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BUILDING MATERIALS: PATHWAYS TO EFFICIENCY IN THE SOUTH ASIA BRICKMAKING INDUSTRY

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The Potential for Emissions Reduction and Investment in Efficiency Technologies for the Asian Brick Industry

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Executive Summary

From the coal consumed, the brick industry in the top five Asian brick-producing countries emits 1.2% of total global anthropogenic CO_2 emissions

Asia produces approximately 1.2 trillion bricks per year (Heierli & Maithel, 2008). The global brick industry is a major source of carbon dioxide (CO_2) emissions. This does not include any of the other inputs used during the brick production process or the diesel required to transport the bricks. Just from the coal consumed, the brick industry in the top five Asian brick-producing countries emits 1.2% of total global anthropogenic CO_2 emissions.[1] Brick kilns are significant emitters of black carbon, which is known to contribute to climate change and local health problems. Black carbon and suspended particulate matter (SPM) are the second-largest contributors to global warming after CO_2. More than 2.4 million premature deaths can be attributed to black carbon every year (Baron et al., 2009).

Significant emissions reductions can be achieved through a portfolio of solutions, specifically kiln switching, improved firing processes and dissemination of resource-efficient bricks (REBs). Despite the challenges of scaling-up emissions-reducing technology, this report identifies a series of opportunities for energy investment, knowledge sharing and potential partnerships in the brick industry.

Brickmaking Process

In Asia, brickmaking is both energy and Labor intensive. The kiln technologies used can be divided into intermittent and continuous kiln types. Clamp kilns are the most commonly used in South Asia and are the most energy intensive. Bull's trench kilns are the primary kiln technology used by large-scale manufacturers. Vertical shaft brick kilns (VSBKs) are the most energy-efficient kiln technology but have not been widely adopted throughout South Asia.

Emissions Profile

The brick industry in Asia produces more than 1.2 trillion bricks per year. The largest brick manufacturers are China, India, Pakistan, Bangladesh and Vietnam. The brick sector also emits large volumes of black carbon and other suspended particulate matter (SPM). For example, India's brick sector is the third-largest industrial user of coal.

Market Analysis

The two largest brick producing countries in Asia are China and India. Given their market size, these nations have the greatest emissions reduction potential. However, the Asian brick industry is particularly resistant to change because of four interconnected factors: Labor patterns, brick quality, government regulation and land ownership rights.

Reducing Emissions

Three different strategies for emissions reductions are analysed: switching kiln technologies, improving firing practices and utilising REBs.

Investment Opportunities

Fuel-efficient brick kiln technologies, such as VSBK, can generate high rates of return through fuel cost savings and additional revenue through participation in carbon offset credit markets. Other technologies such as changes in firing practices and REBs also have the potential to provide financial and environmental returns.

Challenges and Solutions to Reducing Emissions

There are four primary barriers to the wider use of more efficient kilns, firing process improvements and dissemination of REB technologies: informational, financial, social and institutional. The interplay of these barriers has prevented the adoption of energy-efficient technologies. Emissions reduction in the brick sector requires not only innovative financial solutions but also broad-based stakeholder engagement, both internationally and domestically.

[1] See Annex 1

2.4 million premature deaths can be attributed to black carbon every year.

Abbreviations

BTK	Bull's Trench Kiln
CDM	Clean Development Mechanism
CGB	Coal-Gangue Brick
CDCF	World Bank Community Development Carbon Fund
CER	Certified Emissions Reduction
FCBTK	Fixed Chimney Bull's Trench Kiln
GEF	Global Environmental Facility
GHG	Greenhouse Gas
IRR	Internal Rate of Return
LEED	Leadership in Energy and Environmental Design
MCBTK	Movable Chimney Bull's Trench Kiln
NPV	Net Present Value
PEPUS	Paryavaran Evam Prodyogiki Utthan Samiti
REB	Resource-Efficient Bricks
SEC	Specific Energy Consumption
SPM	Suspended Particulate Matter
TARA	Technology and Action for Rural Development
TERI	The Energy and Resources Institute
UNDP	United Nations Development Program
VER	Voluntary Emissions Reductions
VSBK	Vertical Shaft Brick Kiln

Brickmaking Process

BRICKMAKING PROCESS

Brickmaking in Asia is highly energy and Labor intensive. Traditionally, bricks are hand moulded, laid out to dry in the sun, stacked in a kiln, fired, and then unloaded. There are many different types of kiln technologies worldwide. While the kilns and firing practices may differ, the process of moulding and drying the bricks before firing is the same. Due to Labor shortages and increased costs, the brickmaking industry in Asia is transitioning towards greater mechanisation of the moulding process, despite the high capital costs associated.

Moulding & Mechanisation

Outdoor moulding and drying is not possible during the monsoon season – typically from June to September – resulting in a limited timeframe within which brick entrepreneurs can operate. In India, moulding relies primarily on a migratory Labor force. Moulding is not a highly skilled process and as a result the workers receive minimal compensation. Itinerant Laborers often face poor working and living conditions, as well as occupational health hazards. In India, new economic development and rural job-guarantee schemes have created employment alternatives for families working in moulding.[2] This has created a Labor shortage and an increase in Labor costs (Maithel et al., 2000). Some kiln entrepreneurs have responded to Labor shortages and rising Labor costs through the mechanisation of the brick moulding process.

Mechanised moulding increases brick consistency and flexibility. The moulder can adjust the clay mix, modify the brick size and shape, and create hollow or perforated bricks. Mechanisation of the moulding process also allows for the incorporation of carbonaceous biomass or fly ash into the clay mix. This contributes to emissions reductions because of coal savings. Savings in moulding Labor costs can also be realised at an early stage, despite the high upfront capital investment for mechanisation – one entrepreneur cited a 40% decrease in Labor costs.

Entrepreneurs are also looking for ways to improve the drying process; some have constructed sheds for storage. Entrepreneurs are increasingly attempting to mechanise the drying process. This requires not only high capital investments but also a constant and reliable electricity source. In India, electricity is not only intermittent but also unreliable. As a result, mechanisation requires the development and funding of off-grid generation, which also has potential GHG emissions implications.

The brickmaking industry in Asia is transitioning towards greater mechanisation of moulding

Firing

Firemen are responsible for monitoring and maintaining kiln temperature to efficiently fire bricks. Only a few firemen are needed per kiln, so Labor shortages are less of a constraint at this stage. Brick firing is considered a skilled profession even though most firemen are also migrant workers. In India, the Energy and Resources Institute (TERI) has begun to create an education network in conjunction with Paryavaran Evam Prodyogiki Utthan Samiti (PEPUS), a non-governmental organisation (NGO) that works at the grassroots level with migratory firemen to represent their interests when issues arise, including wage disputes and health concerns. TERI's role has been to create a repeat technical training program that lasts two to three months and trains firemen in best practices and minimisation of risk. Thus far, 2,000-3,000 firemen have been trained and issued with technical training certificates. Certification often results in higher wages and increase worker credibility. In addition, training in best practices can increase kiln efficiency by 5-10%. These existing networks have proven effective, but it is necessary to extend these services to moulders and stackers, and to expand regionally.

