Public Disclosure Authorized

Report No. 60155-BD

Introducing Energy-efficient Clean Technologies in the Brick Sector of Bangladesh

June, 2011

Environment, Climate Change, and Water Resources Unit

South Asia Region

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Manufactured in the United States of America
First printing August 2011

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Currency Equivalents

(Exchange rate effective April 1, 2011)

Currency Unit = Bangladeshi Taka (Tk)

US$1 = Tk.71

Fiscal Year

July 1 – June 30

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ACKNOWLEDGMENTS

This report was prepared by a team consisting of Maria Sarraf (Task Team Leader), Lelia Croitoru (Environmental Economist, Consultant), M. Khaliquzzaman (Sr. Environment Specialist, Consultant), Shakil A. Ferdausi (Sr. Environment Specialist) and Jie Li (Energy Specialist).

The team would like to thank Dr. Nasiruddin (Joint Secretary), Swapan Biswas (Air Quality Consultant, CASE Project), and Shamim Hasan (Brick Consultant, CASE Project) of the Ministry of Environment and Forests for their input. The study team benefited from the vast knowledge provided by the Bangladesh Brick Manufacturers and Owners Association. Special thanks go to Messrs. Mizanur Rahman, Mohammed Ali Iftekhar, Mia Hossain, Moizuddin Ahmed, and Hassan Faisal for their cooperation and support during various field visits.

The report draws on two studies completed by Development Alternatives (India) and Practical Action (Bangladesh) in the context of the Clean Air and Sustainable Environment Project (CASE Credit 4581-BD) and special mention goes to Dr. Soumen Maity and Mr. Iqbal Karim for leading these two highly professional studies.

Within the World Bank, the report benefited from input from Mmes/Messrs.: Luis Alberto Andres, Herbert Acquay, Arun Banerjee, Hocine Chalal, Malcolm Cosgrove-Davies, Andras Horvai, Muthukhumara Mani, Michel Pommier, Ernesto Sanchez-Triana, Nadia Sharmin and Christopher Warner as well as administrative support from Poonam Rohatgi and Janet Bably Halder.

Finally, we gratefully acknowledge the financial and technical support provided by the Energy Sector Management Assistance Program (ESMAP). A global knowledge and technical assistance partnership administered by the World Bank and sponsored by bilateral donors, ESMAP assists low- and middle-income countries, its “clients,” to provide modern energy services for poverty reduction and environmentally sustainable economic development. ESMAP is governed and funded by a Consultative Group comprised of official bilateral donors and multilateral institutions representing Australia, Austria, Canada, Denmark, Finland, France, Germany, Iceland, the Netherlands, Norway, Sweden, the United Kingdom, and the World Bank.

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ABBREVIATIONS

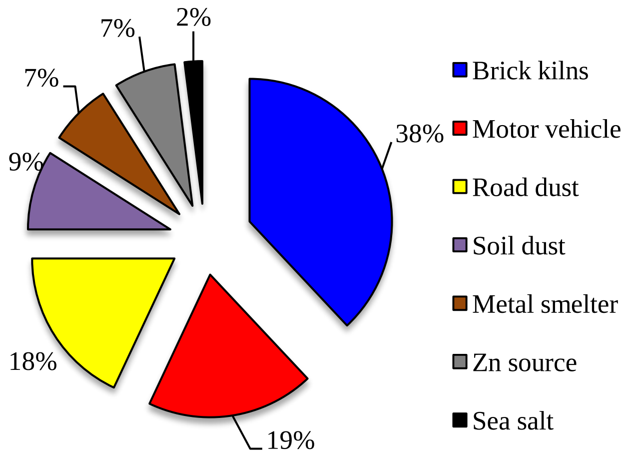
BBMOA	Bangladesh Brick Manufacturers Owners Association
BSCIC	Bangladesh Small and Cottage Industries Corporation
BTK	Bull's Trench Kiln
BUET	Bangladesh University of Engineering and Technology
CASE	Clean Air and Sustainable Environment
CBA	Cost-Benefit Analysis
CBTIA	China Brick & Tile Industry Association
CBRI	Central Building Research Institute (India)
CDM	Clean Development Mechanism
CEF	Carbon Emission Factor (IPCC default)
CERs	Certified Emissions Reductions
DA	Development Alternatives
DALY	Disability Adjusted Life Year
DOE	Department of Environment (Bangladesh)
ESMAP	Energy Sector Management Assistance Program
FCK	Fixed Chimney Kiln
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gas
GOB	Government of Bangladesh
HCA	Human Capital Approach
HHK	Hybrid Hoffmann Kiln
IFCK	Improved Fixed Chimney Kiln
IRR	Internal Rate of Return
MOEF	Ministry of Environment and Forests (Bangladesh)
MOHFW	Ministry of Health and Family Welfare (Bangladesh)
MOI	Ministry of Industries (Bangladesh)
MOLSW	Ministry of Labor and Social Welfare (Bangladesh)
MOWA	Ministry of Women Affairs (Bangladesh)
PA	Practical Action (Bangladesh)
PM	Particulate Matter
PSCST	Punjab State Council of Science and Technology (India)
SEC	Specific Energy Consumption
SME	Small- and Medium-sized Enterprise
SPM	Suspended Particulate Matter
SZigzag	Improved (Standardized) Zigzag
UNDP	United Nations Development Program
VAT	Value Added Tax
VSBK	Vertical Shaft Brick Kiln
VSL	Value of Statistical Life

UNITS OF MEASURES

cft	cubic feet
ft	foot
kg	kilogram
kWh	kilowatt hour
m	meter
mg/m^3	milligram per cubic meter
MW	megawatt
$PM_{2.5}$ PM_{10}	particulates with diameter less than 2.5 microns or less than 10 microns
ppm	parts per million
t	ton
tce	tons of coal equivalent
$\mu g/m^3$	microgram per cubic meter

Brick-making is a significant sector in Bangladesh, contributing about **1 percent** to the country's gross domestic product (GDP) (BUET 2007) and generating employment for about **1 million** people. Due to the unavailability of stone aggregate, brick is the main building material for the country's construction industry, which grew an average of about **5.6 percent** per year in 1995–2005. Despite the importance of brick-making, the vast majority of kilns use outdated, energy-intensive technologies that are highly polluting. In the North Dhaka cluster[1], brick kilns are the city's **main source of fine particulate pollution**[2], accounting for nearly **40 percent** of total emissions during the 5-month operating period (Figure 1). This leads to harmful impacts on health, agricultural yields and global warming.

Figure 1: Sources of fine particulate pollution in Dhaka



Source: Begum et al. (2010)

This report analysis the brick sector in Bangladesh and assesses the feasibility of cleaner alternative technologies. *Chapter 1* introduces the rationale and study objectives. An overview of the challenges and opportunities of the brick sector is presented in *Chapter 2*. *Chapter 3* describes the main brick technologies currently in use in Bangladesh, while *Chapter 4* portrays the main characteristics of cleaner alternative technologies. *Chapter 5* estimates in monetary terms the private and social profitability of the selected technologies. *Chapter 6* presents lessons from China, the world's leading brick producer. Drawing on previous chapters, *Chapter 7* provides the main conclusions and recommendations for a more sustainable brick sector in Bangladesh.

OBJECTIVES

The Fixed Chimney Kiln (FCK) dominates the brick sector in Bangladesh, despite its highly polluting and energy-intensive features. Such technologies as the Improved Fixed Chimney Kiln (IFCK), Improved Zigzag Kiln (IZigzag), the Vertical Shaft Brick Kiln (VSBK), and the Hybrid Hoffmann Kiln (HHK) are substantially cleaner, consuming less energy and emitting lower levels of pollutants and greenhouse gases[3]. But implementation of these technologies in Bangladesh is still at a pilot stage; thus, their financial viability still needs to be demonstrated.

[1] The North Dhaka brick kiln cluster consists of 530 closely spaced kilns, located in the Tangail, Gazipur and the northern Upazilas of Dhaka districts (BUET 2007).

[2] Fine particulates refer to particulate matter (PM) with diameter of less than 2.5 µm, which is more harmful to health than PM with larger diameter (Pope et al. 2002).

[3] BUET 2007; Heirli and Maithel 2008; World Bank 2011a.

This study's **objectives** are: (i) to present the pros and cons of existing and alternative brick technologies[4] in Bangladesh with specific focus on pollution and energy efficiency; (ii) to estimate the private and social benefits of these technologies (iii) to summarize China's experience in the development of the brick industry, as the world leader brick producer and (iv) to provide concrete recommendations for adopting cleaner technologies in Bangladesh.

The originality of this report stems from: (1) ***primary data collection,*** based on the IFCK, VSBK and HHK pilot projects[5] and on interviews with FCK owners; (2) first-time ***economic valuation of the overall impacts*** of different kiln technologies, and ***comparison*** among them; (3) first comprehensive review of 20 years' of ***China's (the world leader brick producer) experience*** in technology change and government regulation in the brick sector. Thus, this report is expected to substantially bridge the knowledge gap in terms of data collection, methodology and realistic recommendations for the improvement of the brick sector in Bangladesh.

SCOPE AND AUDIENCE

The study focuses on the brick cluster located in northern Dhaka, which comprises 530 FCKs that produce 2.1 billion bricks annually (14 percent of the country's brick production). As the brick sector is a prominent contributor to air pollution in Dhaka, it is important to distinguish its contribution to the city's air pollution from other sources, including transport and other industries. Because of limited data availability,[6] the analysis relies on the most realistic assumptions drawn from monitored data in Bangladesh or neighboring countries (i.e., Nepal and India). As a result, the estimated net returns for each technology are ***orders of magnitude*** rather than precise estimates.

The ***primary audience*** and the main ***usefulness*** of the report are:

(i) the Ministry of Environment and Forests (MOEF), who can benefit from an evaluation of the real magnitude of the environmental externalities caused by different brick technologies (health problems and carbon emissions);

(ii) the Bangladesh Brick Manufacturers and Owners Association (BBMOA), who can use the recommendations as a tool for discussing the importance of the brick sector among other industries, and for introducing cleaner brick practices in the country; and

(iii) the Ministry of Industries (MOI),who can use the information to speed up the recognition of the sector as a formal industry.

METHOD

Estimating the net returns from each technology is based on the Cost Benefit Analysis (CBA)

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[4] The analysis covers only a set of technologies for which data could be made available (FCK, IFCK, VSBK, HHK). Other technologies, though successful throughout the region, could not be included, either because of lack of well-documented information (e.g. IZigzag) or their unlikely viability in the Bangladesh context (e.g. technologies based on non-fired bricks due to the non availability of cement and stone chips and weather conditions). Therefore, the implications of this analysis refer only to the technologies covered by this report.

[5] These include an IFCK piloted in Rupganj (Narayangunj) during the preparation of the Clean Air and Sustainable Environment (CASE) project (DA-PA 2009); a VSBK piloted with funding from Energy Sector Management Assistance Program (ESMAP) (DA-PA 2010); and the preparation by the World Bank of an Emission Reduction Purchase Agreement (ERPA) for a HHK in Savar (World Bank 2011a).

[6] For example, data on pollutant emissions per unit of bricks and dispersion patterns.

approach. The analysis measures the net returns from the private and social perspectives, defined as follows:

- The ***private (financial) CBA***: The analysis from the entrepreneur's viewpoint includes all costs and benefits for the entrepreneur.
- The ***social (public) CBA***: The analysis from the social viewpoint includes the costs and benefits from the private CBA, as well as the social and environmental impacts of brick kilns, including the health effect of air pollution and the cost of CO_2 emissions.

Table 1 depicts the valuation methods used to estimate each cost and benefit. The analysis refers to the year 2009, uses a time horizon equal to the life span of a kiln (20 years), and a discount rate of 10 percent. A sensitivity analysis of net returns to changes in discount rates was then carried out.

Table 1: Valuation methods used

Type of analysis	Types of costs and benefits	Valuation method
Private	**Costs: -** Investment, land, buildings, operating costs, taxes **Benefits:** Value of bricks	Market prices Market prices
Social	**Costs: -** Investment, land, buildings, operating costs; - Health impact of air pollution; - CO_2 emissions **Benefits:** Value of bricks	Real prices Disability Adjusted Life Years (DALYs) Price on the carbon market Real prices

RESULTS

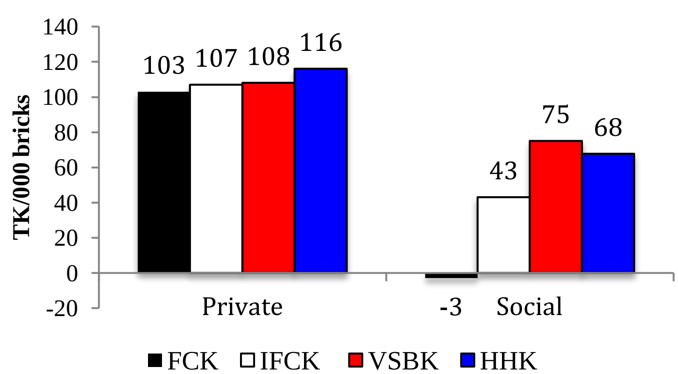
The ***overall results*** of the economic analysis indicate that:

- **Cleaner technologies (i.e. VSBK, HHK) are the most socially profitable ones, while polluting technologies (i.e. FCK) are socially unprofitable**. VSBK and HHK are the most socially profitable technologies, with net benefits of TK68-75 per thousand bricks. In contrast, the high costs of air pollution and CO_2 emissions make the FCK socially unprofitable, with net social costs of TK3 per thousand bricks. (Figure 2).

- **Though socially unprofitable, FCK is the most commonly implemented technology in Bangladesh**. FCK accounts for more than 90 percent of brick kilns in Bangladesh. The low investment cost and the ability to operate on lowlands explain the FCK's dominance in the brick sector.

- **Adopting cleaner technologies is hindered** by their need to operate on flood-free lands (i.e. highlands) which are scarce and expensive. In addition,

Figure 2. CBA results for different brick technologies



some technologies (e.g. HHK) require substantial investments, which are unaffordable for most FCK owners who operate on rented land that cannot be used as collateral.

Specific results of the analysis related to the kilns' social and environmental impacts suggest that:

- **Currently, FCKs contribute up to 20 percent of the total premature mortality caused by urban air pollution in Dhaka (all causes combined).** The Bangladesh Country Environmental Analysis reports that poor air quality in Dhaka contributed to an estimated 3,500 premature deaths in 2002 (World Bank 2006)[7]. Emissions of PM_{10} and $PM_{2.5}$ from the kiln cluster north of Dhaka are responsible for 750 premature deaths annually. Thus, current FCKs are likely to contribute up to 20 percent of total premature deaths in Dhaka due to poor air quality[8].

- **Replacing the brick cluster north of Dhaka with VSBKs** would reduce current premature mortality by more than 60 percent; replacement by HHKs would reduce it by 45 percent.

- **Adopting the VSBK or HHK can provide considerable carbon benefits**. The FCK provides the highest unit cost of carbon emissions (TK4 per brick[9]), primarily because of the high coal consumption. By contrast, the low coal consumption makes the VSBK and the HHK the cleanest technologies in terms of CO_2 emissions (less than TK3 per brick).

The review of China's 20-year experience in the brick industry development shows that transformative change occurred through: (i) diversifying raw materials by using mixed waste materials (e.g. fly ash, gangue, coal dust and coal slurry); (ii) diversifying wall material products, by producing hollow bricks, non-fired bricks (now accounting for 50 percent of total bricks) and (iii) increasing the scale of brick enterprises and productivity, thus saving land and energy. A combination of government intervention (e.g., regulations for phasing out traditional solid clay bricks) and financial incentives (e.g., specific funds and preferential tax policies on promoting new brick products) played an important role for the success of this transformational change. This experience suggests that it is now the time for Bangladesh to begin its transformative development. How to achieve this development over the next 20 years is the focus of the next section.

POLICY RECOMMENDATIONS

Bangladesh's brick sector is characterized by outdated technologies with low energy efficiency and high emissions; low mechanization rate; dominance of small-scale brick kilns with limited financial capacity; and dominance of single raw material (clay) and product (solid clay brick). Adopting gas-based cleaner technologies is hampered by serious energy shortage and land scarcity.

How long can the country afford making bricks in this way? The current status is by no means sustainable. Bangladesh has every reason to upgrade its brick sector in order to save valuable natural resources, reduce air pollution, and increase energy efficiency. The government has already established regulations that ban the use of fuelwood and FCKs and has reconsidered the location

[7] Because respirable PM in Dhaka has concentrations exceeding the standards for more than 100 days a year.

[8] The industry and transport development after 2002 most likely increased the number of premature deaths in Dhaka; however, updated estimates were unavailable at the time of the analysis.

[9] In present value terms.

and height of brick kiln chimneys. However, transformative development of the brick industry has yet to occur.

This report suggests that the development of the brick industry in Bangladesh ***over the next 20 years*** should aim at: (i) moving from traditional brick-making technologies (e.g. FCK) to cleaner ones (e.g. HHK, VSBK); (ii) diversifying products (e.g. hollow and perforated bricks) and locally available alternative raw materials; (iii) increasing the proportion of large-scale enterprises with higher capacity to adapt to cleaner technologies. To achieve these goals, a summary of concrete recommendations is provided below.

In the short-term:

1. Recognize brick kilns as a ***formal industry.*** This would enable easier access to financial resources (which in turn will enable investment in cleaner technologies and access flood free land) and improved working conditions.

2. Create a ***Brick Technology Center*** to raise awareness about the benefits of cleaner technologies. The center should: (a) disseminate information on the *social benefits* provided by cleaner technologies, new wall materials (e.g. perforated and hollow bricks) and alternative raw materials; (b) promote pilot projects of new technologies with improved provisions (e.g., mechanized, higher labor productivity and larger product lines); (c) improve use of existing dissemination channels (e.g., field visits to pilot plants, video demonstrations of the technologies, use of the Bangla language) and introduce new channels (e.g., newsletters, industry journals, conferences, and Internet blogs).

3. Support ***research and development*** aiming at: (a) exploring alternative raw materials[10] that are locally available, brick diversification, and use of higher level of mechanization; (b) conducting new studies such as energy consumption studies, land surveys, and brick technology surveys.

4. Facilitate the availability of ***subsidized credit lines*** to account for reduced health impacts from pollution and of other ***economic incentives*** supporting the production of new wall materials and use of alternative raw materials (e.g. via specific funds and preferential tax policies, as in China).

5. Provide access to ***carbon markets***, on account of the carbon emission reductions provided by cleaner technologies.

6. ***Train*** several stakeholders with regard to the benefits of adopting cleaner technologies (e.g. brick owners, workers and the financial sector).

[10] A word of caution should be mentioned about the use alternative raw materials, where strong quality control should be kept in regulators' mind. Some alternative raw materials, especially wastes, may contain toxics that are harmful to human health. Pertinent policies, laws, and regulations need to be developed and set up to make sure no hazardous raw materials are used while they are adopted in the industry. In the past few years, local governments in China have strengthened regulations to prohibit hazardous materials from being used for wall material production and developed a series of standards for quality control of new products, to safeguard favorable development of this industry.

In the medium term:

7. ***Enforce the existing regulations and policies***, such as the ban of traditional high polluting kilns (e.g. FCK, BTK), particularly those located close to large population centers, upstream of the wind (north) in the dry season (November to April).

8. ***Introduce regulations and policies that encourage adoption of cleaner technologies***, such as: (a) revise emissions standards for brick kilns under ECR97 to make them technology independent and to encourage brick diversification (e.g., perforated or hollow bricks for partition walls); (b) establish proper emission monitoring for brick kilns; (c) impose an emission levy based on "polluter-pay principle"; (d) design rules and standards for the entire brick value chain: from raw materials to production processes and equipment and final products to building designs and construction processes.

9. ***Develop industrial parks*** to accommodate a large number of industries on flood-free land. These parks would mean less cost for kiln owners, due to the economy of scale achieved by providing the basic infrastructure for all kilns (e.g. roads, electricity, water) and other facilities (e.g. schools for the employees' children). They would also require less land for kilns establishment compared to the current situation[11].

10. ***Improve working conditions*** by introducing higher levels of mechanization, social programs to reduce child labor, occupational safety and health measures in kilns.

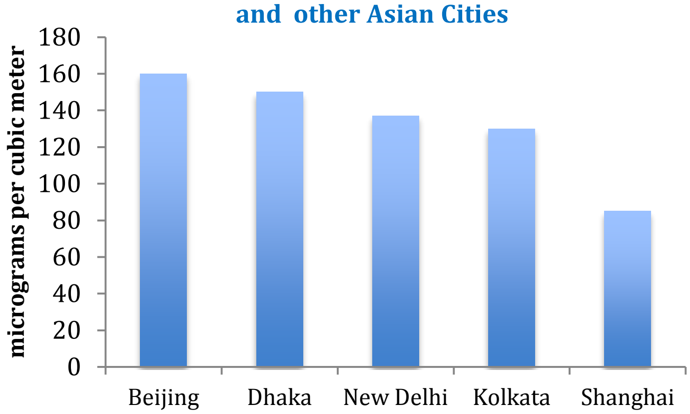
[11] World Bank (2011) assessed that 6,400 acres of land would be needed over a 20-year program to build new factories in either brick parks or in other places specifically designated for brick production. At the same time, about 3,300 FCK entrepreneurs would have switched to VSBK and/or Zigzag factories, freeing up approximately 8,000 acres of lowland for cultivation.

CHAPTER 1. INTRODUCTION

With about 5,000 operating kilns[12], brick-making is a significant sector in Bangladesh (Box 1.1), contributing about **1 percent** to the country's gross domestic product (GDP) and generating employment for about **1 million** people (BUET 2007). Brick is the main building material for the construction industry, which has been growing at about **5.6 percent** annually between 1995 and 2005, leading to an estimated growth rate of 2–3 percent for the brick sector.

