FACTSHEETS ABOUT BRICK KILNS IN SOUTH AND SOUTH-EAST ASIA

PREFACE

In most of the developing countries, brick making enterprises are small, informal and unorganised. They employ traditional techniques and technologies. Near urban areas, brick-making enterprises are generally clustered; while in rural areas they are dispersed. Air pollution from brick kilns, due to incomplete consumption and use of inferior fuels is an area of concern, particularly when brick kilns are clustered together. Information on characteristics, geographical presence and performance of various kiln technologies are not available readily. The objective of developing these factsheets is to make basic technical information readily available on a variety of brick kiln technologies in a standard format.

CONTENTS

OUTLINE OF THE FACTSHEET

Factsheet on each kiln technology consists of 4 pages.

Page 1 provides information on brief introduction and history, geographical presence and basic characteristics of the kiln technology and nature of the enterprises.

Page 2 describes about the working of the technology with the help of a schematic diagram.

Page 3 provides information on performance of the kiln technology based on five parameters – (i) Emissions, (ii) Fuel and specific energy consumption, (iii) Financial performance, (iv) Product quality and (v) Occupational health and safety.

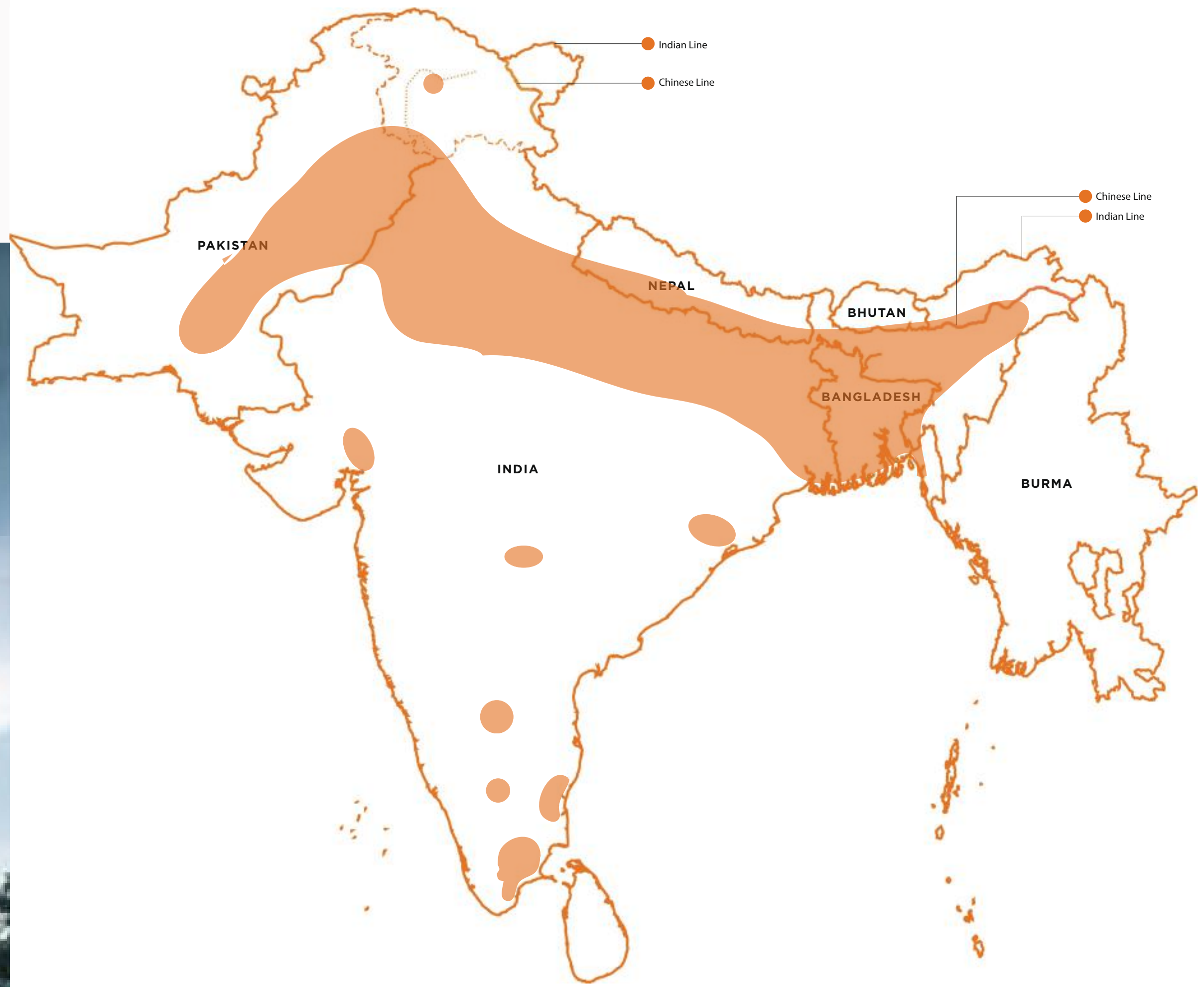
Page 4 provides an overall summary of the performance of the kiln technology and compares it with the most commonly used kiln technology of the type (continuous/intermittent). Page 4 also includes references, acknowledgement and contacts.

1 FIXED CHIMNEY BULL'S TRENCH KILN (FCBTK)

INTRODUCTION AND HISTORY

Fixed Chimney Bull's Trench Kiln (FCBTK) technology is the most widely used brick firing technology in South Asian countries. It is a continuous, moving fire kiln in which the fire is always burning and moving forward in the direction of air flow due to the draught provided by a chimney. The bricks are being warmed, fired and cooled simultaneously in different parts of the kiln. It is a modified version of Bull's trench kiln introduced by a British engineer W. Bull in 1876[1]. Initially it had movable metal chimneys which were placed on the brick setting and were moved as the firing progressed. This technology was modified to more efficient and less polluting fixed chimney Bull's Trench Kilns and there was a large scale shift to fixed chimney Bull's trench kilns (FCBTKs) due to a regulatory ban on use of moving chimney kilns during 1990's in India, followed by similar regulations in Bangladesh and Nepal.

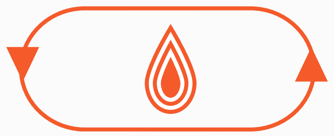
GEOGRAPHICAL DISTRIBUTION



ABOUT THE KILN

ENTERPRISES USING THIS TECHNOLOGY

Kiln



CONTINUOUS MOVING FIRE

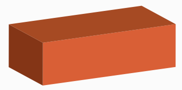
Nature of enterprise

INDUSTRIAL

Level of mechanization

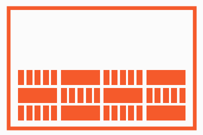
MANUAL

Brick produced



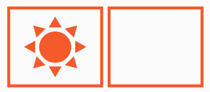
SOLID

Production capacity



MEDIUM
Between
1-10 million bricks

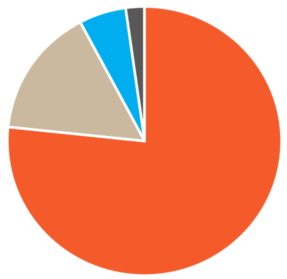
Operational season



DRY SEASON

NUMBER OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION*

Country	Number of enterprises	Total production billion bricks/year
India[2,3]	35,000	185
Pakistan[4]	11,500	56
Bangladesh[5]	4,500	17.4
Nepal[6]	450	2.3
Total	51,450	260.7



*Numbers are estimates only

PER ANNUM CONTRIBUTION TO TOTAL BRICK PRODUCTION IN INDIA, PAKISTAN, BANGLADESH AND NEPAL

79%

Approximately 260 BILLION BRICKS

1 FIXED CHIMNEY BULL'S TRENCH KILN (FCBTK)

DESCRIPTION AND WORKING

1

In FCBTK the fire moves in a closed circular or oval circuit (central perimeter 180-220 m) through the bricks stacked in the annular space between the outer and the inner wall of the kiln.

2

It operates under the natural draught provided by the chimney (20 – 38 m high) located at the center of the kiln.

3

The kiln does not have a permanent roof and bricks stacked in the kiln are covered with a layer of ash & brick dust, which acts as a temporary roof and inhibits the heat loss as well as seals the kiln from leakages.

4

There are 3 distinct zones in an operating FCBTK:

4.1 Brick firing zone where the fuel is fed and combustion is happening,

4.2 Brick preheating zone (in front of the firing zone) where green bricks are stacked and being pre heated by the flue gases and

4.3 Brick cooling zone (behind the firing zone) where fired bricks are cooled by the cold air flowing into the kiln.

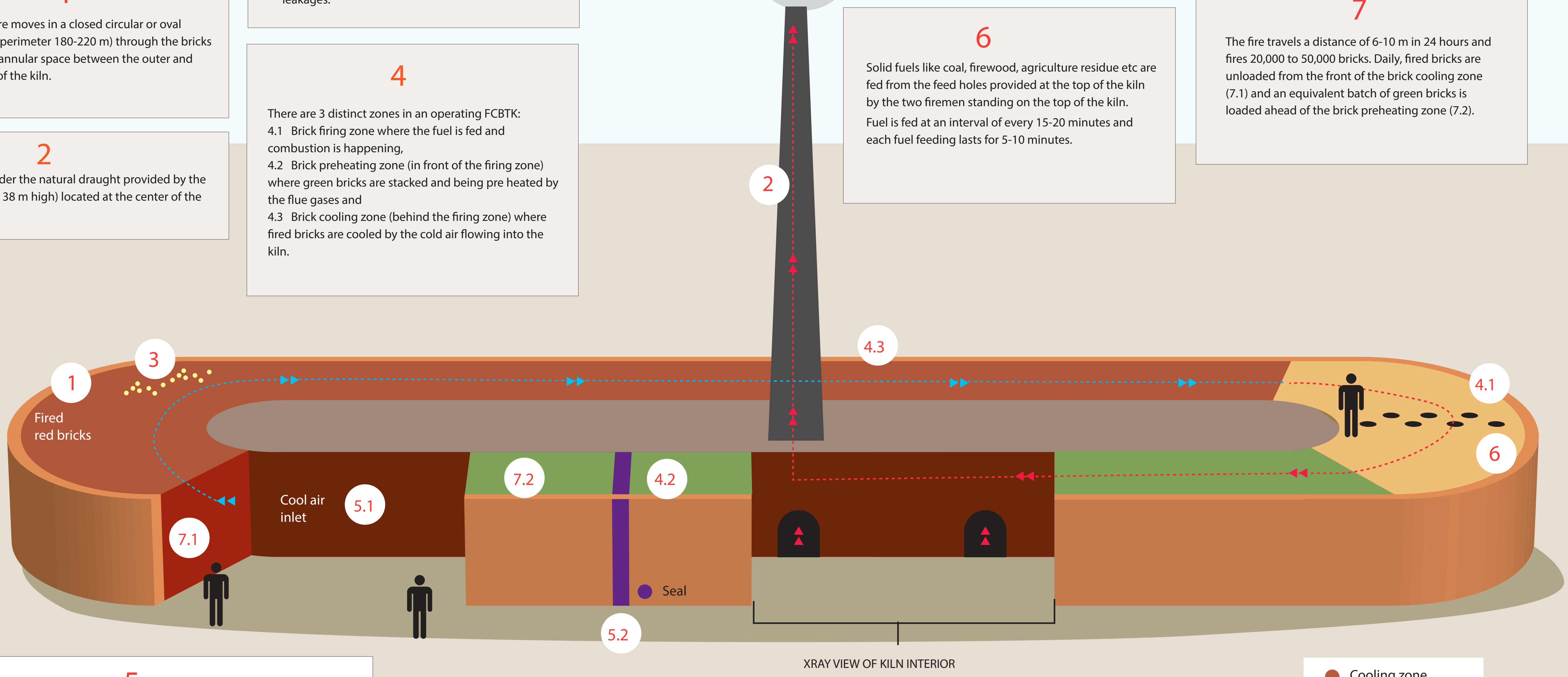
6

Solid fuels like coal, firewood, agriculture residue etc are fed from the feed holes provided at the top of the kiln by the two firemen standing on the top of the kiln.

Fuel is fed at an interval of every 15-20 minutes and each fuel feeding lasts for 5-10 minutes.

7

The fire travels a distance of 6-10 m in 24 hours and fires 20,000 to 50,000 bricks. Daily, fired bricks are unloaded from the front of the brick cooling zone (7.1) and an equivalent batch of green bricks is loaded ahead of the brick preheating zone (7.2).



5

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

5.2 Seal to guide flue gas: Front end of the preheating zone is sealed to guide the flue gas to chimney through the flue gas duct system.

- Cooling zone
- Firing zone
- Preheating zone
- Fuel feed holes

1 FIXED CHIMNEY BULL'S TRENCH KILN (FCBTK)

AIR EMISSIONS AND IMPACTS

MEASURED EMISSION FACTORS[7]

g/kg of fired bricks			
CO_2	Black Carbon	PM	CO
Average			
131	0.13	1.18	2.0
Range			
94.7-163.8	0.07-0.28	0.26-2.63	1.09-3.36

MEASURED PM EMISSIONS

Average: 570 mg/Nm3

(Range: 150 – 1250 mg/Nm3)

EMISSION STANDARDS

Notified for PM only

Country	PM (mg/Nm³)
India	1000 for small kilns < 15000 bricks per day 750 for large kilns > 15000 bricks per day
Pakistan	Emission standards not notified for brick kilns
Bangladesh	1000
Nepal	600 for forced draught kilns 700 for natural draught kilns

COMMENTS ON EMISSIONS

Poor fuel feeding practices and incomplete combustion in an FCBTK result in high emissions of PM and gaseous pollutants leading to poor air quality around FCBTK clusters.

A significant part of the PM emissions consist of smaller particles (PM_{10}, $PM_{2.5}$ and black carbon) which has adverse effects on human health and local vegetation.

FUELS AND ENERGY

COMMONLY USED FUELS

Coal
Most commonly used

Biomass
Eg. sawdust, firewood, biomass briquettes

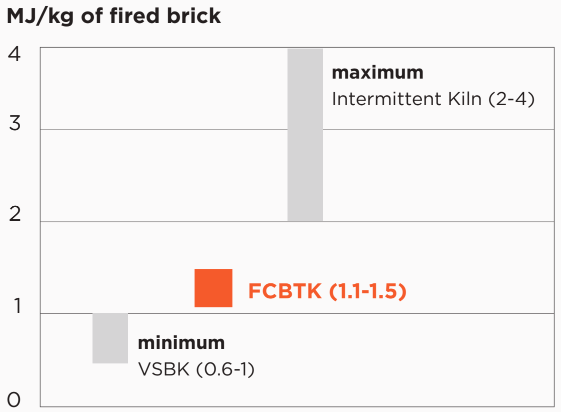
Agricultural residue
Eg. mustard stalk, rice husk

Industrial waste/by-products
Eg. pet-coke, used rubber tyres

SPECIFIC ENERGY CONSUMPTION[8]

Energy consumed for firing 1 kg of fired brick

Average: 1.30 MJ/kg of fired bricks
(Range: 1.1 – 1.46 MJ/kg of fired brick)



Note: Measured at firing temperature of 900-1100°C

FCBTK, being a continuous kiln and having good heat recovery features, is significantly more efficient compared to intermittent kilns but is less efficient compared to some of the other continuous kilns like VSBK and Zigzag.

MAIN CAUSES FOR HEAT LOSS

Incomplete combustion of coal and heat losses from the kiln surface are the two main sources of heat loss in an FCBTK.

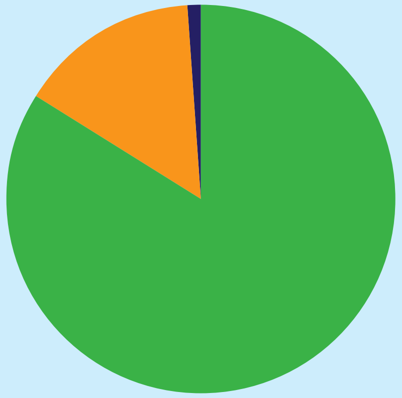
FINANCIAL PERFORMANCE

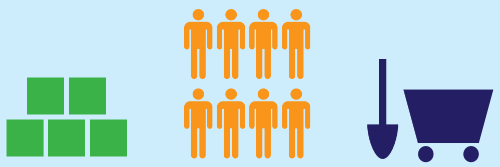
Capital cost of kiln technology
For annual production capacity of 3 – 8 million bricks, excluding land and working capital cost

50,000 to 80,000 USD

Capital cost breakdown

Construction Material	84 %
Labour	15%
Equipment	1%

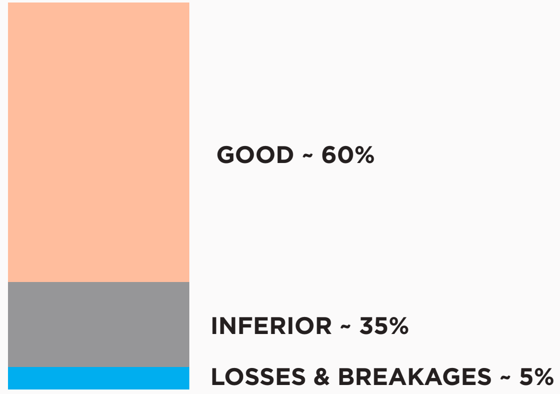




Production capacity	20,000 to 50,000 bricks per day	
Brick size	230 mm x 115 mm x 75 mm	
Number of Operators required	30-40	
Payback Period	Simple Payback	0.4 – 1.1 years
	Discounted Payback (@ 6.5%)	0.4 – 1.2 years

PRODUCT QUALITY

Product Quality
As per the local market perception

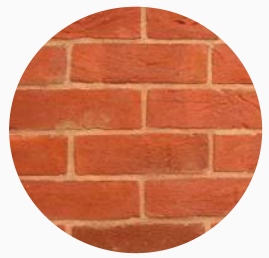


Non-uniform temperature across the cross-section of FCBTK results in under-fired bricks at the side walls and top corners and hence differences in the product quality.

Types of product that can be fired in the kiln		
	Solid bricks	✓
	Hollow/ Perforated bricks	✓
	Roof tiles	✓
	Floor tiles	✓

Usually only solid bricks and to some extent hollow bricks are fired in FCBTKs, however, other products can also be fired in combination with the solid bricks.

GOOD BRICK



INFERIOR BRICK
under-fired and over- burnt

OCCUPATIONAL HEALTH AND SAFETY

Exposure to Respirable Suspended Particulate Matter[9]
Flue gases exhausted from the chimney, ash covering and unpaved surfaces around an FCBTK result in very high concentration of dust in the surrounding environment and the workers are exposed to high concentration of respirable suspended particulate matter (RSPM).

This results in high incidence of respiratory tract infections and cardio vascular diseases among workers.

Exposure to Thermal Stress[10]
Workers such as fireman, while working on the kiln top are exposed directly to radiation from the kiln roof and flames.

This results in eye & skin diseases and dehydration among workers.

Risk of accidents
As the FCBTKs do not have a permanent roof, there is always a danger of caving-in of the brick setting or falling off the kiln structure and this poses serious risks of accidents.

High risk of injuries

Compliance with ILO standards and remarks on migratory labour and conditions of labour
Practices followed at FCBTK enterprises do not comply with the International Labour Standards on occupational health and safety drawn up by ILO.[11]

Majority of the workers of FCBTK are seasonal migrants and they along with their families work on the kilns. They live in temporary housing with poor access to basic amenities like safe drinking water, electricity, education, health and sanitation.

