Small and Medium scale Industries in Asia:

Energy and Environment

Brick and Ceramic Sectors






Asian Institute of Technology

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The *Asian Institute of Technology* (AIT) is an autonomous international academic institution in Bangkok, Thailand. Its main mission is the promotion of technological changes and their management for sustainable development in the Asia-Pacific Regions through high-level education, research and outreach activities which integrate technology, planning and management.

AIT carried out this *Asian Regional Research Programme in Energy, Environment and Climate* (ARRPEEC) Phase-II, with the support of the *Swedish International Development Cooperation Agency* (Sida). One of the projects under this program concerns the **Small and Medium scale Industries in Asia: Energy, Environment and Climate Interrelations**.
The project was aimed at promoting activities to mitigate greenhouse gas (GHG) emissions and other pollutants in *brick and ceramic, desiccated coconut, foundry, tea and textile* sectors in **China, India, Philippines, Sri Lanka and Viet Nam**. The specific project objectives were to:

i) Review the operational practices and technological status of the selected sector;
ii) Identify and study factors for effective promotion of energy efficient and environmentally sound technologies (E3ST);
iii) Enhance capacity mobilization to promote E3ST; and
iv) Review existing policies and develop a scenario for sustainable promotion of E3ST.

Other publications based on this research include:

- Policy Interventions to Promote Energy Efficient and Environmentally Sound Technologies in Small and Medium scale Industries.
- SMI in Asia: Energy and Environment – *Desiccated Coconut* Sector
- SMI in Asia: Energy and Environment - *Foundry* Sector
- SMI in Asia: Energy and Environment – *Tea* Sector
- SMI Newsletter (Quarterly), since March 1999
- A Road Map CD on SMI

For details regarding ARRPEEC, please visit: www.arrpeec.ait.ac.th

For details regarding publications of the SMI project, please visit:
http://www.serd.ait.ac.th/smi2/smi/roadmap/index.html

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Foreword

After the industrial revolution, anthropogenic greenhouse gas (GHG) emissions have been increasing and a broad consensus has emerged that human life will be affected by earth's climate change. The GHG emissions result from many of the industrial, transportation, agricultural, and other activities through population growth, fossil fuel burning, and deforestation. The economic and social consequences of GHG emission imply that they should be addressed on a global scale. In a joint action under the United Nations Framework Convention on Climate Change (UNFCCC), developed countries committed themselves to reduce their anthropogenic emissions of GHG. They are implementing many partnership programs with industry to reduce emissions of carbon dioxide (CO_2) and other greenhouse gases. To address these issues in developing countries, UNFCCC established funds for their benefits in terms of capacity building and transfer of energy efficient and environmentally sound technological measures.

To enhance this global effort on protection of the environment, the Swedish International Development Cooperation Agency (Sida) initiated the Asian Regional Research Programme on Energy, Environment and Climate (ARRPEEC), a research programme aimed at producing policy-oriented research for mitigation of greenhouse gases and other hazardous emissions resulting from fossil fuel use. In Phase-I of ARRPEEC, studies were carried out in the large-scale industrial sector for the promotion of energy efficient and environmentally sound technologies. This knowledge led to the study of Small and Medium scale Industries (SMI) in Asia.

In Asian manufacturing establishments, SMIs play a vital role by contributing substantially to economic and industrial development. Many SMIs do not perceive their own environmental impacts as significant when set against those of large numbers. But collectively they could make a great impact. Therefore it is important that they are encouraged to improve their efforts towards environmental protection for sustainable development. With this motivation, Sida supported the SMI project to mobilize and strengthen competence and capacity in national research institutions participating in the programme.

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Preface

The *Asian Regional Research Programme on Energy, Environment and Climate* (ARRPEEC) funded by the Swedish International Development Cooperation Agency (Sida) was broadly aimed at studies to promote activities to mitigate greenhouse gas (GHG) emission and other pollutants in various sectors. One of the projects undertaken for study in Phase-II of ARRPEEC was the Small and Medium scale Industries (SMI) sector considering its possible impacts to the environment. Five SMI sectors were identified for this study: brick and ceramic, desiccated coconut, foundry, tea and textile. The study was conducted in China, India, Philippines, Sri Lanka and Vietnam.

This report is based on research conducted on the brick and ceramic sector in the India, Philippines, Sri Lanka, China and Vietnam. And details the production processes, specific energy consumption, technology status, including the important energy and environmental issues related to the sector. It highlights the production and operational practices of the brick and ceramic manufacturing industry, their energy consumption pattern and pollution generation. This report also provides energy efficient and environmentally sound technological (E3ST) options specific to this sector and presents the barriers in promoting E3ST.

It is believed that this report will be useful to policy personnel and government agencies involved in SMI, energy or environment; industrial organizations; researchers as well as other industries. A comparison volume discusses the policy options to promote E3ST in the study countries.

We would like to thank the following experts for critically reviewing this report and providing inputs

- Dr. KGK Warrier, Deputy Director & Head, Ceramic Technology Division, Regional Research Laboratory (CSIR), Trivandrum-695 019.
- Mr. Anand Damle), Managing Director, Damley Clay Structurals, Anant, Plot No. 98, Lane No. 5, Natraj Society, Karvenagar, Pune - 411052.
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- Mr. Noel Verdote, Secretary, Energy Management Association of the Philippines (ENMAP)
- Dr. Bandula Perera, Chairman, Industrial Development Board, Sri Lanka
- Pham Thi Nga, Project Economist, Vietnam Energy Conservation Program Office Ministry of Science, Technology and Environment, Vietnam

On behalf of the national research institutes (NRIs) and on our behalf, we take this opportunity to thank Sida for sponsoring this timely and important study and to AIT for providing an excellent atmosphere for carrying out this research.

S. Kumar
C. Visvanathan

Executive Summary

The Brick and Ceramic sector are considered one of the Small and Medium scale Industries (SMI) that make an important contribution to the economy, construction industry, export earnings and employment of China, India, the Philippines, Sri Lanka and Vietnam. However, they were found to have several issues regarding inefficient energy consumption, environmental degradation due to haphazard manner of raw material mining and deforestation for fuel wood, and mismanagement of waste etc. In growing significance of sustainable development of this sector, these issues need to be properly addressed. This report is an outcome of extensive research done to develop a sustainable strategy for promoting Energy Efficient and Environmentally Sound Technological (E3ST) options to meet these issues in order that energy consumption is reduced and emission of greenhouse gases and other pollutants are mitigated in both brick and ceramic sectors.

Brick sector has a high demand in the construction industry both in developed and developing countries. This sector remains one of the largest employment generating industries in most developing countries. However, the overall brick productivity of developing countries in Asia far behind that of the developed countries. In China, the total brick output is about 800 billion pieces in 1994. At present there are about 110,000 factories involved in brick/tile manufacturing, employing more than 10 million people. The Indian brick industry stands the second largest producer in the world, next to China with more than 100,000 operating units producing about 140 billion bricks annually. On the other hand, there are about 10,000 brick manufacturing units in Sri Lanka with ranging capacities of 15,000 to 24,000 bricks per kiln. This sector employs about 60,000 persons. It is estimated that, annually, over 800 million bricks are produced. In Vietnam, there are about 1,300 brick industries that are owned by both private and public sectors. Annual production is about 9.2 billion pieces.

The brick making technology widely vary from simple hand making to sophisticated computerized systems. The capital cost, labour requirements, and the quality of products also vary according to the technology used. The production process of bricks consists of clay extraction, clay preparation, mixing, forming or molding, drying, firing and distribution. For firing bricks in China, intermittent kiln, natural drying & annular kiln, artificial drying & annular kiln, and tunnel kiln are used. In India, intermittent kiln, Scotch kiln, Buller's Trench Kiln, Hoffmann kiln, tunnel kiln and Vertical Shaft Brick Kiln are used. Down draft batch kiln is used in Sri Lanka. Vertical kiln, Beastly kiln, annular kiln, and tunnel kiln are used in Vietnam for brick firing.

