7,859 operating kilns as of 30 June, 2018. The annual production is estimated at 33 billion bricks annually. The kiln technology wise distribution is presented in Table 17.

Table 17 Brick Kiln Distribution in Bangladesh (2018)

Type of Kiln	Number of kilns	Brick Production (billion bricks/year)
FCBTK	2235	8.9
Zigzag	5524	22.1
Hybrid Hoffman (Gas)	06	0.09
Hybrid Hoffmann (Coal)	36	0.32
Tunnel Kiln	81	1.7

[20] Vietnam Institute of Building Materials. Brick Production and Calculation of CO2 emissions. Policy & Advocacy Networking Meeting, June 20-21, 2019, Bangkok, Organised by CCAC & ICIMOD

[21] Bangladesh Brick Sector Roadmap 2019-2030. Frankfurt School – UNEP Collaborating Centre for Climate & Sustainable Energy Finance Frankfurt School of Finance & Management GmbH. Study funded by the The Climate and Clean Air Coalition (CCAC).

In Bangladesh, brick sector has been identified as one of the main energy consuming industrial sector and one of the key contributor to air pollution. During last 15 years, several internationally funded projects to improve the environment performance of brick kilns have been undertaken (Table 18). During these programmes, HHK and tunnel kiln technology from China has been introduced in the country.

Table 18 Internationally funded brick sector projects in Bangladesh

Programme	Funding Agency & Amount	Result
Clean Air and Sustainable Environment Project (2009-2014)	The World Bank USD 62 million USD	Demonstration projects on cleaner technologies in brick sector.
Improving Kiln Efficiency In Brick Making Industry (2010-2016)	UNDP-GEF USD 7.89 million USD	The project aimed to implement 15 demonstration energy efficient HHKs. The project could demonstrate six HHK.
Financing Brick Kiln Efficiency Improvement Project (2012-2019)	ADB USD 50 million (credit) 0.75 million USD (technical assistance)	The project has financed 19 energy efficient kilns (7 HHK and 12 tunnel kilns) along with environmental and social due diligence and technical feasibility studies including design of the kilns.

As can be seen that despite more than a decade of effort, the adoption of capital intensive HHK and tunnel kiln technology is lower than expected. The main barriers that have been identified are:

- low levels of awareness of available modern technologies,
- limitations regarding technological and operational capacity,
- high cost of financing
- lack of financial assistance and attractive lending terms from local financial institutions.

In 2019, a roadmap document for brick industry has been prepared through support from the CCAC. The main recommendations of the roadmap are:

- Shut down all Fixed Chimney Kilns by the end of 2020, and 80% of Zig-Zag kilns by 2025
- Promote non-fired bricks so that by 2030, they contribute to almost 50% of the brick demand
- Provide a new line of credit for entrepreneurs who intend to establish new Tunnel kilns
- Build investment projects for R&D, raw material mapping and market demand generation for non-fired bricks
- Begin training programs to build technical expertise among brick sector workers (from laborers to senior design technicians) and lenders

7.3 National Programme for Brick Sector

Based on the cluster studies, review of the international experience, interactions with the stakeholders and barrier analysis, two sets of recommendations are being presented

a) Policy recommendations for BEE in section 7.4, which essentially focuses on implementation of incremental improvements or low-cost improvement measures to improve resource efficiency in brick sector

b) Outline of a programme for the transformation of the sector, which is a pre-requite for the implementation of capital-intensive measures e.g. shift to HHK or Tunnel kiln technology or shift to natural gas, etc. This outline is presented in Table 19.

Table 19 Outline of a Programme for the Transformation of Brick Industry

Component & Specific Actions	Government stakeholders involved
1. Strengthening the policy environment	
a) Update the emission standards for brick kilns e.g. • review the particulate matter concentration limit • check if gaseous pollutants need to be included • bring brick clamps under the purview • include tunnel and HHK • Check the provisions from the point of view of implementation	MoEFCC, CPCB
b) Technology upgradation policy/programme for brick industry	MoMSME
c) Updation and new product and technology standards	BIS, BMTPC
d) E3 certification scheme	BEE/ MoP
e) Inclusion of the provisions of the Eco Niwas Samhita and ECBC in the model building bye-laws and the revision of state and ULB building bye-laws/regulations	MoHUA, State Governments, ULBs
2. Strengthen the technology eco-system	
a) Develop indigenous industrial capacities to manufacture and supply extruders, clay preparation machinery, tunnel kiln, hybrid Hoffmann kiln, chamber dryers, etc. This could be done through technology transfer and promoting joint industrial production	MoMSE, Ministry of Commerce & Industry
b) Develop regional laboratory facilities for brick industry modernisation	MoMSE, DST
c)Research programme focussed on development of indigenous technology for heavy clay industry	DST, CBRI
d) Pilot demonstration programmes on cleaner technologies	DST, CPCB, BEE
e) Resource mapping of clay and waste materials available in India	Department of Space, Department of Mining, State Governments
3. Strengthen human capacities	
a) Skill development programme for brick kiln workers	Ministry of Skill Development & Entrepreneurship, State Skill Missions
b) Degree/Diploma programmes in Heavy Clay Technology	MoHRD, State Governments
c) Increasing awareness and technical capacities of the brick kiln owners and managers	BEE, CPCB, State Governments

4. Facilitate access to finance and incentives	
a) Establish credit channels or a dedicated credit programme to fund the establishment of new, energy efficient brick kilns, thus increasing their market share	Ministry of Finance, MoMSE, BEE
b) Provide seed funding to traditional brick kiln owners for livelihood alternatives	MoMSE
c) Create financial incentives (e.g., preferential tax and/or interest rate options) for clean production and also custom duty rebate for import of machinery	Ministry of Finance, MoMSME

7.4 Policy Recommendations for BEE

The key policy recommendations for the next 5 year period (2022-2026) addressed primarily to BEE are as follows:

1. Formation of state level cells to drive low-cost energy efficiency measures (low hanging fruits) in brick sector: India has around 200 districts which can be classified as major brick manufacturing ldistricts. These districts are estimated to produce around 75% of India's total brick production.

Table 20 States and number of major brick producing districts

S.No	State	Approximate number of Major brick producing districts
1	Uttar Pradesh	75
2	Bihar	35
3	West Bengal	20
4	Punjab	20
5	Haryana	20
6	Assam	5-10
7	Gujarat	5-10
8	Maharashtra	5-10
9	Rajasthan	5-10
10	Tamil Nadu	5-10
11	Karnataka	5-10

It is recommended that the BEE should support a "brick industry cell" at the SDA of each of these states. If the state has a "industrial efficiency cell", that can also be given this task. The main objective of the "brick industry cell" at the state would be to coordinate with the state and district level brick manufacturers associations and drive the adoption of low-cost energy efficiency improvement measures by running awareness generation programmes and providing technical training at the district/cluster level. This action would help in partially addressing the "capacity and knowledge barrier". BEE may like to partner with CPCB and SPCBs as they will also be involved in the implementation of the new emission standards, which directs all existing FCBTKs to be converted into zigzag or VSBK in two years' time period.

2. Implementation of Energy Efficient Enterprise (E3) certification scheme for brick industry by BEE:
   BEE has launched an Energy Efficient Enterprise (E3) certification scheme[22] for brick industry in March 2021. The BEE has asked for application from the brick industry for piloting the scheme, but the certification of the qualifying enterprises is yet to be done. It is recommended that BEE should take immediate steps to implement the scheme. The implementation of the scheme will try to address both the "market" and the "capacity and knowledge" barriers.

The overall objective of the "Energy Efficient Enterprise" (E3) certification is to accelerate the shift in the Brick manufacturing sector towards energy efficiency through a market-based approach. E3 certificate will be awarded to Brick Manufacturing Enterprises that meet the minimum Specific Energy Consumption (SEC_{Vol}) performance criteria specified in this Scheme. The minimum Specific Energy Consumption (SEC_{Vol}) performance criteria can be met by Brick Manufacturing Enterprises by adopting a combination of measures aimed at a) improving energy efficiency in manufacturing, and b) producing Bricks having lower (bulk) densities e.g. porous, perforated and hollow bricks. Low density Bricks provide better thermal insulation and hence assist in reducing operational energy in buildings. E3 certificate is therefore a means for the enterprises to differentiate themselves in the eyes of end consumer through superior energy efficiency in Brick production and manufacturing Bricks that saves operational energy of a building during its lifetime.

3. Inclusion of skilling of workers on resource efficient brick production as a part of the National Skill Development Mission
   Brick industry employs more than 10 million workers. There is no formal skill development or vocational training programmes for brick workers. To improve the energy performance of the brick kilns, skilling of key worker groups is extremely important. It is proposed that the existing workers who are working on brick kilns can be trained under the "Recognition of Prior Learning" segment of the ongoing national skill initiative. Change over from FCBTK to zigzag kiln and proper operation of zigzag kiln can bring 20-25% savings in energy and would require training of two types of workers a) brick kiln loaders b) brick kiln firemen. Climate and Clean Air Coalition is planning to initiate work with Skill Council for Green Jobs (SCGJ) to develop the required "Qualification Packs". BEE may join the initiative and work towards further implementation of the skill programme in

[22] https://beeindia.gov.in/content/e3-scheme-brick-sector

coordination with major brick manufacturing states. This will help in addressing the "capacity and knowledge" barrier.