Despite the importance of the brick sector, about 95 percent of kilns use outdated, energy-intensive technologies that are highly polluting. Those located in the North Dhaka cluster are the city's **main source of fine particulate pollution**[13], accounting for **40 percent** of it during the 5-month operating period. This causes harmful impacts on health (from particulate matter) and agricultural yields (from nitrogen oxides) and contributes to global warming (from carbon dioxide). As Dhaka is one of the most polluted cities in Asia (Figure 1.1[14]), addressing the impact of brick kilns on pollution in this city is very important.

Figure 1.1. PM_{10} Concentration levels: Dhaka and other Asian Cities



New technologies, such as the Vertical Shaft Brick Kiln (VSBK) and the Hybrid Hoffmann Kiln (HHK), are substantially cleaner than the Fixed Chimney Kiln (FCK) currently used. These improved technologies consume less energy and emit lower levels of pollutants and greenhouse gases (GHGs) (BUET 2007; Heirli and Maithel 2008; World Bank 2011a). However, because the use of these technologies in Bangladesh is still in the pilot stage of implementation, their financial viability (compared with that of the FCK) still needs to be demonstrated.

The **objectives** of this study are: (i) to present the pros and cons of existing and alternative brick technologies in Bangladesh, with specific focus on pollution and energy efficiency; (ii) to estimate the private and social benefits of these technologies (iii) to summarize China's experience in the development of the brick industry, as the world leader brick producer and (iv) to provide concrete recommendations for adopting cleaner technologies in Bangladesh.

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[12] Kiln estimates vary by source, ranging from 4,140 (GEF–UNDP, 2006) to 5,000 (BUET, 2007) and up to 6,000 (informal estimate) (DOE 2010). This report uses the latest survey-based data of 5,000.

[13] Fine particulates refer to PM with a diameter of less than 2.5 µm, which are more harmful to health than particulates with larger diameters (Pope et al. 2002).

[14] Data refer to 2006 and are based on the Department of Environment (DOE) for Dhaka and http://www.baq2008.org/about-bangkok/air-quality-and-climate-change-action for the other cities

The study conducts a Cost Benefit Analysis (CBA) that considers not only the direct costs and benefits for the entrepreneur, but also the impacts of air pollution on health and the effects of CO_2 emissions on climate change. The analysis focuses on the brick kiln cluster north of Dhaka city, which is one of the country's major brickfield areas.

The originality of this report stems from: (1) ***primary data collection,*** based on the IFCK (DA-PA, 2009), VSBK (DA-PA, 2010) and HHK (CDM, 2009) pilot projects[15] and on a series of interviews conducted with FCK owners near Dhaka. (2) first-time ***economic valuation of the overall impacts*** of different kiln technologies, and ***comparison*** among them; (3) first comprehensive review of 20 years' of China's (***the world leader brick producer)*** experience in technology change and government regulation in the brick sector to provide lessons learned for Bangladesh. As such, this report is expected to substantially bridge the knowledge gap in terms of data collection, methodology and realistic recommendations for the improvement of Bangladesh brick sector.

As the first attempt to estimate the social impacts of brick kilns in Bangladesh, the accuracy of the estimates is sometimes constrained by data limitations. In some cases, data constraints imposed the use of conservative assumptions. In other cases, the lack of data was replaced by information available from the implementation of these technologies in neighboring countries (e.g. Nepal, India). As a result, all valuations should be regarded as **orders of magnitude** rather than precise estimates.

The study was initiated in 2009, following several consultations with stakeholders in Bangladesh. It draws on two analyses completed under the Clean Air and Sustainable Environment Project (Credit 4581-BD) (DA–PA 2009 and 2010). The present study provides input to a potentially large brick operation that will result in cleaner air quality for the city of Dhaka.

This report is organized as follows. *Chapter 2* presents an overview of the brick sector in Bangladesh, focusing on its challenges and opportunities. *Chapter 3* describes the main brick technologies used in Bangladesh, while *Chapter 4* portrays the main characteristics of cleaner, alternative technologies. *Chapter 5* estimates in monetary terms the private and social profitability of selected technologies. *Chapter 6* presents the experience of China, the world's leader in brick production. *Chapter 7* provides the main conclusions and recommendations for achieving a more sustainable brick sector in Bangladesh.

[15] These include an IFCK piloted in Rupganj (Narayangunj) during the preparation of the Clean Air and Sustainable Environment (CASE) project; a VSBK piloted with funding from Energy Sector Management Assistance Program (ESMAP) and the preparation by the World Bank of an Emission Reduction Purchase Agreement (ERPA) for a HHK in Savar.

Box 1.1 Brick is an important construction material in Bangladesh.

Bangladesh has very limited supplies of natural stones. About 44% of houses in Dhaka (according to the 1991 census) were built using bricks as the major wall material (Rashid, 2007). Bricks are also widely used, not only for housing construction, but also for construction of roads, pavements, bridges, irrigation structures and as aggregate in concrete mix (FAO, 1993).

Houses (dwelling units) by construction material in Dhaka City		
Material of wall	Total no of houses	%
Straw, Bamboo	342,820	31%
Mud, un-burnt brick	125,467	12%
C.I. Sheet, Metal	142,319	13%
Wood	2,969	<1%
Brick / cement	**474,803**	**44%**
Total	**1,088,378**	**100%**

Source: Bangladesh Population Census 1991. Vol. 3., Urban Area Report, 1997 (Cited by Rashid, 2007)

In Bangladesh, for centuries traditional houses have been built using locally available materials. Historically, bamboo has been the most important building material for housing. Even today bamboo is still widely used. As a result of economic growth, construction activity expanded steadily and more houses are nowadays being constructed with brick material (along with cement, titled roof, corrugated iron sheets and reinforced concrete).

Brick making is indispensable for Bangladesh' economy. Though not formally recognized as an industry, brick-making is a significant economic activity in Bangladesh (Ministry of Industries 2010).[16] The country's overwhelming dependence on bricks is due to its lack of stones in any sizable quantity or other alternative building materials at comparable cost. Table 2.1 summarizes the main characteristics of the brick sector in Bangladesh.

Table 2.1: Snapshot of Bangladesh's brick sector (2011)

Parameter	Value
Estimated total number of **coal**-fired kilns	5,000
Number of natural **gas** fired kilns	20
Annual brick production	17.2 billion
Value of output	TK83 billion (~US$1.2 billion)*
Contribution to GDP	~1%
Coal consumption	3.5 million tons
Value of imported coal	TK22.6 billion (~US$322 million)
Firewood consumption	1.9 million tons
Emissions CO_2	9.8 million tons
Clay consumption	45 million tons
Total employment (incl. supply of clay and coal, transport of bricks)	~1 million people
Growth rate of the construction industry (1995-2005)	5.6%
Estimated future growth rate of the brick sector over the next ten years	2-3%

Sources: BUET (2007), Gomes and Hossain (2003) and World Bank (2011b)
*Estimated at a per-brick price of TK5.5.

Brick kilns in Bangladesh are mostly informal and small-scale operations. More than 90 percent of brick kiln owners are small-scale operators. Most FCKs are individually owned, with each owner possessing one kiln only. Multiple ownership of one kiln and multiple kilns under the same ownership are rare. In a few cases, established business houses own brick kilns that are part of a portfolio of industrial establishments. The kiln owners are organized as the Bangladesh Brick Manufacturers Owners Association (BBMOA). This association is expected to support actions perceived as beneficial to the interest of its members; thus, it must be involved in any reform concerning the brick sector.

[16] There are two main underlying reasons for lack of industry recognition. First, while Small- and Medium-sized Enterprises (SMEs) in Bangladesh are defined in terms of employment provided, brick kilns are seasonal operations that do not provide year-round employment. Second, most brick kilns are located on rented land and do not have fixed assets (except for the chimney).

Regulating the brick sector has improved considerably; however, enforcement is still needed. The Government of Bangladesh (GOB) has demonstrated serious commitment to regulating the brick industry through a series of measures[17]:

- *1989*. The Brick Burning (Regulation) Act of 1989, Bangladesh's first brick-making law, banned the use of firewood for brick manufacturing and introduced licensing for brick kilns.
- *2001*. The 1989 Act was amended to regulate the location of brick kilns. The new provision required that brick kilns not be set up within 3 km of the upazilla[18] or district center, municipal areas, residential areas, gardens, and the government's reserve forests.[19] Despite this amendment, the location requirements have not been enforced, and use of firewood still continues on a limited scale.
- *October 2002*. The GOB introduced a rule that made the use of 120-ft chimneys for brick kilns compulsory. This requirement was successfully enforced, especially in the vicinity of urban areas, and most Bull's Trench Kilns (BTKs) were upgraded to FCK technology.[20]
- *March 2007*. The GOB issued notification that environmental clearance certificates would not be renewed if the owners did not shift to alternative fuel and improved technologies by 2010. However, this regulation has not been implemented since little on-the-ground activity occurred to facilitate the switch.
- *July 2010*. A new notification was issued banning FCK operation three years from this date.

Outdated brick-production technology and seasonality of kiln operations hinder brick-sector productivity. FCK technology is more than a century old. The brick sector has largely grown by replication of existing kilns, with little variation in kiln design or operation. Brick-making is a seasonal operation. Because kilns are often located in low-lying areas that are flooded during the monsoon, the operational period averages about 5 months out of the year. Employment in brick kilns is therefore also seasonal, involving migrant workers who receive low wages and perform hard physical labor under hazardous conditions. As a result, annual production averages about 3–4 million bricks per enterprise (BUET 2007), compared to 12 million standard Chinese bricks (equivalent to 9.2 million Bangladesh bricks)[21] per enterprise in China (MoEP 2009).

Most brick kilns have low energy efficiency and are highly polluting. Most brick kilns in Bangladesh burn low-quality coal imported from India with a high content of sulfur (about 5 percent) and clinker content[22]. Dependence on this type of coal is likely to continue in the foreseeable future. Owing to Bangladesh's current energy shortage, the GOB decided not to

[17] Annex D presents a detailed review of the laws and regulations related to the brick sector in Bangladesh.

[18] The term *upazilla,* which literally means subdistrict, refers to an administrative entity in a district (several upazillas constitute a district).

[19] It should be noted that *residential area* is defined as an area having at least 50 families, while *garden* is defined as one having 50 fruit or forest plants. Using these definitions, it is nearly impossible in reality to find land for brick kilns in Bangladesh. The BBMOA often cites this as a major deficiency in the law.

[20] However, some BTKs continue to operate, albeit illegally.

[21] Bricks produced in China are smaller than the bricks produced in Bangladesh (they are referred to as "Standard Chinese Bricks"). 1 Bangladesh brick = 1.317 Standard Chinese Brick. For comparison purposes, Chinese Standard Bricks have been also expressed in the equivalent Bangladesh size (detail information on the size is provided in Chapter 6).

[22] Although Bangladesh produces high-quality coal with low sulfur content (i.e., less than 0.5 percent), virtually all of it is used for a mine mouth power plant and thus is unavailable for brick kilns. Occasionally, during non-operational periods of the power plant, local coal becomes available for brick kilns.

provide natural gas for new brick kilns. Moreover, the 20 existing gas-fired kilns are facing closure (Box 2.1).

Box 2.1: Bangladesh's Energy Shortage

Bangladesh faces up to 1,800 MW of load shedding. According to the latest data from the Power Division of the Ministry of Power, Energy, and Mineral Resources, the country's generation capacity is about 3,800–4,300 MW, with a peak demand of about 5,500–5,800 MW.

At present, the electricity-access rate is still as low as 47 percent. In 2009, per-capita electricity consumption was only 220 kWh (50 percent of India's, 40 percent of Vietnam's, and 9 percent of China's).

In addition, more than 88 percent of electricity is generated from natural gas–based power plants. The reserve of natural gas is limited, and domestic production is expected to peak soon if new reserves are not found. Power plants and other industrial sectors, such as fertilizer and steel production, compete for the limited natural gas supply. Under these circumstances, the GOB has decided not to provide natural gas to brick kilns, and existing gas-fired ones face closure due to supply shortage. The country expects an enormous increase in electricity demand as economic growth continues (at a rate of 5–6 percent per year). As supply shortages of natural gas are likely to grow in the future, more coal might be demanded for power generation and industrial sectors.

Source: GOB (2010)

Most operating kilns consume about 18–22 tons of coal to produce 100,000 bricks (BUET 2007). Coal burning by kilns releases pollutants into the atmosphere, leading to harmful effects on health (e.g., from PM) and agricultural yields (e.g., from NO_x) and contributing to global warming and climate change (e.g., from CO_2). Adopting such modern kilns as the Improved Zigzag, VSBK or HHK would mitigate some of the above-mentioned impacts due to their lower coal consumption (12–15 tons per 100,000 bricks) (BUET 2007; World Bank 2011).

Brick kilns have a negative effect on agricultural productivity. Almost invariably, good-quality topsoil from agricultural fields with high clay content is used in Bangladesh's brick kilns. Depletion of topsoil with high organic content for brick-making is a major concern for agricultural production. In addition, acid deposits from the sulfur dioxide (SO_2) and NO_x emitted from the brick kilns negatively affect agricultural productivity.

The weak financial situation of most kiln operators hinders the adoption of modern technologies. Most kiln operators have a weak financial base, with limited or no access to bank financing. Because brick-making is not formally recognized as an industry, kiln owners cannot avail themselves of the concessional loan windows of financial institutions for the SMEs. In addition, most kilns are established on rented lowlands that cannot be used as collateral to access finance. As a result, only short-term working capital financing is available to kiln owners. Box 2.2 summarizes the main barriers faced by the brick sector in Bangladesh.

Box 2.2: Barriers facing the brick sector in Bangladesh

The barriers that have contributed to the current state of the country's brick sector and its inability to bring about changes include:

- *Lack of supporting regulations, fiscal incentives and standards to encourage more energy efficient practices and technologies.* Except for some efforts to regulate the sector, the government has made little effort to establish effective boundary limit emission standards;

- *Little and no governmental activity to assist the brick sector to undertake comprehensive programs so as it to make it cleaner and more profitable.* Brick owners usually were left to bring in changes of their own which they have often failed to do, because of the vicious cycle of low efficiency – low income.

- *Lack of knowledge and access to energy efficient technology*, which can lower production costs at the same time. Comprehensive dissemination programs that demonstrate the potential economic benefits of energy efficient technologies have yet to be carried out.

- *Lack of access to liquidity to finance modernization of brick making operations.* As traditional brick kilns have seasonal employment, they have not been included in the list of recognised SMEs and thus, are not eligible for concessional SME loan windows.

- *Lack of capacity in terms of technical and business skills at the enterprise level*, that could bring changes towards improved efficiency and reduced pollution.

- *Limited experience of commercial lending institutions with SMEs and in particular, brick SMEs.*

Source: UNDP (2010)

Lack of access to finance constrains the owners' capacity to adopt improved technologies that would reduce pollution and increase energy efficiency. Thus, for small operators, incremental, low-cost retrofit technology appears better suited for upgrading kilns.[23] Lower-emission, higher-efficiency kilns (e.g., coal-based HHKs) cost 10 times or more than the FCKs (World Bank 2011a). Moreover, these kilns operate year-round on highlands above flood level; these are scarce and those near major cities are very expensive. Because of these constraints, current FCK owners are unlikely to adopt the HHK or other modern technologies unless flood-free land is made available to them at an affordable cost.

[23] Retrofits for existing FCKs are improvements to increase energy efficiency and reduce pollution levels. Energy-efficiency improvements are achieved by using internal fuel (i.e., mixing powdered coal in green bricks), a brick-stacking arrangement, and better insulation to reduce heat loss to ground and through the roof and sidewalls. Decreasing pollution levels is achieved through flue-gas scrubbing and use of internal fuel.

Bangladesh uses **four main types** of kiln technologies, as presented in Table 3.1. The Fixed Chimney Kilns (FCKs) and the Bull's Trench Kilns (BTKs), which form more than 90 percent of kilns, are very polluting and relatively inefficient. The gas-based Hoffmann kilns and the coal-based Zigzag kilns are substantially cleaner, but represent just a few percent of the total. The following sections discuss the characteristics of all these technologies, except for the BTK, which is now banned.

Source: DA-PA, 2010

Table 3.1: Existing brick kiln technologies in Bangladesh (2009)

Kiln type	Number	Percent of total kilns (%)	Brick production[24] (billion bricks)	Percent of total production (%)
FCK	≤ 4,500	92	15.8	91.4
BTK	n.a.	n.a.	n.a.	n.a.
Zigzag	≤ 150	3	0.6	0.0
Hoffmann (gas)	≤ 20	0.4	0.2	3.5
HHK	≤ 10	0.2	0.2	1.4
Others	≤ 200	4.0	0.5	0.9
Total	**≤ 4,880**	**100**	**17.2**	**100**

Source: DOE 2010a. n.a. = not applicable.

3.1. Fixed Chimney Kiln

FCK is the mainstay technology for the brick sector in Bangladesh. It is very polluting, energy intensive and requires relatively low-cost investment[25]. FCK dominates the northern Dhaka kiln cluster, are located on lowlands and operate for 5-6 months a year.

The above figure illustrates an FCK under operation emitting black smoke because of incomplete combustion of coal. The FCK is based on the traditional BTK technology, which dates back to the 19^{th} century. While the BTK uses two 30 feet[26] (ft) high moveable chimneys[27], the FCK has a fixed chimney of about 120-130 ft height. The tall chimney provides a faster and better dispersion of the flue gas and its pollutants, compared to the BTK. The FCK has an elliptical shape and measures about 250 ft long and 60 ft wide. It is constructed mostly in open fields either over ground or partially underground. The bottom and the sidewalls are lined with bricks. The FCK uses green bricks that are manually produced from mud processed in pug mills[28], as presented in Box 3.1. The

[24] Based on an average production for each kiln type: about 3.5 million bricks for the FCK, 4 million bricks for Zigzag, 12 million bricks for Hoffman, 15 million bricks for HHK and 2.5 million bricks for others.

[25] The average investment cost is about TK4.8 million and includes the costs of construction (kiln structure, chimney) and of machineries and other equipment (based on a September 2009 field survey in Dhaka).

[26] 1 foot (ft) = 0.3 meter (m)

[27] This causes a very poor dispersion of the emission plume, thus a high level of local air pollution.

[28] Stamping machines are rarely used for green bricks forming.

wet green bricks are sun dried and loaded in the kiln in a standard way developed over time with provisions for airflow and coal stoking. Once the green bricks have been loaded in the kiln, the top is covered with two layers of bricks and dirt for insulation.

Box 3.1 Green brick preparation

Step 1:Pugging

Pugging can be done either manually or by machine. Pugging is the process of breaking soil lumps into smaller grain size and uniformly mixing it with water. Pugging ensures homogeneity of soil for brick making.

Step 2: Manual Molding

Molding is the process where pugged soil is given a specified shape of the bricks, using mould boxes.

Step 3: Drying

Drying occurs naturally under the sunlight. It is the process of removing the water content from green bricks. Drying is important because green brick require less energy.

3.2. Zigzag Kiln

The Zigzag kilns used in Bangladesh are replications of similar Indian kilns developed by the Central Building Research Institute (CBRI) in Roorkee, India during the 1970s. They are fairly similar to Habla kilns once widely used in Germany and Australia. In Bangladesh, the Zigzag kilns are concentrated in the Comilla region (Gomes and Hossain 2003). If properly constructed and operated, zigzag kilns would result in better energy efficiency and lower emissions. The *energy efficiency* gains are due to better insulation and improved heat transfer to the green bricks[29]. The *emission reductions* are due to lesser fuel use, better brick stacking, zigzag air flow over longer path and flue gas scrubbing in a water filled duct connecting to the outlet chimney.

A Zigzag kiln is rectangular and typically measures about 250 ft long and 80 ft wide. It has a 55 ft high fixed chimney located on one side of the kiln. An induced draft fan located at the bottom of the chimney draws the flue gas from the kiln and discharges it into the atmosphere. The induced draft fan ensures a well-controlled airflow through the kiln. The kiln is divided into 44 to 52 chambers, separated from each other by green bricks in a way that the hot gas moves in a zigzag path through small openings. The long travel path of bricks in a zigzag pattern and the contact of hot gas from the firing zone with bricks in the preheating zone contribute to the transfer of more heat in the preheating zone. Thus, the flue gas - rather than the fuel - heats up the bricks. In addition, the waste heat in the flue gas helps to better drying and reducing the moisture content in bricks. These effects promote reduced fuel consumption, greater efficiency and higher brick quality compared to the FCK's.

The flue gas' repeated changes in direction and impinging on the walls and stacked bricks lead to the deposition of significant amounts of particulate matter mostly on the green brick surface. The deposition of particulates implies that the flue gas has much less particulate load. This could be the reason for reduced Zigzag emissions compared to FCKs emissions (Figure 3.6).

The Zigzag kiln also incorporates a simplified flue gas scrubber. The connecting duct between the center of the kiln and the inlet of the induced draft fan is half to two-third filled with water. The flue gas laden with dust particles impinges on the water thus losing some of its particulate load (Figure 3.4). The water is periodically cleaned to ensure continued scrubbing.

The Zigzag kilns in Bangladesh have been implemented with the help of artisans without expert supervision. Thus, it has not been possible to ensure proper construction according to certified design, which is important in reducing the level of particulate emissions. To achieve this goal, it is essential to: (1) try out the technology with expert professional input; (2) develop certified design specifications for construction and standard operating procedures; (3) establish good operational practices and management. In the absence of such a systematic approach, not only there may not be significant reductions in emission levels, but the local pollution may actually increase due to reduced chimney height[30].

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[29] By allowing the heat to flow in a zigzag pattern rather than in a straight line, the combustion rate is substantially increased.

[30] As previously noted, a Zigzag kiln usually has a 55ft chimney compared to the FCK's 120ft or higher chimney. Some Zigzag kiln owners have increased the chimney height when they found the poor emission levels from these kilns. (Personal communication with kiln owners, Dhaka, 2010).