The primary energy sources used by the brick sector in the study countries are varied according to the available energy sources. Coal and electricity are the main sources of energy in Chinese brick sector. In India, coal is used as main fuel for brick making and presently it consumes about 6.3 million tones of coal, which is more than 6% of the industrial coal consumption. The fuel cost in India alone account for almost 30 – 40% of total production cost. Rubber wood is the main energy source used in brick industry in Sri Lanka. The rubber wood meets about 86% of the fuel wood demand. Electricity is mainly used to run pug mills and pressing bricks and tiles. In Vietnam,

electricity and various kinds of oil are used as energy sources in brick industry. Coal is the main energy source in northern part of the country while in the southern part, rice husks are used as the main fuel. Vertical Shaft Brick Kilns (VBSK) has the highest firing efficiency and traditional clamp kiln has the lowest firing efficiency.

Ceramic sector is an important foreign exchange earner in the study countries. The Indian ceramic industry produced over 147 million US $ worth of ceramic goods in 1990, including ceramic floor tiles, sanitary wares, tablewares and ornamental products. In the Philippines, it is estimated that the number of ceramic industries is about 2,500, which employs more than 15,000 persons. On the other hand, in Sri Lanka there are about 550 ceramic factories, which provide direct employment for over 27,000 persons. Many ceramic manufacturing centers in Vietnam, produces several millions of products for both domestic and international markets. The capacity of both private and public sector factories is about 3 – 5 million products per year.

There are two essential processes for the production of ceramics, the manipulation of raw materials and firing. The ceramic production process consists of clay extraction, crushing, blending and kneading, forming, drying, and firing.

In ceramic sector of study countries, electricity, coal, and LPG are the main energy sources. Most factories heavily use electricity for raw material preparation. Electric motors are used for ball milling, filter press, pug mill, casting, jiggering, ram press, trimming, sponging, lights, and air conditioning units in offices. LPG, diesel, firewood, and rice husks are used for drying and firing processes. Based on simple heat balance in some ceramic industries in the Philippines, it is found that only 25% of the heat supplied to the kiln is used in actual production and 75% of heat supplied is lost in the exhaust, losses due to improper combustion, radiation, and convection losses in kiln walls. Key areas where loss can be reduced have been identified. Other issues of the ceramic sector include the continued use of outmoded inefficient technologies and the lack of finance to replace them. The need for more research and development and human resource training were also recognized as major concerns.

Major environmental impacts by the brick and ceramic sectors are deforestation (fuel wood and mining), land degradation accompanied by soil erosion, localized pollution, GHG emission in firing, loss of flora and fauna diversity and reduced aesthetic values of natural woodlands. Fluidized bed combustion units ensure the removal of the most of the sulfur, nitrogen oxides, and carbon monoxides due to low grade coal burning. In brick sector, burning of agricultural residues in intermittent kilns also create pollution such as smoke, tars, suspended particles, fly ash etc unless the residues are burnt in a special furnace. On the other hand, the use of natural gas for drying and firing in ceramic industry, release substantial quantities of carbon dioxide and water vapour directly into the atmosphere. However, emissions from kilns are greatly varied according to the kiln type and fuel type used. In ceramic industry, liquid effluent is discharged in the form of wastewater from ball milling, pug mill, casting, molding, glazing, acid picking, wet grinding etc. Solid waste is generated in several stages in the ceramic industry and it consists of dust particles mainly from ball milling, waste clay materials from filter press and pug mill, sponge from sponging process and biscuit rejects from biscuit kiln. The damaged fired products cannot be recycled and thrown as solid waste. The ash from kiln is also dumped considering as non-hazardous waste.

One of the best approaches in addressing energy and environmental issues is to apply preventive measures like shifting to E3ST options that basically use energy resources more efficiently and generate lesser waste. Specific E3ST options for improving thermal and electrical energy efficiency, wastewater management, air pollution management, and solid waste management are described along with the benefits derived from adopting them. Some illustrative cases of successful implementation of E3ST in existing brick and ceramic sectors are given.

Barriers encountered by the both brick and ceramic sector in adopting E3ST options include the lack of information on the benefits of improved energy and environmental performance, inadequate technological training of its human resources, absence of research and development at the factory level, uncertainties in energy prices and trading practice, financial constraints, poor working conditions and weak implementation of relevant policies and regulations if any. In aid of formulating policies for adopting E3ST in the brick and ceramic sector, some general policy guidelines are recommended such as formation of industrial clusters, encouraging the use of renewable energy sources, enforcing energy pricing, taxes and subsidies strategically, strengthening research and development, providing financial instruments, establishing standards and norms and implementing energy and environmental rules and regulations firmly.

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AiCC	-	Associazione Italiana Citta della Ceramica
BTK	-	Bulls Trench Kiln
^0C	-	degree Centigrade
CAC	-	Command and Control
CEA	-	Central Environment Authority
CESTT	-	Centre for Environmentally Sound Technology Transfer
Cd	-	Cadmium
CH_4	-	Methane
COD	-	Chemical Oxygen Demand
CO	-	Carbon Monoxide
CO_2	-	Carbon Dioxide
Cr	-	Chromium
DO	-	Diesel Oil
DSM	-	Demand Side Management
EIA	-	Environmental Impact Assessment
E3ST	-	Energy Efficient and Environmentally Sound Technologies
ESP	-	Electro Static Precipitates
Fe	-	Ferrous
FO	-	Furnace Oil
GDP	-	Gross Domestic Product
GHG	-	Greenhouse Gases
GWh	-	Giga Watts hour
ha	-	hectare
HF	-	Hydrogen Fluoride
HNO_3	-	Nitric Acid
H_2SO_4	-	Sulphuric Acid
Hrs	-	Hours
ISB	-	Industrial Service Bureau
INEST	-	Institute for Environmental Science and Technology

Units And Abbreviations

kg	-	Kilogram
kcal	-	Kilocalorie
kJ	-	Kilo Joule
kWh	-	Kilowatt hour
LNG	-	Liquefied Natural Gas
LPG	-	Liquefied Petroleum Gas
MEMR	-	Ministry of Energy and Mineral Resources
m	-	Meter
m^3	-	Cubic Meter
MJ	-	Mega Joule
MPE	-	Ministry of Power and Energy
Ni	-	Nickel
N_2O	-	Nitrous Oxide
NO_X	-	Oxides of Nitrogen
NGO	-	Non-Governmental Organisation
NRI	-	National Research Institute
NSTC	-	National Science and Technology Centre
Pb	-	Lead
Pcs	-	Pieces
PCAPI	-	Pollution Control Association of the Philippines
PM	-	Particulate Matter
RH	-	Relative Humidity
RM	-	Raw Material
SEC	-	Specific Energy Consumption
S^{2-}	-	Sulphide Ions
SO_2	-	Sulphur Dioxide
SMIs	-	Small and Medium-scale Industries
SPM	-	Suspended Particulate Matter
Ste	-	Standard ton of equivalent wood
tce	-	tonnes of coal equivalent
TERI	-	Tata Energy Research Institute
TSS	-	Total Suspended Solids

TVEs	-	Town and Village Enterprises
US$	-	United States Dollars
UNEP	-	United Nations Environment Programme
VOC	-	Volatile Organic Compounds
VSBK	-	Vertical Shaft Brick Kiln
WHO	-	World Health Organisation
Zn	-	Zinc

CHAPTER 1: OVERVIEW OF THE BRICK AND CERAMIC SECTORS

The objective of this research is to study the energy-environment interrelation in the brick and ceramic sector in the selected Asian countries. This research is mainly focused on developing a sustainable strategy for promoting Energy Efficient and Environmentally Sound Technologies (E3ST) in these sectors.

This chapter describes the overview of the brick and ceramic industries in China, India, Philippines, Sri Lanka and Vietnam.