Kiln Technology

With more than 300,000 kilns worldwide, there are two general categories of kiln technology: intermittent and continuous (CPCBMEF, 2007). Intermittent kilns have low energy efficiencies. After the firing process is complete, both the kiln and bricks are cooled, which releases much of the heat before the process begins again. Continuous kilns are more efficient because the heat given off during the cooling process is utilised to preheat the incoming bricks. Bricks are either moved through a stationary firing zone or remain fixed, and the heat is moved through the kiln using a chimney or a suction fan.

Figure 1: Kiln Types

INTERMITTENT

Clamp

CONTINUOUS

Moving firing

Bull's Trench Kiln (BTK)

- Zig Zag

Moving Ware

- Tunnel
- Vertical Shaft Brick Kiln (VSBK)

Tunnel Kiln A continuous kiln in which bricks move though a stationary fire zone. As long as there is a ready and reliable source of electricity, tunnel kilns can produce a large amount of bricks at very low operational costs. These are primarily used in developed countries, as tunnel kilns are fully automated and mechanised.

[2] The Labor shortage is related to the implementation of the Mahatma Gandhi Rural Labor Employment Guarantee Act (MGRLEGA) in 2007. The MGRLEGA aims to promote rural livelihood by guaranteeing 100 days of wage employment to rural households whose adults volunteer unskilled manual Labor.

Clamp The most common, versatile and cheap form of kiln is the clamp kiln. The production capacity of a clamp ranges anywhere from 5,000 to 500,000 bricks per firing (Maithel et al., 2012). While clamp kilns can be constructed in different shapes and sizes, they are usually built on a surface of pre-fired bricks, with firing tunnels on the bottom and green bricks stacked up to 40 layers high. As clamp kilns can only fire a limited number of bricks during each firing, many are built and operated together. Clamps do not require a permanent structure, making them extremely versatile and easy to install, maintain and operate.

However, the fuel combustion of the clamp kiln is both uncontrollable and inefficient, making it difficult to ensure the quality of bricks produced. Most are either over- or under-fired. The efficiency of clamp kilns can be improved slightly by reducing the fuel used per fired brick. Including fuel in the clay can also reduce the amount of coal and associated emissions, but this process usually requires a machine for the mixing process.

Bull's Trench Kiln (BTK) There are two types of Bull's Trench Kiln – fixed chimney (FCBTK) and movable chimney (MCBTK). BTKs can utilise different firing processes, which can provide significant emissions reductions. Traditionally, bricks are stacked vertically, but there are new stacking practices that provide better airflow and can reduce emissions significantly.

- **Zig-Zag Stacking** This consists of a long firing zone that is divided into various chambers using green bricks. While some utilise a natural draft, others use a fan to draw the fire and heat through the zig-zag stacking pattern. This firing process requires a set of highly trained and skilled workers to operate and maintain the kiln. This technology has not yet been standardised and, as a result, there is a varied performance level and emissions profile associated with switching to the zig-zag firing process. One brick entrepreneur achieved a 20-30% reduction in coal use after switching to the zig-zag stacking process. This also reduced the amount of black carbon and SPM.

Vertical Shaft Brick Kiln (VSBK) These consist of one or more shafts, with each producing approximately 135,000 bricks per month (CPCBMEF, 2007). These kilns are 20-40% more efficient than BTKs (CPCBMEF, 2007). However, transitioning from BTKs to VSBKs seems unlikely for several reasons. First, VSBKs require green bricks to be loaded at the top of the shaft, which poses an operating constraint compared to other technologies. Second, they also require a higher level of technical expertise to maximise the efficiency and output of the kiln. Third, the number of VSBKs needed to meet the same capacity of one BTK means that kiln switching on a large scale is highly unlikely unless it is during the end of lifecycle of the BTK.

Industry Emissions Profile

INDUSTRY EMISSIONS PROFILE

Asia produces approximately 1.2 trillion bricks per year. China produces 54% of the world's bricks, followed by India at 11%, Pakistan at 8%, and Bangladesh at 4% (Baum, 2010). However, each nation utilises a variety of different kiln technologies. For example, in China 90% of bricks are produced using Hoffman kilns. In India there are more than 60,000 clamp kilns and 3,000 BTKs (Heierli & Maithel, 2008). Since brickmaking is highly unregulated and unorganised, it is difficult to estimate brick production from each type of kiln and its associated CO_2 emissions. Moreover, during the firing process the burning of coal results in the release of numerous other pollutants into atmosphere, including, but not limited to, carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NOx), and particulate matter.

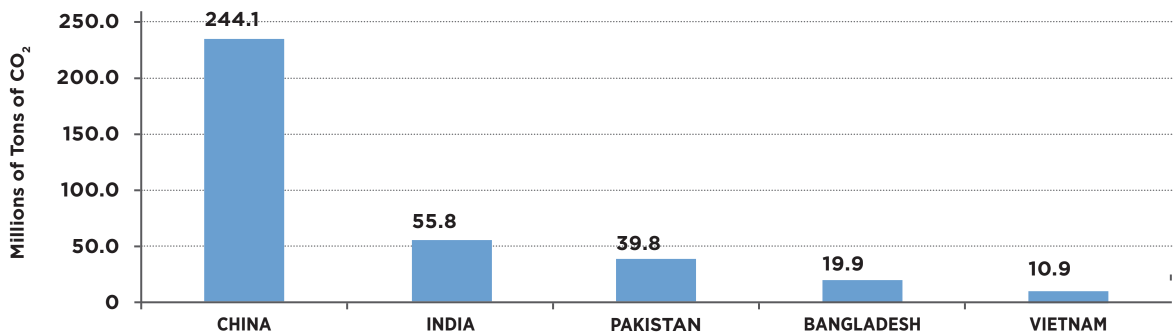
CO_2 Emissions

Using specific energy consumption (SEC) to estimate CO_2 emissions shows that those from the top five Asian brick-producing countries total more than 359 million metric tons[2], equivalent to 1.24% of total global anthropogenic CO_2 emissions. Of these countries, China accounts for 65.9% of CO_2 emissions and India over 16% (Figure 2).