1 FIXED CHIMNEY BULL'S TRENCH KILN (FCBTK)

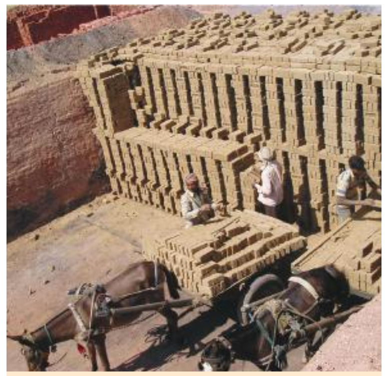
MARCH 2014

CONCLUSION

Facts about FCBTK, the most commonly used kiln.

PARAMETERS		FCBTK	COMMENTS
AIR EMISSION (g/kg FIRED BRICK)	CO2	131	Incomplete combustion in FCBTK results in high value of emissions. The average value of PM emissions lie within the notified limit, however, some of the kilns emit higher PM.
	Black Carbon	0.13	
	PM	1.18	
	CO	2.0	
FUEL & ENERGY	SEC (MJ/kg fired brick)	1.30	Incomplete combustion and heat losses result in increase in the fuel consumption in FCBTK.
FINANCIAL PERFORMANCE	Capital Cost (USD)	50,000-80,000	Low capital investment and high return is one of the main reasons for popularity of FCBTK technology among brick makers.
	Production Capacity	3-8 million bricks/year	
	Simple Payback	0.4 – 1.1 years	
PRODUCT QUALITY	Types of product	All types of product	Non-uniform temperature distribution across the kiln cross-section results in variation in product quality.
	Good Quality Product	60 %	
OHS	Exposure to dust		FCBTK has poor OHS conditions and it is a major shortcoming of this technology.
	Exposure to Thermal		
	Risk of accidents		

Unloading of fired bricks



Stacking of green bricks

FOR MORE INFORMATION: www.gkspl.in/whats_new.html www.ecobrick.in

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4 Report on 'Evaluating Energy Conservation Potential of Brick Production in Pakistan' prepared by Techno Green Associates for SAARC Energy Centre, 2012.
5 Report on 'Introducing Energy-efficient Clean Technologies in the Brick Sector of Bangladesh' prepared by World Bank, 2011 available at https://openknowledge.worldbank.org/bitstream/handle/10986/2797/601550ESW0P1110e00201100Color0FINAL.pdf
6 Report on 'Evaluating Energy Conservation Potential of Brick Production in Nepal' prepared by MinErgy Initiatives for SAARC Energy Centre, 2013.
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Report on 'Brick Kiln Performance Assessment' available at http://www.unep.org/ccac/Portals/24183/docs/Brick_Kilns_Performance_Assessment.pdf
8 Report on 'Brick Kiln Performance Assessment' available at http://www.unep.org/ccac/Portals/24183/docs/Brick_Kilns_Performance_Assessment.pdf
9 Report on 'Occupational health and safety study (OHSS) of brick industry in the Kathmandu valley' by Department of Environmental Sciences and Engineering (DESE), Kathmandu University, Nepal
10 Ibid.
11 International Labour Standards are instruments drawn up by ILO in the form of conventions (the basic principles to be implemented) and recommendations (more detailed guidelines). Details on the standards for OHS can be found at http://www.ilo.org/global/%20standards/subjects-covered-by-international-labour-standards/occupational-safety-and-health/lang--en/index.htm. A list of all such instruments on OHS with their status is available at HYPERLINK "http://www.ilo.org/dyn/normlex/en/

ACKNOWLEDGEMENTS

The project team would like to acknowledge the financial support received from the Swiss Agency for Development and Cooperation for preparation of the fact-sheets.

Note: In the initial stage of this initiative of developing factsheets on brick kiln technologies, factsheets are developed for South and South-East Asia and Latin America regions. Factsheets on brick kiln technologies of other regions will be developed over time.

Disclaimer: The country borders indicated on the map do not necessarily reflect the FDFA's official position. The red dotted line represents approximately the Line of actual Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

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Confédération suisse
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Swiss Agency for Development and Cooperation SDC

Greentech Knowledge Solutions Pvt. Ltd.

2 NATURAL DRAUGHT ZIGZAG FIRING TECHNOLOGY (ZIGZAG ND)

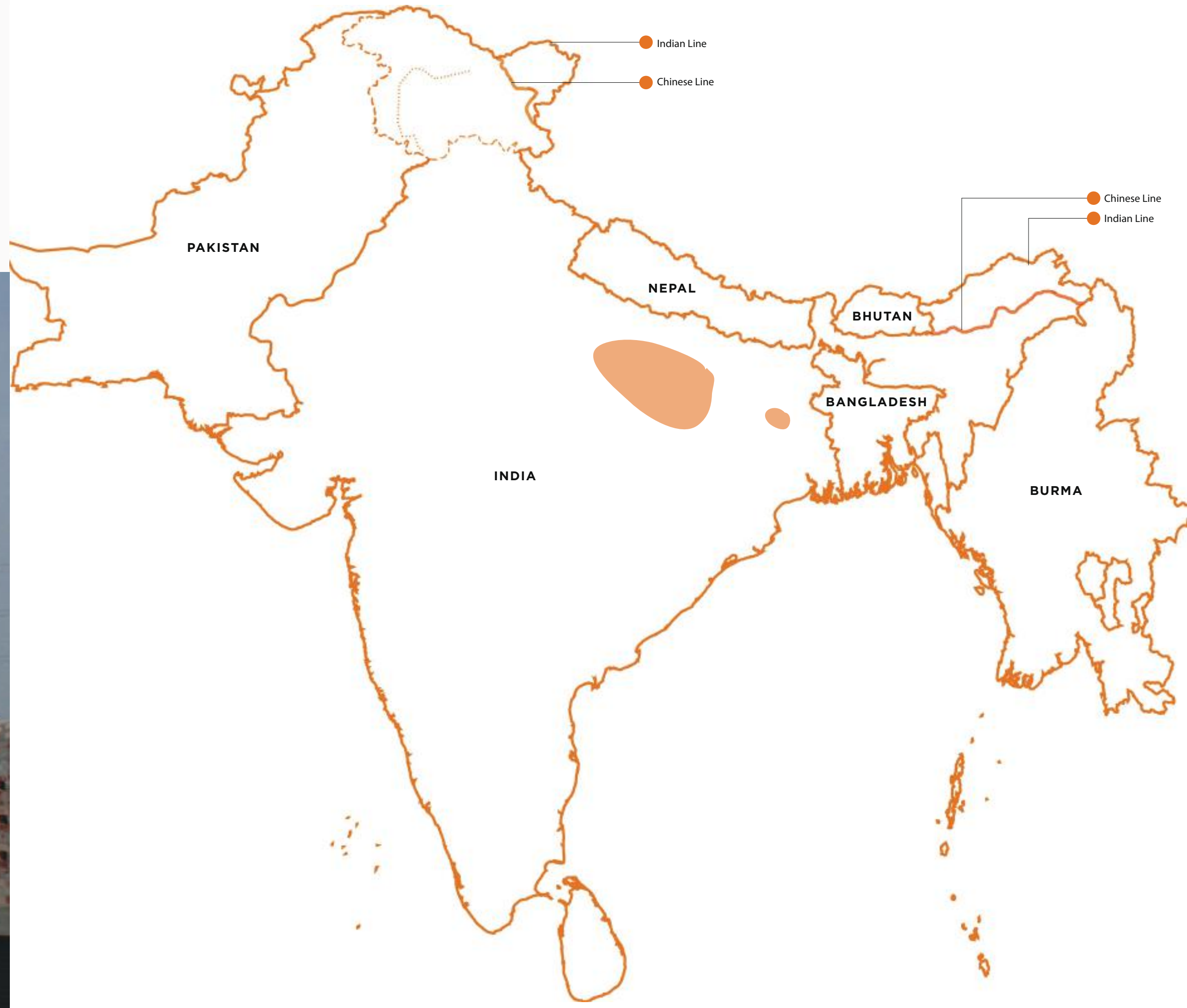
INTRODUCTION AND HISTORY[1,2]

Natural Draught Zigzag Firing kiln is a continuous, cross draught, moving fire kiln in which the air flows in a zigzag path due to the draught provided by a chimney. It has many similarities with FCBTK technology; the main difference being the zigzag air flow path.

Zigzag firing concept was first used in Buhrer kiln (Patented in 1868). The concept was later used in Habla kilns. In India, Central Building Research Institute (CBRI) first introduced the zigzag firing technology based on induced draught (with the help of a fan) during early 1970's.

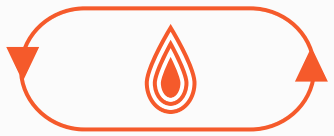
As per available information, Natural Draught Zigzag firing technology was first used in India in 1997 by Priya Bricks in Kolkata by modifying an existing FCBTK. The technology was adopted by Prayag Clay Products at Varanasi and, through them, has been propagated to more than 50 kilns by the end of 2013. It is now gaining popularity as an alternate to FCBTK technology.

GEOGRAPHICAL DISTRIBUTION



ABOUT THE KILN

Kiln



CONTINUOUS MOVING FIRE

ENTERPRISES USING THIS TECHNOLOGY

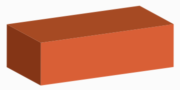
Nature of enterprise

INDUSTRIAL

Level of mechanization

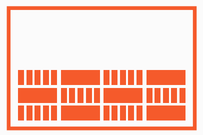
MANUAL

Brick produced



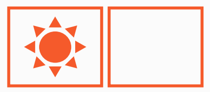
SOLID

Production capacity



MEDIUM
Between
1-10 million bricks

Operational season



DRY SEASON

NUMBER OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION*

Country	Number of enterprises	Total production billion bricks/year
India[3]	~50	~0.25

*Numbers are estimates only

% CONTRIBUTION TO THE TOTAL BRICK PRODUCTION IN INDIA

~1%

Out of the total annual production of 250 billion bricks in India, only around 250 million bricks are produced by Natural Draught Zigzag firing technology

2 NATURAL DRAUGHT ZIGZAG FIRING TECHNOLOGY (ZIGZAG ND)

DESCRIPTION AND WORKING

1

Natural Draught Zigzag firing kiln is a moving fire kiln in which the fire moves in a closed rectangular circuit (central perimeter 140-180 m) through the bricks stacked in the annular space between the outer and the inner wall of the kiln.

2

It operates under the natural draught provided by the chimney (30 – 40 m high) located at the center of the kiln.

3

The bricks are stacked in such a manner to form distinct chambers (~2 m long) and guide the air flow in a zigzag path. Zigzag flow increases the air flow path length and turbulence in the air, thereby resulting in improved combustion & heat transfer rate and uniform temperature across the kiln cross section.

4

The kiln does not have a permanent roof and bricks stacked in the kiln are covered with a layer of ash & brick dust, which acts as a temporary roof and inhibits the heat loss as well as seals the kiln from leakages.

6

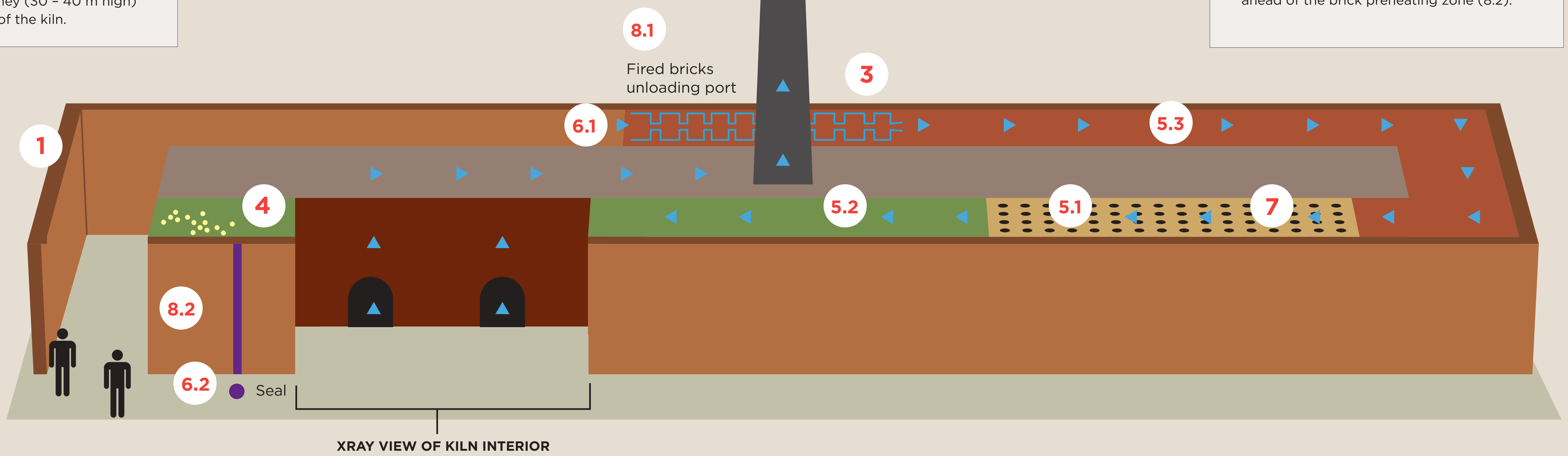
6.1 Air Inlet: Air enters into the kiln from back end of the cooling zone which is kept open to allow air entrance.
6.2 Seal to guide flue gas: Front end of the preheating zone is sealed by a plastic sheet to guide the flue gas to chimney through the flue gas duct system.

7

Firing zone extends to 6 chambers (~12 m) and solid fuels like coal, firewood, agriculture residue etc are fed through the feed holes provided at the top of the kiln continuously by a single fireman standing on the top of the kiln.

8

The fire travels a distance of 6-7 m in 24 hours and fires 20,000 to 50,000 bricks. Daily, fired bricks are unloaded from the front of the brick cooling zone (8.1) and an equivalent batch of unfired bricks is loaded ahead of the brick preheating zone (8.2).



5

There are 3 distinct zones in an operating zigzag kiln:
5.1 Brick firing zone where the fuel is fed and combustion is happening,
5.2 Brick preheating zone (in front of the firing zone) where green bricks are stacked and being pre heated by the flue gases and
5.3 Brick cooling zone (behind the firing zone) where fired bricks are cooled by the cold air flowing into the kiln.

- Cooling zone
- Firing zone
- Preheating zone
- Fuel feed holes

2 NATURAL DRAUGHT ZIGZAG FIRING TECHNOLOGY (ZIGZAG ND)

AIR EMISSIONS AND IMPACTS

MEASURED EMISSION FACTORS[4]

g/kg of fired bricks			
CO_2	Black Carbon	PM	CO
Average			
105	0.01	0.22	0.29
Range			
100.2-117.1	0.0063-0.0119	0.04-0.47	0.21-0.57

MEASURED PM EMISSIONS

Average: 144 mg/Nm³

(Range: 31– 263 mg/Nm³)

EMISSION STANDARDS

Notified for PM only

Country	PM (mg/Nm³)
India	1000 for small kilns < 15000 bricks per day 750 for large kilns > 15000 bricks per day

COMMENTS ON EMISSIONS

Improved combustion in a natural draught zigzag kiln results in significantly low emissions of PM and CO. Also the long path traversed by flue gases due to zigzag flow helps in settling of the particulate matter in the kiln.

FUELS AND ENERGY

COMMONLY USED FUELS

Coal
Most commonly used

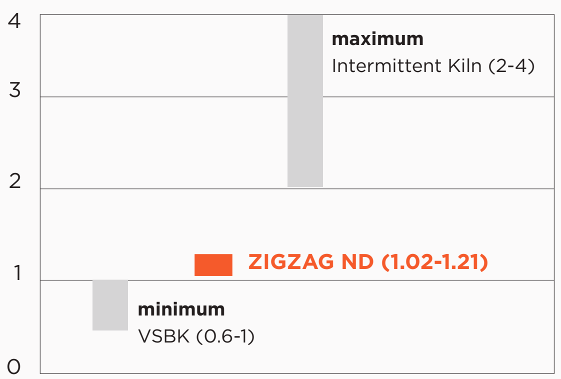
Biomass
Eg. sawdust, firewood, biomass briquettes

Industrial waste/by-products
Eg. pet-coke, used rubber tyres

SPECIFIC ENERGY CONSUMPTION[5]

Energy consumed for firing 1 kg of fired brick

Average: 1.06 MJ/kg of fired bricks
(Range: 1.02 – 1.21 MJ/kg of fired brick)



Note: Measured at firing temperature of 900-1100°C

Being a continuous kiln having good heat recovery features and improved combustion, natural draught zigzag kiln is significantly more efficient compared to intermittent kiln and some of the continuous kilns like FCBTK. However, it is less efficient than another continuous kiln, VSBK. Better air fuel mixing and sufficient time available for combustion due to zigzag air flow and long firing zone results in complete combustion of fuel.

MAIN CAUSES FOR HEAT LOSS

Heat losses from the kiln surfaces are the main source of heat loss in a natural draught zigzag kiln.

FINANCIAL PERFORMANCE

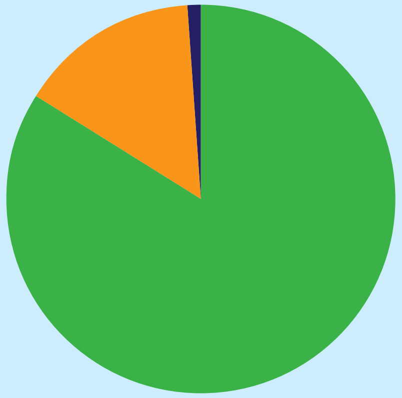
Capital cost of kiln technology

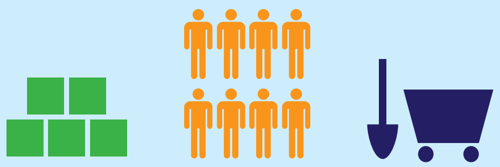
For annual production capacity of 3 – 8 million bricks, excluding land and working capital cost

50,000 to 80,000 USD

Capital cost breakdown

Construction Material	84 %
Labour	15%
Equipment	1%





Production capacity	20,000 to 50,000 bricks per day	
Brick size	230 mm x 115 mm x 75 mm	
Number of Operators required	30-40	
Payback Period	Simple Payback	0.3 – 0.9 years
	Discounted Payback (@ 6.5%)	0.3 – 1 years

PRODUCT QUALITY

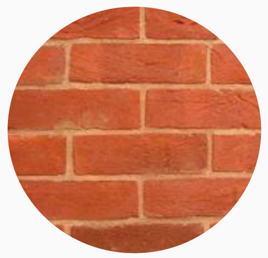
Product Quality
As per the local market perception

Better heat distribution in the kiln results in uniform temperature across the kiln cross section in the firing zone. This results in uniform quality of bricks across the kiln cross-section.

Types of product that can be fired in the kiln		
	Solid bricks	✓
	Hollow/ Perforated bricks	✓
	Roof tiles	✓
	Floor tiles	✓

Usually only solid bricks and to some extent hollow bricks are fired in natural draught zigzag kiln, however, other products can also be fired in combination with the solid bricks.

GOOD BRICK



INFERIOR BRICK
under-fired and over- burnt

OCCUPATIONAL HEALTH AND SAFETY

Exposure to Respirable Suspended Particulate Matter[6]

Ash covering, brick dust and unpaved surfaces around natural draught zigzag kiln result in high concentration of dust in the surrounding environment and the workers are exposed to high concentration of respirable suspended particulate matter (RSPM).