Profile of Study Countries

The study countries together represent over 40% of world population. China is the world's largest single party state, and its economy and the living standard of the people have increased very rapidly. India is the world largest democracy and, its economy encompasses traditional village farming to a wide range of modern industries and a multitude of support services. The Philippines is a multi-island nation with a completely free market economy. Sri Lanka is an island state with a quasi-free economy. Vietnam is a densely populated country that has slowly implemented the structural reforms needed to revitalize its economy.

Brick Industry

Bricks have been around for a few thousand years. There is still a huge demand for bricks in the construction industry of both developed and developing countries, and brick making remains one of the largest employment generating industries in most developing countries.

Brick kilns can be classified into three categories based on production capacity: small, medium and large. Small kilns are known as clamp kilns and are located mainly in rural areas.

Selected Indicators of Study Countries

	China	India	Philippines	Sri Lanka	Vietnam
Area (million sq. km)	9.61	3.29	0.30	0.066	0.33
Population (million)	1271.1	1,017.5	80.1	18.7	78.9
GDP (billion US$)	4,500	2,200	75.2	48.1	24
GDP per head (US$)	871	471	959	810	300
GDP annual growth (%)	7.8	5.4	3.9	4.7	6.8
Exchange rate per US$ (August 2002)	8.28 (Yuan)	48.63 (Rupee)	51.82 (Pesos)	96.25 (Rupee)	15,323 (Dong)

Source: ADB, 2002

Medium and large kilns are of Bull's trench kiln (BTK) type and are generally located near urban and more densely populated rural areas.

Comparison of the employment generation and the overall productivity of brick industry in a developing country and some developed countries

	China		USA	UK
	Small plants	Large & medium plants		
Number of plants	100,510	1,182	265	157
Employment	4,794,000	N/A	15,000	9,000
Employees per plant	48	N/A	58	70
Production per year (billion bricks)	417	70	≈ 8	≈ 4
Production per plant (million bricks)	4	50 - 60	30	35
Production per employee (thousand bricks)	48	N/A	58	70

Source: Zhang, 1997 N/A – Not Available

The overall brick productivity of developing countries in Asia still lags far behind that of the developed countries, mainly due to the predominance of labor-intensive small-scale plant and outdated production technologies.

The brick making technology varies widely from simple hand making to sophisticated computer-based systems. The capital cost, labour requirements and the quality of products also vary according to the technology used.

The labour ratio of small-scale manual traditional brick making technology is about 8-10 times higher than a moderately mechanized factory. While the mechanized factory required only about 20 person-years for 10 million bricks, the traditional technology required 160-200 person-years for the same output.

Profile of Brick Industry in Study Countries

China

The township and village enterprise (TVEs) brick sector has expanded rapidly in the late 1970's in China.

Contribution of brick making TVEs to the economy in China

	1987	1990	1995	1996
Number of Enterprises	119,000	100,500	98,500	95,440
Production (billion of pieces)	382.4	417.4	755.1	828.1
Output Value (Billion RMB)	20.0	32.0	110.2	140.9
Number of Employees (million)	5.39	4.79	4.87	4.95

Source: Zhang, 1997

The total brick output was about 150 billion pcs in 1980, but increased to 800 billion pcs by 1994 (Zhang, 1997).

Brick making TVEs are mainly distributed over 14 provinces and the total brick production in each of these provinces presently exceeds 20 billion pieces per annum. At present, there are 110,000 factories in brick/tile making. The number of employees involved in the sector is more than 10 million and the land used for the industry is 333,000 ha.

Brick Production in Fourteen Provinces in China (1996)

Province	Production (billion pcs)
Hebei	69.99
Hanan	98.31
Shanxi	38
Jiangsu	65.57
Zhejiang	24.59
Anhui	67.19
Fujian	19.89
Shandong	94.3
Guangdong	50.87
Jiangxi	21.63
Hunan	51.06
Hubei	42.58
Shanxi	28.02
Sichuan	41.07

Source: CESTT, 2000

Currently, the numbers of brick making TVEs are declining, but the total production has increased. The demand for other building materials such as cement based hollow bricks and perforated bricks have increased significantly.

The majority of bricks produced are common clay bricks (84%), and others are hollow bricks and perforated bricks. The average production scale is 36 million pieces per year. The production output of the largest scale industry is 120 million pieces and that for the lowest scale industry is 6 million pieces per year.

India

Brick remains one of the most important building materials in India. Even though brick making has become more widespread in India, most units remain unorganised. This sector is utilising traditional technology.

Brick making industries in India are generally confined to rural and peri-urban areas. It is one of the largest employment generating industries with about 1.5 million workers compared to other developing countries. The Indian brick industry stands the second largest producer in the world, next to China, with more than 100,000 operating units, producing about 140 billion bricks.

Brick industry in Indo-Gangetic plain differs from brick industry in peninsular plateau and coastal India. Indo-Gangetic Plains accounts for about 65% of the total brick production. Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal are the major brick producing states in this region. Brick kilns (approximately 30,000 BTKs) generally of medium and large production capacities (2 million to 10 million bricks per year) are located in clusters around major towns and cities. Coal is the main fuel for firing bricks.

The peninsular and coastal India accounts for rest of the 35% of the brick production. In this region, bricks are produced in numerous small units (production capacities generally range from 0.1 to 3 million bricks per year). Gujarat, Orissa, Maharashtra, Madhya Pradesh, Tamil Nadu are important brick producing states in Peninsular Plateau and coastal India. Clamps and moving chimney BTKs are employed for firing bricks in this region. Apart from coal, a variety of biomass fuels, such as, firewood, dry dung, rice husk, are used for firing bricks. The fuel cost accounts for almost about 30% of the production cost. The estimated coal consumption for firing bricks is about 24 million tonnes annually, in addition to several million tonnes of biomass fuels (TERI, 2001).

Properties of Wire-cut and Country made bricks in India.

Property	Wire-cut /Extruded brick	Country -made brick
Comprehensive strength (kg/cm²)	80 - 110	20 - 24
Water absorption (%)	13 - 15	15 - 20
Density (g/cm³)	1.85 – 1.90	1.75 – 1.85
Colour	Brick red	Brick red
Size (cm)	19x9x9	Varying
Average weight (kg)	2.2 – 2.5	2.0 – 2.5

Source: PSG, 1998

The main bricks produced are sand lime bricks and stabilized soil bricks. These bricks are free from defects of efflorescence and lime brushing. The Indian brick manufacturers use two methods, namely, Wire-cut (extruded brick) and country-made bricks, respectively.

Sri Lanka

Burnt brick technology, was known to the Sri Lankans at the dawn of its civilisation. King Mahasen used fired bricks in the lower most areas of the tallest Brick edifice of mankind-the Jethewana Stupa (Rowland Silva, 1990). These days, brick making is a traditional home based industry, and is well established in Sri Lanka. It is widely spread all over the country. In general, simple technology, such as, clamp kilns, is employed. The total employee involved in the brick industry was estimated at 60,000 in 2000.

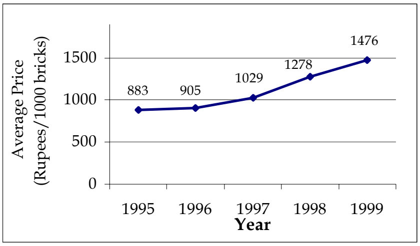
Majority of the brick industries are concentrated in few specific areas in Sri Lanka, where the raw materials are mostly available.

Brick industry in Sri Lanka uses a red firing clay, which is a mixture of Kaolinitic, Mica, Montmorillonite clay and minerals (Herath, 1973). There are about 10,000 brick manufacturers and most of them are restricted to small-scale operations with kiln capacities ranging from 15,000 to 24,000 bricks per kiln. It is estimated that annually over 800 million bricks are being produced in the country. There has been a gradual increase in the selling price of the bricks every year but the prices of input materials are increasing at a faster rate.