Carbon dioxide emissions from the top five brick-producing countries total more than 359 million metric tons[2]

During the firing process, the burning of coal results in the release of numerous pollutants into the atmosphere

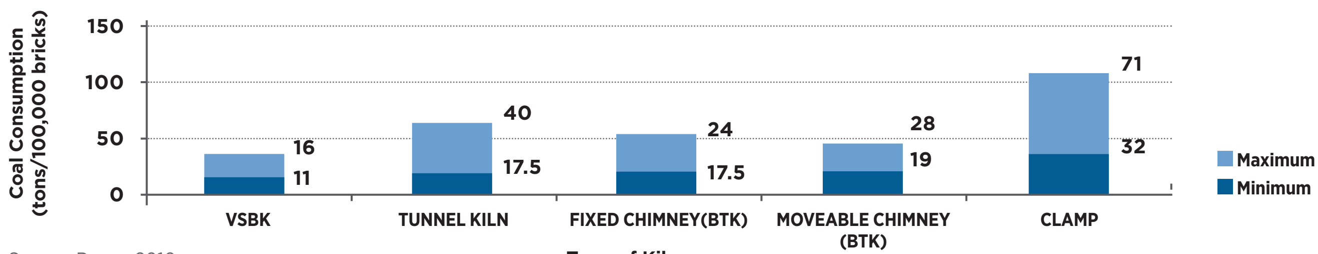
Figure 2: Annual CO_2 Emissions: Specific Energy Consumption Method



Emissions from Different Kiln Technologies

Coal is the primary fuel in the brickmaking process. On average, 11-70 tons of coal are needed to fire 100,000 bricks, depending on the different style and size of the kiln (Heierli & Maithel, 2008). The minimum and maximum amount of coal that is consumed by each kiln can be seen below in Figure 3.

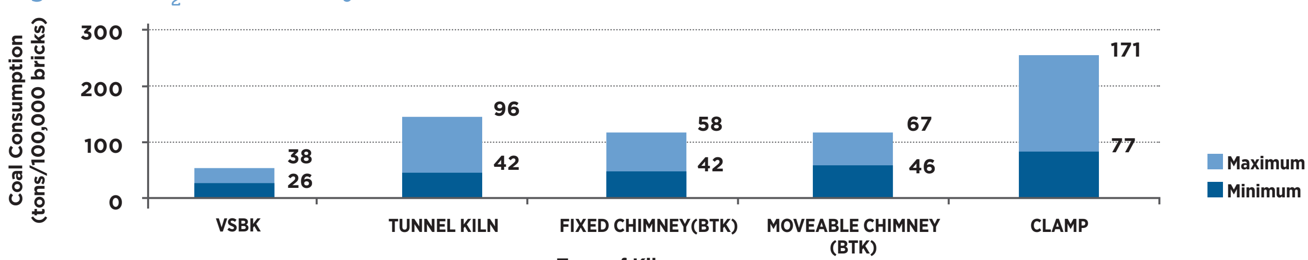
Figure 3: Coal Consumption by Kiln Type



Source: Baum, 2010.

Based on the coal consumption of the different technologies, the CO_2 emissions level of the primary kiln technologies is estimated in Figure 4.

Figure 4: CO_2 Emissions by Kiln

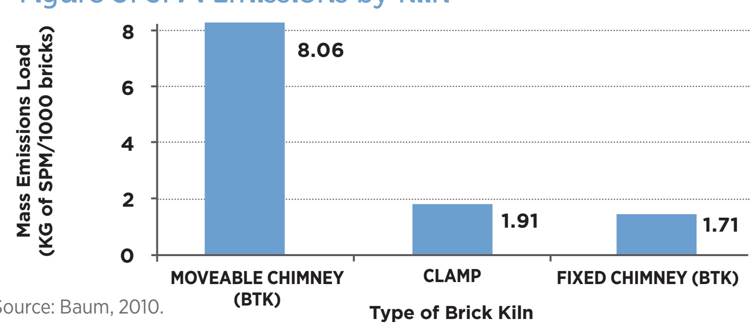


Source: Baum, 2010.

Particulate Emissions from Different Kiln Technologies

Particulate matter emitted, such as black carbon, is the result of the incomplete combustion of coal and other fuel sources. As seen in Figure 4, VSBK produces the lowest amount of SPM vis-à-vis other technologies.

Figure 5: SPM Emissions by Kiln



Source: Baum, 2010.

Key Markets

KEY MARKETS

The two largest brick markets in Asia are India and China. Given their market size, these two nations have the greatest emissions reduction potential.

India

The brick sector is the third-largest industrial coal consumer in India, using 24 million tons of coal, thereby emitting 78 million tons of CO_2 annually (Development Alternatives, 2005). India's 100,000 brick kilns use 400 million tons of good quality topsoil each year. India faces an ongoing trade-off between development and the environment; the importance of the brick industry to its infrastructure and GDP growth is only set to increase. A recent report from the McKinsey Global Institute estimates that cities could generate 70% of net new jobs created to 2030 and produce approximately 70% of Indian GDP (Sankhe, 2010). In order to meet this urban demand, India will have to build between 700 million and 900 million square metres of residential and commercial space a year (Sankhe, 2010).

China

China dominates global brick production, representing 54% of the global market, producing a total of 700-800 billion bricks per year (Baum, 2010). Chinese brick production uses almost 100 million tons of coal per year and consumes around one billion tons of clay per year (Baum, 2010; Murray et al., 2010). Chinese brick production is characterised by use of extruders for brick forming and the use of Hoffmann and tunnel kilns for firing of bricks for medium- and large-scale production (Heierli & Maithel, 2008). Several types of traditional kilns are used for firing bricks in rural areas on a smaller scale, such as the more efficient VSBK. However, Hoffman kilns produce almost 90% of all bricks in China (Baum, 2010).

China dominates global brick production, representing 54% of the global market

Market Trends

Co-operation between government and industry is critical to incentivise uptake of brickmaking technologies that reduce emissions

MARKET TRENDS

Even though the brick market in each nation displays different market characteristics, the Asian brick industry is particularly resistant to change because of four interconnected factors: Labor patterns, brick quality, government regulation and land ownership rights (Figure 6). No one factor is solely responsible for the difficulties in scaling-up emissions-reducing technologies, but each one needs to be addressed in order to affect the necessary change.

Figure 6: South Asian Brick Industry Barriers to Change

Labor

Labor scarcity is the most pressing issue facing brick kiln entrepreneurs as it directly affects the quality of bricks produced and number of workers available each season. In addition, many new kiln technologies and firing practices require the retraining of workers. For example, VSBKs and switching to zig-zag firing require a certain degree of technical knowledge and co-ordination, without which maximum efficiencies cannot be achieved. Thus, many zig-zag kilns have the same energy consumption as BTKs, negating any potential environmental benefits.

Brick Quality

In South Asia, brick quality is assessed by the sound and colour of the brick. In northern India, for example, the high-quality clay soil supports various grades of high-quality bricks, hand moulded and fired according to the traditional English red-brick style. Mechanisation is standardising brick production, which may create demand for different brick styles, including resource-efficient bricks (REBs).