This results in high incidence of respiratory tract infections and cardio vascular diseases among workers.

Exposure to Thermal Stress[7]

Workers such as fireman, while working on the kiln top are exposed directly to radiation from the kiln roof and flames.

This results in eye & skin diseases and dehydration among workers.

Risk of accidents

As this kiln do not have a permanent roof, there is always a danger of caving-in of the brick setting or falling off the kiln structure and this poses serious risks of accidents.

High risk of injuries

Compliance with ILO standards and remarks on migratory labour and conditions of labour

Practices followed at natural draught zigzag kiln enterprises do not comply with the International Labour Standards on occupational health and safety drawn up by ILO . [8]

Majority of the wo rkers of natural draught zigzag kiln are seasonal migrants and they along with their families work on the kilns. They live in temporary housing with poor access to basic amenities like safe drinking water, electricity, education, health and sanitation.

2 NATURAL DRAUGHT ZIGZAG FIRING TECHNOLOGY (ZIGZAG ND)

MARCH 2014

CONCLUSION

Performance of natural draught zigzag kiln is compared with the most commonly used continuous kiln technology in the region which is FCBTK.

PARAMETERS		NATURAL DRAUGHT ZIGZAG	FCBTK	COMMENTS
AIR EMISSION (g/kg FIRED BRICK)	CO2	105	131	Natural draught zigzag kiln emits ~80% lower PM and ~90% lower Black Carbon as compared to FCBTKs. This is mainly because of better combustion of fuel and settling of particulates in the kiln itself due to zigzag flow. Emission of CO2 and CO from zigzag kiln is lower because of less consumption of fuel and improved combustion.
	Black Carbon	0.01	0.13	
	PM	0.22	1.18	
	CO	0.29	2.0	
FUEL & ENERGY	SEC (MJ/kg fired brick)	1.06	1.30	Natural draught zigzag kiln consumes ~20% less fuel as compared to FCBTK because of better combustion and heat recovery.
FINANCIAL PERFORMANCE	Capital Cost (USD)	50,000-80,000	50,000-80,000	Capital cost of setting up of a natural draught zigzag kiln and its production capacity range is the same as that of a FCBTK. However, due to less fuel consumption and better product quality return on investment of natural draught zigzag kiln is higher than FCBTK.
	Production Capacity	3-8 million bricks/year	3-8 million bricks/year	
	Simple Payback	0.3 - 0.9 years	0.4 - 1.1 years	
PRODUCT QUALITY	Types of product	All types of products	All types of products	The range of products of natural draught zigzag kiln is the same as that of FCBTK. But due to improved combustion and uniform temperature attained throughout the kiln cross-section in natural draught zigzag kiln, product quality is improved.
	Good Quality Product	85 %	60 %	
OHS	Exposure to dust			On OHS, natural draught zigzag kiln offers no improvement over FCBTK. Both kilns have poor OHS conditions, which is a major shortcoming of these technologies.
	Exposure to Thermal			
	Risk of accidents			

FOR MORE INFORMATION:
www.gkspl.in/whats_new.html
www.ecobrick.in

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2 World Bank Report on 'Introducing Energy-efficient Clean Technologies in the Brick Sector of Bangladesh', 2011 available at https://openknowledge.worldbank.org/bitstream/handle/10986/2797/601550ESW0P1110e00201100Color0FINAL.pdf
3 Policy brief on 'Towards cleaner brick kilns in India' available at http://www.unep.org/ccac/portals/24183/docs/Brick_kiln_policy_brief_April_2013.pdf
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Report on 'Brick Kiln Performance Assessment' available at http://www.unep.org/ccac/Portals/24183/docs/Brick_Kilns_Performance_Assessment.pdf
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7 Ibid.
8 International Labour Standards are instruments drawn up by ILO in the form of conventions (the basic principles to be implemented) and recommendations (more detailed guidelines). Details on the standards for OHS can be found at http://www.ilo.org/global/%20standards/subjects-covered-by-international-labour-standards/occupational-safety-and-health/lang--en/index.htm. A list of all such instruments on OHS with their status is available at http://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12030:0::NO:::#Occupational_safety_and_health

ACKNOWLEDGEMENTS

The project team would like to acknowledge the financial support received from the Swiss Agency for Development and Cooperation for preparation of the fact-sheets. A large part of the information on natural draught zigzag kiln has been sourced from Prayag Clay Products Pvt. Ltd. (www.pcppl.in). This is gratefully acknowledged.

Note: In the initial stage of this initiative of developing factsheets on brick kiln technologies, factsheets are developed for South and South-East Asia and Latin America regions. Factsheets on brick kiln technologies of other regions will be developed over time.

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3 HIGH/INDUCED DRAUGHT ZIGZAG FIRING TECHNOLOGY (ZIGZAG HD)

INTRODUCTION AND HISTORY[1,2]

High/Induced Draught Zigzag Firing kiln is a continuous, cross draught, moving fire kiln in which the air flows in a zigzag path. The draught required for the air flow is provided by a fan.

Zigzag firing concept was first used in Buhrer kiln (Patented in 1868) which was similar to a Hoffmann kiln in construction. This concept was later used in Habla kilns, which were widely used in Germany between the first and Second World Wars. They were also very popular in Australia.

In India, high draught zigzag firing technology was first introduced by Central Building Research Institute (CBRI) during early 1970's which, later on, was replicated in Bangladesh and Nepal. In the last forty years, many modifications have happened to the original design and several different variations of high draught zigzag kilns can be found in the field.

GEOGRAPHICAL DISTRIBUTION

ABOUT THE KILN

Kiln

CONTINUOUS MOVING FIRE

ENTERPRISES USING THIS TECHNOLOGY

Nature of enterprise	Level of mechanization	Brick produced	Production capacity	Operational season
INDUSTRIAL	MANUAL	SOLID	MEDIUM Between 1-10 million bricks	DRY SEASON

NUMBER OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION* IN INDIA, BANGLADESH AND NEPAL

Country	Number of enterprises	Total production billion bricks/year
India[3]	~2000	~10
Bangladesh[4]	~150	~0.75
Nepal[5]	~150	~0.60

*Numbers are estimates only

% CONTRIBUTION TO THE TOTAL BRICK PRODUCTION IN INDIA, BANGLADESH AND NEPAL

~4%

Out of the total annual production of around 270 billion bricks in India, Bangladesh and Nepal, only around 11 billion bricks are produced by high draught zigzag firing technology

3 HIGH/INDUCED DRAUGHT ZIGZAG FIRING TECHNOLOGY (ZIGZAG HD)

DESCRIPTION AND WORKING

1

High draught zigzag firing kiln is a moving fire kiln in which the fire moves in a closed rectangular circuit (central perimeter 120-140 m) through the bricks stacked in the annular space between the outer and the inner wall of the kiln.

2

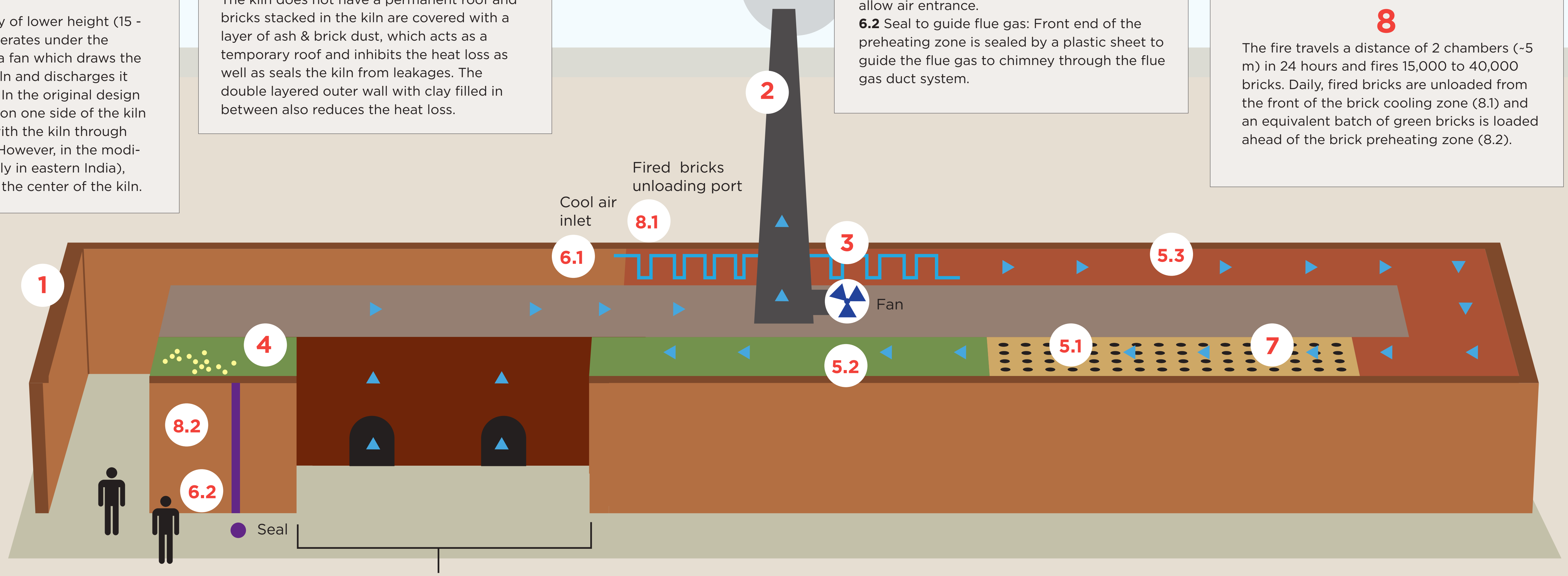
The chimney is usually of lower height (15 - 30 m) and the kiln operates under the draught provided by a fan which draws the flue gases from the kiln and discharges it through the chimney. In the original design chimney was located on one side of the kiln and was connected with the kiln through underground tunnel. However, in the modified designs (especially in eastern India), chimney is located at the center of the kiln.

3

The bricks are stacked in such a manner to form distinct chambers (~2.5 m long) and guide the air flow in a zigzag path. Zigzag flow increases the air flow path length and turbulence in the air, thereby resulting in improved combustion & heat transfer rate and uniform temperature across the kiln cross section.

4

The kiln does not have a permanent roof and bricks stacked in the kiln are covered with a layer of ash & brick dust, which acts as a temporary roof and inhibits the heat loss as well as seals the kiln from leakages. The double layered outer wall with clay filled in between also reduces the heat loss.



6

6.1 Air Inlet: Air enters into the kiln from back end of the cooling zone which is kept open to allow air entrance.
6.2 Seal to guide flue gas: Front end of the preheating zone is sealed by a plastic sheet to guide the flue gas to chimney through the flue gas duct system.

7

Firing zone extends to 3 chambers (~7.5 m) and solid fuels like coal, firewood, agriculture residue etc are fed through the feed holes provided at the top of the kiln continuously by a single fireman standing on the top of the kiln.

8

The fire travels a distance of 2 chambers (~5 m) in 24 hours and fires 15,000 to 40,000 bricks. Daily, fired bricks are unloaded from the front of the brick cooling zone (8.1) and an equivalent batch of green bricks is loaded ahead of the brick preheating zone (8.2).

5

There are 3 distinct zones in an operating high draft kiln:
5.1 Brick firing zone where the fuel is fed and combustion is happening,
5.2 Brick preheating zone (in front of the firing zone) where green bricks are stacked and being pre heated by the flue gases and
5.3 Brick cooling zone (behind the firing zone) where fired bricks are cooled by the cold air flowing into the kiln.

- Cooling zone
- Firing zone
- Preheating zone
- Fuel feed holes

3 HIGH/INDUCED DRAUGHT ZIGZAG FIRING TECHNOLOGY (ZIGZAG HD)

AIR EMISSIONS AND IMPACTS

MEASURED EMISSION FACTORS[6]

g/kg of fired bricks			
CO_2	Black Carbon	PM	CO
Average			
97.5	0.02	0.24	1.62
Range			
88.4-109.4	0.0-0.05	0.09-0.47	0.85-2.37

MEASURED PM EMISSIONS

Average: 96 mg/Nm³

(Range: 34 – 183 mg/Nm³)

EMISSION STANDARDS

Notified for PM only

Country	PM (mg/Nm³)
India	1000 for small kilns < 15000 bricks per day 750 for large kilns > 15000 bricks per day
Bangladesh	1000
Nepal	600

COMMENTS ON EMISSIONS

Improved combustion in a high draught zigzag kiln results in significantly low emissions of PM and CO. Also the long path traversed by flue gases due to zigzag flow helps in settling of the particulate matter in the kiln.

FUELS AND ENERGY

COMMONLY USED FUELS

Coal
Most commonly used

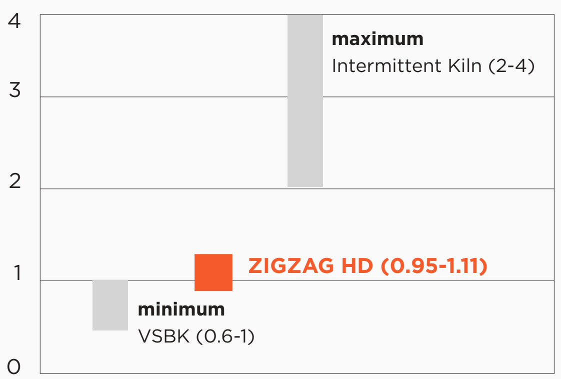
Biomass
Eg. sawdust, firewood, biomass briquettes

Industrial waste/by-products
Eg. pet-coke, used rubber tyres

SPECIFIC ENERGY CONSUMPTION[7]

Energy consumed for firing 1 kg of fired brick

Average: 1.03 MJ/kg of fired bricks
(Range: 0.95 – 1.11 MJ/kg of fired brick)



Note: Measured at firing temperature of 900-1100°C

Being a continuous kiln having good heat recovery features and improved combustion, high draught zigzag kiln is significantly more efficient compared to intermittent kiln and some of the continuous kilns like FCBTK. However, it is less efficient than another continuous kiln, VSBK. Better air fuel mixing and sufficient time available for combustion due to zigzag air flow and long firing zone results in complete combustion of fuel.

MAIN CAUSES FOR HEAT LOSS

Heat losses from the kiln surfaces are the main source of heat loss in a high draught zigzag kiln.

FINANCIAL PERFORMANCE

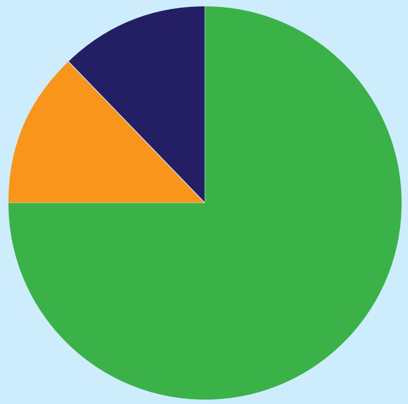
Capital cost of kiln technology

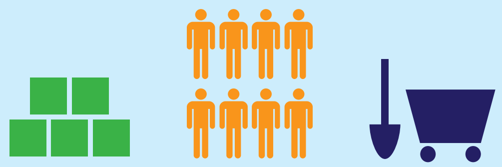
For annual production capacity of 2.5 - 6 million bricks, excluding land and working capital cost

50,000 to 80,000 USD

Capital cost breakdown

Construction Material	75 %
Labour	13%
Equipment	12%





Production capacity	15,000 to 40,000 bricks per day	
Brick size	230 mm x 115 mm x 75 mm	
Number of Operators required	30-40	
Payback Period	Simple Payback	0.4 – 1.1 years
	Discounted Payback (@ 6.5%)	0.5 – 1.1 years

PRODUCT QUALITY

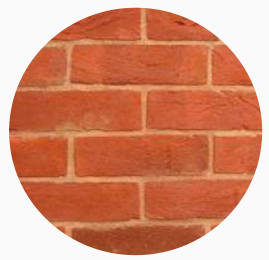
Product Quality
As per the local market perception

Better heat distribution in the kiln results in uniform temperature across the kiln cross section in the firing zone. This results in uniform quality of bricks across the kiln cross-section.

Types of product that can be fired in the kiln		
	Solid bricks	✓
	Hollow/ Perforated bricks	✓
	Roof tiles	✓
	Floor tiles	✓

Usually only solid bricks and to some extent hollow bricks are fired in high draught zigzag kiln, however, other products can also be fired in combination with the solid bricks.

GOOD BRICK



INFERIOR BRICK
under-fired and over- burnt

OCCUPATIONAL HEALTH AND SAFETY

Exposure to Respirable Suspended Particulate Matter[8]

Ash covering, brick dust and unpaved surfaces around high draught zigzag kiln result in high concentration of dust in the surrounding environment and the workers are exposed to high concentration of respirable suspended particulate matter (RSPM).

This results in high incidence of respiratory tract infections and cardio vascular diseases among workers.

Exposure to Thermal Stress[9]

Workers such as fireman, while working on the kiln top are exposed directly to radiation from the kiln roof and flames.

This results in eye & skin diseases and dehydration among workers.

Risk of accidents

As this kiln does not have a permanent roof, there is always a danger of caving-in of the brick setting or falling off the kiln structure and this poses serious risks of accidents.

High risk of injuries

Compliance with ILO standards and remarks on migratory labour and conditions of labour

Practices followed at high draught zigzag kiln enterprises do not comply with the International Labour Standards on occupational health and safety drawn up by ILO.[10]

Majority of the workers of high draught zigzag kiln are seasonal migrants and they along with their families work on the kilns. They live in temporary housing with poor access to basic amenities like safe drinking water, electricity, education, health and sanitation.

3 HIGH/INDUCED DRAUGHT ZIGZAG FIRING TECHNOLOGY (ZIGZAG HD)

MARCH 2014

CONCLUSION

Performance of high draught zigzag kiln is compared with the most commonly used continuous kiln technology in the region which is FCBTK.

PARAMETERS		HIGH DRAUGHT ZIGZAG	FCBTK	COMMENTS
AIR EMISSION (g/kg FIRED BRICK)	CO2	97.5	131	High draught zigzag kiln emits ~80% lower PM and ~85% lower Black Carbon as compared to FCBTKs. This is mainly because of better combustion of fuel and settling of particulates in the kiln itself due to zigzag flow. Emission of CO2 and CO from zigzag kiln is lower because of less consumption of fuel and improved combustion.
	Black Carbon	0.02	0.13	
	PM	0.24	1.18	
	CO	1.62	2.0	
FUEL & ENERGY	SEC (MJ/kg fired brick)	1.03	1.30	High draught zigzag kiln consumes ~20% less fuel as compared to FCBTK because of better combustion and heat recovery.
FINANCIAL PERFORMANCE	Capital Cost (USD)	50,000-80,000	50,000-80,000	Capital cost of setting up a high draught zigzag kiln is slightly higher than that of an FCBTK for same production capacity. This is because of cost incurred for fan. However, due to less fuel consumption and better product quality, payback period for high draught zigzag kiln is equivalent to FCBTK.
	Production Capacity	2.5-6 million bricks/year	3-8 million bricks/year	
	Simple Payback	0.4 – 1.1 years	0.4 – 1.1 years	
PRODUCT QUALITY	Types of product	All kind of products	All kind of products	The range of products of high draught zigzag kiln is the same as that of FCBTK. But due to improved combustion and uniform temperature attained throughout the kiln cross-section in high draught zigzag kiln, product quality is improved.
	Good Quality Product	80 %	60 %	
OHS	Exposure to dust			On OHS, high draught zigzag kiln offers no improvement over FCBTK. Both kilns have poor OHS conditions, which is a major shortcoming of these technologies.
	Exposure to Thermal stress			
	Risk of accidents			

FOR MORE INFORMATION:
www.gkspl.in/whats_new.html; www.ecobrick.in

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1 Report on 'Evaluating Energy Conservation Potential of Brick Production in India' prepared by Greentech Knowledge Solutions Pvt Ltd for SAARC Energy Centre, 2012.