Brick Production in Sri Lanka (1995-1999)

Year	Production (000'nos)	Value of Production (million SL rupees)
1995	601,089	1,469
1996	649,176	1,394
1997	701,110	1,468
1998	750,188	1,703
1999	802,701	1,839

The demand for brick products was greatly hampered by poor quality control. Most of the bricks produced do not meet the specifications as mandated for in the national standards for building bricks. This resulted in various brick sizes produced not only among the same areas but also among different manufacturers.



Average Selling Price of Bricks in Sri Lanka during 1985 - 1999

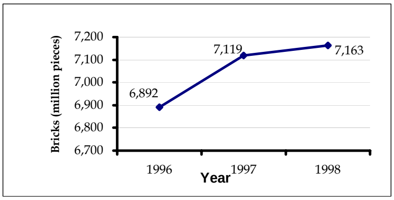
Vietnam

The brick industry in Vietnam is widely spread in four key economic regions in the northern part of the country. The development of high quality brick products in Vietnam is faster due to the increasing demand of the consumers.

Over the last 10-15 years, handmade bricks have been non-existence to a large extent. Locally made extruders are now common in most brick-manufacturing facilities/plants. These extruders range from very simple with a low output, to a basic extruder with a relatively larger output.

Even though the state enterprises involved in the brick industry play a leading role in process technology, its annual production is only about 7% of total national production. The non-state units, including the medium, small and family-based enterprises produce annually about 700 - 800 million pieces, accounting for over 70% of the total brick production.

Every year, brick production grows rapidly. There were about over 300 enterprises of brick making (this does not include more than 1,000 private units). Based on the ownership, these enterprises are divided into two kinds: state sector (about 100 units) and non-state sector (about 200 units) (UNDP, 2002). At present, the annual production is nearly 9.2 billion pieces with 7,194 million bricks from traditional kilns and 1,973 million from tunnel kilns.



Brick Production in Vietnam (1996-1998)

Ceramic Sector

Recent ceramic industry constituents range from home-based pottery producers to highly advanced materials engineering firms.

Ceramics offer many advantages compared to other materials. They are harder and stiffer than steel; more heat and corrosion resistant than metals or polymers; less dense than most metals and their alloys; and their raw materials are easily available and inexpensive.

Ceramics can be divided into two classes: traditional and advanced. Traditional ceramics include clay products, silicate glass and cement.

Types of Ceramics

Name	Type	Characteristics
Opaque terracotta		Decorative, architectonic brick works, garden vases, etc
Painted terracotta		Classical ceramics, black and red pictures
Faience (opaque)	Siliceous plumbiferous slip stanniferous	Muslim ceramics Italian scratched ceramics Majolica
Stone ware (opaque)	Salted painted Glazed	
Ordinary		
Porcelain biscuit	White porous Vases	
Translucent porcelain	Glazed or soft (or artificial) porcelain biscuit	Medicean porcelain or French Porcelain, Far East Ceramics and European ceramics

***Source:* AiCC, 2000**

Advanced ceramics consist of carbides, pure oxides, nitrides, non-silicate glasses and many others. Ceramic materials display a wide range of properties, which facilitate their use in many different product areas. Some of those products are as follows,

- Aerospace (special refractory-ceramic fibres) - *space shuttle tiles, thermal barriers, high temperature glass windows, fuel cells*

- Consumer Uses – *glass wares, windows, pottery, Corning¨ ware, magnets, dinnerware, ceramic tiles, lenses, home electronics, microwave transducers.*
- Automotive - *catalytic converters, ceramic filters, airbag sensors, ceramic rotors, valves, spark plugs, pressure sensors, thermistors, vibration sensors, oxygen sensors, safety glass windshields, piston rings*
- Medical (Biomedical Alumina and other bio-ceramics) - *orthopedic joint replacement, prosthesis, dental restoration, bone implants*
- Military - *structural components for ground, air and naval vehicles, missiles, sensors*
- Computers - *insulators, resistors, superconductors, capacitors, ferroelectric components, microelectronic packaging*
- Communications - *fiber optic/laser communications, TV superconductors and radio components, microphones.*

Profile of Ceramic Industry in Study Countries

India

India's ceramic industry began during the British rule, with the demand for commodities originating from the army. Since then the industry has grown to its present size, processing close to 800,000 tonnes of ceramic tiles and 75,000 tonnes of sanitary ware. The unorganized sector has a significant share of 55% in the sanitary ware segment, and 20% in the ceramic tiles segment, though its influence is declining in the wake of excise duty reductions on ceramics which have reduced price differentials considerably. The market break-up of the organized sector is roughly 250,000 tonnes of floor tiles, 400,000 tonnes of wall tiles, and 68000 tonnes of sanitaryware - commodes, flushing cisterns and washbasins, valued at Rs. 14 billion. The present growth rate of 8% is considered sluggish, but is expected to pick up in the coming years.

Capacity utilization is below 65% in the sector, due to rapid anticipatory expansion of capacities, which were perhaps not justified by market growth. North and West India account for the bulk of ceramic sales (35% each) in India, though the south is fast catching up. Though the institutional market is still the largest segment, retail markets, accounting for 45% of volumes, are becoming instrumental to profit growth in the sector. Consumption for ceramic is primarily an urban phenomenon, with rural areas generating only 20% of present demand.

Several plants have capacities that are below international scale (120,000 tonnes minimum per kiln, as recommended), and use older and expensive fuels, which make prices internationally uncompetitive. In spite of this, two players have resized their plants to international scale capacities and also upgraded to use more efficient and versatile fuels, such as LNG and LPG, which offer substantial cost advantages. Such players now compete with European ceramic companies at the low end of the international market. Import of tiles was opened up in 1999, but import tariffs of 68% render imports prohibitively expensive for the Indian market. Imports have been negligible except for large sizes and in vitrified granite tiles, which are not yet produced in India. As a result, Indian manufacturers are fairly isolated from import competition, given that India's binding tariffs are higher than current levels, and can support an increase in tariffs to arrest imports to safeguard the domestic industry. With the low capacity utilisation already slowing Indian industry, excessive imports are prone to be countered by protective duties. Therefore, given the high import duties, import opportunities appear to be linked with evaluating complementary strengths of suitable Indian players and offering products at prices that can be interesting in the Indian market.

Philippines

The Philippines ceramic industry started when tribesman used hand formed terra cotta containers for food storage, urns and vases for burial jars and figurines for religious objects. Today, the Philippines is considered as one of the major sources of fine quality handcrafted and hand-painted ceramic products, those of which are comparable with the best sources of ceramic products made in developed countries.

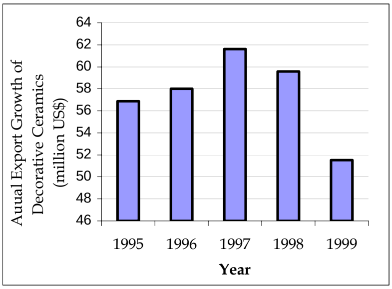
The Philippines has a growing ceramics industry. This industry is envisioned as a growing source of better quality, design oriented decorative ceramic items for the medium to high-end niche of the market. Moreover, the country has a large number of highly skilled and creative workers, who create products both for aesthetic and utilization purposes. Ceramic is one of the top ten manufacturing sectors in small and medium scale industry.

Traditional potteries, novelty wares, wall tiles, dinnerware and sanitary wares are some of ceramic products that are manufactured in the Philippines.

The small and medium scale ceramic enterprises manufacture products by using casting methods rather than using machineries. Therefore, their capital expenditure is very low.

The decorative ceramic industry is one of the fastest growing sub sectors among the gift and houseware sectors in Philippines. However, the historical export performance highlights that the annual export growth rate of decorative ceramic sector has reduced during the past few years. The estimated 2,500 ceramic industries are mostly small and medium scale. The ceramic production is 115 million pieces per year in thirty-eight registered companies. The number of workers employed in the industry is about 15,000 in 2000.