4. Demonstration Programme on Advanced Brick Firing Technology & Community facilities: The BEE may start a programme to provide financial and technical support to brick enterprises which adopt new brick kiln technologies (e.g. HHK and tunnel kiln), use cleaner fuels or adopt measures to significantly reduce the energy use in brick making. Also, BEE or MSME can start a scheme or include brick industry in the existing schemes to develop community facilities in clusters. This may include setting up of cluster level testing laboratories and energy auditing facilities, cluster level coal procurement and storage systems, procurement of energy-efficient fans and VFDs for induced draught zigzag kilns, etc. This will help in addressing the "technical" barrier.

5. Formation of Task Force at the National level to bring Resource Efficiency Transformation in Brick Sector: Energy Efficiency improvements in brick industry in India so far have been driven primarily through the implementation of emission standards and technology promotion programmes of BEE and other development sector organisations. To bring synergy between different actions by different central ministries aimed at improving energy and resource efficiency, reducing air pollution, technology upgradation in MSMEs, it is recommended that a task force having representation of Bureau of Energy Efficiency (BEE), MoEFCC and M/o MSME be formed to drive resource efficiency improvements in the brick sector. BEE may take a lead in initiating the formation of the task force. The All-India Brick & Tiles Manufacturers Federation (AIBTMF) should be invited as a member of the task force. The three Ministries may decide on other members who should be part of the task force.

   The immediate objectives of the task force would be:

   - To bring synergy in government policies applicable to brick industry concerning air pollution, fly ash utilisation, energy efficiency in MSMEs and MSME development.
   - To undertake two studies to guide future policy development for the brick sector:
     - Study on "Technology Roadmap for a resource efficient brick industry in India". The study can cover issues such as
       - Future demand, market and product-mix,
       - Raw material resource availability,
       - Environment and energy performance benchmarks,
       - Manufacturing technology and technology packages,
       - Availability and techno-economics of using clean energy sources like natural gas, and renewable energy (modern biomass and solar energy) for brick manufacturing

- Study on “Transformation Roadmap for brick industry in India”. This study would take the inputs from the Technology Roadmap and would cover aspects such as:
    - Assessing the capacity building requirements of the brick sector MSMEs to undergo the transformation
    - Policy changes required to facilitate the transformation process
    - Assessing the status and developmental needs of the brick machinery manufacturing industry in India to support the transformation
    - Quantifying the financing requirement and the instruments required to finance the transformation.

This will help in addressing the “policy and regulatory” and “financing” barriers.

Annexures

Annexure 1: Production process and technology adopted

1. Type of production process in Brick sector

In the process of manufacturing bricks, the following four distinct operations are involved.

1. Preparation of clay
2. Moulding
3. Drying
4. Firing in Kiln or Burning

Fig Clay brick manufacturing process

Each of these operations of manufacturing bricks is discussed as below:

Preparation of Clay

The clay for bricks is prepared in the following order:

a) Un-soiling
b) Digging
c) Cleaning
d) Weathering
e) Blending

f) Tempering

Un-soiling

The top layer of soil, about 200 mm in depth, is taken out and thrown away. The clay in top soil is full of impurities and hence it is to be rejected for the purpose of preparing bricks.

Digging

The clay is then dug out from the ground. It is spread on the levelled ground, just a little deeper than the general level of ground. The height of heaps of clay is about 600 mm to 1200 mm.

Cleaning

The clay, as obtained in the process of digging, should be cleaned of stones, pebbles, vegetable matter, etc. If these particles are in excess, the clay is to be washed and screened. Such a process naturally will prove to be troublesome and expensive. The lumps of clay should be converted into powder form in the earth crushing roller.

Weathering

The clay is then exposed to atmosphere for softening or mellowing. The period of exposure varies from few weeks to full season. For a large project, the clay is dug out just before the monsoon and it is allowed to weather throughout the monsoon.

Blending

The clay is made loose and any ingredient to be added to it is spread out at its top. The blending indicates intimate or harmonious mixing. It is carried out by taking small portion of clay every time and by turning it up and down in vertical direction. The blending makes clay fit for the next stage of tempering.

Fig - Blending of soil

Tempering

In the process of tempering, the clay is brought to a proper degree of hardness and it is made fit for the next operation of moulding. The water in required quantity is added to clay and the whole mass is kneaded or pressed under the feet of men or cattle. The tempering should be done exhaustively to obtain homogeneous mass of clay of uniform character. For manufacturing good bricks on a large scale, the tempering is usually done in a pug mill. A typical pug mill capable of tempering sufficient earth for a daily output of about 15000 to 20000 bricks. The process of grinding clay with water and making it plastic is known as the pugging.

A pug mill consists of a conical iron tub with cover at its top. It is fixed on a timber base which is made by fixing two wooden planks at right angles to each other. The bottom of tub is covered except for the hole to take out pugged earth. The diameter of pug mill at bottom is about 800 mm and that at top is about one metre. The provision is made in top cover to place clay inside the pug mill. A vertical shaft with horizontal arms is provided at the centre of iron tub. The small wedge-shaped knives of steel are fixed on horizontal arms.

The long arms are fixed at the top of vertical shaft to attach a pair of bullocks. The ramp is provided to collect the pugged clay. The height of pug mill is about 2 m. Its depth below ground is about 600 mm to 800 mm to lessen the rise of the barrow run and to throw out the tempered clay conveniently. In the beginning, the hole for pugged clay is closed and clay with water is placed in pug mill from the top. When the vertical shaft is rotated or turned by a pair of bullocks, the clay is thoroughly mixed up by the actions of horizontal arms and knives and a homogeneous mass is formed.

The rotation of vertical shaft can also be achieved by using steam, diesel or electric power. When clay has been sufficiently pugged, the hole at the bottom of tub is opened out and the pugged earth is taken out from ramp by barrow i.e., a small cart with two wheels for the next operation of moulding. The pug mill is then kept moving and feeding of clay from top and taking out of pugged clay from bottom are done simultaneously. If tempering is properly carried out, the good brick earth can then be rolled without breaking in small threads of 3 mm diameter.

In addition to the traditional vertical flow pugging machine described above, now several new types of pugging machines are available. In some cases, the machines can be moved around on a tractor trolley within the premises thus feeding pugged clay to moulders.

Fig-Pugging of soil using machine

Moulding

The clay which is prepared as above is then sent for the next operation of moulding. Following are the two ways of moulding:

A. Hand moulding
B. Machine moulding

Hand Moulding

In hand moulding, the bricks are moulded by hand i.e., manually. It is adopted where manpower is cheap and is readily available for the manufacturing process of bricks on a small scale. The moulds are rectangular boxes which are open at top and bottom. They may be of wood or steel. It should be prepared from well-seasoned wood. The longer sides are kept slightly projecting to serve as handles. The strips of brass or steel are sometimes fixed on the edges of wooden moulds to make them more durable.

Steel mould is prepared from the combination of steel plates and channels. It may even be prepared from steel angles and plates. The thickness of steel mould is generally 6 mm. They are used for manufacturing bricks on a large scale. The steel moulds are more durable than wooden moulds and they turn out bricks of uniform size. The bricks shrink during drying and burning.

Hence the moulds are to be made larger than the size of Steel mould fully burnt bricks. The moulds are therefore made longer by about 8 to 12 per cent in all directions. The exact percentage of increase in dimensions of mould is determined by actual experiment on clay to be used for preparing bricks. The bricks prepared by hand moulding are of two types namely Ground-moulded bricks and Table-moulded bricks.

A. Ground- moulded bricks:

The ground is first made level and fine sand is sprinkled over it. The mould is dipped in water and placed over the ground. The lump of tempered clay is taken and it is dashed in the mould. The clay is pressed or forced in the mould in such a way that it fills all the corners of mould.

The extra or surplus clay is removed either by wooden strike or metal strike or frame with wire. A strike is a piece of wood or metal with a sharp edge. It is to be dipped in water every time. The mould is then lifted up and raw brick is left on the ground. The mould is dipped in water and it is placed just near the previous brick to prepare another brick. The process is repeated till the ground is covered with raw bricks.

Fig Hand moulding process

A brick moulder can mould about 750 bricks per day with working period of 8 hours. When such bricks become sufficiently dry, they are carried and placed in the drying sheds. The bricks prepared by dipping mould in water every time are known as the slop-moulded bricks. The fine sand or ash may be sprinkled on the inside surface of mould instead of dipping mould in water. Such bricks are known as the sand-moulded bricks and they have sharp and straight edges. The lower faces of ground moulded bricks are rough and it is not possible to place frog on such bricks. A frog is a mark of depth about 10 mm to 20 mm which is placed on raw brick during moulding. It serves two purposes:

- It indicates the trade name of the manufacturer.
- In brickwork, the bricks are laid with frog uppermost. It thus affords a key for mortar when the next brick is placed over it.