2 World Bank Report on 'Introducing Energy-efficient Clean Technologies in the Brick Sector of Bangladesh', 2011 available at https://openknowledge.worldbank.org/bitstream/handle/10986/2797/601550ESW0P1110e00201100Color0FINAL.pdf

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Report on 'Brick Kiln Performance Assessment' available at http://www.unep.org/ccac/Portals/24183/docs/Brick_Kilns_Performance_Assessment.pdf

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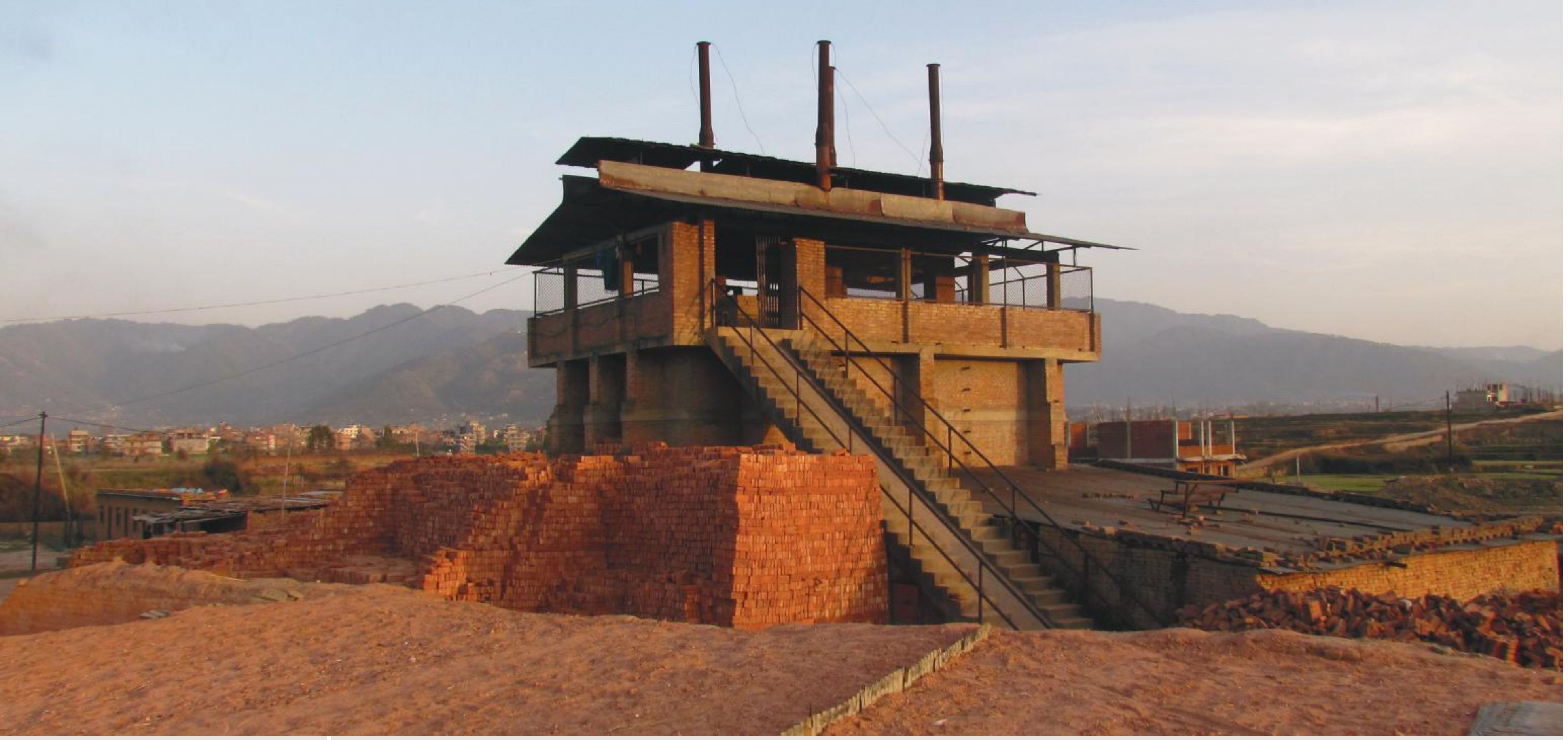
4 VERTICAL SHAFT BRICK KILN TECHNOLOGY (VSBK)

INTRODUCTION AND HISTORY[1]

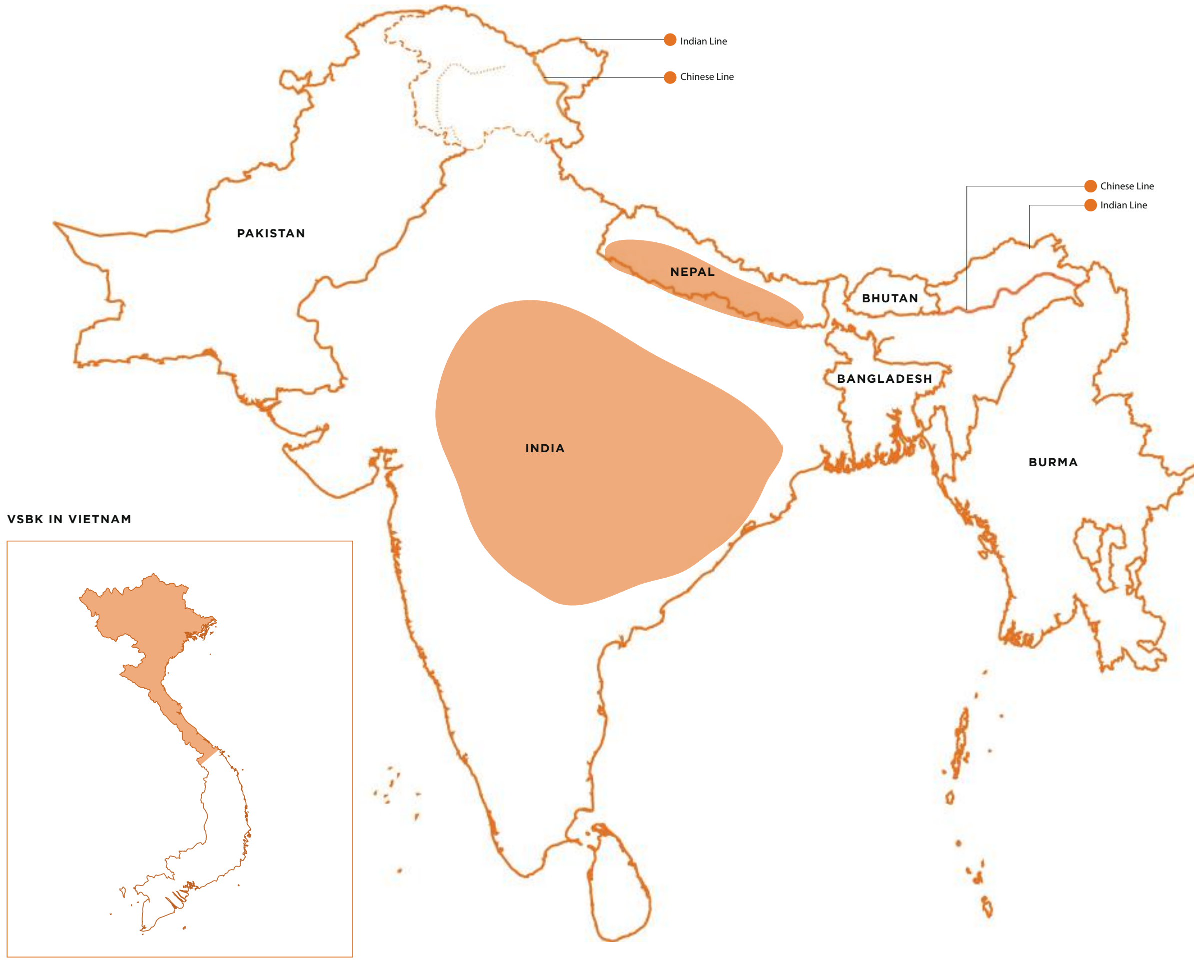
Vertical shaft brick kiln (VSBK) is a continuous, updraft, moving ware kiln in which the fire remains stationary while there is counter current heat exchange between air (moving upward) and bricks (moving downward).

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. At its peak during the mid 1990s, thousands of VSBKs were reported to be operating in China.

Since 1990, under different technology transfer projects the technology has been transferred to several developing countries including India, Nepal and Vietnam. Whereas the dissemination of VSBK technology in India and Nepal has been relatively slow, the experience in Vietnam has been very positive. Vietnamese brick makers have been able to innovate and have added new features to the technology, and in the process have transformed a rural technology into an industrial technology.



GEOGRAPHICAL DISTRIBUTION



VSBK IN VIETNAM

ABOUT THE KILN

Kiln

CONTINUOUS MOVING WARE

ENTERPRISES USING THIS TECHNOLOGY

Nature of enterprise

INDUSTRIAL

Level of mechanization

SEMI MECHANIZED

Brick produced

SOLID

Production capacity

SMALL & MEDIUM
Between
0.5-10 million bricks

Operational season

PERENNIAL

NUMBER OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION* IN INDIA, NEPAL AND VIETNAM

Country	Number of enterprises	Total production billion bricks/year
India[2]	~110	~0.3
Nepal[3]	~25	~0.1
Vietnam[4]	~600	~1.8

*Numbers are estimates only

% CONTRIBUTION TO THE TOTAL BRICK PRODUCTION IN INDIA, NEPAL AND VIETNAM

~1%

Out of the total annual production of around 280 billion bricks in India, Nepal and Vietnam only around 2.2 billion bricks are produced by VSBK technology

4 VERTICAL SHAFT BRICK KILN TECHNOLOGY (VSBK)

DESCRIPTION AND WORKING

1

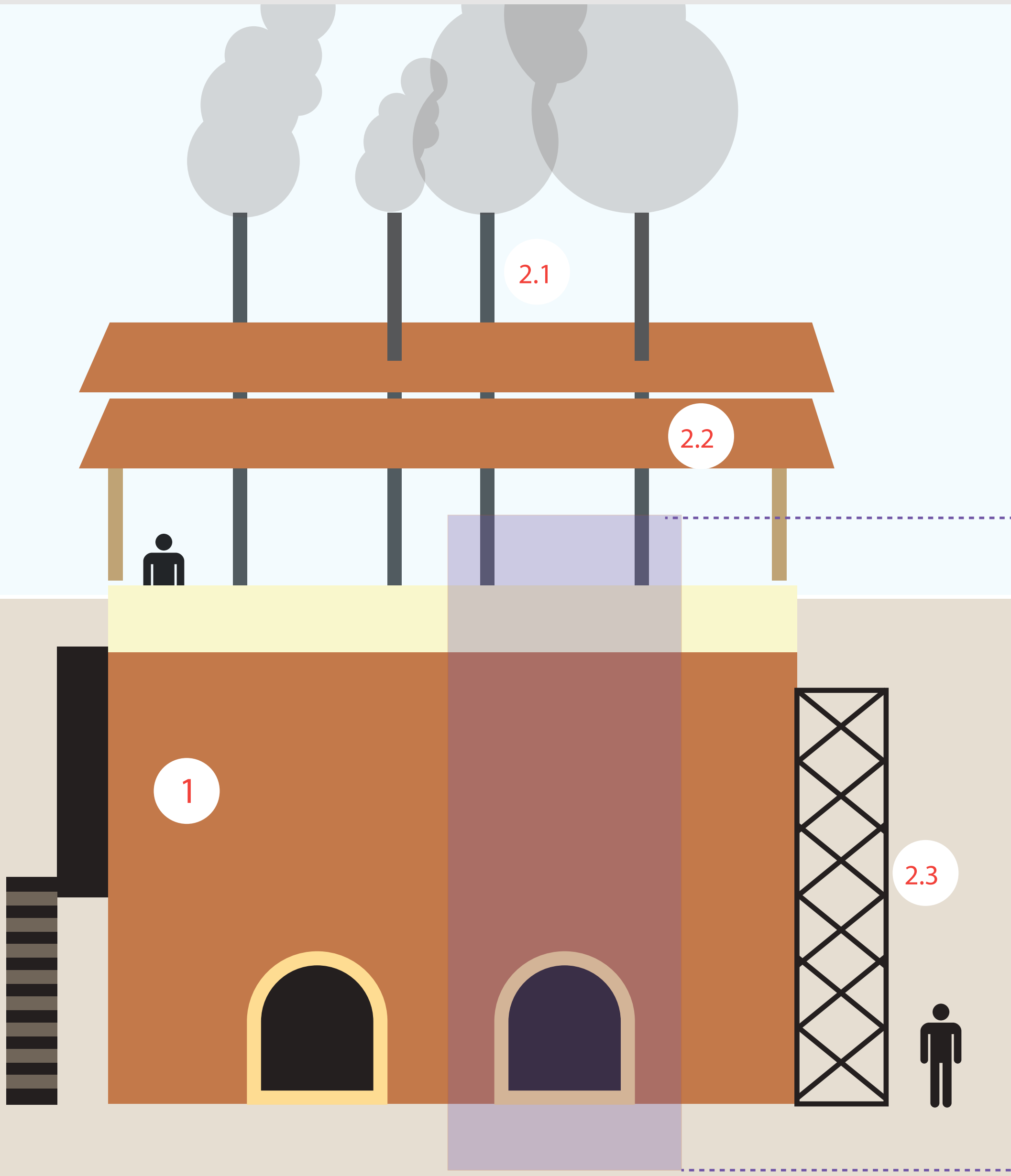
Vertical shaft brick kiln is a continuous, moving ware kiln in which bricks are fired in a vertical shaft of rectangular/square cross-section. The height of the shaft is around 6 – 10 m and the cross-section of the shaft can range from 1.0 x 1.5 m to 1.75 x 3.75 m. Mostly, the kiln consists of two or 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.

2

Generally each shaft is connected with two chimneys (2.1), located at diagonally opposite corners of the shaft. The working platform (the top of the shaft) is usually shaded by a roof (2.2). Green bricks and fuel, which are loaded in the shaft from the top, are lifted to the working platform using conveyors or lifts (2.3). However, in some of the traditional kilns manual transportation of bricks is also practiced.

3

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 supplemented by a small quantity of external fuel is widely in practice.



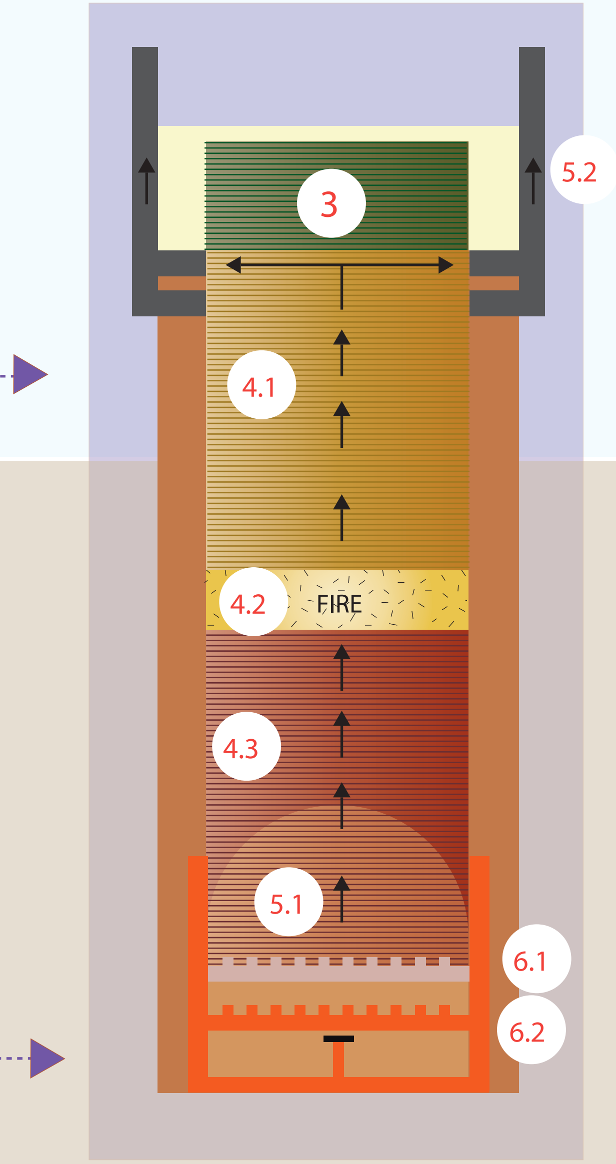
4

Green bricks loaded from the top gradually move down the shaft. The peak firing temperature is at 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:

4.1 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.

4.2 Brick firing zone: It is located in the middle of the shaft where fuel combustion is taking place.

4.3 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.



5

Air for combustion enters the shaft from the bottom (5.1). 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 (5.2). 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.

6

The brick setting in the shaft is supported on removable bars (6.1) provided at the bottom of the shaft. Brick unloading is carried out in batches from the bottom with the help of a trolley (6.2). 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.

4 VERTICAL SHAFT BRICK KILN TECHNOLOGY (VSBK)

AIR EMISSIONS AND IMPACTS

MEASURED EMISSION FACTORS[5]

g/kg of fired bricks			
CO_2	Black Carbon	PM	CO
Average			
70.5	0.001	0.15	1.84
Range			
62.2-78.7	0-0.002	0.12-0.19	0.85-2.83

MEASURED PM EMISSIONS

Average: 107 mg/Nm³

(Range: 101 – 114 mg/Nm³)

EMISSION STANDARDS

Notified for PM only

Country	PM (mg/Nm³)
India	250
Nepal	600
Vietnam	No emission standard has been notified for brick kilns

COMMENTS ON EMISSIONS

Low fuel consumption and better combustion result in low emissions. Practice of using internal fuel, mainly in Vietnamese VSBKs, further helps in reducing the emissions.

FUELS AND ENERGY

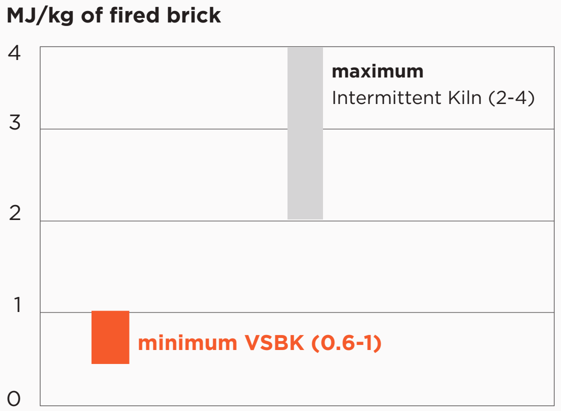
COMMONLY USED FUELS

Coal
Most commonly used

SPECIFIC ENERGY CONSUMPTION[6,7]

Energy consumed for firing 1 kg of fired brick

Average: 0.8 MJ/kg of fired bricks
(Range: 0.54 – 1.1 MJ/kg of fired brick)



Note: Measured at firing temperature of 900-1050°C

Because of proper combustion of fuel, efficient heat transfer and minimal heat losses, VSBK is one of the most energy efficient brick kiln technologies.