Figure 3.1[31] Placing bricks for firing: Bricks are placed in blocks in each chamber according to the shape and size of the chamber. In this picture, each block has 7 columns, each column contains 13-18 bricks, and there are 17-21 layers of brick.

Figure 3.3 Hollow Space for fire and air movement. There is 3”-4” hollow space in between the column and the row and also in between two chambers for fire and air movement.

Figure 3.5 Firing bricks. There are 18 furnaces on top of each chamber through which coal is poured intermittently for burning the bricks.

Figure 3.2 One of the furnaces on top of a chamber through which coals are poured.

Figure 3.4 Deposited residues from smoke. Smoke from the chamber comes to a channel before it is released. The channel is connected to another underground channel which is half filled with water. The smoke and vapor from the kiln is extracted by a blower pump. Since the smoke flows over water into the underground channel, a large portion of the suspended particulate matter is extracted from the smoke and deposited.

Figure 3.6 In the front the zigzag chimney emitting cleaner smoke, than the FCK black smoke in the rear.

[31] Figures 3.1, 3.2 and 3.6 were taken by M. Sarraf in 2010. Figures 3.3, 3.4 and 3.5 were taken by N. Sharmin in 2010

3.3. Hoffman kiln (natural gas)

Hoffman Kiln (HK) was developed in Germany by Friedrich Hoffman in the mid 19th century and was once widely used in Europe for brick, ceramics and lime production. Natural gas-fired Hoffman kilns were introduced in Bangladesh during the 1980s. A Hoffman kiln is rectangular and measures 300-400 ft long and 60 ft wide. HK have excellent insulation provided by the thick kiln walls thus heat loss is greatly reduced. The emissions are also very low due to the use of natural gas as fuel.

Figures 3.8 to 3.13 illustrate the general configuration of a Hoffmann kiln. Building this type of kiln requires special engineering expertise. The main difference between Hoffman and the traditional kilns is that HK is build on high land, which does not get flooded and hence can produce throughout the year. In addition, the HK has a roof which makes it possible for the plant to operate even during the rainy season[32]. The inside roof of the kiln is arched and has a firebrick lining on the inside surface. The thick walls provide good insulation that minimizes heat loss.

The chimney is about 80-100 ft high with an induced draft fan at the bottom. The flue gas is conveyed towards the chimney through a network of channels just below the kiln. The fire is controlled by merely adjusting the gas flow rate and by opening and closing the dampers located at selected points in the flue gas network[33].

Green bricks are stacked in the kiln in the same way as in FCKs. The bricks are fired from the top by introducing the natural gas into the combustion zone through pipe-type burners. This firing practice is identical for all types of kilns in Bangladesh, except that in the other kilns, coal particles are manually charged every 20-30 minutes from stoking holes located at the top of the kiln. The gas burners operate in a steady state. When the bricks from the firing zone are sufficiently burnt, they are moved to the next section. During the firing process, the burnt bricks are unloaded at the back, while green bricks are stacked in front of the firing zone.

[32] However, during the rainy season (off-season), brick production decreases significantly because of frequent rainfall, high humidity and reduced sunshine. For this reason, some manufacturers overproduce green bricks during the dry season and store them for the rainy season. However, this requires adequate storage facilities (which are expensive) and clay production during off-season (as harvesting of clay is extremely difficult during the rainy season).

[33] Controlling the fire is the most difficult part of the whole operation, because burners have to be physically moved. The process requires closing of pressurized gas lines and shifting of burners to other points on the supply line without the knowledge of brick temperature.

Figure 3.7[34] Hoffman Kiln.

Figure 3.8 Mechanical transport of green bricks.

Figure 3.9 Transportation of large quantities of soil from storage for pugging.

Figure 3.10 Gas pipeline to the brick chamber for firing bricks.

Figure 3.11 Semi mechanically molded green bricks.

Figure 3.12 Outlet for burnt brick collection.

[34] Figures 3.7 to 3.12 taken by M. Sarraf in 2010

3.4 Environmental and Energy-efficiency Issues

Most brick kilns in Bangladesh are highly polluting since they use crude technology and low-quality coal for fuel. Burning of coal in the kilns releases various pollutants into the atmosphere, including PM, sulfur dioxide (SO_2), carbon monoxide (CO), CO_2 , and NO_x. Table 3.2 summarizes the available information on estimated emission levels of pollutants, based on secondary data.[35]

Table 3.2: Energy consumption particulate and CO_2 emissions for existing technologies

Kiln type	Coal per 100,000 bricks (t)	Particulates (mg/m^3)	CO_2 emitted per 100,000 bricks (t)	Reduction in CO_2 emissions (%)
FCK	20–22[a]	1,000 +	50	n.a.
Zigzag[b]	16–20	500-1000 +	40–45	10–20
Hoffmann (natural gas)	16,000 m^3	< 100	30	40

Source: BUET (2007).
[a] World Bank (2011a) uses a coal consumption of 24 t per 100,000 bricks for the FCK.
[b] BUET (2007) undertook a qualitative (mostly visual) survey that assessed coal consumption and particulate emissions of various Zigzag kilns.

Among the three kiln types, the FCK releases the highest level of PM and SO_2, primarily because of the high ash and sulfur content of the coal. Evidence is inconclusive on PM emissions of the Zigzag kiln. In terms of pollutants, the Hoffmann kiln, fired by natural gas, is considerably superior to all coal-burning kilns (PA 1999). Unfortunately, due to natural-gas supply constraints, the expansion of this technology stopped and existing kilns are facing closure.

The main environmental impacts of operating brick kilns, which are particularly evident for the FCKs, are as follows:

- ***Health***. Pollutants from brick kilns (particularly PM and SO_2) contribute to health problems of the exposed population. These include: (i) adult mortality from cardiopulmonary diseases and lung cancer caused by long-term $PM_{2.5}$ exposure (Pope et al. 2002); (ii) infant and child mortality from respiratory diseases caused by short-term PM_{10} exposure (Ostro 2004); and (iii) all-age morbidity resulting from PM_{10} exposure (Ostro 1994; Abbey et al. 1995). Among existing technologies in Bangladesh, the FCK is likely to cause the worst health problems due to the highest level of particulate emissions.

- ***CO_2 emissions and poor energy efficiency***. Burning coal emits CO_2, which contribute to global warming and climate change. In addition, low-quality coal is energy inefficient and produce further CO_2 emissions. Similarly, poor insulation and heat losses require additional coal, whose use leads to further CO_2 emissions.

- ***Crop yields (from air pollution)***. Air pollution in the areas where brick kilns are located contributes to the decline of agricultural yields. Evidence of reduced yields from orchards and crops due to air pollution is well-documented (Naqvi 2004). Dust deposition on leaves of plants (i.e., crops and orchards) hinders photosynthesis, which reduces productivity. Acid

[35] Measurements of emission levels (e.g., for suspended particulate matter) in Bangladesh are limited (World Bank 2008).

deposition from the SO_2 and NOx emissions from brick kilns also causes injury to plant tissues, with a negative effect on agricultural productivity.

- ***Crop yields (from use of agricultural topsoil).*** Topsoil containing organic matter and other nutrients is the mainstay for sustainable agriculture. Use of topsoil for brick-making leads to land degradation, which reduces agricultural yields. In India, for example, the use of topsoil for brick-making has been restricted (Ministry of Environment and Forests 1998), and moves are afoot to substitute burned clay bricks with Flyash-Lime-Gypsum (FALG) bricks. Unfortunately, in Bangladesh, the raw materials for such an alternative are unavailable in any substantive quantity.

- ***Forests***. Although the use of firewood is banned in Bangladesh, anecdotal evidence suggests that a considerable amount of firewood is still used for brick-making. This can lead to deforestation or forest degradation, with loss of environmental services (e.g., watershed protection) and biodiversity.

3.5 Social Issues

The FCK and Zigzag kilns usually operate 5–6 months out of the year (from November to April) because most of them are located in low-lying areas, which experience flooding during the rainy season.[36] Migrants from northwestern Bangladesh comprise most of the kiln workforce due to the seasonality of kiln operations, their clustering, and lack of local workers. The workers are not organized and lack trade unions to promote their interests. Thus, the existing kilns involve many social issues related to migrant work, gender and child labor, and health and sanitation.

Worker safety and health concerns. Most migrants work in kilns for lack of better alternatives. They usually perform unskilled, low-wage work, requiring hard physical labor for long hours[37] (e.g., mud-pugging by foot, brick-molding by hand, and carrying headloads of bricks), which can cause severe muscular and skeletal stress. In many cases, workers temporarily migrate with families and take up residence near kilns.[38] The sanitary conditions in such residences are often abysmal. Moreover, the high level of air pollution in the kiln area is a health hazard for workers. Overall, the hard physical labor and unsafe conditions likely cause both short- and long-term health problems for workers (Nordin, Andersson, and Pope 2006).

Child labor and gender issues. While each kiln employs about 150 workers, migrant families usually bring some 30–50 children to live nearby. Although banned from working by law, older children often join in work to improve their family's income. Families, including children, often collect partially-burned coal to use for household cooking. Younger children play in unsafe conditions (e.g., mud, dirt and coal), and young girls sometimes perform domestic chores. Women are usually paid less than men, although they do equally arduous jobs; and children are paid even less. While children in villages can attend government primary school for free, kiln workers'

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[36] In addition, during the rainy season, dry green bricks cannot be made or stored at comparatively low cost as in the dry season and open-air kilns cannot operate.

[37] Except for firemen, who are skilled and better paid; yet they perform strenuous and unhealthy work due to the heat and stress involved.

[38] Usually in self-made, ramshackle structures made of bamboo, wood, cardboard, and corrugated iron sheet.

children are deprived of this opportunity during the working season, as there are often no schools close to kiln sites (DOE 2010b).

An opportunity for modernization. In general, many of the shortcomings associated with work in the brick sector stem from use of outdated production techniques. For example, most loads are still carried on heads, wheel barrows are infrequently used, and green brick molding is primarily done by hand. However, in recent years, kilns have faced a labor supply shortage as older workers have become increasingly unwilling to do this arduous work (even when owners offer advance payment);[39] this has led to a partial mechanization of the work (e.g., introduction of pug machines in kilns near Dhaka). The current labor supply shortage could be the opportunity for this change. Green-brick making, usually referred to as the "back process," needs to be mechanized in order to reduce the harsh labor involved and increase production efficiency. Any measure designed to improve the manufacturing processes in the existing kilns should consider all social and health problems.

[39] In such cases, better work opportunities are opening up in organized industries (especially textile and garment).

As Chapter 3 indicates, traditional kilns in Bangladesh have particulate emissions above 1,000 mg per m^3 and coal consumption of 20–22 tons per 100,000 bricks produced (BUET 2007). Reduced stack emissions and increased energy efficiency can be achieved either by retrofitting existing kilns or adopting newer technologies. Retrofitted technologies include the Improved Fixed Chimney Kiln (IFCK) and the Improved Zigzag (IZigzag), while newer technologies include the Hybrid Hoffmann Kiln (HHK) and the Vertical Shaft Brick Kiln (VSBK). The retrofit approach is cheaper than the newer technologies; however, it provides fewer improvements in terms of emission reduction and energy efficiency (Heirli and Maithel 2008). The following sections discuss in detail the pros and cons of each of these technologies.

4.1 Improved Fixed Chimney Kiln (IFCK)

Existing FCKs can be retrofitted by one or more improvements, such as use of internal fuel, back-process mechanization, improved firing practices, improved operating practices, and introduction of gravity settling chambers or scrubbers. The Clean Air and Sustainable Environment (CASE) project piloted an IFCK for demonstration of internal fuel in green-brick making and better feeding and firing practices (DA–PA 2009).[40]

In addition to reducing emissions and increasing energy efficiency, these improvements are expected to lessen the labor hardship, improve product quality and productivity, and increase profitability. Table 4.1 compares several parameters for standard and the retrofitted FCKs. The following paragraphs describe each type of improvement.

Use of internal fuel. This practice, as old as brick-making itself, incorporates carbonaceous materials into clay to form green bricks in order to reduce pollution. The emissions and fuel-savings benefits due to the internal fuel process are yet to be demonstrated for the FCKs in Bangladesh. However, qualitative monitoring of emissions shows that the intensity of smoke is reduced for kilns using internal fuel, compared to FCKs (Figure 4.1).

Various types of materials can be used as internal fuel, such as mixing coal with bricks. Obtaining a high quality of the fired bricks depends on the internal fuel's particle size (maximum of 3 mm), calorific value (greater than 1,000 kcal/kg), amount used (depending on the calorific value), and mixing process (preferably mechanical) (DA–PA 2009).

[40] The manufacturing company Rose Bricks carried out the pilot project in Rupganj, Narayangunj by integrating in the same kiln the use of internal fuel, as well as better feeding and firing practices.

Figure 4.1: Comparison of FCK and IFCK emission reductions

Source: DA–PA (2009).

Newer technologies usually employ the internal fuel. The pilot implementation of the VSBK in Bangladesh has demonstrated that the internal fuel helps to reduce emissions, increase energy efficiency, and yield stronger bricks.[41] (DA–PA 2010).

Back-process mechanization. The processes used in green-brick making—including coal pulverization, coal sieving, mixing of coal with clay in measured proportion, pugging the mix, and brick-molding—form the back process, which is often performed manually (e.g., materials and bricks carried by headload). As discussed in Chapter 3, this arduous work can cause severe muscular and skeletal stress, and workers increasingly are unwilling to undertake it. Thus, the adoption of back-process mechanization would reduce hardship for workers and introduce better paid, semi-skilled jobs.[42]

If the increased cost of the back-process mechanization can be recouped through better productivity and revenues, this move can be successful, even without regulatory pressure. Though yet to be demonstrated, back-process mechanization is believed to be a "win-win" situation for all stakeholders: Kiln owners would benefit from increased productivity and potentially lower labor costs, workers would perform less stressful labor and would receive higher income, and the public would benefit from reduced emissions from internal fuel use.[43]

[41] Barriers to the use of internal fuel include the additional cost of machinery (if mechanization is adopted) and the increased labor cost (if manual implementation is introduced). Demonstrating that the increased returns from the use of internal fuel outweigh the increased expenses may facilitate the adoption of internal fuel by the entrepreneurs.

[42] For example, use of trolleys and wheel barrows would speed up the transport of materials and green bricks, to match with the higher productivity of the machines. This would especially benefit women and children, who carry most head loads.

[43] The mechanized process includes internal fuel and mixing of coal with clay.

Improved firing practices. The highest level of pollution occurs when coal feeds into the combustion zone. Visual observations reveal that feeding coal produces a thick black smoke, which progressively becomes less dense and eventually white. Coal feeding is usually done every 20–30 minutes. If the feeding is done slowly or less quantity is fed more frequently (e.g., every 10 minutes), pollution can be reduced substantially. The pilot demonstration of the IFCK recommended use of a **small spoon** (750 mg) to feed coal more frequently, as depicted in Figure 4.2.

Figure 4.2. Small spoon for better firing

Source: DA-PA 2009

While continuous feeding is a better approach for pollution reduction, it is not feasible for manual feeding as currently practiced. The size of coal particles is also important; if particles are too fine, burning occurs too fast; if they are too big, incomplete burning may occur, reducing energy efficiency. Thus, a graded mixture of various particle sizes can optimize the efficiency and pollution levels from coal burning.

Improved operating practices. In the existing FCKs, as much as 35 percent of total heat is lost through kiln surfaces (15 percent from the top and the rest from the sides and bottom) and an additional 12 percent is lost to moisture in the green bricks (Maithel et al. 2002). The heat loss is caused by air leakage from numerous points in the kiln and by conduction through sidewalls and to the top. These losses can be minimized through improvements in current operating practices, as follows:

- *Plastering the interior kiln wall* to avoid air leakage through the sidewalls and provide better insulation.[44]
- *Insulating the kiln top* using a soil and coal ash mixture to reduce heat loss through the top[45].
- *Adding coal ash to the kiln bottom and loading burned bricks* as the first layer to reduce ground-level heat loss because burned bricks are better insulators than green bricks.
- *Using better-dried green bricks* to reduce heat loss caused by brick moisture[46].

Gravity settling chamber. The gravity settling chamber helps to reduce PM emissions in the atmosphere. The chamber is a large space situated at the bottom of the chimney and has many baffles, which reduce the speed of the flue gas.[47] Because heavy particles cannot move with the gas stream, they are deposited in the settling chamber. FCKs in Bangladesh do not use settling

[44] Plastering by using a mixture of mud, coal ash, and cow dung has shown good results in India (Maithel et al. 2002). Soil provides the binding for the mix, coal ash provides insulation, and cow-dung containing fibers help reduce shrinkage during drying of plaster.

[45] Maithel et al. (2009) found that a 4-inch layer can reduce maximum surface temperature from 350°C to 150°C, leading to a substantial decline in heat loss. Considerable amount of heat can be lost also from coal feedholes on the top. Using insulated and better-fitted feedhole caps can minimize this loss.

[46] By operating the dampers appropriately, heat in the flue gas can be used for better drying the green bricks loaded in front of the firing zone, thus reducing the need for fuel for brick-drying.

[47] Its use in India led to a speed decline from 3 to 0.3 meters per second (Maithel et al. 2002; BUET 2007).

chambers; Zigzag kilns use a similar device with water filling. Gravity chambers can be introduced at a reasonable cost.[48]

Scrubbers. Scrubbers with water spray may offer an even better alternative to gravity settlement chambers. In the scrubbers, flue gases pass through falling water spray, which reduces PM emissions and soluble gases in the flue stream.

Table 4.1: Comparison of existing and improved FCK parameters

Parameter	Existing FCK	Improved FCK	Comments
Land	2.5 acres, of which 1 acre used round the year	2.5 acres, of which 1 acre used round the year	No change from existing practice
Production period	November to April	November to April	No change from existing practice
Raw material (clay)	200,000 cft.	200,000 cft.	Waste with calorific value can be mixed with green bricks
Fuel type	Coal	Pulverized coal	Pulverization machine will be part of back process
Internal fuel	No	Yes	50 percent or even more of powdered coal to be mixed with clay
Labor	150 (15 percent skilled, 15 percent semi-skilled)	150-175 (15 percent skilled, 20 percent semi-skilled)	Increase in labour cost unless back process is automated
Electricity/ diesel engine	5kW for operation of pugmill	50kW for operation of pugmill and back process machines	More power will be needed to operate the back process machines
Back-process mechanization	No	Yes	50 percent or even more coal is mixed with clay and labor cost unchanged
Gravity settlement chamber/scrubber	No	Yes	Likely to lead to lower emission
Insulation	Standard practice	Improved insulation	Expected reduced heat loss from surface and top of the kilns
Firing practice	Standard practice	Improved practice	Better firing practice and feed hole caps with better insulation
Brick quality	As per current standard	Improved quality	Higher percentage of grade A bricks and brick of better strength. Perforated bricks can be produced.
Pollution level	1,000 mg/m^3	200- 500 mg/m^3, (141- 187 mg/m^3)	Lower figure for kilns with gravity settlement chamber. Numbers in bracket are from India.
Energy efficiency	20-22 tons/100,000 bricks	16-18 tons/100,000 bricks	A 20 percent improvement is expected but even 30 percent may be possible. Expected to lead to similar CO_2 reduction

Sources: BUET (2007); Pandit, Basnet, and Joshi (2004); Maithel et al. (2008); and World Bank (2008).

4.2 Improved Zigzag Kiln (IZigzag)

To date, there have been no systematic measurements of emission levels from the Zigzag kilns operating in Bangladesh. Qualitative evaluation of Zigzag indicates that poorly managed kilns are as polluting as the FCKs, while better-managed kilns produce about half of the FCK pollution level.

[48] The accurate cost is not known; however, the range is US$1,000–2,000.

An Improved or Standardized Zigzag (IZigzag) kiln includes a standard design that leads to lower emissions and increased energy efficiency. It includes such improvements as use of internal fuel, better insulation with reduced heat loss, and better flue gas scrubber.

A standardized design for the Zigzag kiln should be developed through piloting under expert supervision. The firing and operating practices should be tested during piloting and appropriate approaches should be documented and made available to kiln operators. Only when this is achieved can the full benefit of the Zigzag kiln be realized in practice. The current FCKs can also be converted into Zigzags, and the FCK's tall chimney can be retained (BUET 2007). This would yield a better dispersion of pollutants and would lower the capacity requirement for the ID fan. Currently under the CASE project (Credit 4581-BD) one improved zig zag is being piloted in 2011 and seven more will be piloted in 2012-13. It was too early to include any of these results into the current study. However, the findings will certainly be beneficial to scale the use of this technology.

4.3 Vertical Shaft Brick Kiln (VSBK)

Main features. Developed in China 50 years ago, the VSBK technology was later adopted by various South and East Asian countries, including India, Nepal, Pakistan, and Vietnam. VSBK is a small-scale technology that operates year-round in highland areas. Compared to FCK, VSBK uses less energy and emits considerbly fewer emissions.[49] Other key advantages include more modest capital and land requirements, as illustrated in the subsequent presentation of the pilot VSBK in Dhaka.

Photo: A. Hoel, 2011

A standard VSBK consists of two shafts, which produce 8,000–10,000 bricks per day. A larger production facility can be built by adding more shafts. Green bricks are usually carried to the top of the kiln by a conveyor belt and stacked at the top platform. A feedstock of green bricks remains on the platform for several days to guard against supply shortfall due to inclement weather when green bricks cannot be moved. Fired bricks are unloaded at the bottom 24 hours after loading at the top.

Using green bricks with internal fuel is standard practice for the VSBK. Up to 50 percent of the pulverized coal is mixed in with clay. Internal fuel may include waste materials with some calorific value. The rest of the coal is charged along with the green bricks in the loading process. As the coal is stationary and enters the hot combustion zone slowly, it tends to burn out completely, providing higher efficiency and less pollution. This contrasts with other coal-fired kilns, where coal is charged periodically.