The ground-moulded bricks of better quality and with frogs on their surface are made by using a pair of pallet boards and a wooden block. A pallet is a piece of thin wood. The block is bigger than mould and it has a projection of about 6 mm height on its surface. The dimensions of projection correspond to the internal dimensions of mould. The design of impression or frog is made on this block. This wooden block is also known as the moulding block or stock board.

The mould is placed to fit in the projection of wooden block and clay is then dashed inside the mould. A pallet is placed on the top and the whole thing is then turned upside down. The mould is taken out and another pallet is placed over the raw brick and it is conveyed to the drying sheds. The bricks are placed to stand on their longer sides in drying sheds and pallet boards are brought back for using them again. As the bricks are laid on edge, they occupy less space and they dry quicker and better.

B. Table- moulded bricks:

The process of moulding these bricks is just similar as above. But here the moulder stands near a table of size about 2 m x 1 m. The clay, mould, water pots, stock board, strikes and pallet boards are placed on this table. The bricks are moulded on the table and sent for the further process of drying. However the efficiency of moulder decreases gradually because of standing at the same place for long duration. The cost of brick moulding also increases when table moulding is adopted. Table moulding is practiced at some places in South India.

Machine Moulding

The moulding may also be achieved by machines It proves to be economical when bricks in huge quantity are to be manufactured at the same spot in a short time. It is also helpful for moulding hard and strong clay. These machines are broadly classified in three categories:

i. Soft-mud moulding machines
ii. Extruders machines
iii. Dry clay machines.

A. Soft- mud moulding machine:

Such machines mimics the hand moulding process. It consists of several metal moulds, which are filled by the machine and then demoulded. In most of the cases the bricks are demoulded on palettes and then are transported on palettes for drying. There are various types of soft-mud moulding machines available in the market ranging from rudimentary machines to highly mechanized machines.

Fig-Machine moulding process

B. Extruder machines:

Such machines contain a rectangular opening of size equal to length and width of a brick. The pugged clay is placed in the machine and as it comes out through the opening or the die, it is cut into strips by wires fixed in frames. The arrangement is made in such a way that strips of thickness equal to that of the brick are obtained. As the bricks are cut by wire, they are also known as the wire cut bricks. Through use of appropriately designed dies, it is possible to manufacture perforated of hollow bricks.

Fig-Extruder machines

C. Dry Press Machines:

In these machines, the lay is first converted into powder form. A small quantity of water is then added to form a stiff plastic paste. Such paste is placed in mould and pressed by machine to form hard and well-shaped bricks. These bricks are known as the pressed bricks and they do not practically require drying. They can be sent directly for the process of burning. The machine made bricks have regular shape, sharp edges and corners. They have smooth external surfaces. Solid machine-made bricks are heavier and stronger than ordinary hand-moulded bricks. They carry distinct frogs and exhibit uniform dense texture.

Drying

The damp bricks, if burnt, are likely to be cracked and distorted. Hence the moulded bricks are dried before they are taken for the next operation of burning. For drying, the bricks are laid longitudinally in stacks of width equal to two bricks. A stack consists of eight or ten tiers. The bricks are laid along and across the stack in alternate layers. All bricks are placed on edge. The bricks should be allowed to dry till they become at least leather hard. The important facts to be remembered in connection with the drying of bricks are as follows:

Natural Drying

The bricks are generally dried by natural process (without use of external energy) that is by drying them under open sun or air drying by keeping them under the shed.

Fig-Natural drying of bricks in open Sun

Artificial Drying

But when bricks are to be rapidly dried on a large scale, the artificial drying may be adopted. In such a case, the moulded bricks are allowed to pass through special dryers which are in the form of tunnels or hot channels or floors. Such dryers are heated with the help of special furnaces or by hot flue gases. The tunnel dryers are more economical than hot floor dryers and they may be either periodic or continuous.

Fig-Artificial drying in tunnel dryer

In the former case, the bricks are filled, dried and emptied in rotation. In the latter case, the loading of bricks is done at one end and they are taken out at the other end. The temperature is usually less than 120°C and the process of drying of bricks takes about 1 to 3 days depending upon the temperature maintained in the dryer, quality of clay product, etc.

Circulation of Air

The bricks in stacks should be arranged in such a way that sufficient air space is left between them for free circulation of air.

A. Drying Yard:
   For the drying purpose, special drying yards should be prepared. It should be slightly on a higher level and it is desirable to cover it with sand. Such an arrangement would prevent the accumulation of rain water.

Period for Drying

The time required by moulded bricks to dry depends on prevailing weather conditions. Usually it takes about 3 to 10 days for bricks to become dry.

Screens

It is to be seen that bricks are not directly exposed to the wind or sun for drying. Suitable screens, if necessary, may be provided to avoid such situations.

Firing of bricks

This is a very important operation in the manufacture of bricks. It imparts hardness and strength to the bricks and makes them dense and durable. The bricks should be burnt properly. In the process of burning, the dried bricks are burned either in clamps (small scale) or kilns (large scale) up to certain degree temperature. In this stage, the bricks will gain hardness and strength so it is an important stage in the manufacturing of bricks. The temperature required for burning is about 800 to 1050°C based quality and type of mud used. If they burnt beyond this limit they will be brittle and easy to break. If they burnt under this limit, they will not gain full strength and there is a chance to absorb moisture from the atmosphere. Hence burning should be done properly to meet the requirements of good brick.

If bricks are over-burnt, they will be brittle and hence break easily. If they are under-burnt, they will be soft and hence cannot carry loads. When the temperature of dull red heat, about 650°C, is attained, the organic matter contained in the brick is oxidized and also the water of crystallization is driven away. But heating of bricks is done beyond this limit for the following purposes:

- If bricks are cooled after attaining the temperature of about 650°C, the bricks formed will absorb moisture from the air and get rehydrated.
- The reactions between the mineral constituents of clay are achieved at higher temperature and these reactions are necessary to give new properties such as strength, hardness, less moisture absorption, etc. to the bricks.

The overall firing process can be categorized in three steps – heating, soaking and cooling. As shown below.

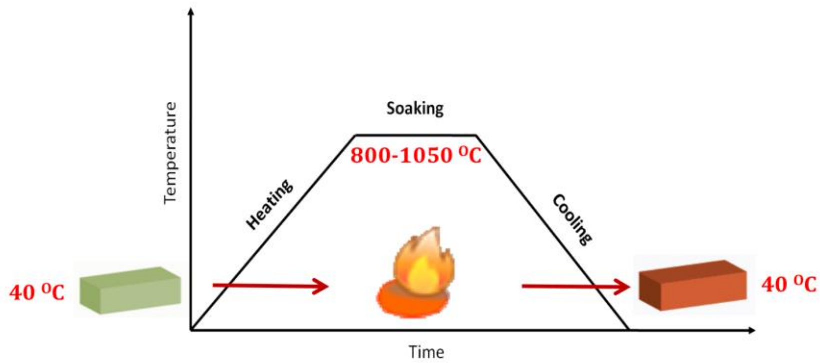


Fig-Firing process

When the temperature of about 1050°C is reached, the particles of two important constituents of brick clay, namely, alumina and sand, bind themselves together resulting in the increase of strength and density of bricks. Further heating is not desirable and if the temperature is raised beyond 1050°C, a great amount of fusible glassy mass is formed and the bricks are said to be vitrified. The bricks begin to loose their shape beyond a certain limit of vitrification.

The burning of bricks is done either in clamps or in kilns. The clamps are temporary structures and they are adopted to manufacture bricks on a small scale to serve a local demand or a specific purpose. The kilns are permanent structures and they are adopted to manufacture bricks on a large scale.

2. Technologies used in Brick sector

Brick Kilns can be classified as intermittent and continuous. Clamps and Downdraft kilns are intermittent while the Bull Trench (BTK), Hoffman, Zig-zag, Tunnel and Vertical Shaft Brick Kilns (VSBK) are continuous. The continuous kilns are more efficient as they have heat recovery features from both the heat in fired bricks and flue gases unlike the intermittent ones.

Intermittent Kilns

The oldest kiln is the clamp. Invented in 4000 BCE, these are still very common in India. Clamps are temporary constructions made of green bricks or clinker. The clinker can be reused while the green bricks are sold. Certain brick makers use permanent clamps made of refractory bricks. Two basic variations of kilns are the updraft and the downdraft kilns, named after the direction of heat movement. The updraft ones or Scotch have flues running through the floor of the kiln with spaces between the stacks of bricks to allow heat to circulate, while the top is covered for insulating the kiln. The downdraft ones are circular with the flue running from the floor to the chimney stack. The hot air is then directed downwards from the dome through the stacks of bricks.