A very efficient counter flow heat transfer arrangement between air and bricks, uniform fuel distribution and sufficient insulation around the kiln attribute to the efficiency of a VSBK.

MAIN CAUSES FOR HEAT LOSS

The main sources of heat loss in a VSBK are the flue gases and fired bricks coming out of the kiln.

FINANCIAL PERFORMANCE

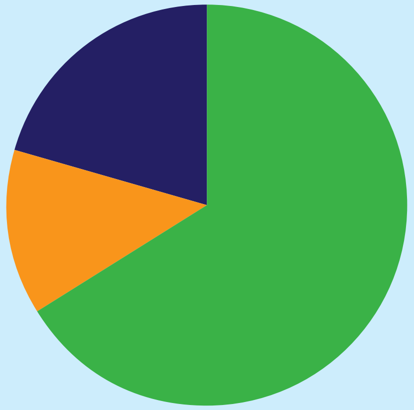
Capital cost of kiln technology

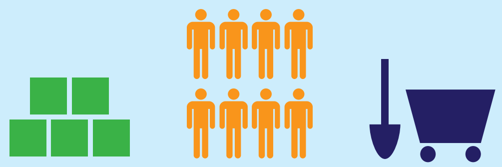
For a two-shaft VSBK with annual production capacity of 1.5 - 3 million bricks and excluding land and working capital cost

60,000 to 80,000 USD

Capital cost breakdown

Construction Material	65 %
Labour	15%
Equipment	20%



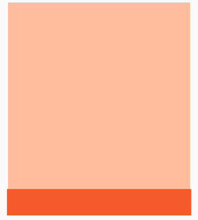


Production capacity	8000 to 12,000 bricks per day	
Brick size	230 mm x 115 mm x 75 mm	
Number of Operators required	10	
Payback Period	Simple Payback	0.9 – 1.8 years
	Discounted Payback (@ 6.5%)	1.3 – 2.0 years

PRODUCT QUALITY

Product Quality

As per the local market perception

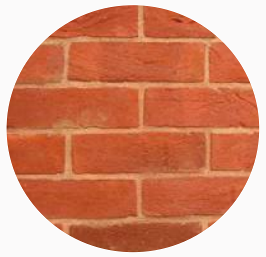


Fast heating and cooling of the bricks and high load in the lower section of the brick stacking are the main factors which can cause cracks and damages to the bricks in the VSBK. These factors are more prominent in case of hand moulded bricks which have low density and low compressive strength. However, with extruded or machine moulded bricks, breakages and losses are very low.

Types of product that can be fired in the kiln	Solid bricks	✓
	Hollow/ Perforated bricks	✓
	Roof tiles	X
	Floor tiles	X

VSBK is well suited for firing solid bricks. It can also be used to fire bricks with perforations, but is not suitable for firing hollow bricks or thinner products like tiles.

GOOD BRICK



INFERIOR BRICK

under-fired and over- burnt

OCCUPATIONAL HEALTH AND SAFETY

Exposure to Respirable Suspended Particulate Matter[8]

The VSBK has a permanent kiln structure and with introduction of the chimneys in the kiln (the initial VSBKs of China did not have chimneys), the air pollutants concentration in the surrounding environment is quite low and the exposure of workers to air pollution is less. However, the workers loading bricks in the kiln shaft are exposed to air pollutants.

The workers loading bricks can develop respiratory tract infections.

Exposure to Thermal Stress[9]

Because of shading and insulation of the kiln, workers working on the kiln are protected from the direct exposure to Sun and exposure to heat from the kiln is also very low.

This reduces the thermal stress and consequent risk of eye & skin diseases and dehydration among workers.

Risk of accidents

With properly constructed VSBKs having mechanised brick lifting and brick unloading processes, the exposure of workers to accidents is low. However, with VSBKs which are not properly constructed and involve manual lifting and unloading of bricks, the risk of injuries could be high.

Low risk of injuries

Compliance with ILO standards and remarks on migratory labour and conditions of labour

Practices followed at vertical shaft brick kiln enterprises do not always comply with the International Labour Standards on occupational health and safety drawn up by ILO[10] .

The working conditions in the Vietnamese kilns which involve local labour are better compared to VSBKs in India and Nepal, which employs migrant labour.

4 VERTICAL SHAFT BRICK KILN TECHNOLOGY (VSBK)

MARCH 2014

CONCLUSION

Performance of vertical shaft brick kiln is compared with the most commonly used continuous kiln technology in the region which is FCBTK.

PARAMETERS		VSBK	FCBTK	COMMENTS
AIR EMISSION (g/kg FIRED BRICK)	CO2	70.5	131	Vertical shaft brick kiln emits ~85% lower PM and negligible amount of Black Carbon as compared to FCBTKs. This is mainly because of better combustion of fuel and use of internal fuel. Emission of CO2 from VSBK is lower because of less consumption of fuel.
	Black Carbon	0.001	0.13	
	PM	0.15	1.18	
	CO	1.84	2.0	
FUEL & ENERGY	SEC (MJ/kg fired brick)	0.8	1.30	VSBK consumes ~35% less fuel as compared to FCBTK because of better combustion & heat recovery and low heat losses.
FINANCIAL PERFORMANCE	Capital Cost (USD)	60,000-80,000	50,000-80,000	Capital cost of setting up of a VSBK is around 1.5-2 times more as compared to FCBTK for the same production capacity. This is mainly because of the cost of equipments and construction of the kiln.
	Production Capacity	1.5-3 million bricks/year	3-8 million bricks/year	
	Simple Payback	0.9 – 1.8 years	0.4 – 1.1 years	
PRODUCT QUALITY	Types of product	Solid & Perforated bricks	All kind of products	VSBK is suited for firing only solid and perforated bricks; however, all types of product can be fired in a FCBTK. The quality of bricks fired in VSBKs are better as compared to those from FCBTKs.
	Good Quality Product	90 %	60 %	
OHS	Exposure to dust			Vertical shaft brick kiln enterprise offers better OHS conditions as compared to a FCBTK enterprise.
	Exposure to Thermal stress			
	Risk of accidents			

FOR MORE INFORMATION:

www.gkspl.in/whats_new.html; www.ecobrick.in

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6 Ibid 1.

7 Report on 'Brick Kiln Performance Assessment' available at http://www.unep.org/ccac/Portals/24183/docs/Brick_Kilns_Performance_Assessment.pdf

8 Report on 'Occupational health and safety study (OHSS) of brick industry in the Kathmandu valley' by Department of Environmental Sciences and Engineering (DESE), Kathmandu University, Nepal

9 Ibid.

10 International Labour Standards are instruments drawn up by ILO in the form of conventions (the basic principles to be implemented) and recommendations (more detailed guidelines). Details on the standards for OHS can be found at http://www.ilo.org/global/%20standards/subjects-covered-by-international-labour-standards/occupational-safety-and-health/lang--en/index.htm. A list of all such instruments on OHS with their status is available at http://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12030:0::NO:::#Occupational_safety_and_health

ACKNOWLEDGEMENT

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5 HOFFMAN KILN TECHNOLOGY

INTRODUCTION AND HISTORY[1,2]

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.

Hoffman kiln was developed and patented by Friedrich Hoffman in Germany in the year 1858. These kilns were once widely used in Europe for bricks, ceramics and lime production. Hoffman kiln technology was introduced in India in the Malabar coastal region (south-west coast) by the German missionaries in 19th century and is still prevalent in the same region.

The original design of Hoffman kiln had a circular circuit built around a central chimney. However, this design has been modified with time and now Hoffman kilns with elliptical or rectangular shape are more in practice.

GEOGRAPHICAL DISTRIBUTION

ABOUT THE KILN

Kiln

CONTINUOUS MOVING FIRE

ENTERPRISES USING THIS TECHNOLOGY

Nature of enterprise

INDUSTRIAL

Level of mechanization

SEMI MECHANIZED

Brick produced

SOLID & HOLLOW

Production capacity

MEDIUM
Between
1-10 million bricks

Operational season

PERENNIAL

NUMBER OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION*

Country	Number of enterprises	Total production billion bricks/year
India[3]	~500	~2

*Numbers are estimates only

% CONTRIBUTION TO THE TOTAL BRICK PRODUCTION IN INDIA

~1%

Out of the total annual production of around 250 billion bricks in India, only around 2 billion bricks are produced by Hoffman kiln technology

5 HOFFMAN KILN TECHNOLOGY

DESCRIPTION AND WORKING

1

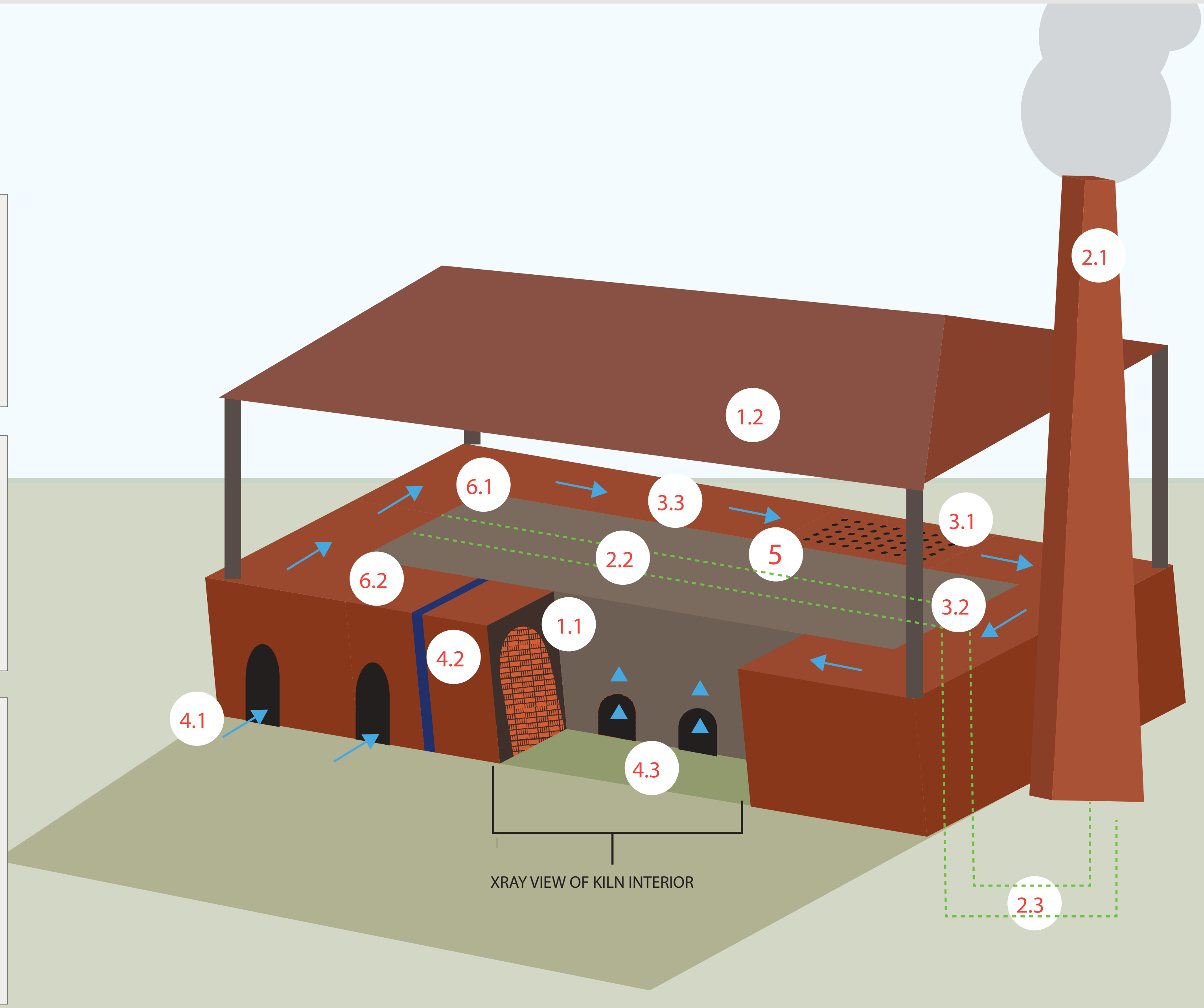
In a Hoffman kiln, the fire moves through the bricks stacked in an elliptical or rectangular shaped annular circuit (central perimeter 80 – 90 m) which is covered with an arched roof (1.1). The kiln structure is usually covered with a shade (1.2) to protect it from rains.

2

The fire movement is caused by the draught provided by a chimney (2.1) (25 – 35 m 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 (2.2) of the kiln through an underground duct (2.3).

3

There are 3 distinct zones in an operating Hoffman kiln:
3.1 Brick firing zone where the fuel is fed and combustion is happening,
3.2 Brick preheating zone (in front of the firing zone) where green bricks are stacked and being pre heated by the flue gases and
3.3 Brick cooling zone (behind the firing zone) where fired bricks are cooled by the cold air flowing into the kiln.



4

4.1 Air Inlet: Air enters into the kiln from the back end of the cooling zone which is kept open to allow air entrance.
4.2 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.
4.3 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.

5

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.

6

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 (6.1) and an equivalent batch of green bricks is loaded ahead of the brick preheating zone (6.2).

5 HOFFMAN KILN TECHNOLOGY

AIR EMISSIONS AND IMPACTS

MEASURED EMISSION FACTORS

g/kg of fired bricks			
CO_2	Black Carbon	PM	CO

Measured values for emission factors of pollutants are not available for Hoffman kilns in India.

MEASURED PM EMISSIONS[4]

Average: 260 mg/Nm^3

(Range: 200-315 mg/Nm^3)

EMISSION STANDARDS

Notified for PM only

Country	PM (mg/Nm^3)
India	Emission standard has not been notified for Hoffman kilns.

COMMENTS ON EMISSIONS

Better combustion in well operated Hoffman kilns results in low particulate matter emissions.

FUELS AND ENERGY

COMMONLY USED FUELS

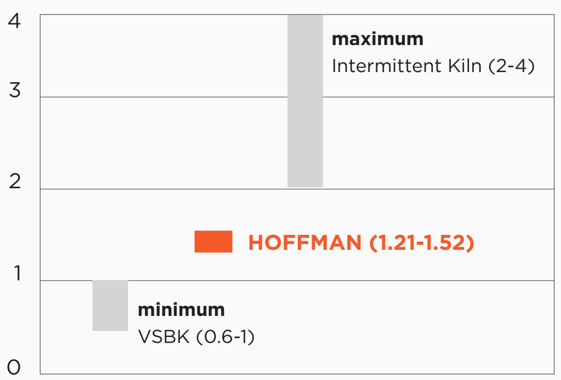
Biomass (mainly firewood)

Coal

SPECIFIC ENERGY CONSUMPTION[5]

Energy consumed for firing 1 kg of fired brick

Average: 1.36 MJ/kg of fired bricks
(Range: 1.21 – 1.52MJ/kg of fired brick)



Note: Measured at firing temperature of 650-800°C

Being a continuous kiln and having good heat recovery features, Hoffman kiln is significantly more efficient compared to intermittent kilns but is less efficient compared to some of the other continuous kilns like VSBK.

MAIN CAUSES FOR HEAT LOSS

The main sources of heat loss in a Hoffman kiln are the heat losses in the flue gases, fired bricks and high thermal mass of the kiln structure.

FINANCIAL PERFORMANCE

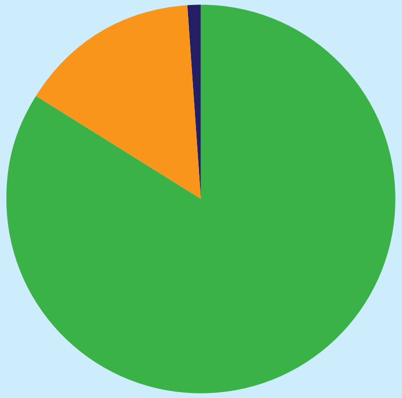
Capital cost of kiln technology

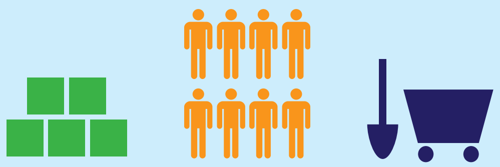
For annual production capacity of 3 – 6 million bricks, excluding land and working capital cost

100,000 to 150,000 USD

Capital cost breakdown

Construction Material	82 %
Labour	15%
Equipment	3%



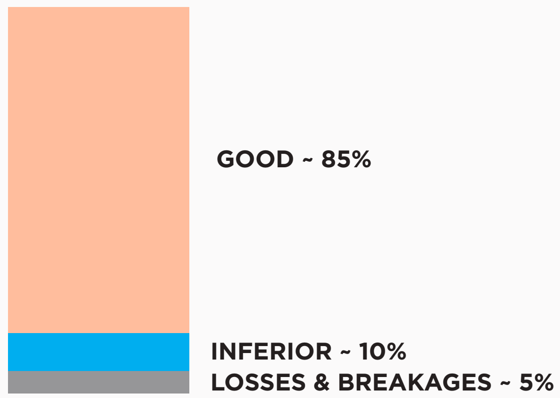


Production capacity	10,000 to 20,000 bricks per day	
Brick size	230 mm x 115 mm x 75 mm	
Number of Operators required	15-20	
Payback Period	Simple Payback	0.8 – 1.1 years
	Discounted Payback (@ 6.5%)	0.9 – 1.2 years

PRODUCT QUALITY

Product Quality

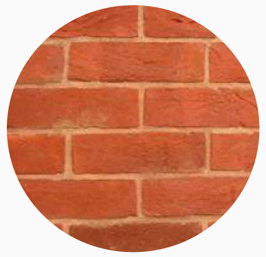
As per the local market perception



Better heat distribution and lower heat losses from kiln walls and roof result in uniform temperature across the kiln cross section in the firing zone thereby resulting in higher percentage of good quality bricks.

Types of product that can be fired in the kiln	Solid bricks	✓
	Hollow/ Perforated bricks	✓
	Roof tiles	✓
	Floor tiles	✓

GOOD BRICK



INFERIOR BRICK

under-fired and over- burnt

OCCUPATIONAL HEALTH AND SAFETY

Exposure to Respirable Suspended Particulate Matter[6]

The concentration of air pollutants in the surrounding environment of a Hoffman kiln is quite low. However, the workers unloading the bricks are exposed to high concentration of dust because of ash of burned fuel.

The workers unloading the bricks have the risk of developing respiratory tract infections and cardio vascular diseases.

Exposure to Thermal Stress[7]

Workers unloading the bricks from the kiln are exposed to high temperature due to radiation from the hot kiln structure.

The workers unloading the bricks bear high thermal stress and the risk of consequent diseases and dehydration.

Risk of accidents

In a properly constructed Hoffman kiln, the risk of accidents is low.

Low risk of injuries to workers.

Compliance with ILO standards and remarks on migratory labour and conditions of labour

Practices followed at Hoffman kiln enterprises do not always comply with the International Labour Standards on occupational health and safety drawn up by ILO.[8]

5 HOFFMAN KILN TECHNOLOGY

MARCH 2014

CONCLUSION

Performance of Hoffman kiln is compared with the most commonly used continuous kiln technology in the region which is FCBTK.