However, the decorative ceramics have performed a great role in the export market during the past few years compared to the other major exporters like France, Germany, Japan, UK and USA. Meanwhile, the Philippines import decorative ceramics from China, Hong Kong, Italy, Japan and USA.



Source: National Statistics office, Philippines

Sri Lanka

The historical ruins in the country bears testimony to the rich diversity of ancient craftsmanship and the skills of the then craftsmen. The distinctive designs and exquisite elegance of the ceramic products manufactured by the Sri Lankan ceramic industry today vividly illustrates the influence of that rich heritage and its inherited traditional skills.

Sri Lankan's traditional skills in the ceramic industry

Moreover, Sri Lanka is rich in mineral deposits such as China Clay, Ball Clay, Feldspar, Dolomite, Calcite, Zircon, Quartz and Silica sand. The abundance of these raw materials, sold at very reasonable cost is one of the main advantages enjoyed by Sri Lanka's ceramic industry.

The ceramic industry in Sri Lanka is widely distributed all over the country in small, medium and large scale units. Government and multinational companies own large-scale factories, while small and medium-scale factories are managed by individuals and companies with limited liability.

There are over 550 factories operating in all parts of the country that provide direct employment to over 27,000 people. There are about 50 factories in small and medium scale but some of them are operating at very low level. Due to high competition among the local companies, SMIs are required to maintain high quality and wide product range for survival. These cottage industries or the small-scale manufacturers are more concerned in maintaining continuous production throughout the year and at producing attractive items. These small companies have a total production capacity of about 40,000 – 50,000 pieces per month.

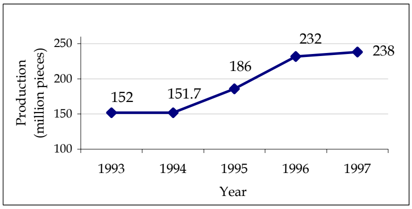
Sri Lanka supplies quality ceramic products mainly porcelain tableware, porcelain ornamental ware and glazed wall and floor tiles to discerning buyers in the world market. The major buyers are the USA, Australia, Italy, Germany, U.K., France, Canada, Netherlands, Japan, Singapore and Spain.

Presently, ceramic tile manufacturing is one of the key industrial sectors of the country. Production of floor and wall tiles in Sri Lanka is around 4.5 million square meters per annum. The excellent quality and purity of these materials contribute to the exquisite standard of the products, which are internationally reputed.

Vietnam

Learning about the development of ceramics in Vietnam is yet another way of getting a glimpse into the people's way of life in the past and the influences that ebbed throughout the country's history.

Even though Vietnam is not the largest exporting country for ceramics at present, its industries are still very lively and there are a number of active centers around the country. The ceramic producers of today are building on the wealth of indigenous talent and materials.



Ceramic Production in Vietnam (1993-1997)
Source: Thuong, 1999

Also, the country has many deposits of the basic ingredient, Kaolin with extremely high quality.

Many ceramic producing centers in Vietnam produce several million pieces of products for both domestic and export market. The capacity of both private and local state factories is about 3-5 million products per year. Family scale producers produce nearly 75%-85% of total ceramic production in Vietnam.

Currently, however, only large-scale industries produce ceramic products for export, as a large amount of investment is required. Most products from the small and medium scale producers are used in the rural and remote areas in the country.

Chapter 2: BRICK PRODUCTION PROCESSES

This chapter describes the production processes of brick. The production process is the same in all the study countries except for the firing process. A brief description on trends in production techniques is also discussed at the end of this chapter.

Raw Materials

Bricks are mainly made from local clay. Sand is sometimes added to get the right properties. A number of additives are added to the clay to increase the strength of the bricks, these include fuel wood, cattle dung, stone dust, rice-husks and other agricultural residues. Recently, addition of fly ash or coal ash to clay is also being considered. Clay bricks require a soil with clay and sand combination of not less than 50 % by weight of the former and fired at high temperature (800-1000^{o}C) to make it dense and hard.

Bricks are mainly made from local clay

There are several types of soil used in brick making. They include alluvial soil, black cotton soil and red soil.

Alluvial soils, contains around 20 to 30 % clay and are good for brick making. The black cotton soil needs to blend with other additives before being used. Red soil does not make good bricks due to their coarse and sandy nature and low plasticity.

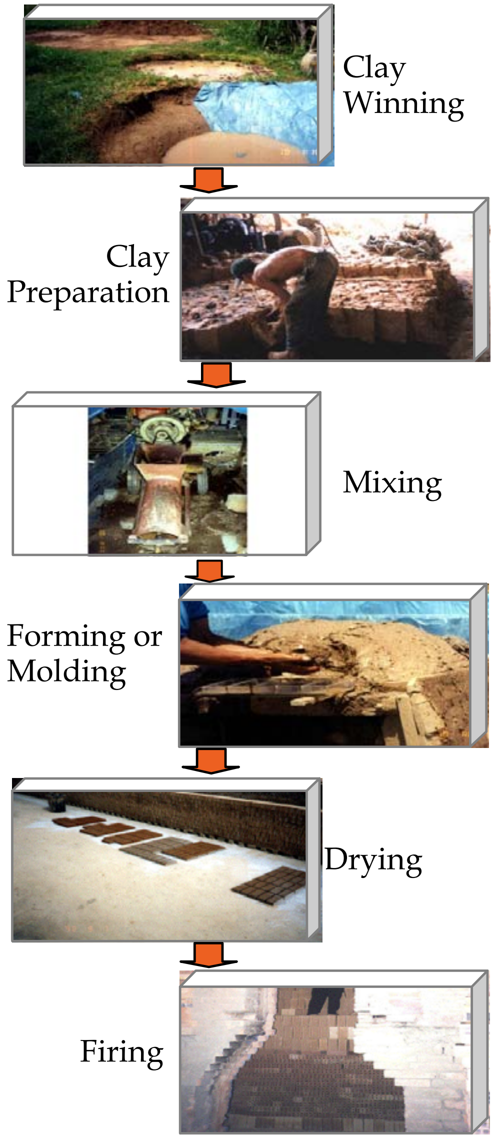
The raw material for brick making is usually extracted from local lands. However, India imports 20% of clay from China, while Vietnam possesses large quantities of quality clay. When high sand contained soil is used, addition of pure clay during the clay preparation stage is required. The bulk density and compressive strength of the bricks could be improved by incorporating 20% of coconut pith in the building bricks based on plastic clay.

Production Processes

The brick production processes consists of clay extraction, clay preparation, mixing, forming or molding, drying, firing and distribution.

Clay Winning

Clay is extracted from the riverbed, agricultural lands or rice field. During the collection of the clay, the top layer of soil is removed as it contains many organic impurities.



Brick-making Process Flow Diagram

The clay so collected should be free from gravel, coarse sand, lime, particle, vegetable matter, and other impurities.

Clay Preparation

This process is done depending on the clay properties and the finished product requirements. The preparation process typically involves crushing the raw material, mixing with water, blending and screening to ensure its consistency.

Clay preparation

Clay Mixing

It is normal to mix different types of clay and even sand at this stage to achieve the correct plasticity, optimum drying and firing conditions. Waste fuels or other carbonaceous materials can be added to the clay to enable green bricks to burn internally during the firing process. Such process not only saves fuel for brick firing but also makes the brick lighter, cheaper, portable during transportation and contributes to faster drying rates. It also reduces the losses through breakage.

Brick Molding

There are several processes for brick molding including extrusion, soft-mud molding, semi-dry or dry pressing, and vibration-compaction. In the molding process, the clay is first blended in the pug mill. Next step is to feed into the extruding machine, which consists of a helical auger rotating within a cylindrical barrel. After being forwarded to an auger extractor, the clay is forced through a die to form a column of clay and then cut to the desired size.

Brick Drying

Newly formed bricks are called Green bricks and can be dried naturally (i.e. in open air) or artificially (i.e. by using some kind of dryer). This requires a large amount of heat energy, which is met by raising the temperature of the green bricks by heated air, which favors drying. This is because during drying process, water contained in the green bricks are evaporated.