There is also a widespread perception that VSBK bricks are of a lower quality than those produced by BTKs (Heierli & Maithel, 2008). As a result of the difference in soil quality, companies that produce bricks using VSBK technology find it harder to compete in northern India than in the south where, traditionally, poorer soil quality has supported only one type of lower-quality brick produced by traditional kiln technologies.

In China, recent policies aim to limit the manufacture of clay bricks and encourage the use of industrial waste materials instead, in particular coal gangue. In 2006, Chinese coal-gangue brick (CGB) production reached 1.42 billion bricks. Of the 80,000 brick enterprises in China, 5,000 are engaged in CGB production. Approximately 10% of these factories use tunnel kilns, around 60% are small-scale operations producing fewer than 30 million bricks per year; 20-30% are medium-scale operations producing 30 to 100 million bricks; and the remaining large-scale factories make more than 100 million bricks (Murray et al., 2010).

Land Ownership

Rural land ownership in India is not considered sufficient collateral for bank loans to obtain the necessary financing for technology upgrades. In addition, many entrepreneurs do not own the land on which their kiln operates; this reduces motivation for kiln improvements. As a result, kiln operators not only lack incentives to switch to VSBK or other technology, but they also often lack the means.

Regulation

A lack of organised and coherent regulation thus far has made it hard to establish an efficient market for alternative kiln technologies. It is hard to achieve emissions reductions while the license to pollute remains largely unchallenged. Effective government regulation is necessary but by no means sufficient.

China is currently on the path to developing stricter regulations on brick production. In 1992, concerned with the destruction of farmland due to brickmaking, the State Council of China issued policies to strictly limit the use of solid burnt clay brick. The State Tax Bureau issued favourable tax policies to promote the development of new wall materials, which contribute to energy conservation and waste utilisation (Heierli & Maithel, 2008). The Chinese government has set a basic national policy of developing new energy-saving wall materials and reducing the production of traditional solid burnt clay bricks (Heierli & Maithel, 2008). These regulations will only be successful in reducing emissions on a large scale if they are accompanied by financing options for more efficient technologies and practices.

Future Trends

India and China have both undergone dramatic urbanisation and modernisation in addition to steady economic growth; this has resulted in a booming construction industry. Traditional building materials are increasingly less popular due to government attempts to reduce solid brick production. Steel, cement and wood are slowly replacing clay bricks as the dominant construction materials. Co-operation between government and industry is critical to incentivise uptake of different brickmaking technologies that reduce emissions.

Reducing Emissions

Switching to VSBK saves 30-50% of energy per kilogram of fired bricks

REDUCING EMISSIONS

There are significant opportunities for lowering emissions in the brickmaking industry. This section identifies three different strategies to reduce emissions: kiln switching, changes in firing practices, and utilising resource-efficient bricks.

Kiln Switching

Energy-efficient brick kiln technologies have lower SEC, measured in kilojoules required per kilogram of fired brick, and therefore burn less fuel and release fewer GHGs per unit of output. Reducing energy consumption can generate anywhere between a 30-60% reduction in CO_2 emissions (Heierli & Maithel, 2008). Additionally, energy-efficient technologies give operators more control over the fuel combustion process, which results in a more complete combustion of carbonaceous fuel and decreased emissions of black carbon and other SPM. These technologies can provide financial returns through savings in fuel cost per unit of output.

Improving kiln efficiency depends on the choice of technology, continuous or batch operation, fuel availability, quality and preparation, firing processes and waste heat recovery systems. There are several kiln types that can reduce emissions. For example, VSBKs release less CO_2 emissions per 100,000 bricks than any other proven kiln technologies (Figure 7) and reduce CO_2 emissions by more than 42-77%, compared to clamps and BTKs (Development Alternatives, 2005).

Benefits of VSBK

There are four major benefits of switching to a VSBK kiln: fuel efficiency, optimal resource utilisation, lower air pollution, and social benefits. VSBK saves 30-50% of energy per kilogram of fired bricks (Maity, 2009). In addition, there are social benefits to adopting VSBK technology, such as lower accident rates for workers (Premchander et al., 2011).

Figure 7: CO_2 Reduction Potential of VSBK

KILN TYPE	% REDUCTION IN CO2 EMISSIONS FROM VSBK INTERVENTION
Clamp	58%
MCBTK	43%
FCBTK	35%
Hoffmann Kiln	32%

Source: UNIDO, 2010.

VSBK has the lowest emissions intensity profile among the proven technologies and can reduce black carbon approximately ten-fold compared to other technologies (Premchander et al., 2011). In a comparison of the top five global producers of brick (presented in Figure 8), the emissions reduction potential can be as much as 64.9 millions tons of CO_2. However, it is more feasible to consider a 20% or 40% replacement scenario of traditional kilns to VSBK.

Figure 8: Reduction Potential of Different Replacement Scenarios

EMISSIONS REDUCTION POTENTIAL FROM REPLACING X% OF KILNS WITH VSBK (tCO_2)					
COUNTRY	20%	40%	60%	80%	100%
China	23,068,616	46,137,233	69,205,849	92,274,466	115,343,082
India	3,675,901	7,351,802	11,027,703	14,703,604	18,379,505
Pakistan	2,625,644	5,251,287	7,876,931	10,502,574	13,128,218
Bangladesh	1,312,822	2,625,644	3,938,465	5,251,287	6,564,109
Vietnam	889,231	1,778,462	2,667,692	3,556,923	4,446,154
Total	31,572,214	63,144,427	94,716,641	126,288,855	157,861,068

Firing Process Changes

There are many different types of zig-zag firing processes that have been adopted and modified by brick kiln entrepreneurs, though no one method that has been widely disseminated.

The zig-zag firing process enables superior combustion of fuel in the firing zone and recovery of waste heat, which results in a lower consumption of fuel per output. This translates to lower CO_2 and black carbon emissions. The zig-zag kiln has a higher fuel efficiency performance than most other kilns on account of three factors: it permits a better mixing of air and fuel, leading to higher combustion efficiency; it pre-heats combustion of air through heat exchange from waste gases; and it utilises the radiant heat from the furnace to raise the temperature of combustion. In addition, there are associated social benefits, including reduced black smoke and soot around working areas.

Resource Efficient Bricks (REBs)

Reductions in GHG emissions can be achieved through the use of resource-efficient bricks (REBs). One type of REB incorporates fuel into the clay mix (coal powder, boiler ash, fly ash, biomass, etc) to accelerate the firing process and reduce emissions (Premchander et al., 2011). Other types of REB include perforated or hollow bricks and bricks made of compressed fly ash that do not require firing.