Continuous Kilns Continuous

Kilns can be based either on the principle of moving fire or on moving ware. The Hoffman, BTK and Zig-zag work on the principle of moving fire. In the Tunnel and VSBK, the firing zone remains constant while the bricks move. Hoffman's kilns are continuous domed kilns invented in Germany. They have a permanent arched masonry and tall chimney. The circular arched tunnel surrounding the chimney has various chambers where green bricks are placed and the fuel is added via vents in the roof.

The Bull Trench Kiln (BTK), which is very popular in the Indian sub-continent, is an arch-less modification of the Hoffman's kiln. It is circular or elliptical in shape. Bricks to be fired are arranged in a trench and tall movable metal chimneys are placed on the brick setting. They are moved as the firing progresses. There are also modifications of the BTK which have a permanent fixed chimney.

The Habla Zig-Zag Kiln is also a German invention. It is an automated tunnel kiln. This one has a fire zone moving through a stack of stationary bricks. The fire moves with the help of an axial fan. The bricks are arranged such that hot flue gases move between them in a zig-zag manner resulting in better heat utilisation and energy efficiency.

Another kind of continuous kiln is the Tunnel Kiln. The principle is to move green bricks through a stationary fire. It is energy intensive and generally used in developed countries. It is essentially a 50-100 ft long rectangular chamber lined with high quality refractory bricks. The bricks are loaded from one end in a car at a predetermined pattern. After a fixed interval of time, depending on the firing cycle, a car is pushed from one end, simultaneously taking one car out from the other end of the tunnel.

The Vertical Shaft Brick Kiln (VSBK) is a Chinese technology based on the traditional updraft intermittent kiln. The kiln consists of one or two shafts in a rectangular structure insulated with agriculture residue and clay. The shaft is loaded from the top in a pre-determined pattern. After being fired in the shaft they are removed batch wise from the bottom via an unloading tunnel. It is well suited to the context of the South Asian brick sector. The technology of various brick kilns and their operating principles are discussed in details as below:

Clamp Kilns

The clamp is the most basic type of kiln since no permanent kiln structure is built. It consists essentially of a pile of green bricks interspersed with combustible material. The green bricks are stacked in the form of a rectangular pyramid which slopes at the sides to provide stability to the structure. The sides and top of the structure are usually covered with burnt bricks for insulation. It consists of piles of green bricks interspersed with combustible material. No permanent structure is required, which lowers the initial infrastructural cost and does away with any maintenance cost.

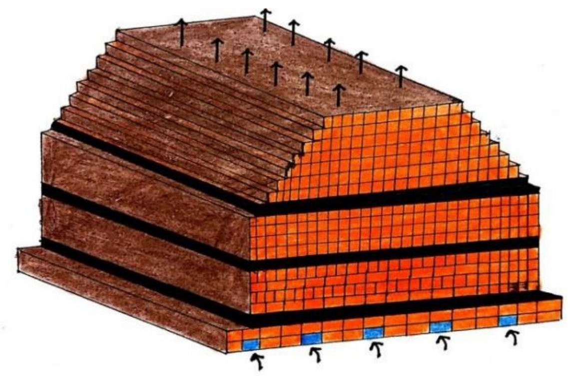


Fig: Clamp kiln

The base of the clamp is first laid with fired bricks. Generally, in case of coal fired bricks, a thin layer of fuel is spread over the base on which the green bricks are stacked. In case of firewood fired clamps, tunnels are made through the base of the pile to feed firewood. In a rice husk fired clamp, bricks are stacked in parallel columns and the fuel is fed from the top and burned in the gaps between the brick columns.

The clamps are ignited at the bottom, Air required for combustion, enters through the openings provided in the base of clamp, during burning, the hot air rises up through the bricks and heats the bricks. Smoke and fumes leave from the top of the clamp. In a clamp, the operator has very little control over the burning rate. The burning rate is affected by the weather particularly by the direction and speed of the wind. Because of heat loss to the surroundings, bricks located on the surface are usually under-fired. Also bricks located near to the fuel layer are usually over-burnt.

In Bigger coal fired clamps, to attain the required firing temperatures throughout the brick stacking, fuel is also added in the spacing/holes provided in the brick stacking. For stability of the clamp structure, usually the upper part of the clamp has a trapezoidal shape.

In case of coal fired clamps, the firing process takes around 4-5 days and then the clamp is left for cooling for 8-10 days before the bricks are taken out. To reduce the heat loss from the surface of the clamps, sometimes the outer walls are plastered with mud or the base and the outer walls are permanently built with bricks. In some cases, green bricks are also stacked along the outer walls to utilise the heat from the kiln for drying of bricks.

The quality of bricks varies within a clamp. While the innermost bricks are the hardest, the outer bricks are usually under-burnt. Sufficient inflow of air results in oxidation, imparting red colour to the bricks, while insufficient air supply results in yellow or orange colour. The fuel efficiency is lower for this middle size clamps because of higher heat loss through the surface.

The advantages of clamps are that they do not require large, expensive kiln structures or the buildings in which to house them, and, they are capable of producing a very rich and varied coloured product that complements traditional brickwork.

Down draught kilns

The down draught kiln is an intermittent kiln in which the bricks are fired in batches. It consists of a firing chamber/kiln connected with a chimney, through an underground flue duct. Fireboxes are provided at the bottom of the chamber on both sides where burning of fuel takes place. The kiln structure is permanently built with fired bricks and the inner surface of the kiln is constructed with refractory bricks.

In this kiln, the hot gases from the burning fuel are first deflected to the roof of the kiln and then are drawn downwards by the chimney draught through the green bricks to fire them. One of the advantages of this kiln is that the fuel and fuel residue do not come into contact with the kiln charge and therefore no pollutants are deposited on the surface of the products. One of the advantages of this kiln is that the fuel and fuel residue do not come into contact with the kiln charge and therefore no pollutants are deposited on the surface of the products.

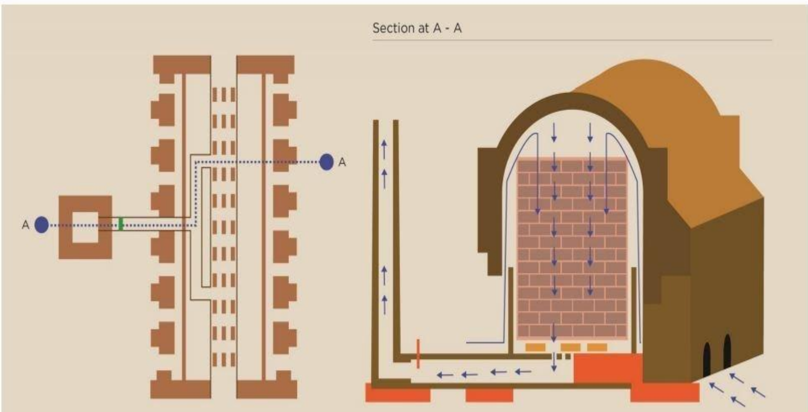


Fig Down draught kiln

Usually 2 chambers are connected to a single chimney and are fired alternately. In some cases there are 4 chambers also connected to a single chimney and are fired alternately. In some cases there are 4 chambers also connected to a single chimney. Each chamber has a capacity of firing 20,000-40,000 bricks in a batch.

The bricks stacked in the chamber/kiln are not in direct contact with each flames. The hot gases from the burning fuel are deflected to the roof of the kiln. They are then drawn downwards by the chimney draught through the green bricks to fire them.

Fuel (usually firewood, twigs and branches) is fed in the fire-boxes by a single fireman. The fuel feeding is continued for around 30 hours. Afterwards the fireboxes are shutoff and it is left for cooling for 2-3 days. The total time required for a batch from loading & firing of green bricks to cooling and unloading of fired bricks is around 7-10 days.

There is uniform heat distribution in a DDK and therefore, the percentage of good quality products is high. DDK has limited heat recovery features, during firing the kiln structure also gets heated up along with the bricks and while cooling, the heat contained in the bricks and kiln structure gets lost into the atmosphere.

Down draught kilns are relatively higher investment than clamps due to permanent kiln structure. Suitable for small to medium scale batch production. It can be used for year round production. It's required capital investment ~14-20 lakh. And production capacity is around 20000 – 40000 bricks per batch. Down draught kiln produces 85% good products, and quality of fired bricks are better than clamp. It is high sensible heat losses because of higher thermal mass of the kiln. Relatively better and homogeneous brick quality as compared to clamps because of uniform temperature distribution.

Fixed Chimney Bull Trench Kilns

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.

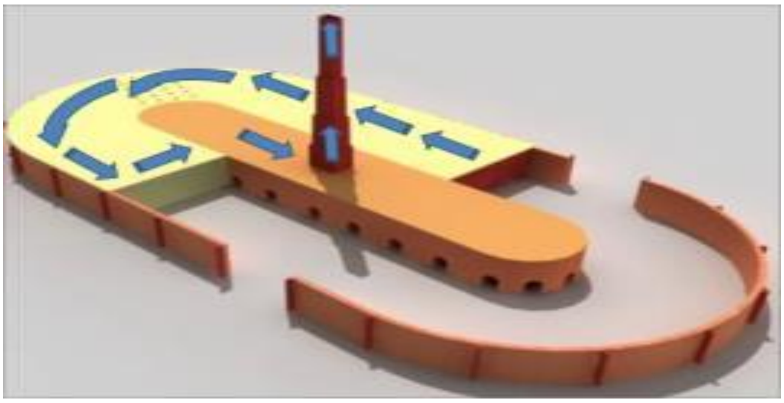


Fig FCBTK Kiln

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.