PARAMETERS		HOFFMAN KILN	FCBTK	COMMENTS
AIR EMISSION (g/kg fired brick)	CO_2	NA	131	NA
	Black Carbon	NA	0.13	
	PM	NA	1.18	
	CO	NA	2.0	
FUEL & ENERGY	SEC (MJ/kg fired brick)	1.36	1.30	The working principles of Hoffman kiln and FCBTK are similar and hence fuel consumption is comparable. In a FCBTK, heat loss from the kiln surfaces is prominent while in case of a Hoffman kiln, heat loss due to the thermal mass of the kiln structure is prominent.
FINANCIAL PERFORMANCE	Capital Cost (USD)	100,000-150,000	50,000-80,000	Hoffman kiln has a permanent roof and shade, hence the capital cost of setting up a Hoffman kiln is almost twice as much as FCBTK of similar annual production capacity. Hoffman kilns are usually used for the production of value added products like good quality solid bricks, hollow bricks, roofing tiles, etc. and the payback period of Hoffman kiln is comparable to FCBTK.
	Production Capacity	3-6 million bricks/year	3-8 million bricks/year	
	Simple Payback	0.8 - 1.1 years	0.4 - 1.1 years	
PRODUCT QUALITY	Types of product	All types of products	All types of products	Both the kiln technologies are suitable for firing all types of product. However, the quality of bricks fired in a Hoffman kiln is better as compared to those from FCBTKs. Also while a Hoffman kiln can be used exclusively for production of roofing tiles and hollow bricks, in an FCBTK such exclusive production is not possible.
	Good Quality Product	85 %	60 %	
OHS	Exposure to dust			Hoffman kiln enterprise offers better OHS conditions as compared to a FCBTK enterprise.
	Exposure to Thermal			
	Risk of accidents			

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3 Presentation by Punjab State Council for Science and Technology, India on the findings of the study on "Revision of Comprehensive Industry Document for Brick Kilns".
4 Ibid.
5 Ibid.
6 Report on 'Occupational health and safety study (OHSS) of brick industry in the Kathmandu valley' by Department of Environmental Sciences and Engineering (DESE), Kathmandu University, Nepal
7 Ibid.
8 International Labour Standards are instruments drawn up by ILO in the form of conventions (the basic principles to be implemented) and recommendations (more detailed guidelines). Details on the standards for OHS can be found at http://www.ilo.org/global/%20standards/subjects-covered-by-international-labour-standards/occupational-safety-and-health/lang--en/index.htm. A list of all such instruments on OHS with their status is available at http://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12030:0::NO:::#Occupational_safety_and_health

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6 HYBRID HOFFMAN KILN TECHNOLOGY

INTRODUCTION AND HISTORY[1,2]

Hybrid Hoffman Kiln (HHK) technology was developed and is widely used in China. 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 tunnel dryer to dry green bricks. These features lead to lower energy consumption and reduction of air pollution.

In South Asia, the HHK technology was first introduced in Bangladesh in 2006 under an UNDP-GEF supported project and since then it is being promoted with support from various development projects. As of June 2011, there were 8 HHKs operating in Bangladesh and another 8 were in pipeline.

Photo Credit: The compendium of Case Studies from the GEF Climate Change Portfolio: Transfer of Environmentally Sound Technologies

GEOGRAPHICAL DISTRIBUTION

ABOUT THE KILN

Kiln

CONTINUOUS MOVING FIRE

ENTERPRISES USING THIS TECHNOLOGY

Nature of enterprise	Level of mechanization	Brick produced	Production capacity	Operational season
INDUSTRIAL	SEMI MECHANIZED	SOLID & HOLLOW	LARGE > 10 million bricks	PERENNIAL

NUMBER OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION*

Country	Number of enterprises	Total production billion bricks/year
Bangladesh[3]	~8	~0.12

*Numbers are estimates only

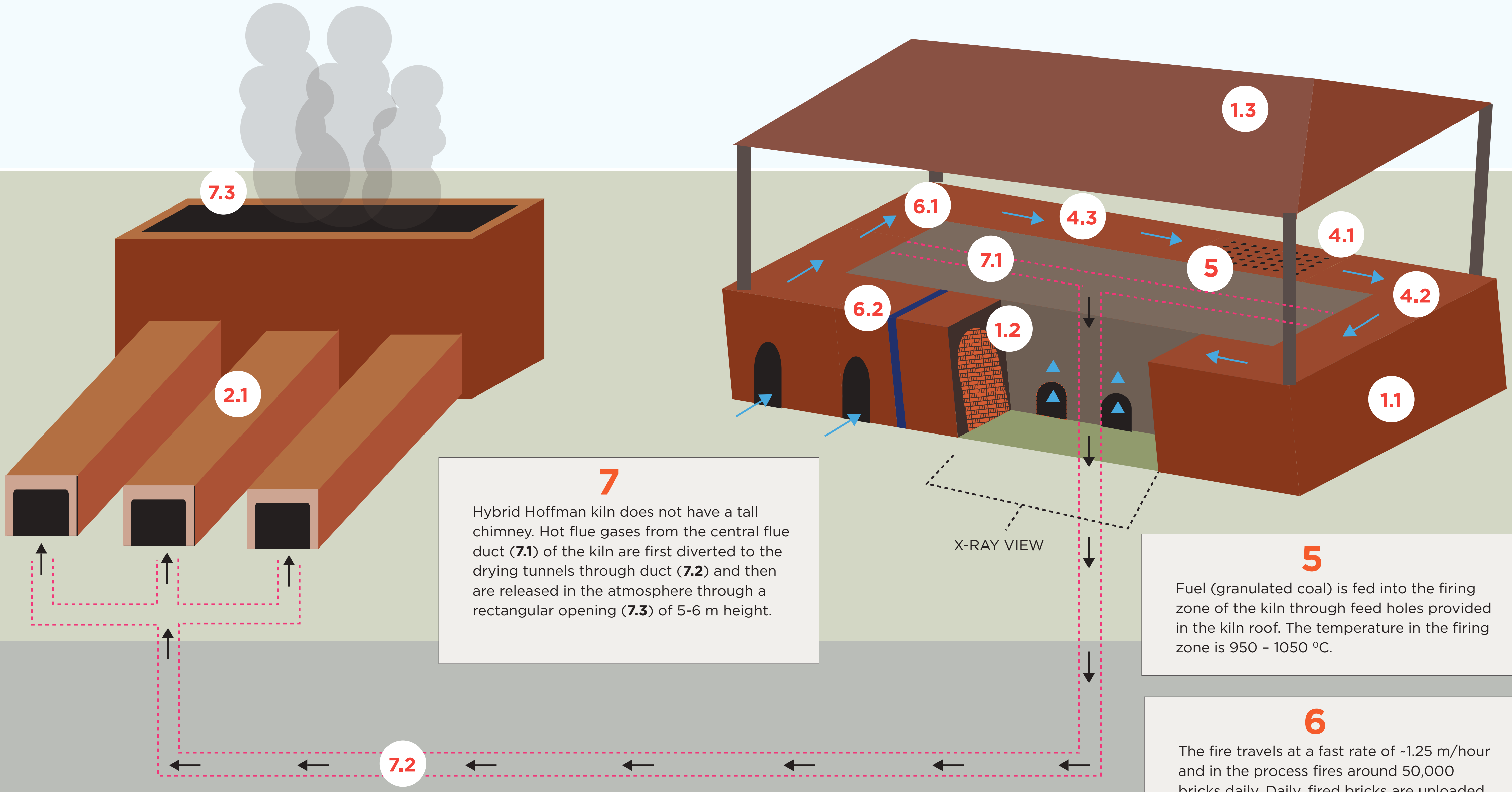
% CONTRIBUTION TO THE TOTAL BRICK PRODUCTION IN BANGLADESH

~1%

Out of the total annual production of around 19 billion bricks in Bangladesh, around 0.12 billion bricks are being produced by hybrid Hoffman kiln technology.

6 HYBRID HOFFMAN KILN TECHNOLOGY

DESCRIPTION AND WORKING



1

In construction, a hybrid Hoffman kiln has a lot of similarities with a Hoffman kiln. The hybrid Hoffman kiln consists of a rectangular shaped annular circuit (**1.1**) (central perimeter 110 – 130 m) with arched roof (**1.2**). The kiln structure is usually covered with a shade (**1.3**) to protect it from rains. The fire moves through the bricks stacked in the annular space. The fire movement is caused by a blower which forces the air required for combustion from behind.

2

Green bricks are produced by mixing powdered fuel with clay. Around 80% of the fuel required for firing bricks is mixed with clay as internal fuel. Green bricks pass through drying tunnels (**2.1**) on trolleys for drying. There are around 8 drying tunnels. Heat contained in the hot flue gases from the kiln is utilized in the drying tunnels. The temperature in the drying tunnel is maintained at around 120 ^{o}C and the drying time is around 24 hours.

3

The dried green bricks are stacked in the kiln such as to form distinct chambers. Each chamber contains 8,000 – 9,000 bricks and is ~5 m in length.

4

Three distinct zones appear in an operating HHK:
4.1 Brick firing zone where the fuel is fed and combustion is happening,
4.2 Brick preheating zone (in front of the firing zone) where green bricks are stacked and being pre heated by the hot flue gases and
4.3 Brick cooling zone (behind the firing zone) where fired bricks are cooled by the cold air flowing into the kiln.

5

Fuel (granulated coal) is fed into the firing zone of the kiln through feed holes provided in the kiln roof. The temperature in the firing zone is 950 – 1050 ^{o}C.

6

The fire travels at a fast rate of ~1.25 m/hour and in the process fires around 50,000 bricks daily. Daily, fired bricks are unloaded from the back end of the brick cooling zone (**6.1**) and an equivalent batch of green bricks is loaded ahead of the brick preheating zone (**6.2**).

7

Hybrid Hoffman kiln does not have a tall chimney. Hot flue gases from the central flue duct (**7.1**) of the kiln are first diverted to the drying tunnels through duct (**7.2**) and then are released in the atmosphere through a rectangular opening (**7.3**) of 5-6 m height.

6 HYBRID HOFFMAN KILN TECHNOLOGY

AIR EMISSIONS AND IMPACTS

MEASURED EMISSION FACTORS

g/kg of fired bricks			
CO_2[4]	Black Carbon	PM[5]	CO
Average			
100	NA	0.29	NA

Emission factor values are available for CO_2 and PM emissions only

MEASURED PM EMISSIONS[6]

Average: 20.3 mg/Nm³

(Range: 15.8 – 26.9 mg/Nm³)

EMISSION STANDARDS

Notified for PM only

Country	PM (mg/Nm³)
Bangladesh	No emission standard has been notified for HHK technology.

COMMENTS ON EMISSIONS

Because of use of internal fuel, particles generated during combustion are reduced significantly. Also a part of the particulate matter gets deposited on green bricks in the drying tunnel; this further reduces the particulate emission.

FUELS AND ENERGY

COMMONLY USED FUELS

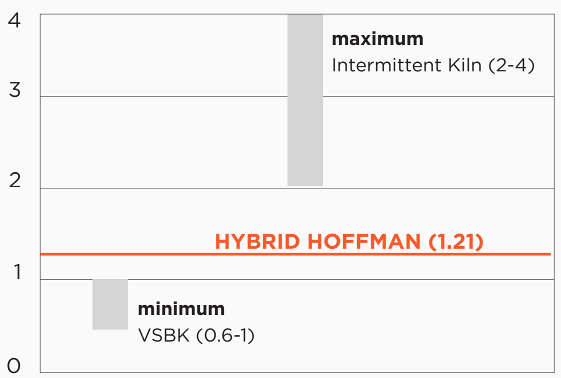
Coal
Most commonly used

SPECIFIC ENERGY CONSUMPTION[7]

Energy consumed for firing 1 kg of fired brick

Average: 1.2 MJ/kg of fired bricks
(Range: As the SEC is measured for only one kiln, range of SEC values is not available.)

MJ/kg of fired brick



Note: Measured at firing temperature of 950-1050°C

Because of good waste heat recovery features, HHK is an efficient kiln technology.

MAIN CAUSES FOR HEAT LOSS

Heat losses in the kiln structure and heat contained in the fired bricks are the main cause of heat losses in HHK.

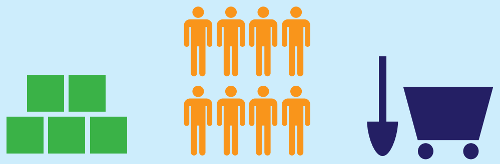
FINANCIAL PERFORMANCE

Capital cost of kiln technology[8]
For annual production capacity of around 15 – 18 million bricks, excluding cost of land and buildings.

600,000 – 650,000 USD

Capital cost breakdown

Construction Material	NA
Labour	NA
Equipment	NA



Production capacity	50,000 bricks per day	
Brick size	250 mm x 120 mm x 60 mm & 240 mm x 115 mm x 53 mm	
Number of Operators required	30-40	
Payback Period	Simple Payback	1.1 – 1.4 years
	Discounted Payback (@ 6.5%)	1.2 – 1.5 years

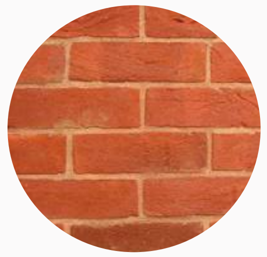
PRODUCT QUALITY

Product Quality
As per the local market perception

Better heat distribution and lower heat losses from kiln walls and roof result in uniform temperature across the kiln cross section in the firing zone thereby resulting in higher percentage of good quality bricks.

Types of product that can be fired in the kiln		
	Solid bricks	✓
	Hollow/ Perforated bricks	✓
	Roof tiles	✓
	Floor tiles	✓

GOOD BRICK



INFERIOR BRICK
under-fired and over- burnt

OCCUPATIONAL HEALTH AND SAFETY

Exposure to Respirable Suspended Particulate Matter[9]
The concentration of air pollutants in the surrounding environment of a hybrid Hoffman kiln is quite low. However, firemen feeding the pulverised coal and workers unloading the bricks are exposed to moderate dust concentration.

Firemen and workers unloading the bricks have moderate risk of developing respiratory tract infections and cardio vascular diseases.

Exposure to Thermal Stress[10]
Workers unloading the bricks from the kiln are exposed to high temperature due to radiation from hot kiln structure.

Workers unloading the bricks have a risk of consequent diseases and dehydration.

Risk of accidents
In a properly constructed hybrid Hoffman kiln, the risk of accidents is low.

Low risk of injuries to workers.

Compliance with ILO standards and remarks on migratory labour and conditions of labour
Practices followed at Hoffman kiln enterprises do not always comply with the International Labour Standards on occupational health and safety drawn up by ILO.[11]

6 HYBRID HOFFMAN KILN TECHNOLOGY

MARCH 2014

CONCLUSION

Performance of hybrid Hoffman kiln is compared with the most commonly used continuous kiln technology in the region which is FCBTK.

PARAMETERS		HYBRID HOFFMAN KILN	FCBTK	COMMENTS
AIR EMISSION (g/kg FIRED BRICK)	CO_2	100	131	Because of efficient combustion and use of internal fuel, hybrid Hoffman kiln emits ~75 % less PM as compared to FCBTK. Emission of CO_2 from HHK is ~25 % lower because of less fuel consumption.
	Black Carbon	NA	0.13	
	PM	0.29	1.18	
	CO	NA	2.0	
FUEL & ENERGY	SEC (MJ/kg fired brick)	1.20	1.30	Because of better heat recovery feature in a HHK, it consumes marginally less fuel as compared to FCBTK.
FINANCIAL PERFORMANCE	Capital Cost (USD)	600,000 - 650,000	50,000-80,000	The capital cost of HHK is substantially higher as compared to FCBTK mainly because of semi-mechanisation of brick production and tunnel drying system.
	Production Capacity	15 – 18 million bricks/year	3-8 million bricks/year	
	Simple Payback	1.1 - 1.4 years	0.4 - 1.1 years	
PRODUCT QUALITY	Types of product	All types of products	All types of products	Both the kiln technologies are suitable for firing all types of product. However, the quality of bricks fired in a hybrid Hoffman kiln is better as compared to those from FCBTKs. Also while a hybrid Hoffman kiln can be used exclusively for production of roofing tiles and hollow bricks, in an FCBTK such exclusive production is not possible.
	Good Quality Product	90 %	60 %	
OHS	Exposure to dust			Hybrid Hoffman kiln enterprise offers better OHS conditions as compared to a FCBTK enterprise.
	Exposure to Thermal			
	Risk of accidents			

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4 Ibid. 1
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10 Ibid.
11 International Labour Standards are instruments drawn up by ILO in the form of conventions (the basic principles to be implemented) and recommendations (more detailed guidelines). Details on the standards for OHS can be found at http://www.ilo.org/global/%20standards/subjects-covered-by-international-labour-standards/occupational-safety-and-health/lang--en/index.htm. A list of all such instruments on OHS with their status is available at http://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12030:0::NO:::#Occupational_safety_and_health

ACKNOWLEDGEMENT

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7 TUNNEL KILN TECHNOLOGY

INTRODUCTION AND HISTORY[1]

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, better control over the firing process and high quality of the the products.

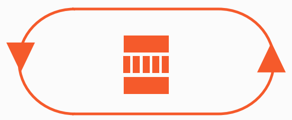
The tunnel kiln technology was developed around mid 19th century in Germany. However, the application of the technology for brick firing took place in the 20th century. After the Second World War, the technology was widely adopted and led to the transformation of the European brick industry from several thousand small and scattered brick making units into a few hundred large scale and highly mechanised tunnel kiln units.

In Asia, China and Vietnam started adopting the technology during the 1970's and now have several hundred tunnel kilns in operation. In India, there are very few (~5) tunnel brick kiln units.

GEOGRAPHICAL DISTRIBUTION

ABOUT THE KILN

Kiln



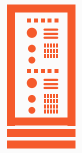
CONTINUOUS MOVING WARE

ENTERPRISES USING THIS TECHNOLOGY

Nature of enterprise

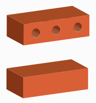
INDUSTRIAL

Level of mechanization



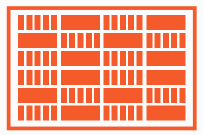
MECHANIZED

Brick produced



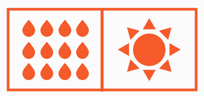
SOLID AND PERFORATED

Production capacity



LARGE
>10 million bricks

Operational season



PERENNIAL

NUMBER OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION*

Country	Number of enterprises	Total production billion bricks/year
Vietnam[2]	~700	~10.5
India[3]	~5	~0.08

*Numbers are estimates only

% CONTRIBUTION TO THE TOTAL BRICK PRODUCTION IN INDIA AND VIETNAM

~4%

Out of the total annual production of around 280 billion bricks in India and Vietnam only around 10.6 billion bricks are produced by tunnel kiln technology

7 TUNNEL KILN TECHNOLOGY

DESCRIPTION AND WORKING

1

In a tunnel kiln, a continuous moving ware kiln, the clay products/bricks to be fired are passed on cars (**1.1**) through a long horizontal tunnel (**1.2**). The firing of bricks occurs at the central part of the tunnel. The length of tunnel can vary from 60 m to 150 m.

2

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.

3

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.

4

Three distinct zones appear in an operating tunnel kiln:
4.1 Brick firing zone where the fuel is fed and combustion is happening,
4.2 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
4.3 Brick cooling zone (ahead of the firing zone) where fired bricks are cooled by the cold air flowing into the kiln.