Perforated and hollow bricks are of lower weight and volume and have a larger surface area. These bricks can be fired with 20% less energy while maintaining the compressive strength of solid bricks (UNDP-GEF, 2010). Perforated and hollow bricks can only be made with a semi-mechanised extrusion press; this requires a consistent source of electricity. In addition, the upfront capital costs can put technology upgrades out of reach of small-business entrepreneurs.

Investment Opportunities

INVESTMENT OPPORTUNITIES

This section will focus on the investment opportunities for kiln switching: clamp to VSBK and BTK to VSBK. Despite the emissions reduction potential of firing process changes and adoption of REBs, it is difficult to quantify the benefits. There are substantial environmental and social benefits from investing in emissions-reducing technologies, despite the upfront capital costs. However, environmental benefits alone are not sufficient incentive for brick kiln entrepreneurs to adopt clean technologies or processes. The business and financial case for kiln switching is made below.

Clamp to VSBK

Clamps are temporary constructions that have low to zero capital costs and can be built quickly to meet a specific market demand. VSBK, on the other hand, is a fixed asset with relatively high capital cost and an average operational lifespan of 15 years. Thus, while clamps and VSBKs have similar production capacities (approximately 7,000 to 10,000 bricks per day), clamps are about three times more energy intensive than VSBK (CDM Executive Board, 2006). Kiln switching from clamps to VSBK can create large fuel cost savings; however, the lack of financial information for clamps precludes accurate analysis. Moreover, clamp owners lack access to capital and technical literacy to develop VSBK. This is an area for further research and study – specifically on the financial realities for clamp owners.

BTK to VSBK

The technical characteristics of BTKs and VSBKs are fairly similar. They are both fixed assets with high capital costs and relatively long lifespans. The capacity of a single-shaft VSBK is approximately one third of an average BTK (TARA, 2009). However, additional shafts can be added to the VSBK to increase capacity at decreasing marginal cost.

The financial analysis in Annex I demonstrates the incremental financial return obtainable through the replacement of BTK with energy-efficient VSBK technology. The financial parameters are based on the Indian market, and the indicators are calculated using an annual capacity of one million fired bricks to allow for comparability.

There are substantial environmental and social benefits from investing in emissions-reducing technologies

Cost Savings VSBKs require approximately 41% less coal than BTKs, therefore providing significant fuel savings. The increase in efficiency for a VSBK generates annual savings of $13,895 in fuel costs. These savings are increasingly important given that the Indian wholesale coal price has tripled in recent years and is expected to continue to rise (TARA, 2009). In addition, the VSBK only requires approximately half the number of workers needed to operate the BTK, which generates additional annual savings in Labor costs of $2,900.

Simple Payback Period Within its first year of operation, the VSBK can achieve simple payback after firing approximately 1.54 million bricks for approximately 5.8 months (Figure 9). The simple payback period for a BTK is about 3.5 months longer than for a BTK due to its higher capital costs. However, the VSBK outperforms the BTK over the average 15-year lifespan of the kiln. Free cashflow analysis reveals that VSBKs deliver significantly higher returns than BTKs. The equity internal rate of return (IRR) is 82% and the net present value (NPV) is over 12,465 (Figure 9).

Figure 9: Economic Performance Comparison BTK to VSBK

INDICATOR	FCBTK	VSBK
Simple Payback Period (Months)	3.5	5.8
CapEx (USD, million brick capacity)	$17,138	$23,160
Net Present Value (USD, million brick capacity)	$36,217	$115,481
Equity IRR	52%	82%

Understanding Scale-up Potential The financial benefits of kiln switching from BTK to VSBK are clear. For the Indian market, the conversion of a one-million-brick-capacity BTK to a VSBK requires $6,000 in additional capital but creates more than $79,000 in additional profits. Scaling this up to the national level, the conversion of only 20% of India's BTKs to VSBKs requires $118 million in additional capital but creates $1.55 billion in additional profits for brick entrepreneurs (Figure 10).

Figure 10: Investment Opportunity BTK to VSBK

FCBTK - VSBK PENETRATION (%)	20%	40%	60%	80%	100%
New VSBKs (No)	9,074	18,148	27,222	36,396	45,370
Additional Capital Requirement (millions of USD)	$211	$423	$634	$846	$1,057
Additional Savings (present value, millions of USD)	$2,784	$5,568	$8,352	$11,136	$13,920
CO_2 Emissions Reduction (tons of CO_2)	3,470,431	6,940,863	10,411,294	13,881,725	17,352,156

Wealth Creation Opportunities Kiln switching has a negative marginal abatement cost. This means that the decision to build a VSBK rather than a BTK will both reduce GHG emissions and generate positive economic returns over the lifecycle of the kiln. Unlocking these environmental and economic returns requires overcoming persistent barriers and market inefficiencies, primarily access to financing. To mitigate one ton of CO_2 requires investing $4.10 toward energy-efficient kiln switching. This in turn generates $53.50 in savings over the lifespan of the kiln. The environmental benefits of kiln switching are realised without investing more than the cost of the technology upgrade.

Firing Process Changes

Better feeding, firing, and operating practices can improve the overall efficiency of the kiln and decrease CO_2 emissions and SPM (Jain & Singh, 2001). Efficient coal-stoking practices improve brick quality and reduce SPM in the flue gas. However, firing process improvements are difficult to quantify because each kiln has different technical specifications. In addition, alternate stacking methods, such as zig-zag stacking, can improve energy efficiency and lower fuel costs in existing BTKs.

Non-Financial Considerations

A comparison of financial returns of different brick kiln technologies also requires consideration of other factors: resource availability, tradition and location. For example, clamps are not easily comparable with industrially automated tunnel kilns because the performance characteristics, financial investment and operational requirements of the two technologies are considerably different.

Converting a one-million-brick-capacity BTK to a VSBK requires $6,000 in additional capital but creates more than $79,000 in additional profits

Challenges & Solutions

> Building VSBKs rather than BTKs reduces GHG emissions and generates positive economic returns over the lifecycle of the kiln

CHALLENGES & SOLUTIONS

This report has identified three key strategies to reduce emissions in the brick kiln sector: these are kiln switching, firing process changes and adoption of REBs. Figure 11 summarises the associated barriers and outlines the proposed solutions to enable successful implementation of each strategy.

Each of these strategies suffers from a combination of informational, financial, social and institutional barriers to scale-up. A lack of information prevents knowledge dissemination. High capital costs are a significant barrier for entrepreneurs wanting to make technology upgrades. South Asia also suffers from a lack of regulatory frameworks to support industry change. Social barriers are perhaps the most challenging to overcome because they are associated with generations of traditions and customs. It is the interplay of barriers, rather than any one in particular, that has prevented progress in this industry.

Strategy 1: Kiln Switching

One of the strategies identified to reduce emissions is through the adoption of VSBKs. Building VSBKs rather than BTKs reduces GHG emissions and generates positive economic returns over the lifecycle of the kiln. However, there are several barriers that prevent the adoption of VSBKs in the marketplace that are identified below.