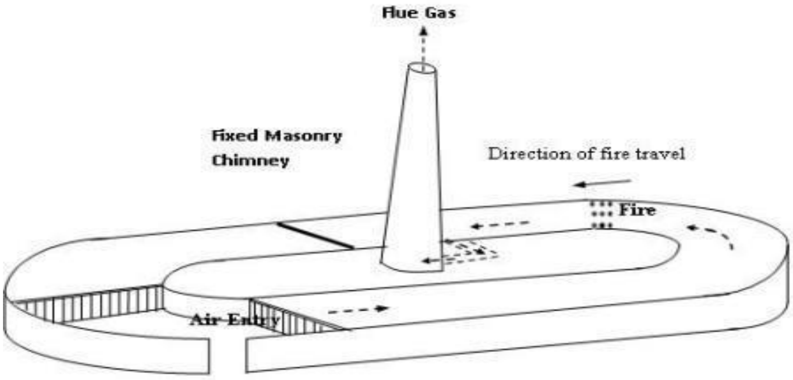
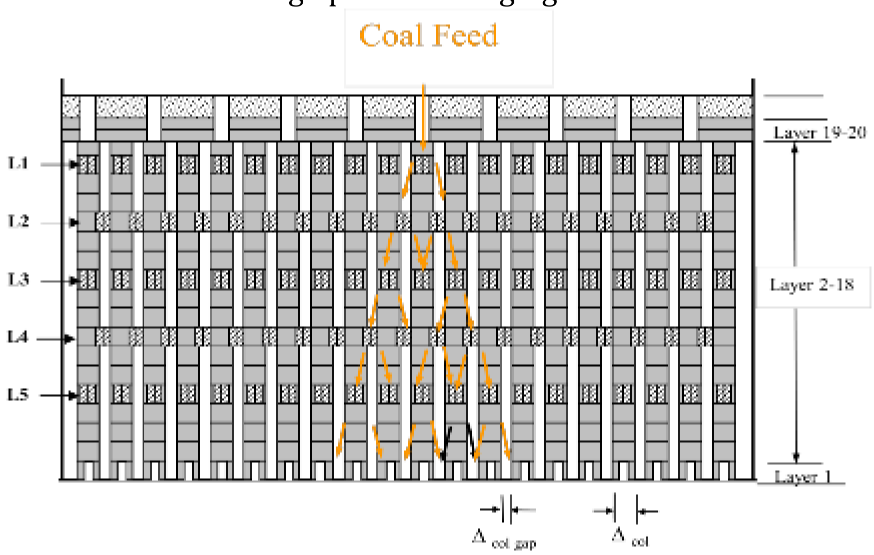


Fig FCBTK kiln sketch

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. 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, sometimes below the ignition temperature of the fuel resulting in incomplete 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 bricks.

Natural draught Zig-zag Kilns

In a natural draught zig zag 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. 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.

In an natural draught Zig-zag kiln(NDZK), the bricks are stacked and fired/burnt in the space (called 'trench' or 'dug') between the rectangular central part of the kiln (called miyana) and the rectangular outer wall of the kiln. NDZK is a continuous moving-fire kiln in which the fire burns continuously and moves in a closed rectangular circuit through the bricks stacked in the trench.

The flow of air into the kiln, which is required for combustion of the fuel and for the movement of fire in the forward direction, is caused by the draught created by the chimney. As the fire moves forward, the fired bricks behind the fire are taken out of the kiln after they cool down, while fresh green bricks are stacked ahead of the fire.

For a kiln of production capacity 20,000–50,000 bricks per day, the central perimeter of the kiln circuit is about 400–500 feet (125–150 m). It usually takes about 25 days for the fire to complete one round of the kiln. Openings for air passage are provided at both ends of the brick setting.

The bricks are stacked in such a manner that distinct chambers of brick setting are formed in the kiln. Just like in the case of FCBTK, in Zigzag Kilns also, the bricks are stacked in vertical columns in a row across the width of the trench. However, unlike in FCBTK, all the brick columns are not of the same width. The rows of brick columns are arranged one ahead of the other in the forward direction of fire travel. In an NDZK, one chamber of brick setting consists of five such rows.

The air flow through the brick setting takes place through the gaps provided in between the brick rows. The openings for air flow in every fifth row (i.e., at the end of each chamber) are provided in such a way that they cause zigzag flow of air in the kiln. Usually double or triple zigzag brick settings are being practised in NDZKs.

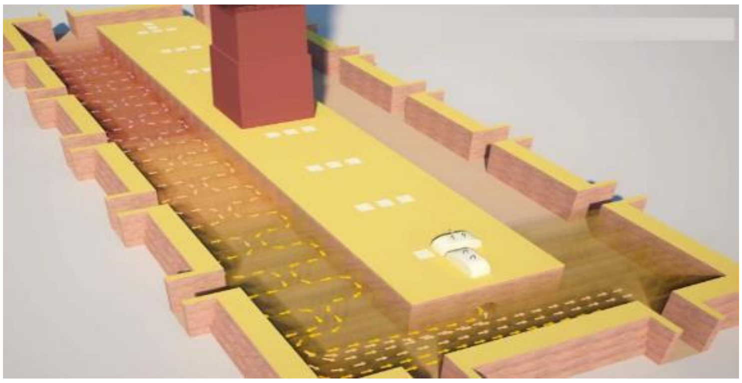
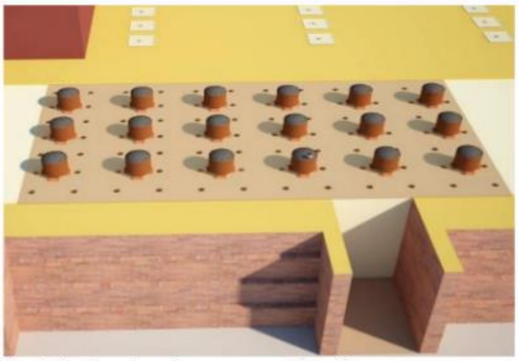


Fig zigzag kiln

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.

In a Zigzag Kiln, powdered coal is fed in small quantities; the fuel feeding zone is six times longer than the FCBTK. 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. The Zigzag Kiln is rectangular in Shape and Zigzag airflow in zigzag natural draught kiln.



Sketch showing longer coal feeding zone

Photo showing longer coal feeding zone

Fig zigzag kiln

Longer coal feeding zone in a natural draught zigzag kiln.

In an operational NDZK, the bricks can be segregated into three distinct zones.

1. Brick firing zone where the fuel is being fed and combustion is taking place.
2. Brick preheating zone (ahead of the firing zone in the direction of air flow) where green bricks are stacked and are preheated by the hot flue gases coming from the firing zone.
3. Brick cooling zone (behind the firing zone) where the burnt bricks are cooled by the cold air flowing into the kiln.

Usually, solid fuels such as coal, firewood, and agriculture residue are used in an NDZK. The fuel is fed in the kiln through the fuel-feed holes provided at the top of the kiln by the firemen standing on the top of the kiln. In each chamber, there are two rows of fuel-feed holes. In an NDZK, the fuel is fed continuously by a single fireman. Usually two firemen are deployed in a shift who feed fuel alternately. The fuel is fed in six chambers of the brick setting simultaneously.

In an NDZK, the fire moves along the forward direction of air flow. The air flow in the kiln is caused by the draught created by the chimney. The air flows in a zigzag path through the brick setting inside the kiln.

The back end of the brick cooling zone, where unloading of fired bricks from the kiln happens, is kept open to allow the entry of air from the surroundings into the kiln. The front end of the brick preheating zone is sealed with the help of polythene sheets or tarpaulin to guide the flue gases to the chimney through the flue gas duct system.

The flue gas duct system consists of a central duct and several side ducts. The central duct originates from the bottom of the chimney and extends along the length of the miyana in both directions till the end. The side ducts are L-shaped ducts, which are provided at regular spacings along the perimeter of the miyana. One end of each side duct opens in the kiln while the other end opens at the top surface of the miyana. Adjacent to the top openings of the side ducts, the central duct also has openings at the top surface of the miyana.

The side ducts are connected to the central duct with the help of a shunt. The shunt is an inverted U-shaped metallic duct that is used to connect the top opening of a side duct to the adjacent opening of the central duct located at the top surface of the miyana. At a time, only one or two side ducts are in use to connect the kiln to the central duct for the passage of flue gases. The top openings of the side ducts and the central duct that are not in use are closed with the help of concrete slabs.