5

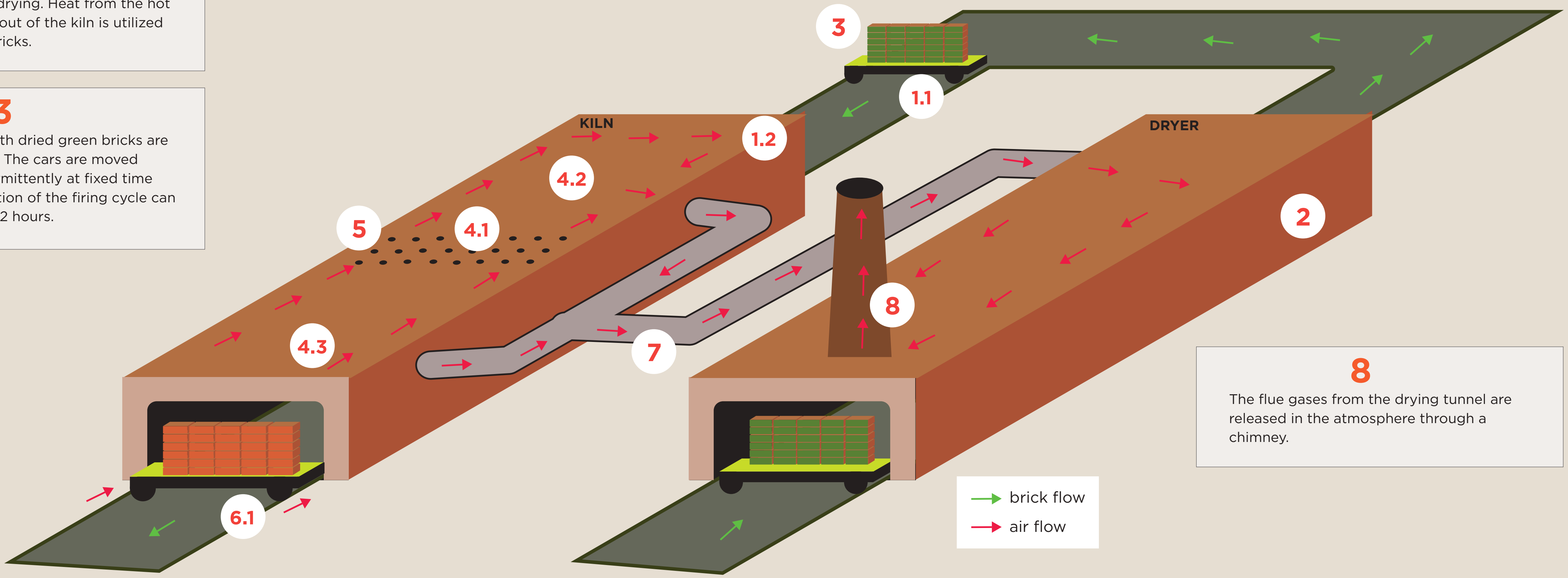
Fuel (granulated/pulverised coal) is fed into the firing zone of the kiln through feed holes provided in the kiln roof. The firing zone usually extends up to 8 cars. The temperature in the firing zone is maintained at 900 – 1050°C.

6

There is counter current heat transfer between the bricks and the air. Cold air enters the kiln from the car exit end (6.1) 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.

7

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.



8

The flue gases from the drying tunnel are released in the atmosphere through a chimney.

7 TUNNEL KILN TECHNOLOGY

AIR EMISSIONS AND IMPACTS

MEASURED EMISSION FACTORS[4,5]

g/kg of fired bricks			
CO_2	Black Carbon	PM	CO
Average			
166.3	negligible	0.24	3.31
Range			
NA	NA	0.175 – 0.31	2.45 – 4.18

MEASURED PM EMISSIONS

Average: 41 mg/Nm³

(Range: 21– 53 mg/Nm³)

EMISSION STANDARDS

Notified for PM only

Country	PM (mg/Nm³)
India	No emission standard has been notified for tunnel brick kilns
Vietnam	No emission standard has been notified for tunnel brick kilns

COMMENTS ON EMISSIONS

Better fuel combustion results in lower emissions from a tunnel kiln.

FUELS AND ENERGY

COMMONLY USED FUELS

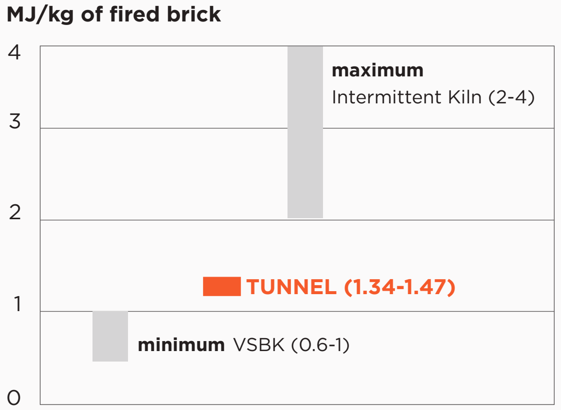
Coal

Petcoke

SPECIFIC ENERGY CONSUMPTION[6,7]

Energy consumed for firing 1 kg of fired brick

Average: 1.4 MJ/kg of fired bricks
(Range: 1.34 – 1.47 MJ/kg of fired brick)



Note: Measured at firing temperature of 950-1000°C

The specific energy consumption in a tunnel kiln is slightly higher as compared to other continuous kiln technologies. This is mainly because the SEC also includes the energy utilised for the drying of bricks in the tunnel dryer.

MAIN CAUSES FOR HEAT LOSS

Heat contained in the kiln cars and fired bricks at the kiln exit and in hot flue gases are the main sources of heat loss in tunnel kilns.

FINANCIAL PERFORMANCE

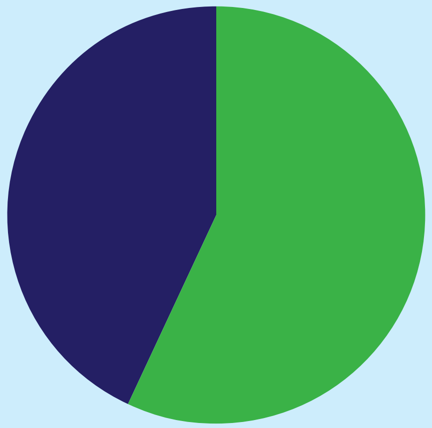
Capital cost of kiln technology

for an annual production capacity of ~15 million bricks, excluding cost of land and buildings

~1,000,000 USD

Capital cost breakdown

Construction Material + labour	57 %
Equipment	43%



Production capacity	~50,000 bricks per day	
Brick size	230 mm x 115 mm x 75 mm	
Number of Operators required	~20	
Payback Period	Simple Payback	~2 years
	Discounted Payback (@ 6.5%)	~2.2 years

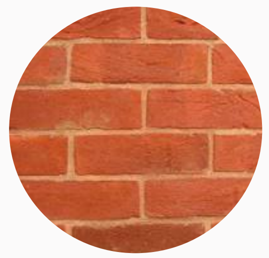
PRODUCT QUALITY

Product Quality
As per the local market perception

Better heat distribution results in uniform temperature across the kiln cross section in the firing zone thereby resulting in a higher percentage of good quality bricks.

Types of product that can be fired in the kiln		
	Solid bricks	✓
	Hollow/ Perforated bricks	✓
	Roof tiles	✓
	Floor tiles	✓

GOOD BRICK



INFERIOR BRICK

under-fired and over- burnt

OCCUPATIONAL HEALTH AND SAFETY

Exposure to Respirable Suspended Particulate Matter[8]

The concentration of air pollutants in the surrounding environment of a tunnel kiln is low

The workers have low risk of developing respiratory tract infections and cardio vascular diseases.

Exposure to Thermal Stress[9]

Exposure of workers to heat from the kiln is quite low.

This reduces the thermal stress and consequent risk of eye & skin diseases and dehydration among workers.

Risk of accidents

In a well operated tunnel kiln, the risk of accidents is low.

Low risk of injuries

Compliance with ILO standards and remarks on migratory labour and conditions of labour

Practices followed at tunnel kiln enterprises do not always comply with the International Labour Standards on occupational health and safety drawn up by ILO.[10]

Because of mechanisation of the processes, the working conditions of workers in tunnel kiln enterprises are relatively better.

7 TUNNEL KILN TECHNOLOGY

CONCLUSION

MARCH 2014

Performance of tunnel kiln is compared with the most commonly used continuous kiln technology in the region which is FCBTK.

PARAMETERS		TUNNEL	FCBTK	COMMENTS
AIR EMISSION (g/kg FIRED BRICK)	CO_2	166.3	131	Tunnel kiln emits ~80% lower PM and negligible BC as compared to FCBTK. This is mainly because of better combustion and use of internal fuel. The emission of CO is higher in case of tunnel kiln, probably due to incomplete combustion of internal fuel.
	Black Carbon	0.00	0.13	
	PM	0.24	1.18	
	CO	3.31	2.0	
FUEL & ENERGY	SEC (MJ/kg fired brick)	1.4	1.30	Tunnel kiln consumes marginally higher energy as compared to FCBTK. It is to be noted that the SEC in tunnel kilns also includes the energy utilised for the drying of bricks in the tunnel dryer.
FINANCIAL PERFORMANCE	Capital Cost (USD)	~1,000,000	50,000-80,000	The capital cost of tunnel kiln is substantially higher as compared to FCBTK mainly because of mechanisation of brick production processes and considerably larger production.
	Production Capacity	~15 million bricks/year	3-8 million bricks/year	
	Simple Payback	~2 years	0.4 - 1.1 years	
PRODUCT QUALITY	Types of product	All types of products	All types of products	Both the kiln technologies are suitable for firing all types of product. However, the quality of bricks fired in tunnel kilns is better as compared to those from FCBTKs. Also while a tunnel kiln can be used exclusively for production of hollow bricks, in a FCBTK such exclusive production is not possible.
	Good Quality Product	95 %	60 %	
OHS	Exposure to dust			Tunnel kiln enterprise offers better OHS conditions as compared to a FCBTK enterprise.
	Exposure to Thermal			
	Risk of accidents			

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9 Ibid.
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8 CLAMPS

INTRODUCTION AND HISTORY[1,2]

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 generally piled up on a thin bed of fuel (usually in case of coal fired clamps). Where spreading of fuel in thin bed is not possible (usually in the case of firewood fired clamps), tunnels are made through the base of the pile in order to feed the fuel. In an improved version of clamp, the outer walls are plastered (scoved) with mud to reduce the heat loss and thus are termed as Scove kiln. The other improvement is Scotch kiln in which the base, fire tunnels and outer walls are permanently built with bricks. In this factsheet, all these variations are referred as clamps.

Till the end of 18th century, bricks were almost exclusively fired in clamps. However, with the introduction of continuous kilns and mechanisation, clamps were gradually phased out from the developed countries, but these are still prevalent in developing countries.

GEOGRAPHICAL DISTRIBUTION

ABOUT THE KILN

ENTERPRISES USING THIS TECHNOLOGY

Kiln	Nature of enterprise	Level of mechanization	Brick produced	Production capacity	Operational season
INTERMITTANT	ARTISINAL	MANUAL	SOLID	MICRO/ SMALL SCALE <1 million bricks	DRY SEASON

NUMBER OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION*

Country	Number of enterprises	Total production billion bricks/year
India[3]	~100,000	~50

*Numbers are estimates only

% CONTRIBUTION TO THE TOTAL BRICK PRODUCTION IN INDIA

~20%

Out of the total annual production of around 250 billion bricks in India, around 50 billion bricks are produced in clamps.

8 CLAMPS

DESCRIPTION AND WORKING

1

A clamp does not have a permanent kiln structure. It consists essentially of an organised pile of green bricks interspersed with combustible material.

2

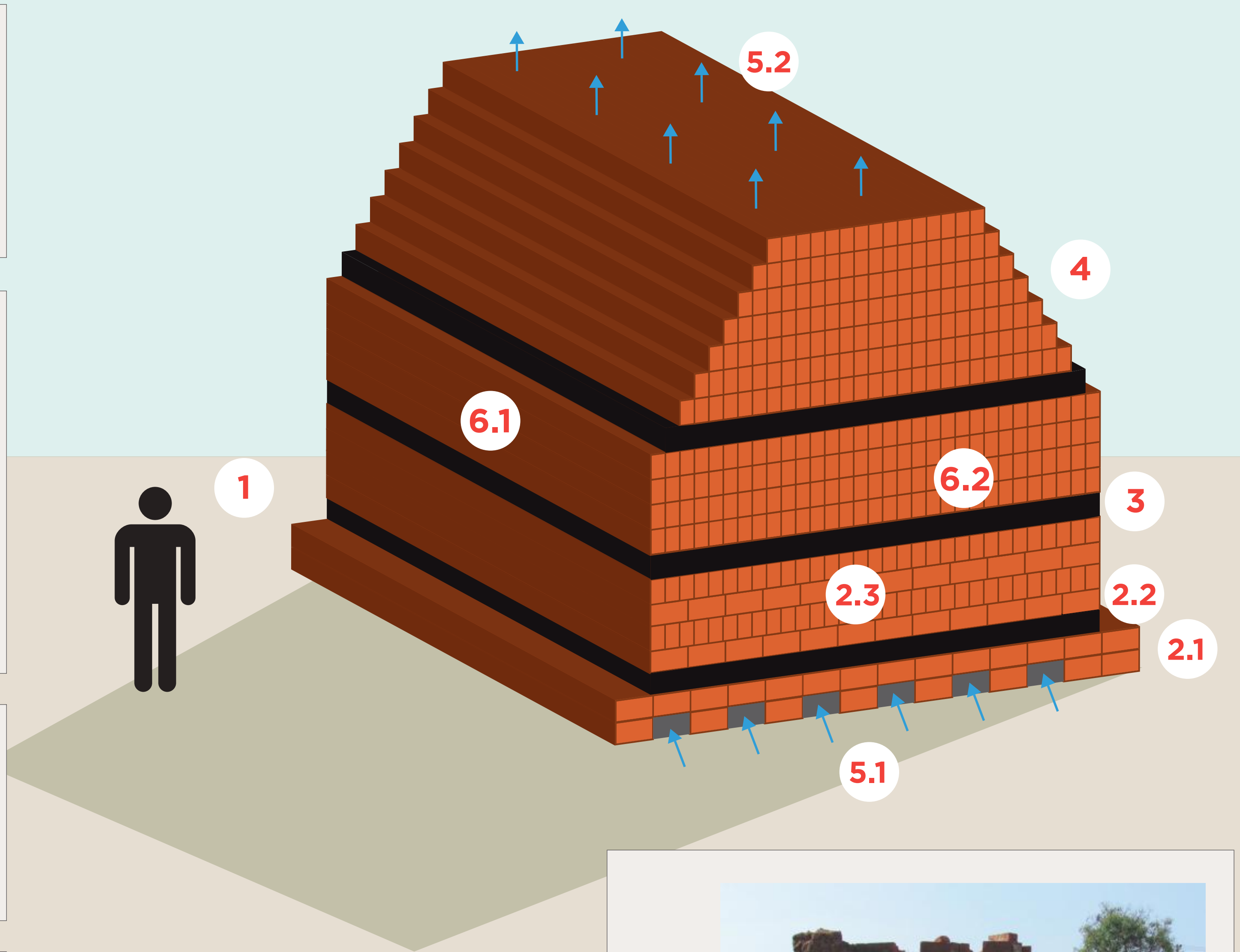
The base (**2.1**) of the clamp is first laid with fired bricks. Generally, in case of coal fired bricks, a thin layer of fuel (**2.2**) is spread over the base on which the green bricks are stacked (**2.3**). In case of firewood fired clamps, tunnels are made through the base of the pile to feed firewood. 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. (**2.4**)

3

In bigger coal fired clamps, to attain the required firing temperature throughout the brick stacking, fuel is also added in the spacings/holes provided in the brick stacking.

4

For stability of the clamp structure, usually the upper part of the clamp has a trapezoidal shape.



2.4

Photograph of rice husk fired clamp

5

The clamps are ignited at the bottom. Air required for combustion, enters through the openings provided in the base of clamp **(5.1)**. During burning, the hot air rises up through the bricks and heats the bricks. Smoke and fumes leave from the top of the clamp **(5.2)**. 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.

6

Because of heat loss to the surroundings, bricks located on the surface are usually under-fired **(6.1)**. Also bricks located near to the fuel layer are usually over-burnt **6.2)**.

7

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.

8

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.

8 CLAMPS

AIR EMISSIONS AND IMPACTS

MEASURED EMISSION FACTORS

g/kg of fired bricks	
Clamps do not have a chimney stack and therefore, stack emissions can't be measured.	

MEASURED PM EMISSIONS

Not available

EMISSION STANDARDS

Notified for PM only

Country	PM (mg/Nm^3)
India	No emission standard has been notified for clamp kilns.

COMMENTS ON EMISSIONS

Emission values are not measured for clamps.

FUELS AND ENERGY

COMMONLY USED FUELS

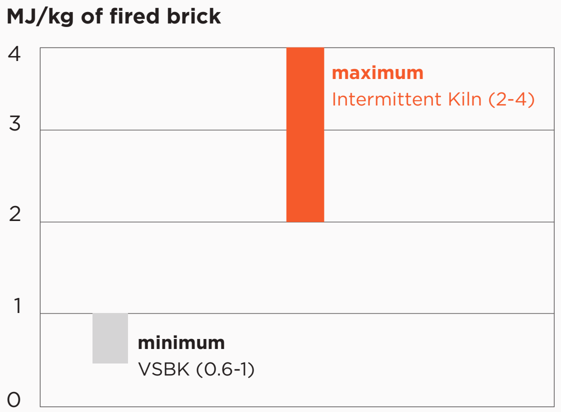
Coal
(Central & Western India)

Biomass
(firewood, rice husk, etc.)
(Southern India)

SPECIFIC ENERGY CONSUMPTION[4]

Energy consumed for firing 1 kg of fired brick

Range: 2.0 - 4.0 MJ/kg of fired brick



Note: Measured at firing temperature of 900-1050°C

Because of inefficient combustion and no heat recovery feature, clamp kilns are inefficient. In clamps, the green bricks are first heated up during firing process and then left for cooling with no heat recovery. Consequently all the heat is lost to the surrounding area.

MAIN CAUSES FOR HEAT LOSS

Heat loss from the kiln surfaces, loss of heat contained in the fired bricks and incomplete combustion are the main source of heat loss in clamps.

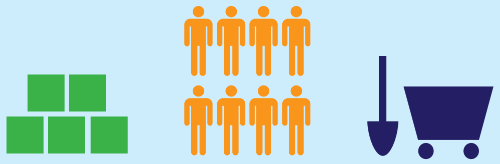
FINANCIAL PERFORMANCE

Capital cost of kiln technology

As the clamps do not have a kiln structure, no capital cost is considered for setting up of a clamp.