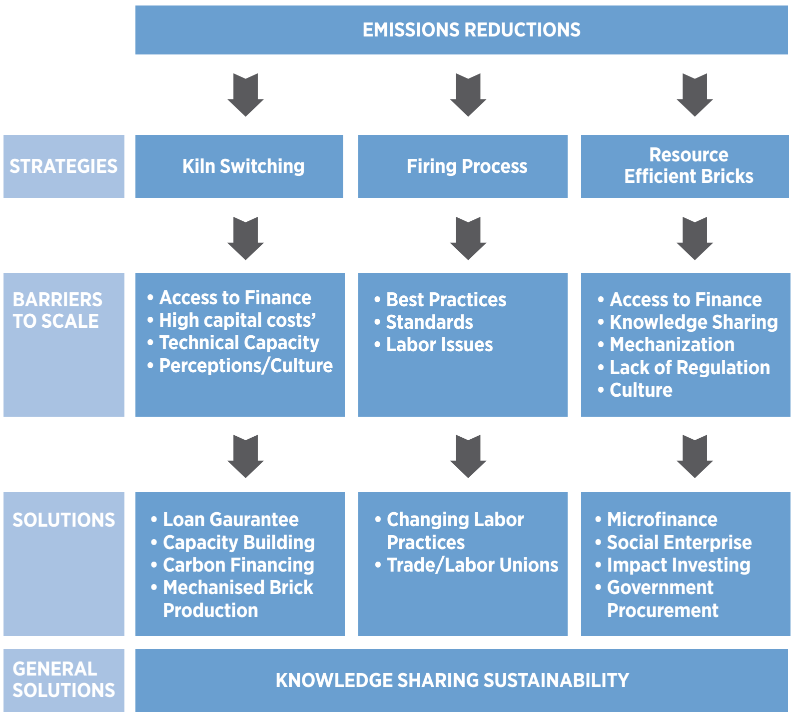
Financial Barriers

High Capital Costs VSBK technology requires high upfront capital costs per unit of output compared to BTK or clamp kilns, often making the investment out of reach to local entrepreneurs. VSBK's lower production capacity compared to BTK means that it is better suited for small-scale brickmaking operations. Yet small-scale entrepreneurs are even less likely to have access to financial services. Until entrepreneurs have access to financing, kiln switching is likely to be beyond the resources of most kiln owners.

Access to Financing The dynamics of the brick industry make commercial financing problematic. Banks are hesitant to make loans to the brick industry because it is highly unregulated and unorganised. Additionally, the sector is associated with poor business practices and Labor law violations, which further impair the credibility of the brick sector (UNDP-GEF, 2010).

Bookkeeping practices in the brick industry are also insufficient for commercial lenders to make credit assessments of entrepreneurs because income and costs are not fully accounted for. For example, Labor and fuel costs are often underreported (UNDP-GEF, 2010). Furthermore, borrowers also have difficulty estimating the amount of credit that they need for a capital loan. These realities force banks to rely on reputation, rather than financial due diligence.

Figure 11: Emissions Reduction Scenarios



Many brick kiln entrepreneurs lease their land rather than own it, which creates at least two additional problems for financing. First, entrepreneurs are less likely to invest in fixed asset improvements on property they do not own. Second, banks require land as collateral. Rural land is not considered sufficient collateral for loans, so even if entrepreneurs own their land, they need to show additional financial assets.

Many brick kiln entrepreneurs lack the financial knowledge and ability to prepare the business plans and documentation needed to apply for a loan. Furthermore, commercial banks have limited experience lending to the brick sector and do not currently offer financial instruments tailored to efficiency improvements in this sector (UNDP-GEF, 2010). This is further exacerbated by a low repayment rate of approximately 60%. These two factors increase the transaction costs, making financing cumbersome and expensive.

Financial Solutions

Carbon Financing Carbon financing could provide the necessary incentives for entrepreneurs to switch to cleaner technologies. The Clean Development Mechanism (CDM) is one of the financial instruments under the Kyoto Protocol that allows Annex 1 (developed) countries to purchase certified emissions reductions (CERs) from developing countries. There are also other financial instruments such as voluntary emissions reductions (VERs); these apply to countries that have not signed the Kyoto protocol. For example, the World Bank Community Development Carbon Fund (CDCF) is supporting Technology and Action for Rural Development (TARA) in India to disseminate VSBK on a large scale (Development Alternatives, 2005). While acknowledging the widely accepted limitations of carbon financing, this is only one potential method for established brick kiln entrepreneurs to upgrade their kiln technologies.

Loan Guarantees A loan guarantee programme can support established kiln owners in their efforts to secure financing. Loan guarantees are risk-hedging mechanisms that help mitigate the financial uncertainties from the brick industry. International financial institutions, such as the Global Environment Facility (GEF), can fund and manage a loan guarantee program for entrepreneurs that have demonstrated financial credibility.

Revolving Fund A revolving fund for energy efficiency investments in the brick sector could overcome the challenges of commercial lending. Such a fund would require initial grant money, but would become self-sufficient and self-replenishing over its operational lifetime as energy efficiency loans are dispersed and repaid with interest. A qualified and impartial fund manager would be needed to select creditworthy projects, ensure loan repayment and avoid potential conflicts of interest.

Technical Barriers

Lack of Information A lack of information makes it difficult to secure investments in alternative kiln technologies. Internationally and domestically, project developers do not have easy access to reliable data and information concerning energy consumption and emissions reduction potential. This makes comparison between different technologies challenging and therefore does not provide the necessary confidence to entrepreneurs that otherwise might consider technology switching.

Many entrepreneurs also lack the necessary technical know-how to operate more energy-efficient kilns. For example, one VSBK owner in India was encouraged to adopt VSBK technology as an experiment in conjunction with TERI but faced at least two years of severe operational difficulties. While the entrepreneur indicated a willingness to educate other entrepreneurs in the specifics of VSBK technology, it is not surprising that there is little demand. In addition, knowledge sharing in India is typically via more traditional kinship methods, with technical know-how passed most commonly from father to son. There are a handful of particularly progressive and innovative entrepreneurs but these are the exception to the norm.

Technical Solutions

Demonstration Centres As previously discussed, switching from BTK to VSBK at scale is unlikely because of the traditional values and capacity constraints of VSBKs. However, given the significant emissions reduction potential, demonstration projects that replace BTK with large-scale VSBKs should be undertaken. This allows kiln owners to see the opportunities of VSBKs and better understand the best practices for operating them.

Capacity Building It is necessary to facilitate information sharing among all the relevant stakeholders. Capacity building through technical assistance programmes and centres can raise awareness of cleaner brick technologies, provide technical and regulatory support to kiln owners, and create bridges between kiln owners, technology providers, and financial institutions. A network of kiln entrepreneurs would serve as an information resource centre, facilitating the exchange of information between entrepreneurs. Accurate emissions data and comprehensive, actionable reports are prerequisites to better understanding the emissions profile of the brick industry.