Brick Firing

Brick firing

Once bricks are set into the kiln, the firing is started. This process normally has five stages. Each stage corresponds to different range of temperatures in the kiln.

- ***Water smoking*** *- is considered to be completed by 120 ⁰C.*
- ***Decomposition*** *- clay contains a vegetable matter, which breaks down at approximately 200⁰C.*
- ***Burning out*** *- requires at least the dull red heat of 700⁰C. Carbon and sulfur present in clay are burned by the oxidation process. Most of the carbon is burnt out by 900⁰C, but some sulfur lingers until 1,100 – 1,150⁰C.*
- ***Vitrification*** *- begins at 800⁰C and progresses throughout the firing process that renders the bricks hard and stone-like.*

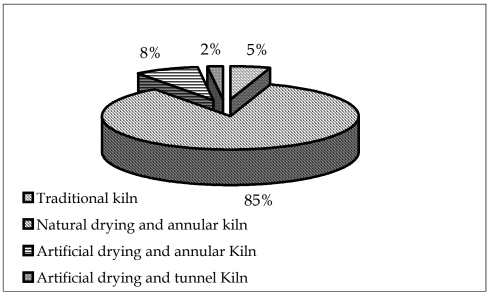
Firing is the main energy intensive process of brick making. But, it again differs depending on the types of kiln used.

Brick Making Technologies

A wide variety of brick making technologies are used throughout the developing countries. These vary from very simple manual operations, which use age-old clamp, or stove kilns, to sophisticated mechanized kilns. Nowadays, computerized technologies are utilized in tunnel kilns. The latter, although common in developed nations, are rare in developing countries.

Developing countries have not accepted new technologies due to lack of resources and high initial cost. Therefore, they mainly use Clamp kiln, Stove kiln, Scotch kiln, Tunnel kiln, Bull's Trench kiln, etc. The intermittent kilns such as clamps, stoves and scotch kilns can often be converted to burn residues as oppose to the difficulty the Bull's Trench kilns will encounter if they do so. These kilns continue to use fuel wood, which is still widely available.

There are three basic types of brick kilns used in China. Those are the intermittent 'horse - foot' kiln, annular kiln and tunnel kiln. Among them annular kilns are widely used for brick making.



Brick Production Techniques in China
Source: CESTT (2000)

In India, out of 115,000 brick making units, about 15,000 are larger units, which use continuous kilns (mainly Bull's Trench kiln). The remaining kilns are of the intermittent type (e.g. clamp, stove, scotch kilns, etc.). The Union Territory of Delhi has over 300 brick making units. Almost all use Bull's Trench kilns of varying types and capacities.

In Sri Lanka, the brick industry uses simple technology, and age-old clamp kilns are mostly used for firing of bricks. A few Hoffman kilns are also used. Fine clay is treated manually or by using buffaloes. Wet clay is moulded in a wooden mould by hand. Natural ventilation is used to dry the wet brick stacks.

In Vietnam, three main types of kiln represent two different technologies. These are the modern technology (*used by the annular and tunnel kiln types*) and handicraft technology (*used by Vietnam traditional vertical kilns*).

Trends in Production Process Improvements

Sun-dried earthen blocks (adobe) have been used as a building material for thousands of years. Clay is mixed with water (sometimes also with straw to keep the finished blocks from cracking) and formed by hand into blocks. The blocks are placed in the sun until they are thoroughly dry. The dried blocks are hard, but can easily soften when it comes in contact with water. Like sun-dried blocks, fired bricks were modular and easily handled. They are very hard, can withstand harsh weather condition and are fire resistant. Fired brick technology made it much easier for people to make durable buildings, walls, roads, and bridges. Today, 65% of the bricks made in the world are used for dwellings while 35% are used for walls, public buildings, and other non-dwelling structures. In addition to common or ordinary building bricks, there are glazed and other decorative bricks and special "firebrick," designed to protect surfaces from intense heat.

The future development of the brick industry will be determined by the market demand for bricks, though the size of the brick market will remain quite large in the near future. The demand for high quality structural facing bricks will pick up with the improvement of the people's living standards and their continuous economic growth. Conventional burnt clay bricks will continue to be the main walling material for meeting the huge demand for housing in the foreseeable future.

Current technologies for brick production such as clamps, downdraught kilns and Bull's Trench Kilns consume large quantities of fuel such as coal, firewood and other biomass materials. The devastating effect of the pollution caused by huge amount of emissions from the brick industry has attracted the attention of regulatory agencies. Several thousand movable chimney BTKs that were found pollutive have been converted to fixed chimney BTKs. Fixed chimney BTKs results in a reduction of 20% in energy consumption and 50% in SPM emissions.

Hoffmann kiln consists of a tunnel of constructed bricks built as a continuous ring with an arched-brick roof. The flues, controlled by dampers, lead the gases of combustion from the burning bricks to a tall chimney, which provides the draught for operating the kiln. The fire front moves forward at the rate of about one chamber/day.

Reasonable flue gas temperature = 100°C. Specific energy consumption of Hoffmann kiln = 1.8 – 2.35 MJ/kg.

In Four-chamber downdraft kiln, all the four processes (cooling, firing, preheating, and drying) take place in each of the four interconnected chambers. The cooling process in the preceding chamber preheats the combustion air of the firing chamber. The exhaust gas from the firing chamber is channelled to preheat and dry the bricks in the next two chambers. As the preheating of both the bricks and the combustion air take place, fuel consumed in firing of bricks is lower. Firing time is about 8.5 hours whereas traditional kilns take 7-15 days per batch. Its energy efficiency is about 62%, and its fuel consumption is reduced by 60% when compared to that of an Open updraft kiln.

Tunnel Kiln consists of long straight tunnels in which green bricks are stacked on cars, which travel through the kiln. The kiln is heated by burning the fuel in the middle section. As the products of combustion pass down the kiln, they preheat the green bricks placed on the cars traveling towards the firing zone. Cold air blown at the car exit cools the fired bricks. At intervals, cars of fired bricks are withdrawn from the kiln and the replacement cars of green bricks are pushed into the kiln at the opposite end. Its combustion temperature is 1100°C, producing an exhaust gas of 100- 450°C. SEC is 0.94 MJ/kg of fired brick. Fuel cost equals to 20-30% of production cost. Energy saving is 16% which is equivalent to 19 m^3 of natural gas/1000 bricks. Fuel savings from using insulated tunnel carts and adjusting production process is 10 m^3 and 9 m^3 of natural gas, respectively. Brick load on cars is 50,000 kg. The capacity of the Tunnel kiln is 0.05 – .15 million bricks/day.

Vertical Shaft Brick Kiln (VSBK) is energy efficient and sustainable alternative to traditional brick kilns. It is compact, weatherproof and easy to operate. Important attributes of this technology are modularity in construction and flexibility in production.

It consists of one or more shafts located inside a rectangular brick structure. The shafts are currently 1m and 1.5 m wide with nominal lengths of 1m, 1.5m, 1.75m or 2m. The inside surface is a brick wall, sometimes lined with refractory bricks. The gap between the shaft wall and the outer kiln wall is filled with insulating materials like clay, fly ash, rice husk etc.

The shaft is loaded from the top with a number of batches of bricks for firing. Each batch normally contains 4 layers of bricks set in a predetermined pattern.

Dimensions of shaft (m)	Rated output (bricks/day)
1 x 1	2000
1 x 1.5	3000
1 x 2	4000
1.25 x 2	5000

The main advantages of VSBK technology are as follows:

- High energy efficiency
- Less pollutive emissions
- Better and uniform quality of fired bricks compared to clamps
- Occupies less space - low land requirement
- Can work throughout the year subject to availability of green bricks
- Quick turnover: bricks are ready for sale after firing within two days of loading
- Minimal maintenance
- Flexibility in volume of production based on market demand
- Highly suitable where part of fuel is traditionally mixed with clay, and
- Construction and operation is easy to learn.