[49] The operation of pilot VSBK kilns in neighboring countries (e.g., India, Nepal, and Afghanistan) has demonstrated energy savings of at least 30 percent in comparison to the best existing kilns. In addition, use of the VSBK reduced air pollution by a factor of 5 or more (PA–DA 2010).

Some operations require more skilled labor than FCK (e.g., carrying green bricks to the top of the kiln, stacking bricks in the shaft at regular intervals, mixing internal fuel with clay, controlling the fire in the firing zone, and unloading bricks). Bricks unloading can also be challenging because bricks tend to crack if withdrawn too quickly from the hot kiln. The VSBK bricks have satisfactory compressive strength and meet Bangladesh standards.[50] Because they have a dull (red) color, their price is usually lower than that of FCK bricks[51].

Despite low capital cost, scalability, and low emissions, the adoption of VSBK has had only limited success in South and East Asia. Existing kiln owners have been reticent to move to an unfamiliar new technology, which requires additional investment. For the few new entrepreneurs entering brick manufacturing, awareness-raising and the supply chain are the main problems in adopting the VSBK. In China, most entrepreneurs are moving toward large-scale production, using the HHK and Tunnel kilns.

Pilot demonstration near Dhaka. In 2010, Conforce Bricks, a local enterprise, implemented a two-shaft VSBK plant in Bangladesh under a project financed by the World Bank / Energy Sector Management Assistance Program (ESMAP). The investment cost was about TK3.5 million for a production capacity of 8,000 bricks per day. The operating plant emits no visible smoke, indicating low PM emissions.

Conforce Bricks has long worked in the brick industry and has all the needed resources (land, human, technical, and financial) to ensure successful kiln implementation. The project consultants were Development Alternatives (DA) from India and Practical Action (PA), its local partner. DA has many years of experience building VSBKs and has worked extensively to introduce the technology in India, Pakistan, Nepal, Afghanistan, Vietnam, and South Africa. Based on the pilot implementation, DA produced three manuals on standard design, construction, and operation of the VSBK (DA-PA, 2010).

Figure 4.5 Pilot VSBK in operation at Savar, near Dhaka, with no visible emissions

Photograph: M. Khaliquzzamann, 2010

One shaft became operational in August 2010 and the second in November 2010. Thus far, the operations have been successful, and the bricks meet Bangladesh standards. The bricks are selling well—at a lower price than that of the products made by the natural-gas Hoffmann kiln located on the same site—and the entrepreneur is planning to invest in a second two-shaft kiln.

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[50] BSTI (2002) provides the standard specifications for bricks in Bangladesh. Accordingly, the standard for compressive strength is 175 kg per cm^2, and the water-absorbency standard is 15 percent. The values found for VSBK bricks are 206 kg per cm^2 for compressive strength and 12.5 percent for water absorbency.

[51] At the time of the analysis, the first category brick price was TK6 per FCK-made brick and TK5.5 per VSBK brick.

4.4 Hybrid Hoffmann Kiln (HHK)

Main features. Developed in China, the HHK represents a hybrid version of the Hoffmann kiln technology developed in Germany in the mid-19th century. Unlike the gas-based Hoffmann kiln, the HHK uses coal as fuel. The HHK combines fuel injection and external firing in highly insulated kilns, leading to lower energy use, high-quality bricks, and reduced pollution. It was introduced in Bangladesh in 2006 under a GEF supported project (UNDP–GEF, 2006). Eight HHKs are operating in Bangladesh, and another eight are in the pipeline.

The HHK design combines a highly efficient kiln technology, known as Forced Draft Tunnel Kiln (FDTK), with a unique technique of forming green bricks: Granulated coal is injected for internal combustion. Nearly 80 percent of the total energy required is injected into the bricks, while the remainder is fed externally into the firing chamber. Most of the fuel injected into the green bricks is completely burned during firing. This technology improves energy efficiency in two ways: (i) internal combustion of injected fuel in green bricks and (ii) application of heat optimization techniques in a minimum heat-loss chamber in the kiln's combustion zone to capture waste heat for recirculation in the drying tunnel[52]. The HHK, like traditional technologies, does not require a tall chimney (IIDFC 2009).

The back process (i.e., coal crushing, coal-clay mixing, pugging, and brick forming by extrusion) is mechanized and rail-mounted trolleys carry the green bricks during most of the process. These mechanizations reduce physical labor and alleviate the problem of labor shortage.

Pilot demonstration near Dhaka. Universal Bricks Ltd established a pilot HHK at Amtali (Dhamrai, Savar) near Dhaka,[53] with support from the GEF project. Xian Research and Design Institute of Wall & Roof Materials of China provided technical assistance for the plant design, supervision of construction, and trial operation. The plant went into trial production in 2009 and is now in commercial operation. It includes two operating kilns, each producing about 40,000 bricks per day. A single mechanized green-brick production line operates for both kilns. Khan (2008) reported measurements of stack emissions of 20.3 mg per m^3. The calculated mass emission load of suspended particulate matter (SPM) per 1,000 brick production is nearly twice as much as that of the FCK (0.879 kg versus 1.71 kg). Measurements of PM concentrations near the gate of the kiln site reveal ambient concentrations of

Hybrid Hoffman Kiln located north of Dhaka (Khan,2008)

[52] Most bricks work as filters inside the drying tunnel and absorb unburnt coal particles from the exhaust during the drying process.

[53] GPS Coordinates: 23°58'52'' N and 90°11'28'' E.

251 µg per m^3 for PM_{10}, 157 µg per m^3 for $PM_{2.5}$, and 1.30 ppm for CO.[54] Despite the HHK's significant emissions reduction compared to the FCK, HHK should not be located close to inhabited areas.[55]

HHK bricks are stronger and their price more competitive than those of FCK. The World Bank has signed an Emission Reduction Purchase Agreement (ERPA) for buying Certified Emissions Reductions (CERs) from the operating 8 kilns. The HHK initiative promises to be successful in the marketplace; however, there are barriers to adopting the technology. First, HHK implementation requires a substantially higher capital (about TK60 million per kiln[56]) compared to FCK (TK5 million[57]). Second, HHK needs higher land (above the monsoon flood level), which is scarce and expensive in the area surrounding the city of Dhaka and other major urban centers.

4.5 Environmental and Energy-efficiency Issues

Table 4.2 summarizes the available information on the energy consumption and estimated levels of PM and CO_2. Accordingly, the retrofit approach can reduce PM emissions by around 50 percent and improve energy efficiency by 20 percent. In contrast, newer technologies can reduce PM emissions by around 80 percent and increase energy efficiency by around 40-50 percent.

Retrofitted kilns are expected to have moderate pollution-reduction and energy-efficiency gains compared to the FCKs. The emission improvements provided by the IFCKs with retrofits are yet to be demonstrated in Bangladesh. The DOE (2010b) reported that a limited trial for the use of internal fuel and improved firing practice was carried out in 2008. Though the trial did not include any emission measurements, visual observations revealed a certain amount of decreased emission. Maithel et al. (2008) reported emission levels from IFCKs[58] in India of 141–187 mg per m^3, or less than 20 percent of the FCK's emissions.[59] Therefore, a combination of several retrofits may decline the SPM emission levels from the FCK by 50–80 percent. The emission levels from properly constructed, well-managed Zigzag kilns are expected to be similar to those from IFCKs. Adopting the IFCK or IZigzag technologies would most likely improve energy efficiency and reduce carbon emissions by at least 20 percent (Table 4.2).

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[54] The measurements were carried out about 100 m from the stack. PM_{10} and $PM_{2.5}$ samples were taken for 24-hour average time, while CO samples were taken for 8-hour average time.

[55] This is because the stack emissions for PM_{10} and $PM_{2.5}$ exceeded the Bangladesh national ambient air quality standards. The 24-hour standards are 150 µg per m^3 for PM_{10} and 65 µg per m^3 for $PM_{2.5}$ and the 8-hour standard for CO is 9 ppm (GOB ECR Notification SRO No: 220-Law/2005).

[56] Based on HHK investments at various companies located near Dhaka. The figure includes the cost of land, kiln, dryer and other civil construction, machineries and equipment, and other.

[57] Result of a field survey of kiln owners near Dhaka in September–October 2009.

[58] The Central Building Research Institute (CBRI) and Punjab State Council of Science and Technology (PSCST) in India executed the improved kiln designs. It is not clear if these kilns used internal fuel.

[59] Maithel et al. (2008) also reported that gravity settling chambers, along with improved coal feeding, can reduce PM emissions below 750 mg per m^3, which is the Indian emissions standard.

Table 4.2: Energy consumption and particulate and CO_2 emissions from kiln technologies

Technologies	Coal consumption (t/100,000 bricks)	Particulates (SPM) (mg/m^3)	CO_2 emissions (t/100,000 bricks)	CO_2 emission reduction (%)
Baseline technology				
FCK	20-22	1,000	50	n.a.
Retrofitted				
IFCK (internal fuel, gravity settling chamber and other[60])	16-18	< 500	40	20
Zigzag (SD + good management)	16-18	270-300[a]	40	20
New technologies				
HHK	12-14 [d]	20.3 [b]	30	40
VSBK	10-12 (11-16)[e]	78 -187 [c]	25	50

Sources: BUET (2007) and [a] Maithel et al. (2002) for high draft kilns in India; [b] World Bank (2008) for measurement for an HHK in Bangladesh; [c] Pandit et al. (2004) for Nepal and Maithel et al. (2003) for India; [d] CDM (2009); [e] Heirli and Maithel (2008).

New technologies can provide considerable pollution-reduction and energy-efficiency gains compared to the FCKs. Emission levels from VSBKs in Bangladesh are yet to be measured. Pandit, Basnet, and Joshi (2004) reported emission measurements for two kilns in Nepal (122 mg per m^3 and 160 mg per m^3), and Maithel, Vasudevan, and Johri (2003) recorded emissions for two kilns in India (78 mg per m^3 and 80 mg per m^3). Thus, it is reasonable to expect that VSBK in Bangladesh would emit less than 200 mg per m^3. In addition, VSBK would likely improve the energy efficiency and carbon benefits by about 50 percent (Table 4.2).

Operating HHKs had positive performance in terms of energy efficiency and emission reduction. Khan (2008) indicates that up to 80 percent of the total fuel required to fire bricks can be incorporated as internal fuel. The energy efficiency and carbon benefits are likely to be 40 percent higher than those of the FCK. The PM_{10} emission measurement of the first established HHK (20 mg per m^3) accounts for only 2 percent of the FCK's emissions. Measuring the emissions from more kilns would be necessary to confirm that such low values can be routinely achieved.

The low emissions can be attributed to the following improvements:

- Using a high proportion of internal fuel, which helps to lock in some combustion products in the brick matrix.
- Directing the hot flue gas in the drying chamber with wet green bricks, which act as a scrubber to clean the flue gas of the PM load.
- Pumping additional fresh air into the flue gas stream, which dilutes and reduces the concentration level of pollutants.

Based on the above data, moving from the FCK to improved or new technologies is expected to result in the following environmental impacts:

[60] These may include improved insulation, modified brick arrangement, and better firing practice.

- ***Health***. Ambient air pollution levels are expected to decline, leading to improved health of the population exposed.
- ***Crop yields (from air pollution)***. The decline in emissions would be beneficial for crop yields. Further assessment needs to be undertaken to better understand the impact of reduced chimney height (in new and improved kilns) on localized pollution (especially agriculture).
- ***Crop yields (from use of agricultural topsoil)***. Use of improved or new kilns would not affect the use of topsoil, unless efforts are made to replace it with river sediment or other sources of clay.
- ***Forests***. The improved and new technologies do not use firewood; thus their adoption would eliminate the negative effects that FCKs currently have (e.g., deforestation or forest degradation).

4.6 Social Issues

Adopting retrofitted kilns would alleviate the existing social problems caused by FCKs. As discussed in Chapter 3, the social issues related to FCK use include stressful and unhealthy physical labor, precarious living conditions of migrant families, and gender and child labor. The introduction of mechanization via IFCK and IZigzag would substantially lessen labor hardship. Higher-paid jobs for skilled labor would also allow for support to distant families and limit the need for family migration, suggesting that women would not be exposed to extremely arduous jobs and children could continue their education.[61]

Introducing VSBK and HHK would transform the nature of existing social issues. As VSBKs and HHKs operate year-round, the non-local workforce would take up residence nearby the kilns to continue their work. This would largely eliminate the problems of migrant labor, by allowing families to receive social services, such as primary education for their children. The mechanization of green-brick making and use of rail-mounted trolleys for green-brick transport would greatly reduce, or even eliminate, the physical hardship of work. The expected 80-percent reduction of PM emissions would decrease exposure to air pollution and improve health. As a large-scale operation, HHKs would also provide better worker facilities.

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[61] However, if IFCKs and SZigzags continue to operate on lowlands, they would still perform seasonally and would not receive the financial facilities as the SMEs do.

In Bangladesh, use of the traditional FCK is profitable for the entrepreneur, but highly polluting for society. Experience in other South and East Asian countries, including India, Nepal, and Vietnam, indicates that the IFCK, VSBK, IZigzag, and HHK are substantially cleaner: they consume less energy and emit lower levels of conventional pollutants and CO_2 emissions[62]. Adopting these technologies would be made easier if they were more socially and financially profitable than the FCK. This chapter assesses the ***social*** (public) and ***private*** (financial) net benefits of the FCK, IFCK, VSBK and HHK.

It should be noted that the analysis is subject to some limitations. *First*, it covers only a set of technologies for which data could be made available. Other technologies, though successful throughout the region, could not be included, either because of lack of well-documented information (e.g. IZigzag) or because of their unlikely viability in the Bangladesh context (e.g. technologies based on non-fired bricks [63]). Therefore, the implications of this analysis refer only to the technologies covered by this report.

Second, despite capturing a large portion of the impacts caused by brick kilns, the analysis does not include some effects, such as the impacts of air pollution on the value of real estate, on recreational areas, and on agricultural productivity. In addition, the negative effects of pollutants other than PM (e.g., SO_2 and NO_x) and of the hard physical labor on workers' health could not be estimated. Because of these limitations, present estimates should be regarded only as **orders of magnitude**.

5.1 Assumptions for the Selected Technologies

The analysis focuses on brick kilns located in the North Dhaka cluster, home to about 530 FCKs, which produce about 2.1 billion bricks, or nearly 15 percent of Bangladesh's total brick production.[64] The assumptions for the selected technologies are as follows:

- ***FCK***. The FCK is assumed to produce about 4 million bricks over a 5-month season.[65]
- ***IFCK***. In this analysis, improvements of the IFCK over the FCK include internal fuel, better feeding and firing practices, molders, and gravity chamber. Brick production can run from

[62] BUET 2007; Heirli and Maithel 2008; World Bank 2011a.

[63] Non-fired bricks require material such as cement, sand and sometimes stone chips, which are not available in Bangladesh. The need to import raw material as well as equipment makes the business financially unattractive for the entrepreneurs. In addition, technologies based on non-fired clay bricks are believed to be unfeasible for Bangladesh, due to unsuitable weather conditions.

[64] The number of kilns in North Dhaka (530) and the total number of bricks in Bangladesh (15 billion) are based on the estimates of BUET (2007). The proportion of bricks in North Dhaka, compared to the total number of bricks, is based on results of a 2009 field survey conducted in the North Dhaka cluster, which found an average brick production of 4 million per kiln, totaling 2.1 billion in North Dhaka.

[65] Based on 2009 field survey estimates.

as low as 4 million (i.e., same as the FCK) to as high as 5.8 million bricks[66]. This analysis considers the minimum production to enable a direct comparison with FCK.

- ***VSBK***. The analysis assumes a 4-shaft VSBK, with an average production of 4.8 million bricks per season (i.e., 83 percent of the kiln's potential capacity).[67]
- ***HHK***. The analysis considers a single-sized HHK with an average production of 15 million bricks (i.e., 83 percent of the kiln's potential capacity)[68] (World Bank 2011a).

5.2 Methodology

Estimating the net returns from each technology is based on the Cost-Benefit Analysis (CBA) approach. The analysis measures the net returns from the private and social perspectives, defined as follows (Table 5.1):

- ***The private (financial) CBA—analysis from the entrepreneur's viewpoint—includes all costs and benefits for the entrepreneur***. Costs include investments (e.g., cost of buildings and kiln chimney, land, other inputs, and taxes), while benefits comprise the value of brick production. The costs and benefits are estimated at market prices. The analysis assumes that the entrepreneur pays all of the above costs and receives all the benefits linked to brick production.[69]

- ***The social (public) CBA—analysis from the social viewpoint—includes costs and benefits from the private CBA, as well as the environmental and social impacts of brick kilns, including the cost of GHG emissions and the health impact of air pollution***. The costs and benefits from the previous step are estimated at real (economic) prices,[70] while taxes are eliminated.

Table 5.1: Valuation methods to estimate costs and benefits

Analysis type	Costs and benefits	Valuation method
Private	**Costs:** Investment, land, buildings, operating costs, taxes	Market prices
	Benefits: Value of bricks	Market prices
Social	**Costs:** Investment, land, buildings,operating costs Health impact of air pollution CO_2 emissions **Benefits :** Value of bricks	 Real prices Disability Adjusted Life Years (DALYs) International prices in carbon markets Real prices

[66] Calculated based on a seasonal increase to 6 months (resulting from use of molders), a quantity of 16,000 bricks per day, and 30 days of work per month.

[67] Based on production of 16,000 bricks per day, 360 work days /yr, and 83% capacity utilization (World Bank 2011a).

[68] Based on production of 50,000 bricks per day, 360 work days /yr, and 83% capacity utilization (World Bank 2011a).

[69] In reality, some entrepreneurs may illegally bypass certain costs. However, this analysis is based on good practices; that is, the costs and the benefits that the entrepreneur is supposed to pay and receive, with no consideration of illegal activities.

[70] If prices are distorted due to public policy or other types of failure, they must be adjusted by eliminating distortions (real or shadow prices) (Monke and Pearson 1989).

Valuation of the health impacts of pollution is complex. The main estimated health impacts of pollution are:

- infant and child mortality related to respiratory disease caused by short-term exposure to PM smaller than 10 microns in diameter (PM_{10});
- adult mortality related to cardiopulmonary disease and lung cancer caused by long-term exposure to PM smaller than 2.5 microns in diameter ($PM_{2.5}$); and
- all-age morbidity related to exposure to PM_{10}, such as chronic bronchitis, hospital admission of patients with respiratory problems, emergency-room visits, restricted activity days, lower respiratory infection in children, and general respiratory symptoms.

Valuation involves the following steps:

- identify the pollutants and measure their concentration,
- estimate the population exposed,
- establish dose-response coefficients, and
- measure the health impacts (physical and monetary valuation).

Estimating the health impacts of air pollution in physical terms is based on the Disability Adjusted Life Years (DALYs) method, which provides a common measure of the disease burden for various illnesses and premature mortality (WHO 2009). The monetary valuation of 1 DALY is based on two approaches: (i) the human capital approach (HCA), which estimates it as a person's average contribution to production or the gross domestic product (GDP per capita and (ii) the Value of Statistical Life (VSL), which is based on willingness to pay to avoid death by observing individual behavior when trading off health and monetary risks (Johansson 2006). In addition, society incurs direct costs of illness, such as treatment costs. Annex 1 presents a detailed description of how these costs are estimated.

The analysis refers to the year 2009 and uses a discount rate of 10 percent. The kilns' lifetime is 20 years for FCK, IFCK and VSBK and 10 years for HHK. Thus, the analysis uses a time horizon of 20 years and accounts for two production cycles of the HHK. Estimated costs and benefits are based on an average kiln. To compare the profitability of the selected technologies, results are reported as net returns per 1,000 bricks. The analyses use secondary data, complemented by a field survey of kiln owners conducted in September–October 2009. The valuation results are presented in the following sections.

5.3 Private Cost-Benefit Analysis

The private cost-benefit analysis considers the direct costs and benefits for the entrepreneur, estimated at market prices for 2009 (Table 5.2).

For the FCK, **costs** include upfront investments and annual costs. Investments cover the kiln structure, chimney, other machineries, and equipment; while annual costs include the land lease, operating costs, taxes and value added tax (VAT), and buildings cost. The land lease varies, depending on land quality; considering an average rental value of TK10,000 per bigha (407 m^2) and an area of 15 bigha per kiln, the annual rental value of land totals TK150,000. The operating costs include the cost of fuel (mainly coal), clay, water and labor, amounting to TK11 million per year.

The taxes and VAT average TK600,000 per year. Because the FCKs are located mainly in low-lying areas prone to annual flooding, they usually do not have buildings. The overall present value of the costs is TK119 million per kiln.

The **benefits** include the value of brick production. Bricks can be broken (5–8 percent of the total number), overburned (5–10 percent), third class (5–10 percent), second class (10–20 percent) and first class (the remainder). The market price is TK6 for first-class, overburned, and broken bricks;[71] TK5.8 for second-class bricks; and TK5.3 for third-class bricks. Accordingly, the annual value of bricks is TK24 million, with a present value of TK198 million. *Overall, the 20-year use of a FCK leads to a net benefit of TK103 per thousand bricks.*

***For the IFCK*,** the **costs** include the same items as for the FCK. The investment cost is higher than for the FCK due to the additional capital investment in internal fuel, better feeding and firing processes, molders, and gravity chamber. Both the IFCK and the FCK occupy the same land area; thus the land cost, taxes, and VAT are similar. Overall, the present value of costs is estimated at TK109 million.

The **benefits** include the value of bricks, which can be broken (5–8 percent of the total number), overburned (5–10 percent), second class (10–20 percent), and first class (80–62 percent). Based on their market price, the present value of benefits is TK200 million. *Overall, the 20-year use of an IFCK leads to a net benefit of TK107 per thousand bricks.*

For the VSBK, investment **costs** include construction, equipment, green-brick transport system, office space, and green-brick storage shed (DA 2009). Operating costs are lower than for the FCK, primarily because of the lower cost of coal[72] and labor.[73] The cost of land is slightly lower than for the other kilns, mainly because the VSBK occupies a smaller area (4 bigha versus 15 bigha). Overall, the present value of the VSBK costs is TK106 million.