Mechanised Brick Production In the United States, most bricks are manufactured in fully automated tunnel kilns fuelled by natural gas. As the Asian brick sector becomes more formalised and mature, brick manufacturing should move towards fully automated tunnel kilns. This will allow economies of scale and significantly reduce emissions.

Social and Cultural Barriers

Labor Shortages Labor is a critical input to brick manufacturing. Consequently, Labor shortages in India affect all brick kiln entrepreneurs. This encourages greater mechanisation, but the capital required for this transition is only accessible to large-scale entrepreneurs. In addition, the scarcity of Labor puts downward pressure on technology switching because this requires a re-education of the workforce.

Brick Perceptions There is a perception that bricks produced from VSBKs are of a lower quality than the traditional 'red bricks' fired since the British colonial era. Unless these perceptions can be overcome, it will be hard to encourage even the switch from clamp to VSBK, let alone BTK to VSBK. Where VSBKs have been chosen over BTKs, this is likely for specific reasons on a case-by-case basis. For example, in India one VSBK operator was previously a BTK fireman and was intellectually interested in experimenting with new technology with the help of TERI.

Strategy 2: Zig-Zag Firing

The second strategy identified to reduce emissions is to improve the energy efficiency of BTK kilns through changes in firing process, more specifically the adoption of zig-zag firing. This deserves attention because of the prevalence of BTK kilns in the marketplace. Changes in the firing process are not capital intensive and can be readily adopted. However, there are several barriers that prevent the adoption of zig-zag firing.

Social Barriers

Lack of Best Practices/Standards Where zig-zag firing is being used, it has been adapted by the specific entrepreneur and financed individually. It is not customary to patent kiln technologies or practices in India and other developing countries. As a result, there is no standardised model for zig-zag firing processes, since entrepreneurs make individual modifications to fit their kilns. More entrepreneurs would be likely to switch to this firing technique if they could be assured of its success.

Labor Currently, there are no Labor unions or associations that organise moulders and stackers. As a result, these workers face harsh Labor conditions. Most kilns only have a 20% retention rate of moulders and stackers. Even entrepreneurs that provide improved housing and living conditions still only enjoy a 50% Labor retention rate. Without higher retention rates, brick entrepreneurs have to retrain their stackers in the zig-zag process, meaning a loss of valuable time and money. Thus, entrepreneurs that want to switch to zig-zag firing must retrain all workers each firing season. Without a dependable supply of Labor, entrepreneurs are unlikely to switch to zig-zag firing.

Social Solutions

Framework for Education and Knowledge Sharing Kiln owners utilising efficient and innovative firing practices should hold workshops to disseminate best practices. This could be aided by organisations such as TERI, but there is also a role for small independent local consulting firms to act as conveners. Third-party organisations can play a key role in conveying the environmental benefits of switching to zig-zag firing. Multi-disciplinary resource teams could offer workshops, seminars and meetings to promote capacity building on regional levels. Different levels of training should be provided to entrepreneurs and workers to acquire the skills necessary for construction and operation of zig-zag kilns.

Labor Unions Organisations are needed to register moulders and stackers, which will further formalise the brick industry. Incentives can be provided for registration, such as formalised training and certification for stacking. Brick entrepreneurs will therefore have access to a portfolio of stackers that are vetted and have a certified understanding of the zig-zag process. These Labor unions or associations can also help improve the Labor conditions for workers by assisting with contract negotiation and developing guidelines for contracts for moulders and stackers.

Strategy 3: Resource Efficient Bricks (REBs)

The final strategy identified to reduce emissions is the utilisation of resource-efficient bricks (REBs). There are a wide range of REBs, including hollow bricks, internal fuel bricks, fly ash compression bricks and others. The financing required for each type of brick is different. Hollow bricks and internal fuel bricks require capital-intensive machinery, whereas the technology for fly ash compression bricks is more affordable for small-scale entrepreneurs. In addition, Labor shortages, coupled with rising fuel prices, are spurring new interest in mechanisation of the moulding process and REBs.

Financial Barriers

Capital-Intensive Technology Financing barriers for hollow bricks and internal combustion fuel bricks requires mixers and presses. In addition, reliable electricity is required to operate these machines. Due to the capital intensity, many of the financial barriers for hollow and internal fuel bricks are the same as for kiln switching (Section 7.11).

Small-Scale Investments There are currently no institutions equipped to provide small-scale financing to the brick sector. Financial institutions, such as microfinance organisations and impact investors, lack knowledge of the brick industry. In addition, entrepreneurs who want to enter this market lack access to basic financial services.

Financial Solutions

Capital-Intensive Technology In addition to the solutions presented above, there are already organisations on the ground, such as the UNDP-GEF, which is implementing a multi-year project to develop a sustainable financing model for REB projects. It is important that other stakeholders contribute to the development of innovative financing solutions, specifically for REB projects.

Small-Scale Investments Microcredit organisations can play an important role in developing financial products for small-scale REB projects with attractive repayment rates. This financing structure could be particularly effective in conjunction with alternative ownership structures, such as co-operatives. A co-operative would allow a network of small-scale kiln owners to jointly invest in REB equipment. The benefits of this are two-fold. First, entrepreneurs gain access to technology otherwise beyond their financial means, and second, dividing the output equally between the kiln owners ensures shared ownership.

Impact investors should be encouraged to focus on the environmental and social benefits of REB technology and consider this industry as a new focus area. More work still needs to be done to quantify and standardise expected environmental and social returns from kiln upgrades. With enough donor interest, these schemes should be relatively easy to roll out.

Cultural Barriers

Perceptions Market acceptance of REBs is low. Consumers traditionally judge the quality of bricks by colour and a metallic ringing sound when struck. Fly ash composite bricks are grey, not red, and may be rejected by consumers due to unfamiliarity or an aesthetic preference for red bricks. Consumers may not realise that hollow and perforated bricks possess similar compressive strengths as solid bricks.

Cultural Solutions

Consumer Education Consumer education regarding the benefits of REBs can help to break down cultural prejudices, but thus far progress has been limited. One method by which REBs could become normalised in the marketplace is through government procurement. This has the potential to create significant demand for REBs and overcome the perceptions that these bricks are of an inferior quality.

General Solutions

There are several other overarching solutions that can contribute to emissions reductions in the brick sector. These require broad-based support from both international and domestic actors.

Sustainability

Brick Certification In the United States 'green building' has become increasingly important, and is promoted by Leadership in Energy and Environmental Design (LEED) Certification and the US Green Building Council. There are opportunities for synergies between brick production and sustainable buildings in Asia. For example, a sustainable brick certification process would allow consumers a choice in the type of bricks they purchase, and sustainable bricks could become part of a green building certification process.