CHAPTER 3: ENERGY ISSUES IN BRICK SECTOR

The building material industry is regarded as a big energy consumer. This chapter highlights the sources used for supplying energy in brick sector, the factors influencing energy consumption, and lastly the factors and issues regarding energy supply for brick making in the study countries.

Energy Sources

The energy sources used for brick making in the study countries are coal, oil, gas, wood, rice husk (firing), solar energy (drying), diesel (drying, clay extraction), and electricity (for machinery).

Sources for supplying energy in brick industry in study countries

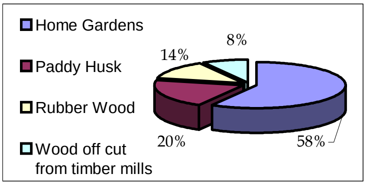
Country	Sources used
China	Coal, Electricity, Diesel, Gasoline
India	Coal, Firewood, Electricity
Sri Lanka	Rubber wood, Firewood, Sawdust, paddy husks, Electricity
Vietnam	Coal, Oil, Wood, Rice husk, Electricity

Coal, electricity and diesel are the main sources of energy used in Chinese brick industries.

In India, coal is used as main fuel for brick making. Presently about 6.3 million tonnes of coal is consumed, which is more than 6% of the industrial consumption.

The fuel costs in India alone account for almost 30-40% of the production cost of brick making.

The brick and tile industry in Sri Lanka yearly consumes in excess of 150,000 tons of wood fuel, half of which is rubber wood.



Energy sources for brick making in Sri Lanka
Source: ISB, 2000a

Electricity is mainly used to run the pug mill and pressing bricks and tiles in Sri Lanka. Some producers have reverted to using off cuts of sawmills and rice husk.

In Vietnam, electricity and various kinds of oil are also used as energy source in the brick industry. In the northern part of its country, coal is the main energy source, while in the southern part, rice husk is used as the main fuel.

Energy Use Pattern

The largest energy consumption process in brick making is in the firing process, where the formed clay body is subjected to high temperature. However, the energy consumption during the firing process in the kiln depends greatly on the technology applied. Apart from this, the following factors also influence the energy consumption for continuous and intermittent kilns:

- The types of kiln,
- The product range,
- Level of production,
- Type of clay, and
- Heat transfer.

Types of Kiln

The type and the age of the kiln will influence firing efficiency. In the case of outwardly similar production

Low energy efficiency kilns are commonly used in study country

units, variations in energy usage can be more directly attributed to specific energy saving measures applied.

Different types of kiln are used in the brick industries. Among them, the annular kiln's fuel consumption

Specific Energy Consumption of different brick making technologies in study countries

Country	Technology	Specific energy consumption *(MJ/kg of product)*
China[1]	Intermittent kiln	2.47
	Natural drying & annular kiln	1.16 – 1.46
	Artificial drying & annular kiln	1.39 – 1.56
	Tunnel kiln	1.29 – 1.52
India[2]	Intermediate kiln	3 – 11
	Scotch kiln	1.5 – 7
	Bull's Trench kiln	1.8 – 4.2
	Hoffmann kiln	1.5 – 4.3
	Tunnel kiln	1.5 – 2
Sri Lanka[3]	Down draft batch kiln	5.83
Vietnam[4]	Vertical kiln	6.15 – 9.23
	Beastly kiln	4.11 – 6.37
	Annular kiln	2.19 – 3.08
	Tunnel kiln	2.42

***Source:** [1]CESTT, 2000; [2]PSG, 1998; [3]ISB, 2000a; [4]INEST, 1998.*

varies from 80 – 100 tce per million solid bricks, with small plants on the high end. The tunnel kilns tend to require more energy to operate than the annular kilns because of its high level of mechanization. In most countries, modern tunnel kilns are typically fired by oil or LPG. The fuel consumption varies from about 150 to 200 tce per million bricks (Zhang, 1997).

The intermittent kiln has the highest level of fuel consumption amounting to as much as 200 to 250 tce of coal per million bricks. Energy efficiency of intermediate clamp, traditional clamp and Scotch kiln is very low compared to the Four-chamber down draft kiln. Even though the energy efficiency of most intermittent kiln is very low, the energy efficiency of Four-chamber down draft kiln is more than 60%.

Fuel consumption of brick industry depends on the scale of operation. The product range for continuous kiln plants in brick making will directly influence the energy used in drying.

Operating Practices

Efficient performance of a kiln during the firing stage is governed by controlling the heat losses. Proper kiln management, loading, unloading operations and kiln maintenance help to reduce energy consumption.

Types of Clay

Variations in the energy consumption will also result from different inherent firing characteristics of the brick making clays. If the clay is sticky or sandy, the specific energy consumption is high. It is advisable to

Comparison of Energy Efficiency in Intermittent Kiln and Continuous Kiln

Kiln type	Category	Fuel Type	Energy Efficiency (%)
Intermittent kiln	Intermediate Clamp	Coal, Coke	19 – 25
	Traditional Clamp	Biomass	10 – 28
	Scotch Kiln	Biomass	12 - 59
	Four chamber down-draft kiln	Biomass	62.6
Continuous kiln	Vertical Shaft Brick Kiln	Coal	60 – 93
	Hoffmann Kiln	Coal, gas, oil	20 – 56
	Bull’s Trench Kiln	Coal	21 - 47
	Tunnel Kiln	Oil, gas	45 – 76

Source: Kumar, et al., 1999.

add some additives during clay preparation stage to reduce the fuel consumption during firing.

Energy consumption in Brick Sector

The study countries use different technologies for firing process. The total energy consumption of brick making industry in China is estimated at about 119 million tce, which is about 30% of the total energy used by TVE industries. It constitutes about 10% of the total energy consumption of China in 1990 (Mohanthy and Visvanathan, 1997). On the average, every 10,000 pieces require 1.52 tons of coal, 360 kWh electricity and 0.25 tons diesel oil.

In India, the conventional practice of firing clay bricks in rural country-clamps and Bull's Trench Kiln consumes huge quantities of fuel in terms of coal, firewood, and other biomass fuels. It is estimated that the Indian brick industry consumes more than 24 million tons of coal annually, in addition to several million tons of biomass fuels (TERI, 2001).

In Sri Lanka, the estimated average total electricity consumption is about 3.6 GWh per annum for a typical brick industry in 1999. The brick and tile industry yearly consumes more than 150,000 tons of wood fuel, half of which comes from rubber wood (Schilderman, 1998).

In Vietnam, the energy consumption varies widely due to types of kiln used. Their average energy consumption is 150-220 kg coal/1000 red bricks and 300 kg coal/1000 anti-fired bricks.

In a nutshell, the brick sector consumes lot of energy during its manufacturing processes. In the mean time other suitable options and technologies to reduce energy consumption in brick industry have been initiated.

There are no benchmarks on energy consumption in brick making in China, Sri Lanka and Vietnam except for India.

Benchmark of brick making energy consumption in India

Type of Kiln	Relative Indicator (MJ/kg of fired brick)
Clamps	1.5
Down draft kiln	2.3
BTK	1.9
Hoffman kiln	1.5
Tunnel kiln	1.5
VSBK	0.75
Fixed chimney BTK	1.1

Source: Rudramoorthy, 2002.

CHAPTER 4: ENVIRONMETAL IMPACTS AND ISSUES IN BRICK SECTOR

The brick industry, which is based on widespread production activity, highly pollutes the environment. Problems in this industry have been exacerbated by cheap access to resources such as soil, water, coal, and biomass materials. Even though, the industry is organized regionally and is controlled by powerful industrial associations, the level of skill development is very poor. This chapter describes the environmental issues and impacts of the brick sector in the study countries.

In most developing countries, intermittent kilns and agricultural residues are widely used. However, burning of residues can pretense other negative impacts on the environment. Burning creates pollution (smoke, tars, suspended particles, fly ash, etc.) unless residues are burnt in a special furnace.