Air from the surroundings enters the kiln at the brick unloading end and flows through the brick cooling zone into the brick firing zone where it is used for burning the fuel. The hot flue gases flow into the brick preheating zone, and then through the open side ducts and central duct before coming out through the chimney. In the process, the cold air gets heated by the burnt bricks and transfers heat from the cooling zone to the firing zone, and the hot flue gases get cooled by the green bricks and transfer heat from the firing zone to the preheating zone.

As burning of bricks gets completed in a chamber, fuel feeding is stopped and fuel-feed holes in a new chamber in front of the firing zone are opened for fuel feeding. Usually in every 24 hours, a new side flue duct in the direction of fire travel is opened to sustain the fire movement.

The fire travels a distance of 15–20 feet (5–6 m, 3 chambers) in 24 hours in the direction of air flow and fires 20,000 to 50,000 bricks daily.

Fired bricks, after having cooled down, are taken out of the kiln daily from the back end of the brick cooling zone. An equivalent batch of green bricks is loaded ahead of the brick preheating zone.

Wicket gates are provided at regular spacings in the outer wall of the kiln to allow the movement of bricks and workers in and out of the kiln.

Induced draught Zig-zag Kilns

In an Induced draught Zig-zag kiln (IDZK), the bricks are stacked and fired/burnt in the space (called 'trench' or 'dug') between the rectangular central part of the kiln (called miyana) and the rectangular outer wall of the kiln. IDZK is a continuous moving-fire kiln in which the fire burns continuously and moves in a closed rectangular circuit through the bricks stacked in the trench.

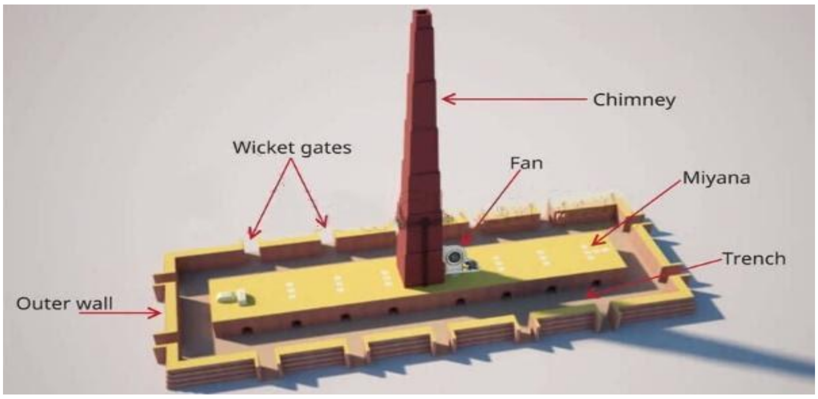


Fig High draught zigzag kiln

The flow of air into the kiln, which is required for combustion of the fuel and for the movement of fire in the forward direction, is caused by the draught created by a fan. As the fire moves forward, the fired bricks behind the fire are taken out of the kiln after they cool down, while fresh green bricks are stacked ahead of the fire.

For a kiln of production capacity 25,000–60,000 bricks per day, the central perimeter of the kiln circuit is about 400–500 feet (125–150 m). It usually takes about 25 days for the fire to complete one round of the kiln.

The bricks are stacked in such a manner that distinct chambers of brick setting are formed in the kiln. Just like in the case of FCBTK, in Zigzag Kilns also, the bricks are stacked in vertical columns in a row across the width of the trench. However, unlike in FCBTK, all the brick columns are not of the same width. The rows of brick columns are arranged one ahead of the other in the forward direction of fire travel. In an IDZK, one chamber of brick setting consists of eight such rows.

The air flow through the brick setting takes place through the gaps provided in between the brick rows. The openings for air flow in every eighth row (i.e., at the end of each chamber) are provided in such a way that they cause zigzag flow of air in the kiln. Usually single zigzag brick setting is practised in IDZKs.

The bricks stacked in the kiln are covered with a layer of ash and brick dust. This layer acts as a temporary roof of the kiln, which helps in preventing heat loss as well as air leakages into the kiln. In an IDZK, the fire moves along the forward direction of air flow. The air flow in the kiln is caused by the draught created by a fan. The air flows in a zigzag path through the brick setting inside the kiln.

The back end of the brick cooling zone, where unloading of fired bricks from the kiln happens, is kept open to allow entry of air from the surroundings into the kiln. The front end of the brick preheating zone is sealed with the help of polythene sheets or tarpaulin to guide the flue gases to the chimney through the flue gas duct system.

The flue gas duct system consists of a central duct and several side ducts. The central duct extends along the length of the miyana in both directions till the end. The side ducts are L-shaped ducts, which are provided at regular spacings along the perimeter of the miyana. One end of each side duct opens in the kiln while the other end opens at the top surface of the miyana. Adjacent to the top openings of the side ducts, the central duct also has openings at the top surface of the miyana.

The side ducts are connected to the central duct with the help of a shunt. The shunt is an inverted U-shaped metallic duct that is used to connect the top opening of a side duct to the adjacent opening of the central duct located at the top surface of the miyana. At a time, only one or two side ducts are in use to connect the kiln to the central duct for the passage of flue gases. The top openings of the side ducts and the central duct that are not in use are closed with the help of concrete slabs. The central duct is connected with the chimney through a fan, which sucks flue gases from the central duct and discharges them through the chimney. In an IDZK, the chimney can be located either at the centre of the kiln or on any side of the kiln.

Air from the surroundings enters the kiln at the brick unloading end and flows through the brick cooling zone into the brick firing zone where it is used for burning the fuel. The hot flue gases flow into the brick preheating zone, and then through the open side ducts and central duct before coming out through the chimney. In the process, the cold air gets heated by the burnt bricks and transfers heat from the cooling zone to the firing zone, and the hot flue gases get cooled by the green bricks and transfer heat from the firing zone to the preheating zone.

As burning of bricks gets completed in a chamber, fuel feeding is stopped and fuel-feed holes in a new chamber in front of the firing zone are opened for fuel feeding. Usually in every 24 hours, a new side flue duct in the direction of fire travel is opened to sustain the fire movement.

The fire travels a distance of 12–15 feet (4–5 m, 1.5–2 chambers) in 24 hours in the direction of air flow and fires 25,000 to 60,000 bricks daily. Fired bricks, after having cooled down, are taken out of the kiln daily from the back end of the brick cooling zone. An equivalent batch of green bricks is loaded ahead of the brick preheating zone. Wicket gates are provided at regular spacings in the outer wall of the kiln to allow the movement of bricks and workers in and out of the kiln.

Hoffman Kilns

Hoffman kiln is a continuous, moving fire kiln in which the fire is always burning and moving forward through the bricks stacked in the circular, elliptical or rectangular shaped closed circuit with arched roof. The fire movement is caused by the draught provided by a chimney or a fan. The Kiln consists of a central chimney, approximately 70m (200ft) high, connected to a main flue running the length of the Kiln. On either side of the main flue there are seventeen barrel-arched firing chambers, each linked to the main flue via damper controlled underfloor ‘steam-flues’.

The chambers are connected via a number of small tunnels, known as fire trace holes, through the dividing walls just above ground level. A number of offtake flues in the chamber walls carry drying and combustion gases down into the 'steam-flues', which are under draught as soon as the damper controls to the main flue are lifted. Each chamber is also connected to a hot air flue, situated around the top of the kiln, which enables hot air, via damper controls, to be recirculated from one chamber to another. Support fuel can be added to each chamber through small openings in the roof. Larger openings allow the control of temperature (reduction) by introducing ingress air.

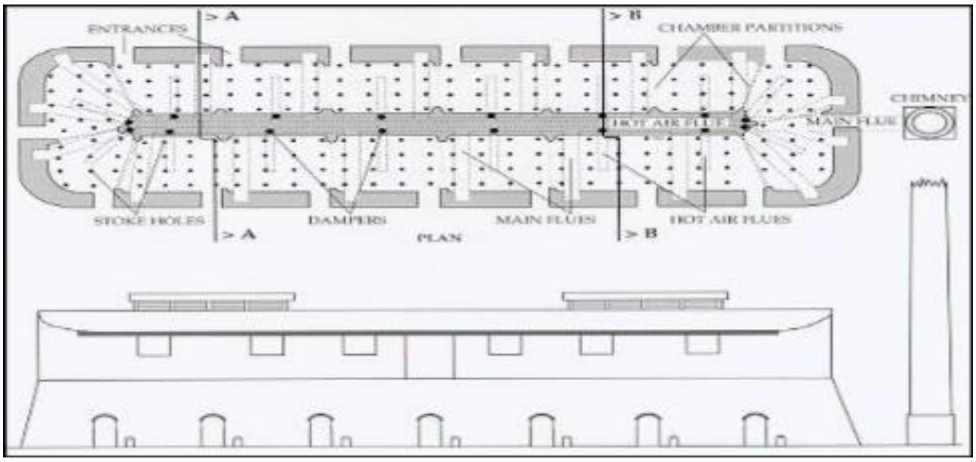


Fig Hoffman kiln

In a Hoffman kiln, the fire moves through the bricks stacked in an elliptical or rectangular shaped annular circuit (central perimeter 80-90m) which is covered with an arched roof. The kiln structure is usually covered with a shade to protect it from rains. The fire movement is caused by the draught provided by a chimney (25-35m high) which is located on one side of the kiln, sometimes a fan is also used to augment the draught. The chimney is connected to the central flue duct of the kiln through an underground duct.