The **benefits** include the value of bricks, of which 95 percent are first class and the remainder broken. Based on their market price, the present value of benefits is TK214 million. *Overall, the 20-year use of a 4 shaft VSBK has a net benefit of TK108 per thousand bricks.*

For the HHK, **costs** are substantially higher than for the other kilns, mainly because of its advanced technology and considerably larger brick production. The investment cost in the first year is about TK60 million (UNDP 2010)[74]; while the cost of coal, clay, and electricity account for the bulk of operating costs. The taxes and VAT are high since they are proportional to brick production. Overall, the present value of costs is TK386 million. The **benefits** include the value of bricks, estimated at TK746 million in present-value terms. *Overall, the net returns from a 20-year use of an HHK kiln are TK116 per thousand bricks.*

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[71] The price of the three categories is similar, because overburned and broken bricks are usually mixed and sold to the cement industry.

[72] The VSBK is more energy-efficient than FCK, using 13 t versus 20 t of coal per 100,000 bricks; since the number of bricks produced is similar to that of the FCK, the total cost of coal is less.

[73] The labor cost is less than for the FCK, mainly because fewer workers are needed.

[74] It includes the costs of kiln, civil construction and machineries (TK47 million), buildings (TK10 million) and land (TK3 million). After the first production cycle, it is estimated that one third of the costs of kiln, civil construction and machineries need to be re-invested, i.e. TK16 million.

Summing up, the HHK is the most profitable technology for the entrepreneur, while the returns from the FCK, IFCK, and VSBK are lower. Despite the higher net returns, adopting the HHK is difficult for two major reasons (i) HHKs operate on high land, which is scarce and expensive and (ii) the adoption requires a substantial investment (TK60 million), which is unaffordable for most FCK owners, who operate on rented land that cannot be used as collateral.

Table 5.2: Private cost-benefit analysis (present value 2009)

Cost/benefit	FCK	IFCK	VSBK	HHK
Annual production (million bricks)	4.0	4.0	4.8	15
Area occupied by the kiln (bigha)[1]	15	15	4	12
Costs (million TK/kiln)	**119**	**109**	**106**	**386**
Investment	4.4	7.4	6.4	55.7
Land	1.3	1.3	0.6	2.7
Buildings	0.0	0.0	0.7	9.1
Operations	108.7	95.3	91.5	300.0
Taxes and VAT	5.1	5.1	6.4	18.7
Benefits (million TK/kiln)[2]	**198**	**200**	**214**	**746**
Net benefit (benefits minus costs)	**79**	**91**	**109**	**360**
Net benefit (TK/thousand bricks)	**103**	**107**	**108**	**116**
Payback period (no. years)[3]	1.8	1.9	1.8	2.2

Sources: 2009 field survey, UNDP (2010), World Bank (2011a)
[1] 1 bigha = 407 m^2.
[2] Includes the value of bricks.
[3] The first year is the year investment occurs.

This analysis does not capture the potential benefits from **financing carbon emission reductions** obtained from adopting cleaner technologies, such as VSBK and HHK. World Bank (2011a) estimated that an HHK provides emission reductions of 5,582t CO_2 per year, which corresponds to a financial annual benefit of TK75 million. If these values were added to the private CBA analysis, the net benefit of an HHK would attain TK340 per thousand bricks.

5.4 Social cost-benefit analysis

The social cost-benefit analysis includes (i) the direct costs and benefits, (ii) the health impacts from PM-related pollution ($PM_{2.5}$, PM_{10}) and (iii) the cost of CO_2 emissions from the brick sector.

Direct costs and benefits. The market prices used for estimating the direct costs and benefits are not distorted (e.g., subsidized), thus they can be considered economic or real prices. Therefore, the social CBA includes all of the direct costs and benefits, as estimated for the private cost-benefit analysis, excluding taxes and the VAT.

Health impacts from air pollution. Estimating the health impacts from pollution is a complex task. The brick sector is one contributor to air pollution, along with transport and other industries. Separating out the brick kilns' contribution to pollution requires data on pollutant emissions and dispersion patterns, which are not always available. Moreover, since the North Dhaka brick cluster consists mainly of FCKs, such an exercise would estimate only the FCK's impact on health. Valuing the health impacts of the IFCK, VSBK, and HHK requires even more precise data. In the absence such information, the most realistic assumptions have been made for the purpose of this analysis.

The kilns' contribution to the average PM ambient concentration depends primarily on their particulate emissions and the brick production for each kiln type[75]. **Annex A** presents in detail the assumptions and the valuation of the health impacts from $PM_{2.5}$ and PM_{10} pollution. Table 5.3 summarizes the estimated impacts in annual and present value terms. The FCK is the most polluting technology, causing annual health damages estimated at about TK0.9 per brick. By contrast, the VSBK is the cleanest technology, with TK0.3 per brick.

Table 5.3: Summary of estimated health-damage cost from air pollution caused by brick kilns

Kiln type (million bricks)	Annual health damages				Present value of health damages			
	Min	**Max**	**Average**	**Damage cost**	**Min**	**Max**	**Average**	**Damage cost**
	(million TK/kiln)			(TK/brick)	(million TK/kiln)			(TK/brick)
FCK (4)	2.5	14.0	8.2	2.1	20.6	117.1	69	0.9
IFCK (4)	1.3	7.1	4.2	1.1	10.5	59.8	35	0.5
VSBK (4.8)	0.9	5.7	3.3	0.7	8.3	47.4	28	0.3
HHK (15)	4.7	26.7	15.7	1.0	39.3	223.6	131	0.5

Source: Annex A for detailed calculations.
Note: Because of data uncertainty, these values should be interpreted with caution.
[1] Based on GDP per capita. [2] Based on VSL. [3] Present value over 20 years with a 10-percent discount rate.

The Bangladesh Country Environmental Analysis reports that poor air quality in Dhaka city (due to all polluting sources, including brick kilns, transport, road dust, metal smelters, and other causes) contributes to an estimated 3,500 premature deaths per year[76] (World Bank 2006). While the 1,200 brick kilns north of Dhaka are an important contributor to air pollution, their overall health impact has not been quantified. This analysis is limited to estimating the health impacts of the North Dhaka cluster (530 kilns) in terms of PM_{10} and $PM_{2.5}$ pollution only. Despite these limitations, the analysis shows that PM_{10} and $PM_{2.5}$ pollution from these 530 kilns currently leads to 750 premature deaths per year, accounting for 20 percent of total premature deaths due to poor air quality.

[75] Dispersion patterns are a secondary factor (Annex B).

[76] Because respirable particulate matters in Dhaka have concentrations exceeding the standards for more than 100 days a year.

It is interesting to estimate the avoided mortality and morbidity that could be achieved by adopting alternative kiln types[77]. Use of the VSBK would reduce current mortality by 63 percent, followed by 45 percent for the HHK and the IFCK (Table 5.4).

Table 5.4: Avoided mortality and morbidity by adopting alternative kiln types

Factor	IFCK (4 mill.)	VSBK (4.8 mill.)	HHK (15 mill.)
Mortality no. cases (percent)	336 cases (45%)	469 cases (63 percent)	336 cases (45 percent)
Morbidity			
Chronic bronchitis (PM_{10}) (no. cases)	0	0	0
Hospital admissions (PM_{10}) (thousands of cases)	2	2	2
Emergency room visits (PM_{10}) (thousands of cases)	32	44	32
Restricted activity days (PM_{10}) (millions of cases)	3	4	3
Lower respiratory illness in children (PM_{10}) (thousands	145	200	145
Respiratory symptoms (PM_{10}) (millions of cases)	9	12	9

Cost of CO_2 emissions. This cost is based on the CO_2 quantity emitted annually by each type of kiln and the average price on the carbon market. According to the CDM (2009), the annual CO_2 emissions are valued as follows:

$$CO_2 \text{ emissions} = TP * SEC * CEF * CF,$$

where,

TP = total brick production (kg of bricks per year),
SEC = specific energy consumption (TJ per kg of bricks),
CEF = IPCC default carbon-emission factor for fuel used (tC per TJ), and
CF = carbon to CO_2 conversion factor.

The FCK has the highest unit cost per brick (TK4.2),[78] primarily because it has the greatest specific coal consumption among the selected technologies. By contrast, low coal consumption (TK2.5 per brick) makes the VSBK and the HHK the cleanest technologies in terms of CO_2 emissions (Table 5.5).

[77] It is assumed that the total brick production from the northern brick kiln cluster (2.1 billion bricks) can be obtained by replacing the 530 FCKs by 530 IFCKs (each producing 4 million bricks), or 442 VSBKs (each producing 4.8 million bricks) or 140 HHKs (each producing 15 million bricks).

[78] in present value terms

Table 5.5: Estimated annual cost of CO_2 emissions by kiln type and brick (2009)

Factor	FCK (4 mill.)	IFCK (4 mill.)	VSBK (4.8 mill.)	HHK (15 mill.)
Total brick production (thousand kg-bricks)[1]	11,600	11,600	13,860	104,580
Coal per 100,000 bricks (t)[2]	22	15	13	13
Specific energy consumption (TJ/kg-brick)[3]	0.0019	0.0013	0.0012	0.0009
Carbon emission factor (tC/TJ)[4]	25.8	25.8	25.8	25.8
Carbon to CO_2 conversion factor	3.66	3.66	3.66	3.66
CO_2 per kiln per season (t)[5]	**2,134**	**1,455**	**1,507**	**4,710**
CO_2 per100,000 bricks per season (t/100,000 bricks)	**53**	**36**	**35**	**31**
Price CO_2 (US$/t)[6]	13.5	13.5	13.5	13.5
Cost of CO_2 emissions (thousand TK/kiln/year)	2,017	1,375	1424	4,451
Cost of CO_2 emissions (TK/brick/year)	**0.50**	**0.34**	**0.30**	**0.30**
Cost of CO_2 emissions (TK/brick, present value)	**4.2**	**2.9**	**2.5**	**2.5**

[1] Based on total number of bricks for each kiln and brick weight (3.5 kg/brick for HHK and 2.9 kg/brick for the other technologies) (World Bank 2011a). [2] FCK (BUET 2007), VSBK (Heirli and Maithel 2008), HHK (World Bank 2011a), and IFCK (2009 field survey in North Dhaka cluster). [3] Estimated as specific coal consumption (kg/100,000 bricks) * calorific value (TJ/kg) * brick weight (kg/brick). [4] IPCC (2006). [5] Equals = total brick production * specific energy consumption * carbon emission factor * carbon to CO_2 conversion factor. [6] Market price for carbon credits for the project Improving Kiln Efficiency in the Brick Making Industry in Bangladesh (World Bank 2011a).

Results of the social CBA. Table 5.6 presents the social CBA and expresses the results in terms of net benefits per thousand bricks. The analysis shows that VSBK and HHK are the most socially profitable technologies, with net benefits of TK68-75 per thousand bricks. In contrast, the high costs of air pollution and CO_2 emissions make the FCK socially unprofitable.

Table 5.6: Social cost-benefit analysis (present value 2009)

Costs/benefits	FCK	IFCK	VSBK	HHK
Annual production (million bricks)	4.0	4.0	4.8	15
Area occupied by the kiln (bigha)*	15	15	4	12
Costs (million TK/kiln)	**200**	**151**	**139**	**536**
Investment cost	4.4	7.4	6.4	55.7
Cost of land	1.3	1.3	0.6	2.7
Cost of buildings	0.0	0.0	0.7	9.1
Operating costs	108.7	95.3	91.5	300.0
Health impacts of pollution	68.8	35.1	27.8	131.5
CO_2 emissions	16.9	11.5	11.9	37.2
Benefits (million TK/kiln)	**198**	**200**	**214**	**746**
Net benefits (million TK/kiln)	**-2**	**49**	**76**	**210**
Net benefits (TK/thousand bricks)	**-3**	**43**	**75**	**68**
Economic IRR (%)	**30**	**84**	**123**	**59**

Sources: 2009 field survey, UNDP (2010), World Bank (2011a) and Annex A.
Note: unless specified in the table. All costs and benefits reflect present (2009) values estimated based on a time horizon equal to a 20-year kiln life span and a 10-percent discount rate. *1 bigha =0 407 m^2.

5.5 Sensitivity Analysis

A sensitivity analysis of net returns at different discount rates (2 and 5 percent) is presented in Table 5.7. The results indicate that for any chosen discount rate, the HHK is the most profitable technology. FCK is the least attractive, and becomes unprofitable from the social viewpoint.

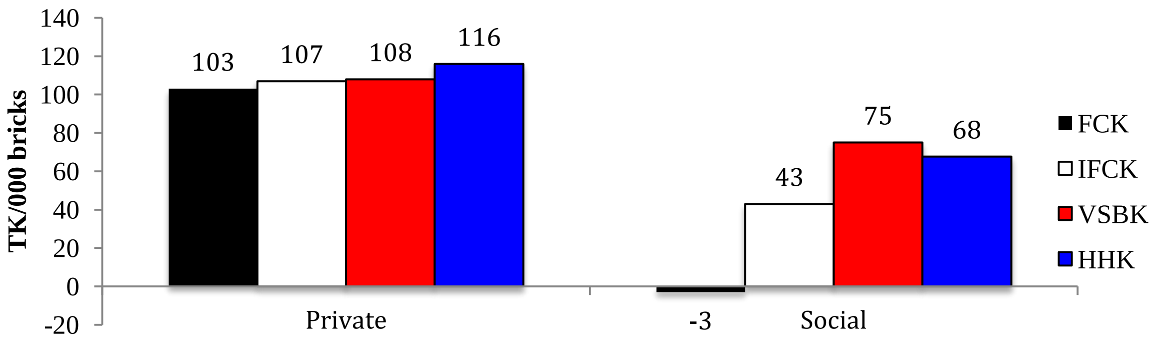
Table 5.7: Estimated net benefits at changes in discount rates (TK/1000 bricks)

Private net benefits	Discount rates		
	10% (base analysis)	5%	2%
FCK	103	109	147
IFCK	107	127	172
VSBK	108	187	269
HHK	116	205	282
Social net benefits			
FCK	-3	-1	-1
IFCK	43	53	73
VSBK	75	106	144
HHK	68	185	256

5.6 Conclusion

Figure 5.1 illustrates the net returns per thousand bricks for each technology for the private entrepreneur and for the society. Despite the higher profitability of VSBK and HHK, most entrepreneurs around Dhaka continue to use FCK, the most polluted technology. As previously mentioned, adopting cleaner technologies is difficult primarily because they operate on flood-free highlands, whereas most FCK owners are located in lowlands. In addition, adopting HHK would involve a substantial added investment (TK60 million); this is unaffordable for most FCK owners, who operate on rented land that cannot be used as loan collateral.

Figure 5.1. CBA results for different brick technologies



Thus, adopting the most sustainable kiln technology must be based on realistic incentives. Economic incentives could include, for example, **'green subsidies'** for adopting cleaner technologies. The subsidy should be based on the value of social benefits (reduced impacts on health) when moving from a polluting technology (e.g. FCK) to a cleaner one (e.g. HHK). Thus, setting up a window to provide subsidized credit and technical extension to brick makers adopting clean technologies could be an important step[79]. Chapter 7 provides a summary of concrete recommendations for adopting cleaner technologies.

[79] See Blackman (2000) and Blackman et al. (2000) for more comprehensive analyses of policy options to address pollution control in the informal sector.

CHAPTER 6. CHINA'S EXPERIENCE IN THE BRICK SECTOR

China is the world's largest developing country with the fastest economic growth rate, averaging to more than 10 percent during the past 3 decades. With 54 percent of global production, it is also the **world's leader brick producer** and has the most advanced brick industry among all developing countries. Brick production is highly concentrated in four countries **– China, India, Pakistan and Bangladesh –** which account for about 75 percent of the world's total production (Baum 2010).Yet, it is hard to claim China as a success story in brick-industry development. Although the country has achieved dramatic improvement in productivity, energy and land saving, and product diversity and quality, small-scale brick kilns using inefficient, high-emission technologies still dominate the industry. Indeed, the existence of numerous small enterprises means that the average efficiency for its brick industry is much lower than that of developed countries.

Both Bangladesh and China have high population densities, and most economic activities occur within limited geographical areas, putting serious pressure on natural resources. Bangladesh's current stage of development similar to that of China in the early 1990s in terms of low-efficient kiln technologies, fuel use, single raw material and brick product and dominance of small brick factories. This suggests that China's brick-industry experience may be even more relevant for Bangladesh than that of developed countries. Moreover, the fast economic growth prompted the evolution of the brick industry in a relatively short period of time, which may result in lessons to be learned for the short, medium and long run. This chapter summarizes the evolution of China's brick industry in recent decades and draws lessons that could be useful for the future development of Bangladesh's brick sector.[80]

6.1 Economic Development: The Driving Force of China's Brick Industry

The development of China's brick industry is closely linked with the country's economic development. In the 1970s and 1980s, the brick industry - referred to as "the mother of township and village enterprises" - played a pivotal role in the development of the rural and township economy. However, with the reform policies introduced in the 1990s, the brick industry gradually began to take a back seat to the boom in other sectors. Yet, the government introduced regulations to promote new wall materials to save clay, land, and energy - a move that brought dramatic changes to the industry.

Economic development in Bangladesh in 2008 is similar to that of China in 1990[81]**.** Comparisons in terms of per capita GDP (US$1,200 in Bangladesh versus US$1,100 in China) and rate of urbanization (27 percent) suggest that economic development in Bangladesh in 2008 was similar to China's status in 1990 (Table 6.1). More importantly, the energy intensity of China in 1990 (13.8-

[80] It should be noted that available data are not always comparable across countries. While information for Bangladesh focuses on kiln technologies and control of emissions, most of the literature for China focuses on alternative raw materials, new brick products, and energy-saving materials. Thus, any lessons drawn from China's experience must be adapted to Bangladesh's unique country conditions prior to implementation.

[81] For comparison, all the indicators in this section are expressed into the unit of Bangladesh bricks. In China, bricks are counted in "Standard Bricks" which are smaller than the bricks produced in Bangladesh. The size of standard bricks in China is 240mm×115mm×53mm, and the size of a normal brick in Bangladesh is 9.5"×4.5"×2.75" (about 241mm×114mm×70mm). Therefore, 1 Bangladesh brick = 1.317 Standard Chinese bricks.

14.5 tce/100,000 bricks) was very similar to that of Bangladesh's current level (15 tce/100,000 bricks). However, China showed better performance than Bangladesh for most economic indicators, including GDP growth rate (11 percent versus 6 percent), per capita brick production (350 versus 90) and unit brick production (4.1 million in 1990 and 5.3 million in 1995 versus 3 million). China's mechanical molding process led to higher labor productivity per employee (70,000 bricks versus 15,000 bricks).[82] Similarly, by 1995, the energy intensity had been reduced to 10.5 tce per 100,000 bricks, which is 30 percent less than that in Bangladesh.

Table 6.1: Comparison of economic development in China and Bangladesh for selected years

Economic indicator	China		Bangladesh
	1990	1995	2008
Macroeconomic			
Urbanization (% of urban population)	27	31	27
Population (million)	1,100	1,200	160
GDP per capita (constant, 2000 US$)	400	660	460
GDP per capita, PPP (constant, 2005 international $)	1,100	1,800	1,200
GDP growth rate (%)	11[3]		6
Brick-industry status			
Total brick production (billion)	350	530	15
Total employment (million)	5		1
Brick production per capita	305	340	94
Brick-sector annual growth (%)	9[3]		5.6[6]
Production units (no.)[1]	85,000	100,000	5,000
Unit brick production (million bricks/factory or kiln/year)	4.1	5.3	3
Labor productivity (1,000 bricks/employee)	70	106	15
Energy intensity (tce[2]/100,000 bricks)	13.8-14.5	10.5	15
Fuel use	Exclusively coal	Exclusively coal	99% coal
Dominant kiln type	Hoffmann (~93%)	n.a.[4]	FCK (75%)
Brick-molding mechanization level	High[5]	n.a.[4]	Very low

Sources: World Bank (2009), Zhang (1997), and BUET (2007). The Chinese indicators related to brick production have been converted in 'Bangladesh bricks', to allow direct comparison between countries,
[1] Refers to enterprises (factories) in China and kilns in Bangladesh.
[2] tce = tons of coal equivalent.
[3] Average for 1990–95.
[4] n.a. = not available.
[5] Mechanization replaced manual work in most parts of the country.
[6] Refers to the construction industry.

[82] The number for Bangladesh also includes employment in upstream (supply of clay and coal) and downstream sectors (transport of bricks and marketing). If these sectors were omitted, the difference between China and Bangladesh in terms of labor productivity would be even higher.

Rapid economic growth in China increased brick demand and diversification. In 1990–2010, China witnessed a significant growth of per capita GDP (more than 4 times),[83] population (14 percent) and urbanization rate (27 to 44 percent) (Table 6.2). This spurred high demand for buildings and construction materials, including bricks. Currently, the existing constructed area exceeds 42 billion m^2. During 1995–2008, the annual "floor space of buildings under construction" and "floor space of buildings completed" increased fivefold; and per capita living space in both rural and urban areas nearly doubled.

Table 6.2: China's economic data, 1990–2009

Economic indicator	1990	1995	2000	2005	2009
Urbanization (% of urban population)	27	31	36	40	44
Population (million)	1,100	1,200	1,300	1,300	1,300
GDP per capita (constant, 2000 US$)	390	660	950	1,460	2,200
GDP per capita, PPP (constant, 2005 international US$)	1,100	1,800	2,700	4,100	6,200
Per capita building space in urban areas (m^2)	13.7	17.0	20.3	26.11	n.a.[1]
Per capita living space in rural areas (m^2)	17.8	21.0	24.8	29.7	32.4[2]
Floor space of buildings under construction (mill. m^2)	n.a.[1]	900	1,600	3,500	5,300[2]
Floor space of buildings completed (mill. m^2)	n.a.[1]	360	800	1,600	2,200[2]

Sources: World Bank (2009) and National Bureau of Statistics of China (various years).
[1] n.a. = not available.
[2] 2008 data.