Capital cost breakdown

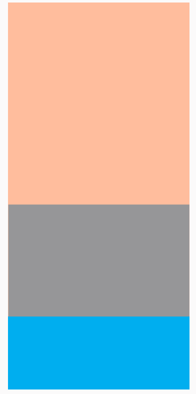
Construction Material	NA
Labour	NA
Equipment	NA



Production capacity	10,000 to 200,000 bricks per batch	
Brick size	230 mm x 115 mm x 75 mm	
Number of Operators required	~10	
Payback Period	Simple Payback	NA
	Discounted Payback (@ 6.5%)	NA

PRODUCT QUALITY

Product Quality
As per the local market perception



GOOD ~ 50%

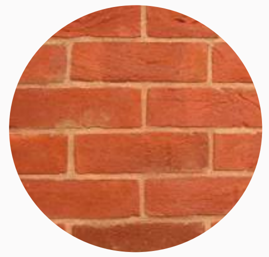
INFERIOR ~ 30%

LOSSES & BREAKAGES ~ 20%

Because of heat loss from the outer surfaces, the bricks stacked in the outer layers of the kiln are usually under-fired. The bricks located near the fuel layer or fuel feeding tunnels may be over fired. Also the operator has very little control over the firing process and hence it is difficult to control the quality of bricks.

Types of product that can be fired in the kiln	Solid bricks	✓
	Hollow/ Perforated bricks	x
	Roof tiles	x
	Floor tiles	x

GOOD BRICK



INFERIOR BRICK

under-fired and over- burnt

OCCUPATIONAL HEALTH AND SAFETY

Exposure to Respirable Suspended Particulate Matter[5]

During the firing of clamps and during unloading of bricks, the workers are exposed to high concentration of particulate pollutants.

These workers have the risk of developing respiratory tract infections and cardio vascular diseases.

Exposure to Thermal Stress[6]

In case of clamps where continuous feeding of fuel is required, firemen are exposed to the radiation from flames and kiln surfaces.

Firemen are exposed to thermal stress and consequent risk of eye & skin diseases and dehydration among workers.

Risk of accidents

During stacking and unloading of bricks there is danger of falling off the brick setting.

Workers stacking and unloading the bricks have risk of injuries.

Compliance with ILO standards and remarks on migratory labour and conditions of labour

Practices followed at clamps do not comply with the International Labour Standards on occupational health and safety drawn up by ILO[7] .

Most of the small scale clamp kilns are family based enterprises. However, in larger units, majority of the workers of are seasonal migrants and they along with their families work on the kilns. They live in temporary housing with poor access to basic amenities like safe drinking water, electricity, education, health and sanitation.

8 CLAMPS

CONCLUSION

MARCH 2014

Facts about clamp kilns, the most commonly used intermittent kilns in the region.

PARAMETERS		CLAMPS	COMMENTS
AIR EMISSION (g/kg FIRED BRICK)	**CO2**	NA	As clamps do not have a chimney stack, stack emissions are not measured. However measurements in similar intermittent kiln like down draught kiln indicates that emissions from clamp are relatively on the higher side.
	Black Carbon	NA	
	PM	NA	
	CO	NA	
FUEL & ENERGY	**SEC (MJ/kg fired brick)**	2.10	Because of inefficient combustion and no heat recovery feature, clamp kilns are inefficient.
FINANCIAL PERFORMANCE	**Capital Cost (USD)**	NA	As the clamps do not have a kiln structure, no capital cost is considered for setting up of a clamp.
	Production Capacity (bricks per batch)	10,000-200,000	
	Simple Payback	NA	
PRODUCT QUALITY	**Types of product**	Only Solid Bricks	Only solid bricks can be fired in clamps. Heat loss from the kiln surfaces results in poor quality of bricks in outer layers, while bricks stacked near the fuel layers are usually over fired.
	Good Quality Product	~50%	
OHS	**Exposure to dust**		Clamp kiln enterprises have poor OHS conditions and it is a major shortcoming of this technology.
	Exposure to Thermal stress		
	Risk of accidents		

Scove Kiln

Scotch Kiln

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3 Presentation by Punjab State Council for Science and Technology, India on the findings of the study on "Revision of Comprehensive Industry Document for Brick Kilns".
4 Ibid.
5 Report on 'Occupational health and safety study (OHSS) of brick industry in the Kathmandu valley' by Department of Environmental Sciences and Engineering (DESE), Kathmandu University, Nepal
6 Ibid.
7 International Labour Standards are instruments drawn up by ILO in the form of conventions (the basic principles to be implemented) and recommendations (more detailed guidelines). Details on the standards for OHS can be found at http://www.ilo.org/global/%20standards/subjects-covered-by-international-labour-standards/occupational-safety-and-health/lang--en/index.htm. A list of all such instruments on OHS with their status is available at http://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12030:0::NO:::#Occupational_safety_and_health

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9 DOWN DRAUGHT KILN (DDK)

INTRODUCTION AND HISTORY[1,2]

The down draught kiln is an intermittent kiln in which the bricks are fired in batches. 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.

Till the end of 18th century, bricks were almost exclusively fired in freely stacked heaps of clamp kilns. However, in early 19th century, various technological modifications were tried aimed at improving the product quality and energy efficiency of the kilns. In the process, first up draught and then the down draught kilns were developed.

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.

GEOGRAPHICAL DISTRIBUTION

ABOUT THE KILN

ENTERPRISES USING THIS TECHNOLOGY

Kiln	Nature of enterprise	Level of mechanization	Brick produced	Production capacity	Operational season
INTERMITTENT	INDUSTRIAL	MANUAL	SOLID	SMALL Between 0.5-1 million bricks	DRY SEASON

NUMBER OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION*

Country	**Number of enterprises**	**Total production** billion bricks/year
India[3]	~300	~0.24

*Numbers are estimates only

% CONTRIBUTION TO THE TOTAL BRICK PRODUCTION IN INDIA

~1%

Out of the total annual production of around 250 billion bricks in India, only around 0.24 billion bricks are produced by down draught kiln technology

9 DOWN DRAUGHT KILN (DDK)

DESCRIPTION AND WORKING

1

Down draught kiln is an intermittent kiln in which bricks are fired in batches. It consists of a firing chamber/kiln (**1.1**) connected with a chimney (**1.2**) through an underground flue duct (**1.3**). Fireboxes (**1.4**) 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.

2

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. Each chamber has a capacity of firing 20,000 – 40,000 bricks in a batch.

3

The bricks stacked in the chamber/kiln are not in direct contact with the flames. The hot gases from the burning fuel are deflected to the roof of the kiln (**3.1**). They are then drawn downwards by the chimney draught through the green bricks to fire them (**3.2**).

4

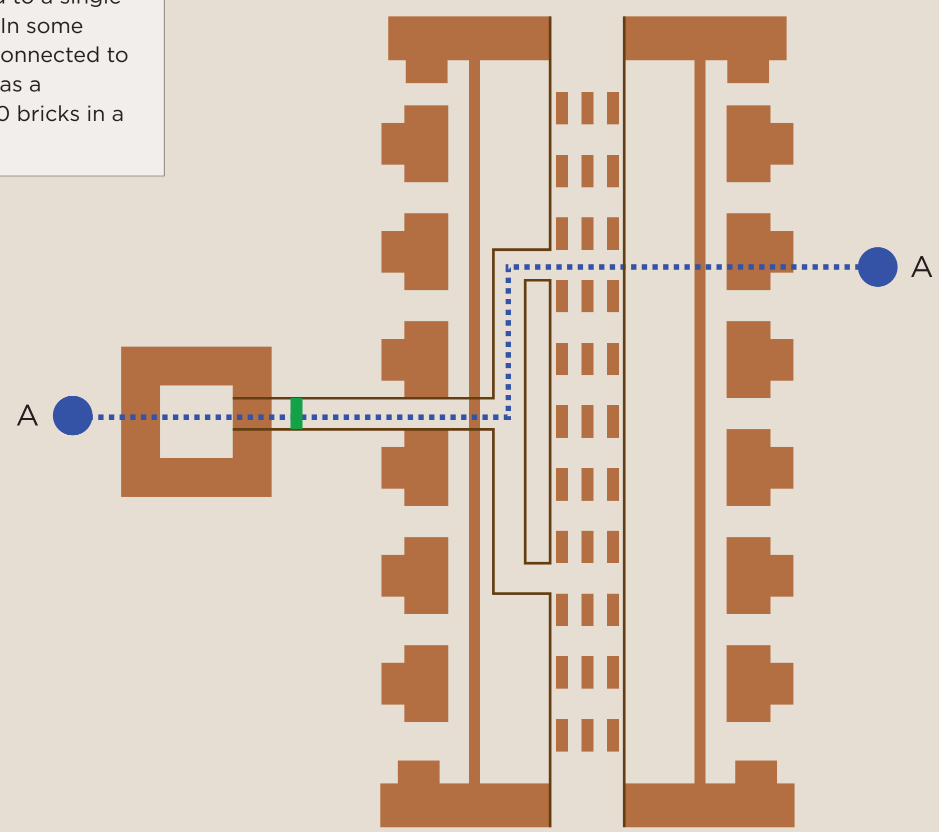
Fuel (usually firewood, twigs and branches) is fed in the fire-boxes by a single fireman. The fuel feeding is continued for around 30 hours. Afterwards the fireboxes are shut off and it is left for cooling for 2-3 days. The total time required for a batch from loading & firing of green bricks to cooling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

5

There is uniform heat distribution in a DDK and therefore, the percentage of good quality products is high.

6

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.



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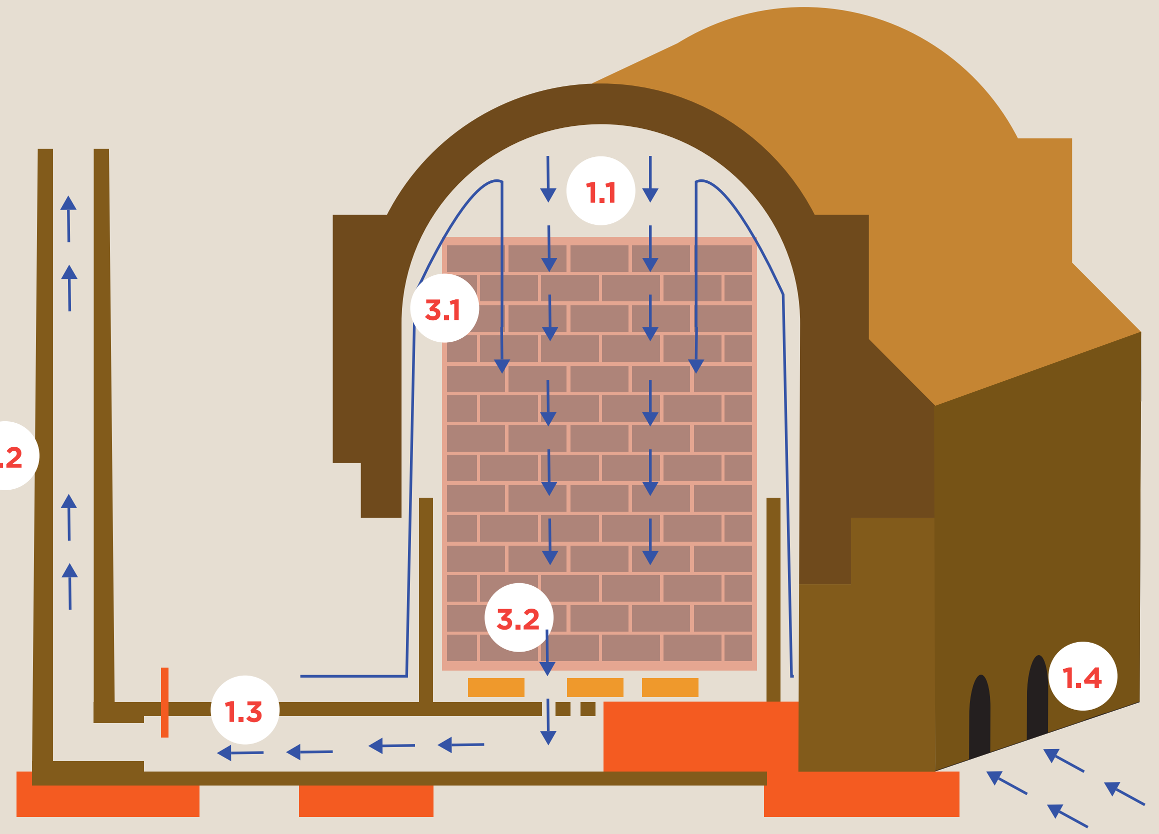


9 DOWN DRAUGHT KILN (DDK)

AIR EMISSIONS AND IMPACTS

MEASURED EMISSION FACTORS[4]

g/kg of fired bricks			
CO_2	Black Carbon	PM	CO
Average			
282.4	0.29	1.56	5.78

As emission factors are measured for only one kiln, range of values for emission factors is not available.)

MEASURED PM[5] EMISSIONS

Average: 531 mg/Nm³

(Range: 240–1088mg/Nm³)

EMISSION STANDARDS

Notified for PM only

Country	PM (mg/Nm³)
India	1200

COMMENTS ON EMISSIONS

Incomplete combustion in a down draught kiln results in the high emission of air pollutants.

FUELS AND ENERGY

COMMONLY USED FUELS

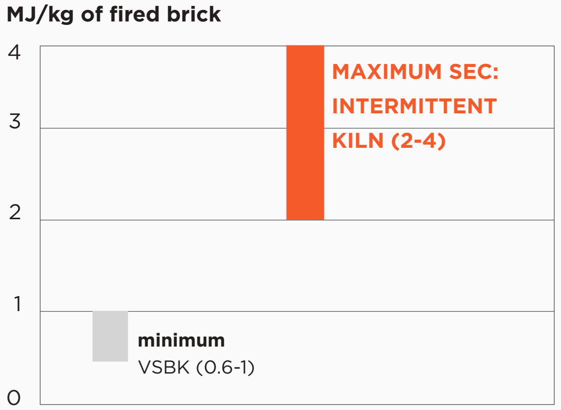
Biomass
Eg. firewood, twigs etc

Coal

SPECIFIC ENERGY CONSUMPTION[6]

Energy consumed for firing 1 kg of fired brick

Average: 2.97 MJ/kg of fired bricks
(Range: 2.80 – 3.14 MJ/kg of fired brick)



Note: Measured at firing temperature of 500-600°C

Because of incomplete combustion and limited heat recovery features, down draught kilns are inefficient.

MAIN CAUSES FOR HEAT LOSS

The main sources of heat loss in a down draught kiln are incomplete combustion and the heat losses from the kiln structure, hot-fired bricks and flue gases.

FINANCIAL PERFORMANCE

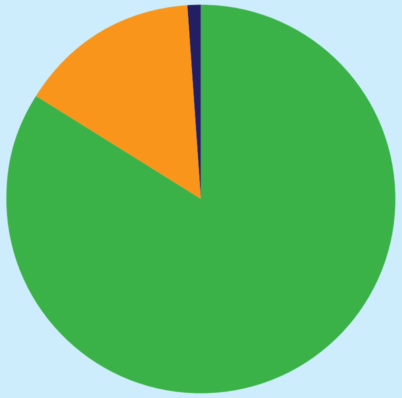
Capital cost of kiln technology

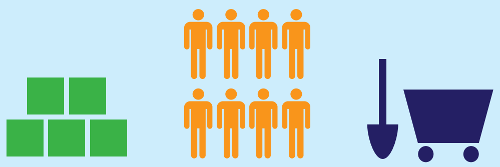
For annual production capacity of 0.6 – 1.0 million bricks (excluding land and working capital cost).

20,000 to 30,000 USD

Capital cost breakdown

Construction Material	84 %
Labour	15%
Equipment	1%





Production capacity	20,000 to 40,000 bricks per batch	
Brick size	230 mm x 115 mm x 75 mm	
Number of Operators required	10-12	
Payback Period	Simple Payback	~1.0 years
	Discounted Payback (@ 6.5%)	~1.2 years

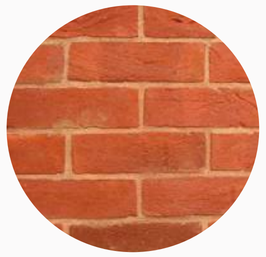
PRODUCT QUALITY

Product Quality
As per the local market perception

Better heat distribution in the kiln results in uniform temperature across the kiln cross section. This results in uniform quality of bricks across the kiln cross-section.

Types of product that can be fired in the kiln		
	Solid bricks	✓
	Hollow/ Perforated bricks	✓
	Roof tiles	✓
	Floor tiles	✓

GOOD BRICK



INFERIOR BRICK
under-fired and over- burnt

OCCUPATIONAL HEALTH AND SAFETY

Exposure to Respirable Suspended Particulate Matter[7]
The firemen feeding fuel and cleaning the fireboxes (removal of ashes) are exposed to a high concentration of air pollutants.

Firemen have the risk of developing respiratory tract infections and cardio vascular diseases.

Exposure to Thermal Stress[8]
In a down draught kiln, the fuel is fed through fireboxes which remain open during the entire duration of fuel feeding. The firemen are thus directly exposed to the flames.

The firemen bear significant thermal stress and risk of consequent diseases and dehydration.

Risk of accidents
In a down draught kiln, the risk of accidents is low.

Low risk of injuries to workers.

Compliance with ILO standards and remarks on migratory labour and conditions of labour
Practices followed at down draught kiln enterprises do not always comply with the International Labour Standards on occupational health and safety drawn up by ILO.[9]

9 DOWN DRAUGHT KILN (DDK)

MARCH 2014

CONCLUSION

Performance of down draught kiln is compared with the most commonly used intermittent kiln technology in the region which is clamps.

PARAMETERS		DOWN DRAFT KILN	CLAMPS	COMMENTS
AIR EMISSION (g/kg FIRED BRICK)	CO_2	282.4	NA	
	Black Carbon	0.29	NA	
	PM	1.56	NA	
	CO	5.78	NA	
FUEL & ENERGY	SEC (MJ/kg fired brick)	2.97	2.1	Though the SEC of down draught kiln is higher compared to clamps, the quality of fired bricks in a down draught kiln is usually better compared to clamps.
FINANCIAL PERFORMANCE	Capital Cost (USD)	20,000 – 30,000	NA	As the clamps do not have a kiln structure, no capital cost is considered for setting up of a clamp.
	Production Capacity	20,000 – 40,000 bricks/batch	10,000 – 200,000 bricks/batch	
	Simple Payback	~1.0 years	NA	
PRODUCT QUALITY	Types of product	All types of products	Only solid products	All types of products can be fired in a down draught kiln while only solid bricks can be fired in a clamp.
	Good Quality Product	85 %	~50 %	
OHS	Exposure to dust			Down draught kiln offers better OHS conditions as compared to clamp kilns.
	Exposure to Thermal			
	Risk of accidents			

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1 Report on 'Small-scale brick making' published by International Labour Office, Switzerland, 1984. http://www.pssurvival.com/ps/bricks/Small-Scale_Brickmaking_1984.pdf

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Report on 'Brick Kiln Performance Assessment' available at http://www.unep.org/ccac/Portals/24183/docs/Brick_Kilns_Performance_Assessment.pdf

5 Ibid. 3

6 Report on 'Brick Kiln Performance Assessment' available at http://www.unep.org/ccac/Portals/24183/docs/Brick_Kilns_Performance_Assessment.pdf
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Greentech Knowledge Solutions Pvt Ltd (GKSPL) is a research and consulting company providing services aimed at accelerating the dissemination and deployment of clean technologies, with a major focus on the brick industry in developing countries. GKSPL has undertaken comprehensive monitoring of energy and environment performance of brick kilns; provided technical assistance for brick kiln projects in Vietnam, Nepal and South Africa; conducted trainings for brick kiln upgrades in India and Nepal; and has developed brick sector development roadmap including recommendations on policy measures for India.

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