There are 3 distinct zones in an operating Hoffman kiln,

1. Brick firing zone where the fuel is fed and combustion is happening.
2. Brick preheating zone (in front of the firing zone) where green bricks are stacked and being pre heated by the flue gases and
3. Brick cooling zone (behind the firing zone) where fired bricks are cooled by the cold air flowing into the kiln.

Air inlet: Air enters into the kiln from the back end of the cooling zone which is kept open to allow air entrance.

Seal to guide flue gas: The front end of the preheating zone is sealed to guide the flue gas to the chimney through the flue gas duct system. The kiln is connected to the central flue duct through openings provided in the inner wall of the kiln. Openings just before the seal are kept open to allow entrance of flue gases from the kiln to the central flue duct.

Feed holes are provided in the kiln roof for feeding of fuels. Solid fuels (mainly firewood or coal) are fed from the feed holes by a single fireman standing on the roof of the kiln. Fuel is fed at an interval of every 15-20 minutes and each fuel feeding lasts for 5-10 minutes. The fire travels a distance of around 10 m in 24 hours and fires 10,000 to 20,000 bricks. Daily, fired bricks are unloaded from the back end of the brick cooling zone and an equivalent batch of green bricks is loaded ahead of the brick preheating zone.

Tunnel Kilns

The Tunnel kiln is a continuous kiln which uses piped natural gas as fuel. In this process, the bricks are pushed into the kiln on “kiln cars' ' at one end and come out fired at the other. The tunnel kiln is 142m long and 3m high.

As the bricks progress through the kiln, they pass through zones of increasing temperature, until they reach the desired soak temperature. Hot air is pulled towards the front of the kiln which heats the bricks in the earlier stages. The bricks are then cooled with the waste heat taken from the cooling zone and fed to the driers. This makes this type of kiln highly efficient in high volume production. Tunnels reuse as much energy as possible. The waste hot air from the tunnel kiln is recycled to provide heat for the dryers.

Fig Tunnel kiln

Tunnel kiln is a continuous moving ware kiln in which the clay products to be fired are passed on cars through a long horizontal tunnel. The firing of products occurs at the central part of the tunnel. The tunnel kiln is considered to be the most advanced brick making technology. The main advantages of tunnel kiln technology lie its ability to fire a wide variety of clay products. Three distinct zones appear in an operating tunnel kiln:

1. Brick firing zone where the fuel is fed and combustion is happening

2. Brick preheating zone (before the firing zone) where the green bricks are being preheated by the hot flue gases coming from the firing zone and
3. Brick cooling zone (ahead of the firing zone) where fired bricks are cooled by the cold air flowing into the kiln.

In a tunnel kiln, a continuous moving ware kiln, the clay products/bricks to be fired are passed on cars through a long horizontal tunnel. The firing of bricks occurs at the central part of the tunnel. The length of tunnel can vary from 60 m to 150 m.

Generally green bricks are produced by mixing powdered fuel with clay. Green bricks are then moved in the tunnel or chamber dryers on cars for drying. Heat from the hot flue gases coming out of the kiln is utilized for the drying of bricks. The cars loaded with dried green bricks are pushed in the kiln. The cars are moved inside the kiln intermittently at fixed time intervals. The duration of the firing cycle can range from 30 to 72 hours.

Three distinct zones appear in an operating tunnel kiln:

1. Brick firing zone where the fuel is fed and combustion is happening,
2. Brick preheating zone (before the firing zone) where the green bricks are being pre-heated by the hot flue gases coming from the firing zone and
3. Brick cooling zone (ahead of the firing zone) where fired bricks are cooled by the cold air flowing into the kiln.

Fuel (granulated/pulverised coal) is fed into the firing zone of the kiln through feed holes provided in the kiln roof. The firing zone usually extends up to 8 cars. The temperature in the firing zone is maintained at 900 – 1050 ^{0}C.

There is counter current heat transfer between the bricks and the air. Cold air enters the kiln from the car exit end and gets heated while cooling the fired bricks. After combustion, the hot flue gases travel towards the car entrance end losing a part of the heat to the green bricks entering the kiln.

Hot air/gases are extracted from the tunnel kiln at several points along the length of the kiln and are supplied to the drying tunnel/chamber. In some of the kilns, there is also provision of a hot air generator to supplement the requirement of hot air for drying. The flue gases from the drying tunnel are released in the atmosphere through a chimney.

Vertical Shaft Kilns

This vertical shaft kilns were developed by china during late 1960s and early 1970s and about 110 kilns are installed in India. Vertical shaft brick kiln (VSBK) is a continuous, updraft, moving ware kiln in which the fire remains stationary while there is counter current heat exchange between air (moving upward) and bricks (moving downward).The VSBK technology has evolved from the traditional up-draught kilns in rural China during late 1950s; however, the widespread dissemination of the technology took place after the economic reforms. It is a continuous, updraft, moving ware kiln in which the fire remains stationary while there is counter current heat exchange between air (moving upward) and bricks (moving downward).

Fig VSBK kiln

Vertical shaft brick kiln is a continuous, moving ware kiln in which bricks are fired in a vertical shaft of rectangular/square cross-section. The height of the shaft is around 6 – 10 m and the 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 shafts are enveloped by an outer wall made up of bricks and the gap between the shaft and outer kiln wall is filled with insulating materials like clay, fly ash and rice husk. Some of the modern kilns in Vietnam are also using glass wool for insulation.

Generally each shaft is connected with two chimneys, located at diagonally opposite corners of the shaft. The working platform (the top of the shaft) is usually shaded by a roof. Green bricks and fuel, which are loaded in the shaft from the top, are lifted to the working platform using conveyors or lifts. However, in some of the traditional kilns manual transportation of bricks is also practiced.

Green bricks are loaded from the top of the shaft in batches. The fuel, generally crushed coal or briquettes, is laid along with the green bricks. In the modern VSBKs, mostly in Vietnam, use of internal fuel supple- mented by a small quantity of external fuel is widely practiced.

Green bricks loaded from the top gradually move down the shaft. The peak firing the temperature is in the middle of the shaft, where combustion of fuel is taking place. Fired bricks after cooling are unloaded at the bottom. There are 3 distinct zones in an operating VSBK:

1. Brick preheating zone: It is in the upper section of the shaft where the green bricks get preheated by the hot flue gases on their way to the chimney.
2. Brick firing zone: It is located in the middle of the shaft where fuel combustion is taking place.
3. Brick cooling zone: It is in the lower section of the shaft where the hot fired bricks are cooled down by the cold ambient air entering into the shaft.

Air for combustion enters the shaft from the bottom. It gets preheated by the hot fired bricks in the lower section of the shaft (brick cooling zone) before reaching the combustion zone. After combustion, the hot flue gases preheat the green bricks in preheating zone before exiting the kiln through the chimneys .The kiln works as a very efficient counter current heat exchanger where the heat transfer takes place between the air moving up (continuous flow) and the bricks moving down (intermittent movement) in the shaft.

The brick setting in the shaft is supported on removable bars provided at the bottom of the shaft. Brick unloading is carried out in batches from the bottom with the help of a trolley. Generally, every 2-3 hours, one batch is unloaded at the bottom and a batch of green bricks is loaded at the top. At any given time, there are typically 8 to 12 batches in the kiln.

Annexure –2: Strategies for De-carbonization and Circular Economy

Potential Renewable Energy Options for brick industry

In a brick manufacturing unit energy is required in mainly two forms – thermal energy for operation of kilns and dryer (if available), and electrical energy for operation of various machinery, equipment, lighting, and ventilation. Typically, in most of the brick kilns in India, the thermal energy requirement is more than 95% of the total energy need of a unit. In some of the highly mechanized units, the electrical energy requirement would be around 15-20% of the total energy requirement.

There is huge potential for deployment of renewable energy options in the brick manufacturing units. The suitable renewable energy options for brick manufacturing units can be:

1. Thermal energy need:
    a. Biogas
    b. Biomass briquettes
2. Electrical energy need:
    a. Solar photovoltaic system

Renewable Energy Options for Thermal Energy Need

Biogas:

Biogas mainly consists of Methane (CH4) and Carbon Dioxide (CO2), with having 50-60% Methane which is a combustible gas. Higher the methane content in a biogas higher would be its calorific value.