Based on data of the Ministry of Environmental Protection (MoEP 2009), China's brick production increased fivefold during 1982–2008. The highest growth occurred mainly in the 1980s (10.6 percent per year) and the first half of the 1990s (9.2 percent per year), matching the country's dramatic increase of per capita GDP. Since then, growth has continued at a slower rate. Similarly, the economic growth rate in Bangladesh may suggest that the demand for brick is expected to grow rapidly.

Economic growth in China not only led to an increased demand for bricks; it also resulted in extraordinary changes in the brick sector. These included improvements in product diversity, scale of product lines, conglomeration and grouping management of brick enterprises, a move toward more environmentally friendly raw materials, and technology upgrades.

6.2 Development of China's Brick Industry

The following subsections present the evolution of China's brick industry over the last two decades (Table 6.3).

[83] In terms of purchasing power parity (PPP).

Table 6.3: Snapshot of China's brick industry, 2008

Parameter	Value (approximate)
Brick-making enterprises (all types) (no.)	80,000
Brick-making fuel used	Exclusively coal
Annual brick production (standard Chinese bricks)	900 billion–more than 1 trillion[1]
Contribution to GDP (%)	1.74
Contribution to the industry value added (%)	4.06
Coal consumption (million tce)	50
CO_2 emissions (million t)	150[2]
Clay consumption (billion m^3)	1.4
Total employment (million employees)	5
Growth rate of construction industry (1998–2008) (%)	7.1
Growth rate of industry of building materials (1998–2008) (%)	20

Sources: MoEP (2009) and China Economic Information Network (2009).
[1] Numbers vary by source.
[2] 2007 data related to other pollutants include SO_2 (260,000–280,000 t); PM (350,000–380,000 t), and NO_x (380,000–410,000 t).

Enterprise structure. In the 1990s, the number of enterprises in China's brick industry increased, followed by a slowdown in the 2000s. During this period, the number of large enterprises increased, bringing in more capital, advanced management techniques, and higher capacity to adapt to new technologies and meet stringent government regulations. As a result, average production more than doubled (Table 6.4).

Table 6.4 Enterprise structure of China's brick industry

Parameter	1990	2005	2008
Number of enterprises (thousand)	85	100	80
Average production capacity (million standard Chinese bricks/enterprise/year)	5.4	7.6	12
Average production capacity (million Bangladesh bricks/enterprise/year)	4.1	5.8	9.1

Sources: Zhang (1997), CBTIA (2005), and MoEP (2009).
Note: Given the scant availability and poor quality of data, years 1990, 2005, and 2008 only are included.

Dramatic changes marked the three-year period of 2005–08 (Table 6.5). The total number of enterprises dropped by 20 percent, mainly because of the declining medium (10–30 million bricks) and small enterprises (less than 10 million bricks). By contrast, large enterprises (30–50 million bricks) doubled, while very large enterprises (more than 50 million bricks) increased by 12 percent. Despite these changes, small-scale enterprises (less than 10 million bricks) still dominated the industry, comprising 60 percent of the total. Large and very large companies produced about half of all bricks, while small companies generated only 20 percent. Upgrading the technology of small enterprises has presented a challenge for China, and will most likely prove extremely challenging for Bangladesh.

Table 6.5: Number of enterprises and share of brick production, 2005 and 2008

Enterprise type (millions of standard Chinese bricks/year)	Number of enterprises			Share of brick production (%)
	2005	2008	Change 2005–08 (%)	
Large (30–50)	9,000	13,600	51	40
Medium (10–30)	25,000	16,800	-33	30
Small (< 10)	65,000	48,000	-26	20
Total	**100,000**	**80,000**	**-20**	**100**

Source: MoEP (2009).

Kiln technologies. In the 1990s, the Hoffmann annular kiln dominated China's kiln technologies. The Hoffmann (natural drying) kiln accounted for 90.8 percent of the total, while the Hoffmann (artificial drying) kiln accounted for 1.6 percent. The Intermittent (primitive) "horse-foot" kiln comprised another 7.5 percent. Though the Tunnel (natural drying) kiln accounted for only 0.1 percent of the total, it remains the most advanced technology because it emits considerably less unorganized pollution,[84] eliminates labor hardship,[85] and improves labor productivity (MoA 1993).

During the 1990s, large- and medium-sized enterprises generally used the Hoffmann and Tunnel kilns, which accounted for about 10 percent of the total brick production. Small-sized enterprises dominated the entire industry, representing 99 percent of total enterprises and 90 percent of production. The township and village enterprise usually operated the small enterprises, whereas the state owned and operated the large- and medium-sized ones.

Today, the Hoffmann kilns continue to dominate the market, representing 90 percent of total kilns, while Tunnel kilns account for less than 5 percent. However, the dominance of Hoffmann kilns means that switching to upgraded technologies is likely to be difficult in the short term.

Diversification of building materials. During the early 1990s, bricks were the most widely used building material, despite the introduction of new wall materials. However, about one-fifth of the brick factories that used Hoffmann kilns started to mix waste materials (e.g., fly ash, gangue, coal dust, and coal slurry) into clay to make bricks. In the molding process, mechanical brick forming replaced manual forming throughout most of the country.

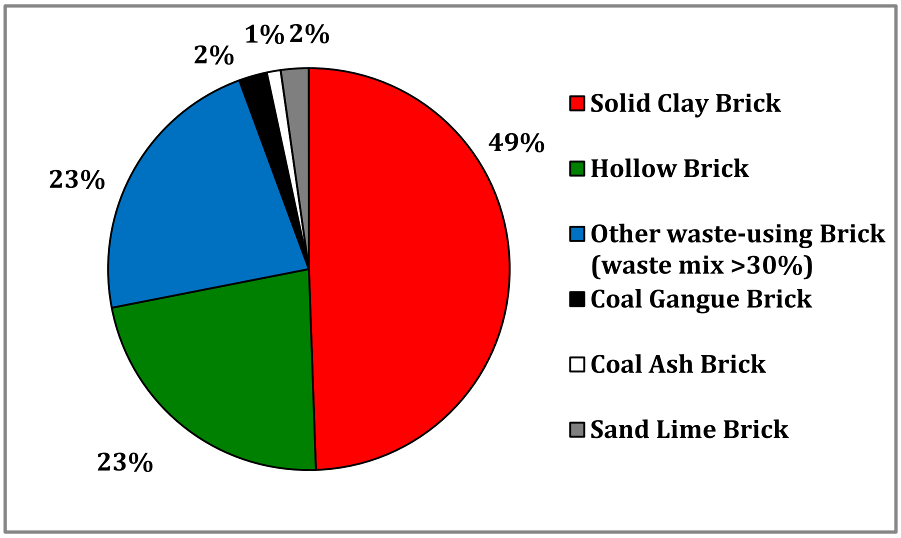
Nowadays, the brick sector uses many new product types in addition to the traditional solid clay bricks. The new brick products mainly consist of perforated and hollow bricks, waste-using bricks, and several types of non-fired bricks, blocks, and slabs.[86] Their novelty stems from the use of new equipment and technologies and raw materials for replacing clay (Figure 6.1). The solid clay bricks and the new brick products each stand for about half of the total. Among the new brick products, hollow bricks and waste-using products each account for nearly a quarter of total production.

[84] Unorganized pollution refers to irregular emissions of dust pollutants without using dust control equipment (e.g., from material pile in the operational field, open transport, and pipe and equipment gas leakage).

[85] Such as manual loading or unloading at elevated brick temperatures.

[86] Such as autoclaved sand-lime bricks, steam-cured slag bricks, cement bricks, gypsum blocks, and slabs.

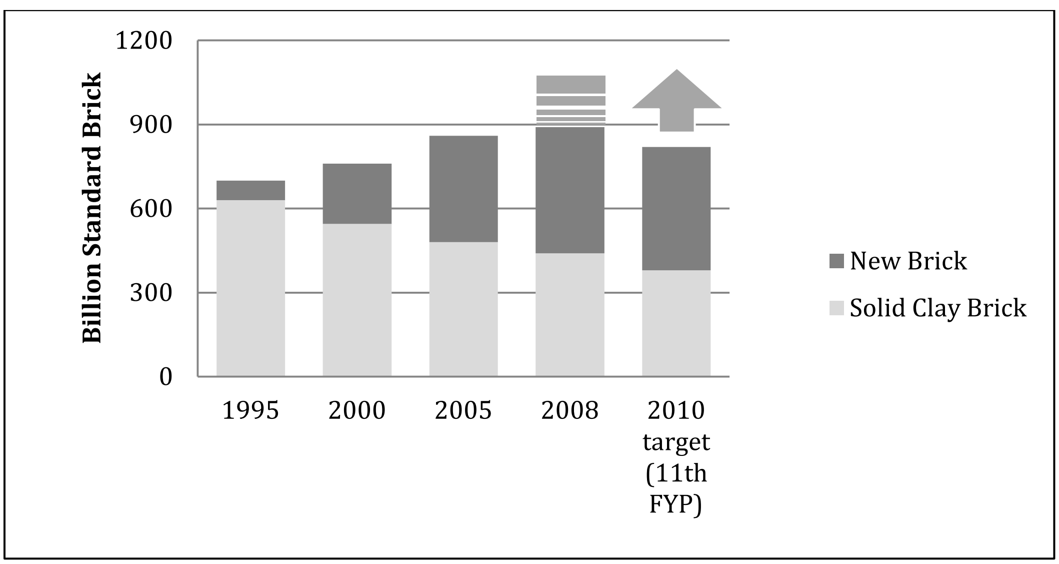
Figure 6.1: Share of various brick products in China, 2008



Source: MoEP (2009).
Note: These brick categories do not exactly match those provided in the text due to the various data sources.

According to the MoEP (2009), China's brick production increased from 200 billion to 1 trillion standard Chinese bricks during 1982-2008. In the last decade, total production expanded, owing to the growing number of new brick products and the declining use of solid clay bricks (from 600 billion to 400 billion). The new bricks target set for the 11th Five-Year Plan (2005–2010) was above 55 percent, while production of solid clay bricks was below 380 billion (Figure 6.2). The diversity of brick raw material continues to increase.

Figure 6.2: Production of solid clay bricks and new brick products, 1995–2010



Sources: Various Chinese sources and author's own estimates.
Note: Data for 2010 represents the estimated target for the 11th Five-Year Plan

Energy efficiency[87]. Improving the energy efficiency of brick-making is strongly aligned with the country's long-term strategy for sustainable development. Replacing clay with alternative raw materials and using natural drying have improved energy efficiency and saved resources considerably. Zhang (1997) reported that coal consumption per 100,000 bricks declined from 18 tce in 1980 to about 13.8–14.5 tce in 1990.[88] China Brick & Tile Industry Association (CBTIA 2005) estimated that coal consumption decreased from 14.5 tce per 100,000 bricks in the 1980s to 5.3–6.6 tce per 100,000 bricks for the 11th Five-Year Plan (2005-10) (Table 6.6).

Table 6.6: Summary of environmental achievements, 1980–2010

Environmenal factor	1980s	1995–2000	2000–05	2005–10 (target)
Energy intensity (tce/100,000 bricks)	14.5	n.a.	6.6~7.9	5.3~6.6
Total energy saved (million tce)	n.a.	60	32	10
Waste used (million t)	n.a.	200	250	300
Clay saved (million t)	n.a.	n.a.	263	n.a.

Source: CBTIA (2005).
Note: n.a. = not available.

Wang, Chang, and Zhu (2009) reported that energy consumption per 100,000 bricks for fired wall materials declined from 11.9 tce in 2000 to 9.2 tce in 2007 (Table 6.7).[89] Growing production of new wall materials, which are more energy efficient than solid clay bricks, drove the average increase in energy efficiency.

Table 6.7: Energy consumption intensity of fired wall materials in China

Consumption type	Unit of measure	1990	2000	2005	2007
Coal	tce/100,000 bricks	13.8–14.5	11.9	10.5	9.2
Electricity	kWh/100,000 bricks	n.a.	2,900	3,300	3,700
Total	tce/100,000 bricks	n.a.	13.0	11.9	10.7

Source: Wang, Chang, and Zhu (2009).
Note: n.a. = not available.

Brick-making processes. China uses various brick-making processes. As the brick industry started to diversify, comparing energy efficiency among processes became more complicated. Energy efficiency depends on the raw material used, the final product, and the techniques applied in the processes of brick molding, drying, and firing. According to the energy-efficiency and production scale,[90] fired brick-making processes in China can be categorized into three tiers (Wang, Chang, and Zhu 2009):

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[87] For comparison, all the energy efficiency/intensity parameters and pollution indicators in this section are converted into the units used in Bangladesh.

[88] In terms of unit energy used by kiln type, the Intermittent kiln has the highest level of fuel consumption per brick. To produce 100,000 bricks, it uses as much as 20–25 tce of coal and no electricity. The Hoffmann kiln uses about 8–10 tce per 100,000 solid bricks, with small plants on the high end and large plants on the low end. Small plants use 3,000–4,000 kWh per 100,000 solid bricks. However, if the combustion body fuel is mixed with clay, considerable reduction in net energy use can be achieved.The Tunnel kiln has a high level of mechanization, which tends to require more energy than the Hoffmann kiln; thus, the tunnel kiln is reported to consume an average of about 13 (10–15) tce of coal per 100,000 bricks and 3,500–4,500 kWh of electricity. To produce hollow bricks using Tunnel kilns, coal use per 100,000 bricks drops considerably to 8 tce, while electricity use increases to 4,500–5,500 kWh (Zhang 1997).

[89] Fired wall materials include most brick products (e.g., solid clay bricks and waste-using bricks).

[90] Considering external fuel consumption only.

- *The first tier* relates to the firing process with coal consumption below 1 tce per 100,000 bricks. The firing process relies mainly on the residual heat from industrial wastes. The main raw materials are shale, coal gangue, and coal ash. Products mainly include hollow bricks, perforated bricks, and hollow blocks. The production process uses vacuum extruder (for molding), artificial drying, and the Tunnel kiln. The enterprises have a production scale of more than 30 million bricks per year and account for 2–3 percent of total enterprises in the brick sector.

- *The second tier* relates to a coal consumption of 6.6–9.2 tce per 100,000 bricks. Shale or clay is the major raw material, mixed with low-quality coal. Coal gangue or coal ash is the internal fuel. The main products are perforated fired bricks, and the production processes combine natural and artificial drying using either the Hoffmann or Tunnel kiln.

- *The third tier* is the least efficient, with 10.5–14.5 tce per 100,000 bricks, accounting for the majority of brick-making enterprises (70 percent of the total). It includes numerous small enterprises that produce solid clay bricks by natural drying and firing. It uses the Hoffmann or primitive Hoffmann kilns, located in rural areas, with an annual production of 6–15 million standard Chinese bricks per kiln.[91]

Pollution levels. Among the various brick kilns in China, the Intermittent kiln emits the highest levels of SO_2 and CO_2 (Table 6.8).

Table 6.8: Emissions of SO_2 and CO_2 in China by kiln technology, 1990

Kiln technology	SO_2 emissions (t/million Bangladesh bricks)	CO_2 emissions (t/million Bangladesh bricks)
Intermittent	6.6	149
Hoffmann		
Natural drying, solid bricks	3.6	82
Artificial drying, solid bricks	3.6	83
Artificial drying, hollow bricks	2.1	49
Tunnel		
Artificial drying, solid bricks	4.6	105
Artificial drying, hollow bricks	2.6	63

Source: Zhang (1997).
Note: The original data, expressed in standard Chinese bricks, have been converted in Bangladesh bricks.

Overall, increasing use of new brick products has accounted for the dramatic growth in China's brick industry. As the industry began to employ newer technologies and materials, energy efficiency and resource conservation (e.g., clay and arable land) increased. The industry also became more conglomerated, with larger emerging product lines and enterprises. In 2005, the new product lines had an annual average capacity of more than 15 million standard Chinese bricks per line. The capacities of new coal gangue brick and coal ash brick lines are more than 30 million bricks per line on average, with the largest reaching 160 million standard Chinese bricks.

[91] Replacing clay with industrial waste can save energy by using the residual heat as internal fuel; but this alone cannot contribute to reducing CO_2 emissions.

6.3 Government Intervention

The Chinese government has promoted a series of policies, laws, and regulations to control solid clay bricks and promote new wall material to save clay, land, and energy. It has also invested considerably in developing new technologies to promote the use of locally available materials for clay replacement. This section reviews the major regulations issued by the Chinese government on the brick industry and the institutions and organizations that have contributed to managing and facilitating its healthy development.

Laws and regulations. In 1988, regulation of the brick and tile industry was initiated by the Chinese government with two objectives: (i) to control the use and production of solid clay bricks and (ii) promote research and development (R&D), production, and use of new wall materials. Table C-1 (Annex C) provides a comprehensive list of the major sector-specific laws and regulations issued by the government, including the responsible institutions[92]. The Wall Material Renovation program includes all policies, laws, and regulations issued by the Chinese government. Many government offices at the ministry level are involved in issuing, monitoring, and implementing the regulations.[93]

- *In 1992* the Government started to control solid clay bricks by issuing the "Circular of advice on how to accelerate wall material renovation and to promote energy efficient buildings".

- *In 1999* the Government banned the use of solid clay bricks in coastal cities and cities where land was scarce. In the same year, the State Office of Wall Material Renovation of the National Development and Reform Commission identified the first 170 cities[94] expected to limit the use of solid clay bricks to certain targets by 2003.

- *In 2005*, the Government banned all clay-building products in the 170 cities and extended the regulation to suburban areas. It also banned the use of solid clay bricks in other 256 cities by 2008.

- *In 2004*, the Government mentioned for the first time the controlled use of solid clay bricks in small towns and rural areas. It established national targets to reduce their production by 80 billion bricks by 2006 and prohibit their use in all cities by 2010.

- *In 2007*, the 11th Five-Year Plan established targets for China's brick and tile industry, centered on (i) developing new wall materials, (ii) conserving land resources, (iii) saving energy and other resources, and (iv) phasing out outdated technologies.

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[92] The compilation is based on a review by Zhang (2009) and the author's review of government websites (Table C-1).

[93] These include the State Council, former Ministry of Construction (MoC), National Development and Reform Commission (NDRC), Ministry of Science and Technology, Ministry of Agriculture (MoA), former Bureau of Land, former Ministry of Economy and Trade, Administration of Taxation, and State Bureau of Quality and Technical Supervision, with strong support from China Bricks and Tiles Industrial Association (CBTIA) and such research institutes as Xi'an Research and Design Institute of Wall and Roof Materials.

[94] the municipalities, middle and large cities in the coastal areas, and middle and large cities in provinces where per capita arable land is below 0.8 mou (about 534 m^2).

Policies supporting new wall materials. Specific policies to support development of new wall materials can be divided in three types, based on their targets: (i) brick industry, (ii) raw materials (upstream sector), and (iii) construction industry (downstream sector). Policy tools include command-and-control and economic instruments. The economic incentives mainly include reduction of and exemption from income tax, VAT, and custom duties, as well as provision of financial support via preferential loans and specific funds. Table C-1 (Annex C) provides specific policies for supporting the new wall materials, based on the CBTIA (2009) and China Energy Information Networks (2010).

Main features of policies, laws, and regulations. The main features of the policies, laws, and regulations for the brick and tile industry, based on more than 10 official regulations issued by the government since 1990,[95] are summarized as follows:

- Command-and-control was the major regulating measure for phasing out solid clay bricks and polluting technologies; this was facilitated via such economic instruments as specific funds and preferential tax policies on promoting new wall materials. The economic instruments have been essential to adjusting the cost and price gaps between traditional solid clay bricks and new wall materials.
- At the outset, national laws set up strategies and macroeconomic development plans pushed by the central and (in many cases) most powerful government ministries (e.g., the NDRC or State Council) and were then detailed with specified regulations and policies.
- The theme was changing the market environment, with intervention focused at the enterprise level.
- Comprehensive policies, laws, and regulations were designed and issued, and the value chain of bricks was extended to raw materials, production processes and equipment, final products, building designs, and construction processes. Upstream and downstream regulations worked together to help guide brick-sector development in the preferred direction.
- Close inter-institutional collaboration was essential for making policies, laws, and regulations work compatibly within the extended value chain of bricks. Table C-1 (Annex C) shows that many policies, laws, and regulations were jointly prepared and issued by several government authorities.
- Implementation was devolved from central to provincial, municipal, and local government.
- Enterprise conglomeration and technology promotion were jointly supported (since they are usually interlinked, supporting one would benefit the other).
- Regulations started from locations with the highest implementation capacity (e.g., municipalities, large cities, and coastal cities with relatively low targets) and then expanded into suburban and even rural areas.
- Policies, laws, and regulations have been consistently monitored, reviewed, and evaluated to identify problems that emerged from implementing earlier regulations; thereafter, they were updated by setting up higher targets through more stringent regulations that provided continuous stimulus for consolidating achievements.

[95] Order of State Council #82, KJ: [1991] No.619, GF: [1992] No. 66, CSZ: [1994] No.1, CSZ: [1995] No.44, GF: [1996] No. 36, GF: [1997] No. 37, KJH: [1998] No. 68, GBF: [1999] No.72, JZ: [1999] No. 295, CS: [2008] Nos.117 and 156, and so on.