In the initial stages, sustainably certified bricks would likely fetch a higher price to cover the high capital costs of investing in environmentally efficient technology. Over time, the hope is that demand for environmentally certified bricks would push less inefficient brick producers out of the market; demand-pull incentives would feed back into priorities for brick kiln entrepreneurs. Government procurement could be one way to encourage market demand. For example, the government could mandate that a certain percentage of purchased bricks for construction must be sustainably certified. This would demonstrate government confidence in the technology. In addition, the government could provide incentives to brick entrepreneurs to fire more sustainable bricks.

The private sector can also play a role in encouraging the development of sustainable bricks. Businesses are increasingly concerned about their corporate social responsibility agendas, which include environmental sustainability. To the extent that corporations use bricks for their supply chain and operations, they should be encouraged to source them from environmentally efficient kilns. This would not only add to their environmental credentials but also save the company money over time; triple bottom-line benefits of sustainability are increasingly apparent.

'One-for-One' Model In order to encourage the transition to sustainable brick production and certification, innovative financing mechanisms are needed. For example, the 'TOMS Shoes' business model can be directly applied to the brick industry. TOMS Shoes operates on the principle that the purchase of a pair of TOMS Shoes directly translates into the provision of a pair of shoes for a child in a developing country. Applying this model to the brick industry, the purchase of sustainable building materials in the United States could contribute to a fund dedicated to helping brick kiln entrepreneurs upgrade to more environmentally efficient technology.

Knowledge Sharing

Wiki-Brick Knowledge-Sharing Platform The creation of an online networking platform called Wiki-Brick would provide a forum for brick kiln entrepreneurs, investors, NGOs and other stakeholders to share best practices, knowledge and information pertaining to regional brick sectors. The hope is that this would help address the lack of communication between relevant stakeholders and facilitate the sustainable development of this industry.

Conclusion

CONCLUSION

There is significant potential for emissions reductions in the Asian brick sector. In order to realise this potential, it is necessary to work with stakeholders both domestically and internationally. The strategies identified in this report cannot be implemented without broad-based support across the public and private sectors. This must include participation from brick kiln entrepreneurs, NGOs, financial institutions and technical experts.

Many of the emissions reduction strategies identified make economic as well as environmental sense. The sustainability challenge for the brick sector is a microcosm of the larger sustainability challenge facing the international community: environmental efficiency generates triple bottom-line payback but initial capital investments to 'go green' can seem prohibitively high. This is complicated in the Asian brick sector by the interplay of developing-world realities, including a lack of access to financing, entrenched cultural attitudes that inform this traditional industry, informal industry organisation and lack of access to technological know-how and best practices. The key to solving this seemingly inexorable set of challenges is to address emissions reductions in the brick sector as a business and economic opportunity. In this instance, there need be no necessary trade-off between development and the environment.

The key is to address emissions reductions in the brick industry as a business and economic opportunity

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ANNEX I: FINANCIAL ANALYSIS OF KILN SWITCHING FROM BTK TO VSBK

The following section presents the findings from a financial analysis of BTK to VSBK kiln switching. Financial indicators are levelised to a capacity of one million bricks in order to aid in comparability.

Specific Energy Consumption

SPECIFIC ENERGY CONSUMPTION (MJ/KG) FIRED BRICK		
KILN	LOW	HIGH
Clamp	2	4.5
MCBTK	1.8	4.5
FCBTK	1.8	1.8
Hoffmann Kiln	1.2	1.5
VSBK	0.7	1

(UNIDO, 2010)

Production Capacity

KILN	BTK	VSBK
Daily Production (bricks)	30,000	10,000
No. of Firing Days per year	180	240
Total Annual Production of Fired Bricks	5,400,000	2,400,000
Class I bricks	80%	90%
Saving in good bricks		
Total Daily Class I Bricks	24,000	9,000
Total Annual Class I Bricks	4,320,000	2,160,000
Selling price of Class I Bricks (USD/Brick)	$ 0.036	$ 0.036
Annual Revenue from Sale of Class I Bricks (USD/year)	$ 154,907	$ 77,453

(TARA, 2009)

Fuel Consumption Per Year

KILN	BTK	VSBK
Coal consumption (tons/mm fired bricks)	140	80
Coal Price (USD/ton of coal)	$ 90	$ 90
Coal Price (USD/mm fired bricks)	$ 12,606	$ 7,204
Coal Price (USD/fired brick)	$ 0.013	$ 0.007
Daily Coal Costs (USD)	$ 378	$ 72
Annual Coal Costs (USD)	$ 68,074	$ 17,289
Annual Coal Saving (USD/million bricks/year)	$ -	$ 50,786

(TARA, 2009)

Labor

KILN	BTK	VSBK
Skilled workforce	Yes	Yes
Moulding Family	45	12
Firing Crew	8	4
Loaders/Unloaders	20	5
Labor Cost (USD/year)	$ 65,033	$ 29,015

(TARA, 2009)

Operating Margin

KILN	BTK	VSBK
Operating Margin (USD/brick)	$ 0.02	$ 0.03
Operating Margin (USD/mm bricks)	$ 23,252	$ 28,654
Daily Operating Margin (USD/kiln/day)	$ 698	$ 287
Annual Operating Margin (USD/kiln/year)	$ 86,833	$ 60,165

Capital Expense

KILN	BTK	VSBK
Total CapEx (USD)	$ 74,037	$ 50,025

Financial Indicators

KILN	BTK	VSBK
Simple Payback (No. of Bricks Sold)	3,184,165	1,745,810
Simple Payback Period (Months)	3.49	5.74
Debt Service Coverage Ratio (Avg.)	4.38	9.28
Debt Service Coverage Ratio (Min.)	3.08	5.08
Project IRR (Unlevered)	77%	118%
Equity IRR	52%	82%
NPV (USD)	$ 156,459	$ 249,439

ABOUT THE CARBON WAR ROOM

Carbon War Room works on breaking down market barriers for capital to flow to entrepreneurial solutions to climate change, by employing a sector-based approach focusing on the solutions that make economic sense right now. We target the movement of institutional capital into a working marketplace and the elimination of market inefficiencies (in the form of insufficient information and high transaction costs, among others). Policy and technology are necessary conditions to the solution, however, they are neither sufficient nor the bottleneck to progress.

Our vision is to see markets functioning properly and clean technology successfully scaling to promote climate wealth, business and economic growth. In the role of a climate wealth catalyst, Carbon War Room focuses on areas where a sector-by-sector approach to climate change can be applied to generate gigaton-scale carbon savings. We seek to complement existing efforts and organisations, leveraging our convening power, our market-driven, solutions-oriented focus, and our powerful global network to develop and implement catalytic change.

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