There are a variety of bio-wastes that are used as sources, or feedstocks, in the digester to produce biogas. Most of biodegradable organic compounds could be transformed into biogas by anaerobic digestion. Raw materials for producing biogas are biomass feedstocks which include; municipal solid waste (MSW), food waste, livestock manure, sewage sludge, agricultural manures, catch crops, energy crops, etc. A schematic of the biogas generation plant is provided in the figure below:

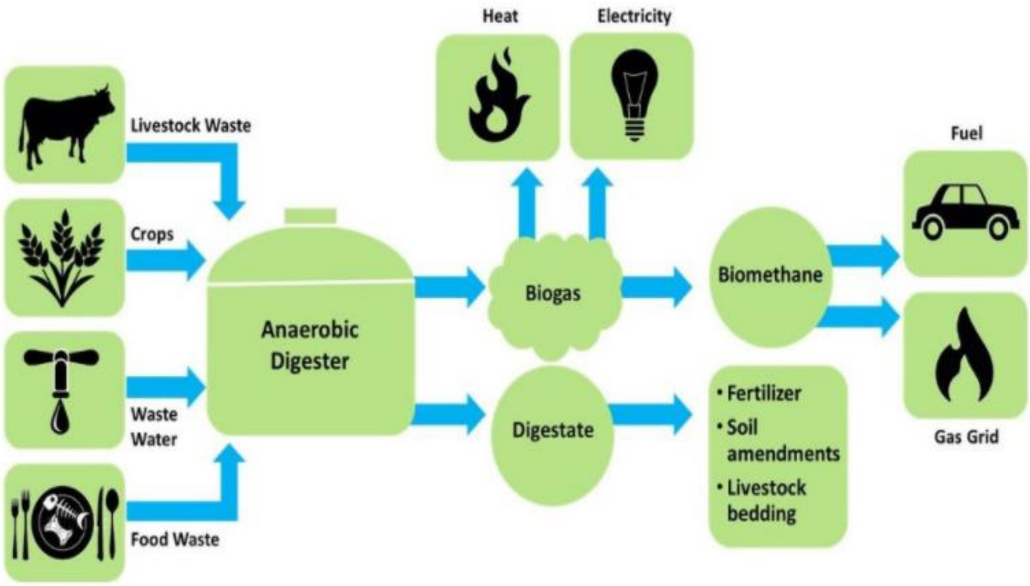


Figure : Biogas generation process

The brick kilns are usually located in rural and peri-urban areas, having availability of feedstocks such as cattle manure, fruit and vegetable wastes, and other biomass from agriculture and plants. Typically, 2-5 ton coal is consumed per day in a brick manufacturing unit. Thus, to cater to this energy demand through biogas, around 50-100 ton per day of fresh cattle manure or 25-60 ton per day of fruit, vegetable or plant waste would be required.

Discussion on challenges/issues in biogas use in brick kilns:

1. Consistent availability of feedstock: The issue of consistent availability of feedstock for few brick kilns in a region may be manageable, but in case of large number of brick kilns located in a cluster, availability of feedstocks in such a large quantity would be an issue.

2. Managing procurement of feedstocks and operation biogas generation unit: Majority of the brick kilns enterprises have very limited technical and managerial capacities to manage the procurement of feedstock and operation of biogas generation unit.

3. Financial viability: Setting up a biogas generation unit would require capital investment and land. There would also be recurring cost in procurement of feedstock and operation of the unit. To fire the bricks using a gaseous fuel, capital investment would also be required for gas burners and gas supply piping network over the kilns. This may not be attractive for a brick kiln enterprise.

4. Role of ESCOs: Role of ESCOs would be important in addressing many of the challenges listed above. They can set up a biogas generation unit in a cluster of bricks and can supply energy as a service to a single or multiple brick manufacturing units.

Biomass briquettes

Briquettes are produced by compacting loose biomass such as sawdust, crop waste, tree branches, rice husk, paddy straw, and bagasse. In northern India, the impact of open burning of agriculture residue, particularly the paddy straw, on air quality is an important issue. Converting agriculture residue into briquettes and using it in brick kilns as fuel has multiple advantages:

- It helps address the air pollution issue due to open burning of agriculture residue
- It can reduce consumption of fossil fuel coal in brick kilns
- It can generate additional revenue for the farmers and livelihood opportunity for briquette manufacturers and supply chain.

Figure : Use of biomass briquette in a brick kiln

Typically, 2-5 ton coal (CV = 5,000 kcal/kg) is consumed per day in a brick manufacturing unit. Thus, to cater to this energy demand through biomass briquette, around 3-7 ton per day of briquette (CV = 3,500 kcal/kg) would be required.

Discussion on challenges/issues in biomass briquette use in brick kilns:

1. Facilitating establishment of a network of enterprises for production and supply of biomass briquettes: Use of biomass briquettes is not new and several of the brick kilns are now using this as a fuel. However, to upscale its use and to address the issue of open burning of agriculture residue, a large network of enterprises would be required for production and supply of briquettes. Facilitation would be required in establishing supply and demand side linkages, and arranging finance for establishing briquetting units.

2. Sensitization of brick manufactures for fuel shift: Sensitization of brick kiln entrepreneurs and associations and cluster level would be required to push for adoption of briquettes as fuel.

Renewable Energy Option for Electrical Energy Need

Grid Connected Solar Photovoltaic System

A grid-connected system is an independent decentralized power system that is connected to an electricity grid. The electricity generated through this system can either be used to meet the local demand or the surplus electricity can be fed to the grid. The system is connected with the utility grid with bi-directional meter which measures the electricity taken from the grid as well as the electricity fed into the grid. The customer is billed based on net-metering facility. Different electricity distribution companies have different billing policies for the net metering scheme.

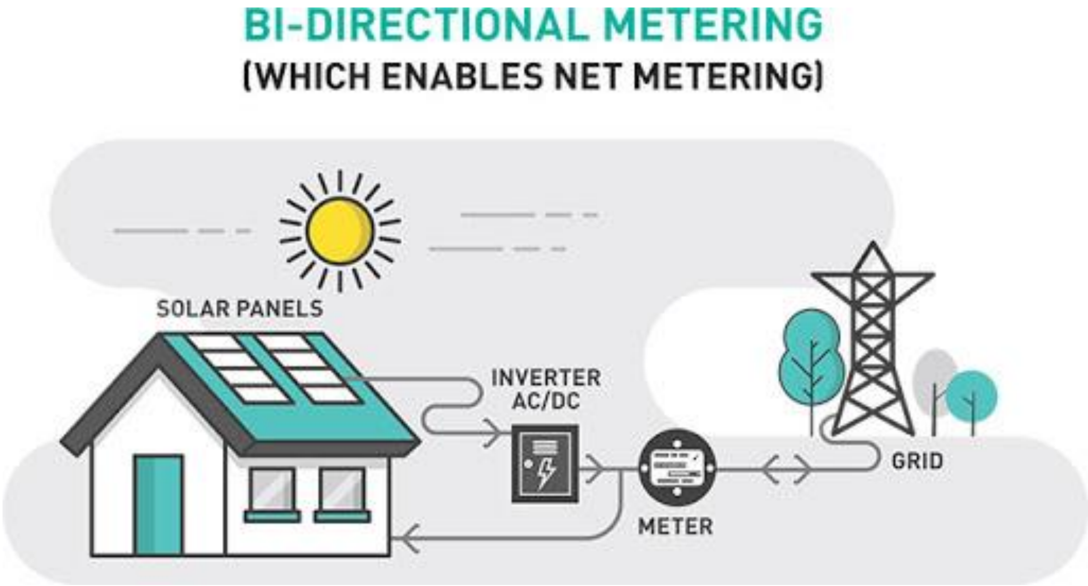


Figure : Grid connected solar PV system23

Typically, a brick manufacturing unit has a land area of 5-6 acres, however, a large part of it is required be unshaded and dedicated for moulding and drying of bricks in open Sun. Still there is huge potential for installation of solar PV systems over the roofs (site office), kiln, stack of coal, clay and fired and green bricks, or in open spaces. Unlike in northern India, where majority of the kilns are in open, in southern India, majority of the kilns have a shed over it. Now the kilns in north India are also gradually adopting shed over the kiln. If a kiln is under a shed, the roof of the shed (typically 1500-2000 square meter are) can also be utilised for solar PV system installation. In total, generally around 2,000-3,000 square meter area in a brick manufacturing unit can be utilised for solar PV system.

The electrical energy demand of a brick manufacturing unit is very less as compared to the space available for installation of solar PV system. Thus, a grid connected solar PV system would be suitable for such enterprises where the access electricity can be

[23] Image Source: http://www.proteustechnologies.co/insights/kb/articles/energy/solar-pv-understanding-net-metering-gross-metering-and-feed-in-tariffs/

fed into the grid. It will generate additional revenue for the enterprises and also help in off-setting the carbon footprint of brick manufacturing.

Discussion on challenges/issues in Solar PV system deployment in brick kilns:

1. Ownership of the land: Many of the brick kilns are located on leased land usually having lease tenure of up to 5 years. Uncertainty around the renewal of lease is a major barrier for an entrepreneur for making a long-term investment in solar PV system.

2. Capital investment: High upfront capital investment would be a challenge for MSME brick manufacturing units.