- To date, government regulations have been driven by energy, clay, and land savings. As a co-benefit, pollution emissions have been reduced substantially; however, emissions control from the brick industry has lagged, compared to other industrial sectors.[96]

6.4 Current Problems and Challenges Ahead

China's brick industry is at a critical stage in the process of transforming its industrial structure, and many serious issues remain; key among them are the following:

- ***Solid clay bricks still account for about half of total brick production.*** Phasing out solid clay bricks confronts significant barriers. As demand for construction materials escalates with the economy, prices for solid clay bricks become more competitive due to relatively cheap labor and clay. Development of new bricks is hampered. Local governments have substantial influence over the brick industry, and local protectionism prevails. Once the central government removed agriculture taxes, the brick industry became a more important source of local fiscal income, especially in less developed, remote regions. Thus, phasing out solid clay bricks is against local governments' interest as tax collectors.

- ***Small enterprises still dominate the brick industry***. About 60 percent of brick enterprises produce less than 10 million bricks per enterprise annually, accounting for about 20 percent of total bricks. These enterprises follow simple production and management models, apply outdated technologies, and use unskilled labor. Therefore, their productivity and energy efficiency are also relatively low. In addition, their dominance makes it difficult to phase out solid clay bricks and encumbers the adoption of new technologies.

- ***Pollutant emissions are rarely controlled and treated***. According to the CBTIA (MoEP (2009), emissions from brick and tile kilns in China are usually not treated. Nationwide, there are fewer than 10 brick and tile enterprises equipped with emissions treatment facilities.[97] In addition, because environmental regulations are loose overall, treatment equipment is not operational most of the time. The brick industry faces two major hurdles to control emissions: (i) most enterprises lack sufficient capital to invest in emissions reduction equipment and (ii) the value added and profit rate are low, leaving little margin for the cost of emissions control. For example, a sulfur scrubber is technologically difficult and unaffordable for small producers. Promoting Tunnel kilns in newly constructed enterprises (and gradually phasing out Hoffmann kilns) and using cleaner fuels (such as industrial waste and low-sulfur coal) can help reducing emissions.

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[96] The draft regulation under discussion is related to establishing standards for PM, SO_2, NO_x, and fluoride. Once finalized, the regulations with emissions indicators will be effective for all new factories immediately after issuance; for existing factories, the new emissions indicators will become effective starting January 1, 2013 (Table C-2, Annex C).

[97] For PM emitted during the processes of grinding and transport, some firms have installed bag filters, while most use air-tight treatment to reduce emissions.

CHAPTER 7. TOWARD A SUSTAINABLE BRICK SECTOR IN BANGLADESH

Bangladesh's brick sector is characterized by outdated technologies with low energy efficiency and high emissions, low mechanization rate, dominance of small-scale brick industries with limited financial capacity, and dominance of single raw material (clay) and product (solid clay brick). Adopting gas-based cleaner technologies is hampered by serious energy shortage and land scarcity.

How long can the country afford making bricks in this way? The current status is by no means sustainable. Bangladesh has every reason to upgrade its brick sector in order to save valuable natural resources, reduce air pollution, and increase energy efficiency. The government has already established regulations that ban the use of fuelwood and FCKs and has reconsidered the location and height of brick kiln chimneys. However, transformative development of the brick industry has yet to occur.

This report suggests that the development of the brick industry in Bangladesh ***over the next 20 years*** should aim at: (i) moving from traditional brick-making technologies (e.g. FCK) to cleaner ones (e.g. HHK, VSBK); (ii) diversifying products (e.g. hollow and perforated bricks) and finding alternative raw materials that are locally available; (iii) increasing the proportion of large-scale enterprises with higher capacity to adapt to cleaner technologies. To achieve these goals, a summary of concrete recommendations is provided below. Table 7.1 presents a comprehensive set of policy recommendations drawn from this study, together with the institutions responsible for their achievement.

In the short-term:

1. Recognize brick kilns as a ***formal industry*.** This would enable easier access to financial resources (which in turn will enable investment in cleaner technologies and access flood free land) and improved working conditions.

2. Create a ***Brick Technology Center*** to raise awareness about the benefits of cleaner technologies. The center should: (a) disseminate information on the *social benefits* provided by cleaner technologies, new wall materials (e.g. perforated and hollow bricks) and alternative raw materials; (b) promote pilot projects of new technologies with improved provisions (e.g., mechanized, higher labor productivity and larger product lines); (c) improve use of existing dissemination channels (e.g., field visits to pilot plants, video demonstrations of the technologies, use of the Bangla language) and introduce new channels (e.g., newsletters, industry journals, conferences, and Internet blogs).

3. Support ***research and development*** aiming at: (a) exploring alternative raw materials[98] that are locally available, brick diversification, and use of higher level of mechanization; (b)

[98] A word of caution should be mentioned about the use alternative raw materials, where strong quality control should be kept in regulators' mind. Some alternative raw materials, especially wastes, may contain toxics that are harmful to human health. Pertinent policies, laws, and regulations need to be developed and set up to make sure no hazardous raw materials are used while they are adopted in the industry. In the past few years, local governments in China have strengthened regulations to prohibit hazardous materials from being used for wall material production and developed a series of standards for quality control of new products, to safeguard favorable development of this industry.

conducting new studies such as energy consumption studies, land surveys, and brick technology surveys.

4. Facilitate the availability of ***subsidized credit lines*** to account for reduced health impacts from pollution and of other ***economic incentives*** supporting the production of new wall materials and use of alternative raw materials (e.g. via specific funds and preferential tax policies, as in China).

5. Provide access to ***carbon markets***, on account of the carbon emission reductions provided by cleaner technologies.

6. ***Train*** several stakeholders with regard to the benefits of adopting cleaner technologies (e.g. brick owners, workers and the financial sector).

In the medium term:

7. ***Enforce the existing regulations and policies***, such as the ban of traditional high polluting kilns (e.g. FCK, BTK), particularly those located close to large population centers, upstream of the wind (north) in the dry season (November to April).

8. ***Introduce regulations and policies that encourage adoption of cleaner technologies***, such as: (a) revise emissions standards for brick kilns under ECR97 to make them technology independent and to encourage brick diversification (e.g., perforated or hollow bricks for partition walls); (b) establish proper emission monitoring for brick kilns; (c) impose an emission levy based on "polluter-pay principle"; (d) design rules and standards for the entire brick value chain: from raw materials to production processes and equipment and final products to building designs and construction processes.

9. ***Develop industrial parks*** to accommodate a large number of industries on flood-free land. These parks would mean less cost for kiln owners, due to the economy of scale achieved by providing the basic infrastructure for all kilns (e.g. roads, electricity, water) and other facilities (e.g. schools for the employees' children). They would also require less land for kilns establishment compared to the current situation[99].

10. ***Improve working conditions*** by introducing higher levels of mechanization, social programs to reduce child labor, occupational safety and health measures in kilns.

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[99] World Bank (2011) assessed that 6,400 acres of land would be needed over a 20-year program to build new factories in either brick parks or in other places specifically designated for brick production. At the same time, about 3,300 FCK entrepreneurs would have switched to VSBK and/or Zigzag factories, freeing up approximately 8,000 acres of lowland for cultivation.

Table 7.1. Recommendations and institutions concerned with their implementation

Recommendations	Institutions concerned
In the short term	
1. Recognize brick kilns as Small and Medium Enterprises (SMEs)	Ministry of Industries (MOI), Department of Environment (DOE),
2.Create a Brick Technology Center	DOE, BBMOA, MOEF
3. Support research and development	DOE, Research and Academic Institutions
4. Facilitate the availability of subsidized credit lines and other economic incentives	MOEF, MOF (Ministry of Finance), Bangladesh Bank, Financing Institutions
5. Provide access to carbon markets	DOE
6. Train several stakeholders with regard to the benefits of adopting cleaner technologies	Brick Technology Center, BBMOA
In the medium term	
7. Enforce the existing regulations and policies	DOE, MOEF, Bangladesh Standards and Testing Institution (BSTI)
8. Introduce regulations and policies that encourage adoption of cleaner technologies	DOE, MOEF
9. Develop industrial parks to accommodate a larger number of industries	Bangladesh Small and Cottage Industries Corporation (BSCIC), MOI, DOE
10. Improve working conditions	DOE, Ministry of Labor and Social Welfare (MOLSW), Ministry of Women Affairs (MOWA), Entrepreneurs, BBMOA

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This annex estimates the health impacts of kiln pollution related to (i) infant and child mortality from respiratory diseases caused by short-term PM_{10} exposure, (ii) adult mortality from cardiopulmonary diseases and lung cancer caused by long-term $PM_{2.5}$ exposure, and (iii) all-age morbidity resulting from PM_{10} exposure. Croitoru and Sarraf (2010) provide a detailed case study of the valuation of health impacts on air pollution.

A five-step process was used to measure the health impacts: (i) identify the pollutants and measure their concentration, (ii) estimate the population exposed, (iii) establish dose-response coefficients, (iv) measure the health impacts (physical valuation), and (v) measure the health impacts (monetary valuation).

Physical valuation was based on the Disability Adjusted Life Years (DALYs), a method developed and applied by the World Health Organization (WHO) and the World Bank in collaboration with international experts that provides a common measure of disease burden for various illnesses and premature mortality (WHO 2009). The method weighs illnesses by severity so that a relatively mild illness or disability represents a smaller fraction of a DALY, while a severe one represents a larger one. The mortality due to health problems is expressed in terms of DALYs: a year lost to premature mortality represents 1 DALY, and future years lost are discounted at a fixed rate of 3 percent. Morbidity is expressed in terms of DALYs and other costs of illness.

Monetary valuation used two approaches to estimate the value of 1 DALY. The first one, the human capital approach (HCA), estimates the indirect cost due to productivity loss through the value of an individual's future earnings (Kirch 2008). Accordingly, 1 DALY corresponds to one person's average contribution to production, namely the GDP per capita. This method provides a lower bound for the loss of 1 DALY. The second approach, Value of Statistical Life (VSL), measures the willingness to pay to avoid death by observing the individual behavior when trading off health risks and money (Johansson 2006). The VSL is estimated by dividing the marginal willingness to pay for reducing the risk of death by the size of the risk reduction. The value of 1 DALY corresponds to the VSL divided by the average number of discounted years of life lost due to an adult's death (World Bank 2005). The VSL method provides an upper bound of health damages.

The direct, illness-related costs that society incurs are computed using the cost-of-illness approach, which estimates the treatment costs linked to various health endpoints (e.g., hospitalization, restricted activity days, or doctor visits) and the cost of time provided by caregivers to treat sick individuals (e.g., caregiver's wage).

Step 1. Identify the pollutants and measure their concentration

This step estimates the contribution of each brick technology to the average $PM_{2.5}$ and PM_{10} concentrations in Dhaka.

Estimating the contribution of the FCK to the average ambient PM_{10} concentration. The PM_{10} ambient concentration averages 150.5 µg per m^3, based on daily measurements for 2006, according to the Department of Environment.[100] Guttikunda (2009) states that brick kilns in the cluster north of Dhaka city contributed two-fifths of the measured fine particulates during the five-month operating period. Using a source apportionment model, Begum, Biswas, and Hopke (2010) estimate that brick kilns are the most important source of pollution, with fine-fraction particulates (PM with a diameter of less than 2.5 μg) during kiln operation accounting for 38 percent of total mass.[101] Based on these data, the annual contribution of the FCKs to the ambient PM_{10} concentration is estimated at 14–36 µg per m^3,[102] which corresponds to an average of 25 µg per m^3 or 17 percent of the average ambient PM_{10} concentration in Dhaka.

Estimating the IFCK, VSBK and HHK contributions to the average ambient PM_{10} concentration. As most kilns in the North Dhaka brick cluster are FCKs, the contribution of the IFCK, VSBK, and HHK to average PM_{10} concentration in Dhaka cannot be measured. Estimating these contributions is also difficult, as it depends on several factors, such as: total emissions from each kiln, kiln type, dispersion patterns of these emissions, location of kilns, etc. Use of elaborate dispersion models accounting for all these factors can produce an accurate estimation of these contributions. Time constraints made it impossible to conduct such an analysis in the context of this study. Thus, it is assumed that pollution concentration at a receptor site is proportional to the emission rate. In other words, emission rates are assumed to have a linear impact on the pollutant concentration at the receptor site. Several emission models have used this assumption (e.g. Meaud 2005; Repace 2005).

Table A-1 estimates the emissions from each kiln type, assuming that total brick production from the northern brick-kiln cluster (2.1 billion bricks) could be obtained by replacing the 530 FCKs with 530 IFCKs, or 442 VSBKs, or 140 HHKs. The valuation is based on measurements of emissions per brick available in Bangladesh (for FCK, IFCK and HHK), and Nepal and India (for VSBK).

Table A-1: Estimate of mass emission load of suspended particulate matter by kiln type

Kiln type	Production capacity (million bricks/kiln)	Number of kilns needed to produce 2.1 bil. bricks	SPM emission load (kg/10,000 bricks)	SPM total emission load from producing 2.1 bil. bricks (000 t/year)
FCK	4	530	17.1[a]	3.6
IFCK	4	530	8.6[b]	1.8
VSBK	4.8	442	5.6[c]	1.2
HHK	15	140	8.7[d]	1.8

Sources: [a]Tuladhur, Acharya, and Raut (2006), Baum (2010), and Khan (2008) for FCK; Baum (2010), [b] Based on emissions-load data for the FCK and BUET (2007) for the ratio in stack emissions between the FCK and the IFCK; [c] Based on measurements per 10,000 bricks of 3.1–28 kg of SPM for 4 VSBKs in India (Ministry of Environment and Forests, 2007) and 5.3–7.2 for 2 VSBKs in Nepal (IEM 2004). [d] Khan (2008) for HHK.

[100] PM values are monitored on a 24-hour average basis; however data are not available for all days in a month, and the number of days per month for which data are monitored is also unequal.

[101] Data refer to the 2005–06 operation period. Other contributors to fine-particulate pollution include motor vehicle (19 percent), road dust (18 percent), soil dust (9 percent), metal smelter (7 percent), Zn source (7 percent), and sea salt (2 percent).

[102] Accordingly, Khaliquzzaman (2006) estimated the contribution of FCKs to the average PM_{10} concentration at 12.56 µg/m^3, as a population-weighted average for each thana of Dhaka; this result is in line with the lower end of the range found in Begum, Biswas, and Hopke (2010).

Table A-2 estimates the contribution of each kiln type to the average PM_{10} concentration, assuming it is proportional with the emissions ratio between the selected kiln types. For example, the contribution of the IFCK is estimated at 12.5 µg per m^3, using the ratio of the SPM emission loads between the IFCK and the FCK (1.8/3.6). The PM_{10} levels are then converted to $PM_{2.5}$ levels, using a factor of 0.6 (Cohen et al. 2004).

Table A-2: Summary of contribution to average PM_{10} and $PM_{2.5}$ concentrations, by kiln type

Kiln type	Production capacity (million bricks/kiln)	Number of kilns needed to produce 2.1 bil. bricks	Contribution to average PM_{10} concentration (µg per m^3)	Contribution to average $PM_{2.5}$ concentration (µg per m^3)	Sources for estimating contribution to average PM_{10} concentration
FCK	4	530	25.0	15	Begum, Biswas, and Hopke (2010)
IFCK	4	530	12.5	7.5	= 25.0 * 1.8/3.6*
VSBK	4.8	442	8.2	4.9	= 25.0 * 1.2/3.6*
HHK	15	140	12.7	7.6	= 25.0 * 1.8/3.6*

* See Table A-1.

Step 2. Estimate the population exposed

Since no accurate information was available on the population exposed to PM_{10} and $PM_{2.5}$ from the brick industry, this was estimated by multiplying the total population of 12.8 million in the metropolitan Dhaka area (BBS 2009) by a coefficient of exposure. It is sometimes argued that all people in Dhaka are exposed to these pollutants due to north-south winds during the brick season.[103] Because of data uncertainty, it was conservatively assumed that about 90 percent of Dhaka's total population, or 11.5 million is exposed.

Step 3. Establish dose-response coefficients

The health impacts on mortality and morbidity were valued based on international coefficients developed in the scientific literature.

Mortality. The impacts of PM_{10} and $PM_{2.5}$ on mortality can be estimated based on mortality rates due to specific diseases and the relative risk (RR) functions provided below (Ostro 2004). As $PM_{2.5}$ data were not available for Bangladesh, they were estimated by converting PM_{10} levels using a factor of 0.6 (Cohen et al. 2004). The threshold levels used were 10 µg per m^3 for $PM_{2.5}$ and 20 µg per m^3 for PM_{10}, based on WHO air-quality guidelines (WHO 2005).[104]

- For mortality related to short-term exposure of children under 5 years,

[103] Personal communication with I. Hossain, September 2009.

[104] These figures represent the baseline concentrations below which there are no health impacts.

$$RR = \exp[\beta\ (x\text{-}x_0)],$$

where

β ranges between 0.0006 and 0.0010,
x = current annual mean concentration of PM_{10} (μg per m^3), and
x_0 = baseline concentration of PM_{10} (μg per m^3).

- For cardiopulmonary mortality related to long-term exposure of adults over 30 years (Pope et al. 2002),

$$RR = [(x + 1)/(x_0+1)]^{\beta},$$

where

β ranges between 0.0562 and 0.2541,
x = current annual mean concentration of $PM_{2.5}$ (μg per m^3), and
x_0 = baseline concentration of $PM_{2.5}$ (μg per m^3).

- For lung-cancer mortality related to long-term exposure of adults over 30 years (Pope et al. 2002),

$$RR = [(x + 1)/(x_0+1)]^{\beta},$$

where

β ranges between 0.08563 and 0.37873,
x = current annual mean concentration of $PM_{2.5}$ (μg per m^3), and
x_0 = baseline concentration of $PM_{2.5}$ (μg per m^3).

Morbidity. The impacts of PM_{10} on morbidity considered the health endpoints of chronic bronchitis, hospital admissions of patients with respiratory problems, emergency room visits, restricted activity days, lower respiratory infections in children, and general respiratory symptoms. The health effects of air pollution were then converted to DALYs (Table A-3).

Table A-3: Dose-response coefficients for morbidity and DALYs by annual health endpoint

Annual health endpoint	Dose-response coefficient*	DALYs lost per 10,000 cases
Chronic bronchitis (per 100,000 adults)	0.9	22,000
Respiratory hospital admissions (per 100,000 people)	1.2	160
Emergency room visits (per 100,000 people)	23.5	45
Restricted activity days (per 100,000 adults)	5,750	3
Lower respiratory illness (per 100,000 children)	169	65
Respiratory symptoms (per 100,000 adults)	18,300	0.75

Sources: Ostro (1994), Abbey et al. (1995), and Larsen (2004).
* Expressed per 1 ug/m^3 annual average ambient concentration of PM_{10}.

Step 4. Measure the health impacts (physical valuation)

Estimating the health impacts of a certain technology is based on its added contribution to PM_{10} and $PM_{2.5}$ average ambient concentrations. For example, the health impacts of FCKs stem from their contribution of 25 $\mu g/m^3$ to the PM_{10} average ambient concentration. Overall, the loss of DALYs per million bricks is the lowest for the HHK (1.6) and VSBK (1.9) and the highest for the FCK (5.5) (Table A-4).

Table A-4: Estimated loss of DALYs from kiln pollution

Annual health endpoint	**DALYs lost per 10,000 cases**	**Total DALYs per Kiln**			
		FCK (4 million)	**IFCK (4 million)**	**VSBK (4.8 million)**	**HHK (15 million)**
Mortality related to short-term exposure to PM_{10} (under 5 years old)	80,000	2.0	1.0	0.8	3.9
Cardiopulmonary mortality related to long-term exposure to $PM_{2.5}$ (over 30 years old)	80,000	8.8	4.6	3.7	0.0
Lung cancer mortality related to long term exposure to $PM_{2.5}$ (over 30 years old)	80,000	0.4	0.2	0.2	0.0
Total mortality		**11.3**	**5.9**	**4.7**	**3.9**
Chronic bronchitis (adults)	22,000	0.0	0.0	0.0	0.0
Respiratory hospital admissions	160	0.1	0.1	0.0	0.2
Emergency room visits	45	0.6	0.3	0.2	1.1
Restricted activity days	3	3.4	1.7	1.3	6.5
Lower respiratory illness (children)	65	3.8	1.9	1.5	7.2
Respiratory symptoms	0.75	2.7	1.4	0.9	5.1
Total morbidity		**10.6**	**5.3**	**4.0**	**20.2**
Morbidity plus mortality		**21.9**	**11.2**	**8.6**	**24.1**
DALYs per million bricks		**5.5**	**2.8**	**1.8**	**1.6**

Sources: World Bank 2005, Larsen 2004.

Step 5. Estimate the health impacts (monetary valuation)

The total cost of the health impacts of pollution includes the monetary value of the DALYs estimated in Step 4 and the cost of illness (Table A-5).

Table A-5: Summary of damage cost of air pollution caused by brick kilns

Kiln type (million bricks)	Annual health damages				Present value of health damages			
	Min	Max	Average	Damage cost	Min	Max	Averag e	Damage cost
	(million TK/kiln)			(TK/brick)	(million TK/kiln)			(TK/brick)
FCK (4)	2.5	14.0	8.2	2.1	20.6	117.1	69	0.9
IFCK (4)	1.3	7.1	4.2	1.1	10.5	59.8	35	0.5
VSBK (4.8)	0.9	5.7	3.3	0.7	8.3	47.4	28	0.3
HHK (15)	4.7	26.7	15.7	1.0	39.3	223.6	131	0.5

Note: Based on GDP per capita, VSL, PV of more than 20 years, and a 10-percent discount rate.

Valuing DALYs. Estimates of DALYs lost are based on the HCA as a lower bound and the VSL as an upper bound, thus obtaining a wide range. Applying the HCA, 1 DALY corresponds to the annual GDP per capita, or TK93,500 (2008) (World Bank 2010).[105] Using the VSL method, 1 DALY in Bangladesh is equivalent to TK620,000, after adjusting for GDP per capita differences between the United States and Bangladesh.[106]

Cost of illness. This includes the direct cost of treating illnesses, the value of lost work days, and the value of the time spent by caregivers with sick children. Interviews with Bangladesh health experts revealed estimates of the costs of hospitalization (TK1,500 per day),[107] doctor visits (TK400 per visit),[108] and emergency visits (TK400 per visit).[109] The World Bank (2006) estimated the value of lost work days and lost caregiver time at TK60 per day. These figures reflect the economic cost for treatment by most privately-owned clinics and hospitals.

In conclusion, the FCK is the most polluting technology, causing annual health damages estimated at about TK0.9 per brick. By contrast, the VSBK is the cleanest technology, with TK0.3 per brick in estimated damages, closely followed by the HHK, with TK0.5 per brick.

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[105] Because 2009 data was unavailable at the time of this writing, 2008 data (the most recent available information) was used.

[106] The United States Environmental Protection Agency (EPA) uses a VSL for the U.S. for 2006 (http://yosemite.epa.gov/ee/epa/eed.nsf/pages/MortalityRiskValuation.html#currentvsl). Using a GDP deflator of 1.1 (2008/2006), GDP for the U.S. of US$46,700 per capita, and GDP for Bangladesh of US$1,335 per capita (based on an exchange rate of 1US$ = TK70) (World Bank 2010), the VSL for Bangladesh is estimated at TK15.5 million. Dividing by a 25-year period, 1 DALY is equal to TK620,000.

[107] Minimum unit cost per bed in a cabin (based on communication with private facilities).

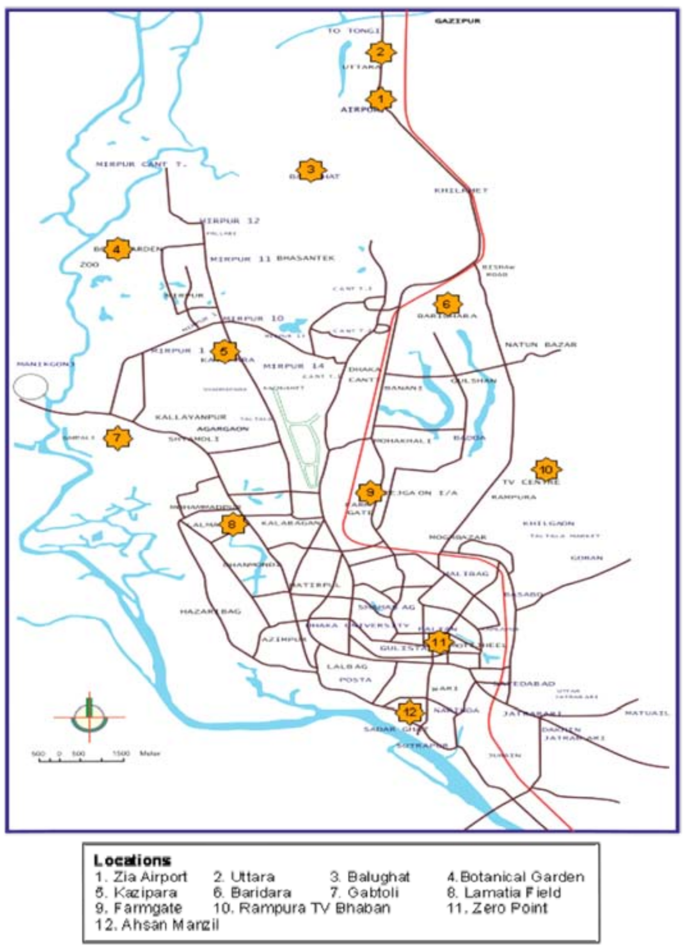
[108] The range is TK300–500 (based on communication with private hospitals).

[109] The nominal cost of emergency visits is free; thus, the economic cost is assumed to equal the cost of doctor visits.

This annex explains the dispersion of air pollutants using a simplified dispersion model. This approach uses a numerical procedure, with fed-in data on sources (e.g., GPS coordinates, emissions, and stack heights) and atmospheric conditions (e.g., temperature, wind speed and direction, mixing height, stability, and precipitation conditions in the form of six hourly data). The numerical procedure calculates pollutant concentrations at given receptor sites. Stack-emissions data are expressed in SPM, while concentrations are calculated for PM_{10}. The dispersion model considers settling of particles of various sizes. BUET (2007) reports model results in terms of averages for a brick-kiln operation period. Model calculations for the 530 kilns of Dhaka city are quite complex.

PM_{10} concentrations have been calculated for 12 locations within roughly a 20 x 30 km area, where most of the Dhaka population resides. These concentrations were used to calculate the annual population exposure to PM_{10} concentrations (Figure B-1).

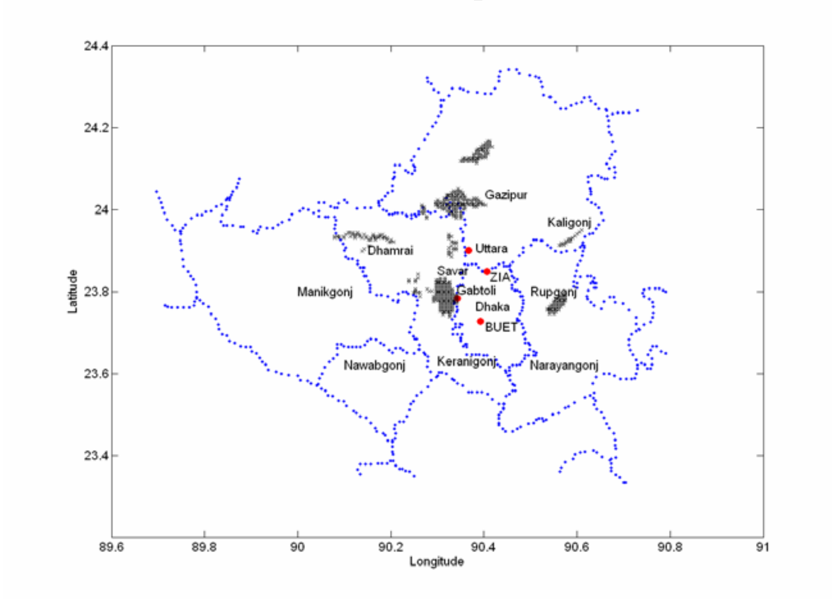
Figure B-1: Locations in Dhaka for which numerical values for PM_{10} concentrations were calculated



Source: BUET (2007).

Of the 530 kilns in the North Dhaka cluster, those located at distances of 5–30 km from the city center have the greatest effect on Dhaka's air pollution due to prevailing wind conditions during the brick-burning season (Figure B-2).

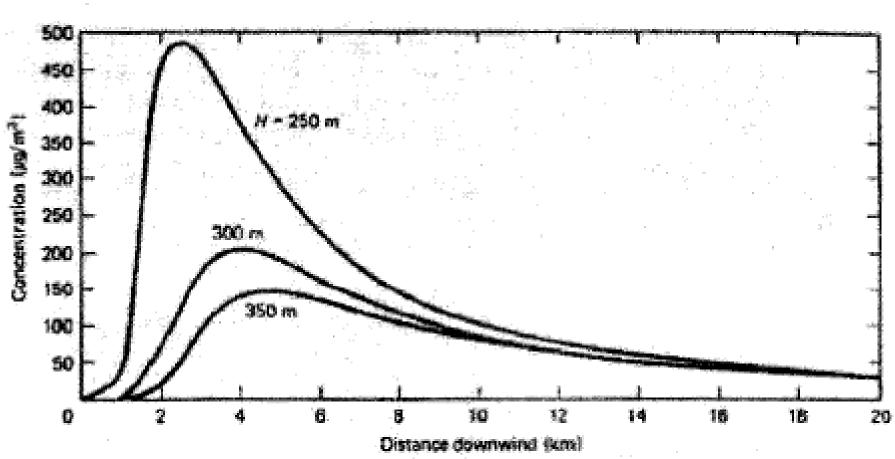
Figure B-2: Location of brick kilns that contribute most to Dhaka's air pollution



Source: BUET (2007).

The standard FCK chimney height is 120 ft (36.6 m), twice the assumed average height of 60 ft for the newer kiln types. At a distance of 5 km or more, a small change in stack height (about 20 m) has no appreciable effect on ground-level concentrations (Figure B-3).

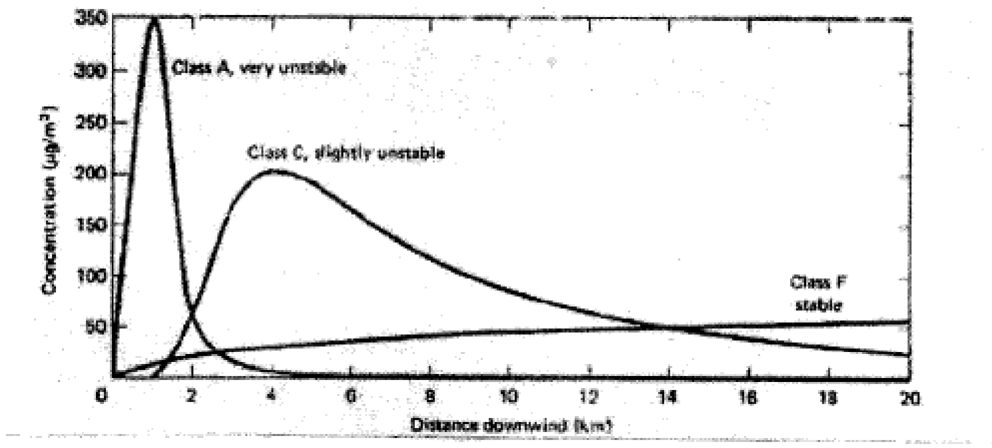
Figure B-3: Effect of stack height on ground-level PM_{10} for constant stability classification



Source: BUET (2007).

The dispersion model included the impact of changes in wind conditions on concentrations, based on data measurements at six-hour intervals. The effect of wind conditions on concentrations is much greater than that of a small (20 m) change in stack height (Figure B-4).

Figure B-4: Effect of stability classification on ground-level concentration for a fixed chimney height



Source: BUET (2007).

Based on the above findings, it can be concluded that exposure data used in the health impact calculations are robust.

Table C-1: Review of government policies, laws, and regulations for China's brick industry

Year	Policies, laws, and regulations	Government units and responsibility	Details	Remarks
1992	"Circular of Advice on How To Accelerate Wall Material Renovation and To Promote Energy Efficient Buildings" (GF[1992] No.66)	Approved and issued by: State Council Submitted by: former Construction Material Bureau; former Ministry of Construction, Ministry of Agriculture, former Bureau of Land	To accelerate wall-material renovation and development of energy-saving construction, the circular asked relevant government offices to set up policies, laws, and regulations to promote new materials, technologies, and policies to control production and use of solid clay bricks; specifically, they were advised to: • Develop and implement the national new wall material industry development outline and annual plan. • Guide the improvement of national construction materials. • Establish standards for new wall material use, design, and construction rules. • Promote wall material renovation; new types of wall material development; and use of new technologies, techniques, and equipment. • Guide management of a special fund for wall rebuilding and materials reinforcement. This notice announced the start of China's wall material renovation.	
1999	"Advice on How To Promote Modernization of Housing Industry and To Enhance the Housing Quality" (GBF: [1999] No. 72)	Forwarded by: State Council Office Issued by: Former Ministry of Construction, former State Planning Commission, State Economic and Trade Commission, Ministry of Finance, Ministry of Science and Technology, State Administration of Taxation, State Bureau of Quality and Technical Supervision, Construction Material Bureau	The Advice encouraged the development of new materials and technologies to improve building and relevant parts system. Beginning June 1st 2000, use of solid clay bricks was forbidden "in coastal and other cities where land resources are rare" and control of the production and use of other clay products was also called for, based on possible conditions. This notice set one of the benchmarks for development of China's brick industry.	

1999	"Circular on Cleaning out Backward Products in Housing Construction" (JZF: [1999] No. 295)	Issued by: Former Ministry of Construction, State Economic and Trade Commission, State Bureau of Quality and Technical Supervision, Construction Material Bureau Executed by: State Office of Wall Material Renovation, National Development and Reform Commission	Beginning June 1st 2000, all new buildings in municipalities, medium and large cities in coastal areas, and medium and large cities in provinces where per capita arable land is below 0.8 mou (about 534 m^2) were advised to gradually phase out use of solid clay bricks according to their local conditions, with a deadline of June 31st, 2003. The State Office of Wall Material Renovation of the National Development and Reform Commission identified the first 170 cities under the SCB phase-out deadline. This was the first wall material regulation with a defined timeline for specific regulated objects.	Started from the demand side.
2004	"Circular of Advice on Further Implementation of Prohibiting the Use of Solid Clay Bricks"[1] (FGHZ[2004] No. 249)	Issued by: National Development and Reform Commission, Ministry of Land and Resources, former Ministry of Construction, Ministry of Agriculture	This circular required that the first batch of cities (among the 170 regulated by the prohibition of solid clay bricks) that failed to meet their objectives adopt firmer measures to achieve them by the end of 2004. It also required local governments to organize and facilitate research and development to provide technology to support the wall material renovation, prohibit solid clay bricks, and help to expand the use of new materials in construction. For the first time, the notice mentioned small towns and rural areas and the government's commitment on wall material renovation was further defined.	Follow-up policies to assess and monitor former regulations and consolidate results.
2005	The National Coercive Industrial Standard: "Industrial Standard of Kiln for Firing Brick and Tile"	Issued by: Standardization Administration of China (JC: [2005] No.982)	This standard prescribed the terms and definitions, categorization, technology requirements, testing measures and rules, and quality examination for brick and tile firing kilns. It covered firing of common, perforated, hollow, and decorative bricks and hollow building blocks.	
2005	"Notice about Further Advancing the Wall Material Innovation and Promoting Energy Conservation Construction"[2]	State Council (GBF[2005] No. 33)	According to this notice, the 170 cities already under regulation of prohibiting solid clay bricks should push toward phasing out all clay products and extend regulations to suburban towns. Other cities should also prohibit or restrict production and use of solid clay bricks, following national arrangements, and gradually extend regulations to suburban and rural areas. The notice set targets to: • Reduce production of solid clay bricks by 80 billion by the end of 2006. • Prohibit the use of solid clay bricks in all cities and reduce nationwide production to under 400 billion by the end of 2010.	

			The notice clearly defined nationwide requirements under the initiative prohibiting solid clay bricks.	
2005	"Notice of the List of the Second Batch Cities Banning Solid Clay Brick by the Set Time"	Issued by: National Development and Reform Commission, Ministry of Land Reform, former Ministry of Construction, Ministry of Agriculture (FGHZ: [2005] No.2656)	The notice identified the second batch of 256 cities under the time constraint to ban use of solid clay bricks by the end of 2008. Local governments were required to make their own annual plans.	
2007	"Circular on Further Enhancing Implementation of Banning the Use of Solid Clay Bricks"[3]	Issued by: former Ministry of Construction (JK: [2007] No. 74)	The circular was issued in response to a rebound in use of solid clay bricks to meet the dramatic increase in demand for building materials due to fast growth of urban and rural construction. It stressed the importance of awareness raising, leadership, management, and monitoring. It suggested expanding areas where solid clay bricks were banned and required local governments to help improve the quality and support of research and development in applying new wall materials. It pushed local governments to improve the collection, management, and application of wall material renovation funds and—in coordination with construction, tax, and wall material renovation institutions—implementation of preferential tax policies on new wall materials.	Start from simple parts and continue improving requirements. Achieve penetration in the end.
2007	"The 11th Five-Year Plan on Brick and Tile Industry in China"[4]	Issued by: National Development and Reform Commission	The plan set up targets to: • Develop new wall materials. In the 11th Five-Year Plan (2005–10), new wall materials were to increase at a rate of not less than 10%; the plan called for development of hollow and heat-insulated wall materials and product improvements to increase energy savings for building. • Conserve land resources. By 2010, the total production of solid clay bricks was to be controlled at less than 380 billion per year, thus reducing their annual production by 20 billion; the plan called for fired hollow products to reach 210 billion (a 5% rate of increase per year) and waste-using bricks to reach 230 billion, thereby saving about 170 million t of clay. • Save energy and other resources. By 2010, energy consumption standards were to be reduced from about 5–6 tce per 100,000 bricks in the 10th Five Year Plan (2000–05) to about 4–5 tce per 100,000 bricks, leading to 10 million tce of energy saved and 300 million t of waste usage. • Phase out outdated technologies. The plan strictly followed the National Coercive Industrial Standard, "Industrial Standard of	

			Kiln for Firing Brick and Tile" (JC982-2005), banning energy-intensive small vertical kilns, small horse-shoe kilns, and small Hoffmann kilns with fewer than 18 gates. For new fired wall materials, the average single-line production capacity was required to reach at least 30 million standard bricks, with production capacity of products from coal gangue, coal ash, etc. comprising at least 50 million standard bricks.	
2007	" Bulletin on Promoting, Limiting, and Prohibiting Technologies in Construction in the 11th Five-Year " (issued in batches)	Issued by: former Ministry of Construction	In the first batch issued in 2007, the bulletin prescribed that light- and high-strength building materials, green new materials, and waste-using, perforated and hollow materials should be promoted in application.	Promote application.
2008	"Energy-Conservation Ordinance of the Civil Construction"	Issued by: State Council	The ordinance targeted strengthened management of energy conservation for civil construction, reduced energy consumption of buildings, and enhanced energy efficiency. It promoted use of new energy-saving technologies, materials, and equipment and limited or banned energy-intensive ones. It called for departments and institutions in charge of energy savings and construction in the State Council edit, update, and broadcast the promoted, limited, and/or prohibited content; construction and design units could not use technologies, materials, and equipment listed in the prohibited content.	Facilitating policies, laws and regulations in both upstream and downstream industries is essential for implementation.
Regulation on air pollution from the brick-and-tile industry				
1996	"Emission Standard of Air Pollutants for Industrial Kiln and Furnace"	Issued by: former State Environmental Protection Agency (GB: [1996] No. 9078)	This is the current emissions-standard regulation for the brick and tile industry. It is general for all industry furnaces and kilns; though not designed specifically for the brick and tile industry, it has played an important role in controlling brick-and-tile industry emissions and promoting advanced technologies.	
2009	"Emission Standard of Air Pollutants for the Brick and Tile Industry"	In June 2006, the former State Environmental Protection Agency issued a request to formulate the "Standard." (Consultation Draft) Drafting was led by the Chinese Research Academy of Environmental Sciences, with involvement of the Xi'an Research and Design Institute of Wall and Roof Materials.	The standard is under revision. Broad consultation was carried out in November–December 2009.[5]	

Table C-2: Limits on air-pollution emissions

Production process	Maximum allowable emissions concentration (mg/m^3)			
	PM	SO_2	NO_x (counted by NO_2)	Fluoride (counted by Fluorine)
Existing firms				
Raw material breaking and molding	100	-	-	-
Drying and firing	100	850	400	6
New firms				
Raw material breaking and molding	50	-	-	-
Drying and firing	50	700	400	6

Annex D. Policies, Laws, and Regulations in Bangladesh' Brick sector

Year	Policies, laws, and regulations	Government responsibility	Details	Remarks
1989	The Brick Burning (Regulation) Act of 1989	DOE, MOEF	Bangladesh's first brick-making law banned the use of firewood for brick manufacturing and introduced licensing for brick kilns.	Use of firewood has large been discontinued, but in remote areas this practice still continues on a limited scale.
2001	Revision of the Brick Burning (Regulation) Act of 1989	DOE, MOEF	The 1989 Act was amended to regulate the location of brick kilns. The new provision required that brick kilns not be set up within 3 km of the upazilla or district center, municipal areas, residential areas, gardens, and the government's reserve forests.	Using the given criteria, it is nearly impossible in reality to find land for brick kilns in Bangladesh. The BBMOA often cites this as a major deficiency in the law. Despite this amendment, the location requirements have not been enforced.
2002 Oct.	Brick Burning rules	DOE, MOEF	The GOB introduced a rule that made the use of 120-ft chimneys for brick kilns compulsory.	This requirement was successfully enforced, especially in the vicinity of urban areas, and most Bull's Trench Kilns (BTKs) were upgraded to FCK technology. However, some BTKs continue to operate, albeit illegally.
2007 March	GOB Notification	DOE, MOEF	GOB issued notification that environmental clearance certificates would not be renewed if owner did not shift to alternative fuel and improved technologies by 2010.	This regulation has not been implemented since little on-the-ground activity occurred to facilitate the switch.
2010 July	GOB Notification	DOE, MOEF	A new notification was issued banning FCK operation three years from this date.	Activities are being undertaken under GOB's CASE project with World Bank support
2011	Revision of Brick Burning Act	DOE, MOEF	The revision of Act has the objective to facilitate transition of the brick industry for improved energy efficiency and lesser pollution level.	Still in process. Promulgation may take more than one year.
Regulations on air pollution				
1977	Environment Pollution control Ordinance,1977.	DOE, MOEF	This Act provided limited provisions for the conservation of the environment	This ordinance had limited provisions and was replaced by ECA95.
1992	Environmental Policy and Action Plan	MOEF	Prioritizes areas of attention for Environment Conservation.	This is a document of intent, without legal mandate. The ECA of 1995 provides the necessary legal framework.
1995	Environmental Conservation Act (ECA), 1995	DOE, MOEF	This Act provides for conservation of the environment, improvement of environmental standards and control and mitigation of environmental pollution.	The 1977 ordinance is replaced by this Act. The Government can issue notification in the official Gazette and make rules for carrying out the purposes of this Act, including emission standards.
1997	Environmental Conservation Rules (ECR), 1997	DOE, MOEF	Sets air emission standards for industries including brick kilns.	The SPM standard for brick kiln emission is set at 1000 mg/m^3, which is rather lenient. Even this standard could not be enforced due to limited capacity in the DOE.
2005	Revision of ECR97	DOE, MOEF	Sets Ambient Air Quality for criteria pollutants and Vehicular Emission standards	$PM_{2.5}$ standard is defined and violation of ambient air quality standards can be enforced under this rule.