The other alternatives, namely the burning of coal, oil, and industrial residues, also have serious environmental drawbacks. The coal used is usually of low quality and often has high sulfur content.

Environmental Impacts

Environmental impacts of this sector are also diverse. The environmental impacts caused by brick industries are deforestation, land degradation accompanied by soil erosion, localized pollution, and loss of floral and faunal diversity, and reduced aesthetic values of natural woodlands.

Land degradation

Due to large scale operations, the excavation sites are correspondingly large and hence the associated problems like dust emission and soil erosion are also evident.

Loss of Agricultural Lands

Clay for brick making is obtained from land, which also has an agricultural value, such as rice fields, etc. Minimal impact on agricultural land is possible, if the topsoil removed is returned back to the site after clay removal. Sadly, this is often not practiced. More often, once the clay has been removed, the pits and land are abandoned. These pits subsequently become breeding grounds for mosquitoes when monsoon arrives. Occasionally, these pits are used as fishponds. But for practical agricultural purposes, the land is lost forever.

Loss of Soil Fertility

Loss of soil fertility is another environmental cost borne by the brick plants. Past studies have shown that concentrations of essential nutrients like nitrogen, phosphorus and potassium are very low in the fields that have been exploited by the brick industries.

Soil Erosion

The soil erosion is caused from the loss of topsoil, which supports the vegetation cover and trees. The excavated soil becomes exposed to the wind and rainfall. Under such circumstances, raindrops erode the soil upon impact with the ground. In cases where brick makers use sleighs to pull tree logs, gullies are eventually formed. These expedite the soil removal when it rains. The main effects from soil erosion are as follows (Tawodzera and Matirekwe, 1999):

- Removal of nutrients and humus from soil;
- Acceleration in declination of soil fertility;
- Shadowing of the soil profiles; and
- The starting point of gully erosion.

Loss of Forests

Another important raw material in the brick industry is fuel. The woodlands become the easiest victims to meet the fuel demand. For example, in Vietnam, it is estimated that the brick/ceramics industries consume approximately 73,170 tons of wood annually, equivalent to 487 ha of 7 – 8 years old eucalyptus.

Fuel wood is widely used in brick industry

Many countries restrict or even banned the logging of natural forests in an effort to avoid the deforestation.

The wood comes from a number of sources: home gardens, land-clearing sites, rubber plantation and sawmill slabs. However, a large part of the supply of fuel wood still comes from illegal logging in forests, which adds further strain on the environment.

Loss of Biological Diversity

Environmental problems associated with the deforestation include loss of nature's biological diversity and its aesthetic values. Loss of woodlands triggers the change in climatic conditions prevailing in that area and will soon lead to extinction of sensitive species.

However, ventures in peri-urban and urban areas that use either boiler waste or coal in brick burning have little impact on biological diversity. For example, Thailand has banned logging due to environmental concerns, but fuel wood is available at around US $(30-50) per ton. In Bangladesh, before 1988, approximately half of the bricks produced were fired with wood, 30% with coal and 20% with gas. In 1990, the government decided to cut gas supplied to most brick enterprises. It also decided to ban the use of firewood due to the unsteady situation of the country's forest cover.

Environmental Pollution

Environmental concerns over the brick industry in study countries include air pollution and particulate emission from brick drying and firing.

Emission details, India

Type of pollution	Pollutants		Quantity	Unit
Air pollution	CO_2		780-880	kg/1000 bricks
	SO_2		0.8-1.2	kg/1000 bricks
	NOx		0.6-0.7	kg/1000 bricks
	CO		11-12	kg/1000 bricks
	CH_4		0.15-0.2	kg/1000 bricks
	N_2O		0.021-0.025	kg/1000 bricks
	Total fluorine		---	---
	Gaseous fluorine		---	---
	Dust	Fly ash	3.5-7.5	kg/1000 bricks
Waste water	Wastewater		5 – 10	L/1000 bricks
Solid waste	Ash		65-85	kg/1000 bricks
	Substandard brick		370-390	kg/1000 bricks

Source: Rudramoorthy, 2002

Air Pollution

Dust Emission

The largest air pollutants in brick plants are the particulate emissions, which consist of carbonates, silicates, fluorides, etc., emitted through gases at temperature of 120–350^{0}C. The air pollution in the brick kiln affected areas is about three times higher than the normal. PM10 has direct relation to the human health, as these particulates are small enough to be inhaled causing serious problems such as asthma and bronchitis.

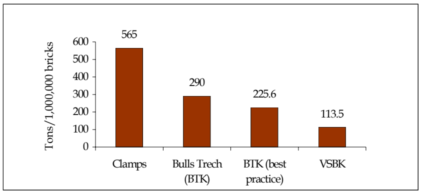
Gas Emission

Beside dust emission, gases are also emitted from brick kilns. The nature and quantity depend on the raw materials, fuel, burning condition, kiln dimension, technology used, etc. SO_2, CO_2, H_2O, NO_x, CO, and other volatile organic compounds are emitted from brick kilns.

As coal is practically the only type of fuel used in China for brick firing, one of the major environmental problems in brick manufacturing is the emission from coal burning.

CO_2

When fuels are burned, most carbon is emitted as CO_2 during the combustion process. Some carbon is released as Carbon monoxide (CO), Methane (CH_4) or non-methane hydrocarbons.



Source: Kumar, A., et. al., 1998.
Specific CO_2 load of some typical brick kilns in India

Though CO_2 is generally not considered as an air pollutant, its contribution to global warming is of great concern.

SO_2

SO_2 is emitted during the firing process of coal or oil in the kiln. SO_2 causes harmful effects on vegetation, living beings and monuments.

NO_x

In addition, a small quantity of NOx is generated, when fossil fuel is burnt at high temperature in the kiln. Nitrous oxide (N_2O) is produced directly from the combustion of fossil fuels. Lower combustion temperatures particularly below 1,200 K causes higher N_2O emission, with the maximum occurring around 1,000 K.

In an urban environment, the primary threat of SO_2 or NO_X may not directly arise from SO_2 or NO_X itself, but from the changes it undergoes in the atmosphere such as the formation of acid (H_2SO_4/HNO_3) and sulfate aerosols or nitrate aerosols.

Fluorine

Another type of emission from brick making is fluorine, which occurs in the clay as fluorides and its subsequent release during the firing stage. Being toxic and chemically reactive it can cause severe problems for vegetation. Fluorine-contaminated leaves are detrimental and even fatal to silkworms.

According to a national survey of major TVE pollution sources conducted in China in 1990, a total of 136,000 tons of fluorine was emitted from brick and ceramics TVEs. Some government, such as the USA, has regulated this emission. Several US brick companies have installed scrubbers to reduce fluorine emission with limestone as the scrubbing agent. But, these systems are expensive. Nevertheless, none of the study countries have air pollution control devices. Coal dust and the gases discharged to the air without any post treatment.

Comparison of specific pollution load in brick/ceramics sector in China, India, Sri Lanka and Vietnam						
Country	**Technologies**		**Specific pollution load**			
			(kg/'000 pieces)		*(kg/ton pieces)*	
			CO_2	**SO_2**	**CO_2**	**SO_2**
China	Intermittent kiln		113	5.0	50.2	2.22
	Annular kiln	Artificial drying – solid bricks	62	2.7	27.6	1.20
		Artificial drying – hollow bricks	37	1.6	21.1	0.91
		Natural drying – solid bricks	63	2.7	28.0	1.20
	Tunnel kiln	Artificial drying – solid bricks	80	3.5	35.6	1.56
		Artificial drying – hollow bricks	48	2.0	21.3	1.14
India*	Clamps	Coal	800	5.23	320	2.09
		Biomass	1276	1.17	490	0.47
	BTK	Coal	571	3.73	228	1.5
		Biomass	876	0.836	350.4	0.334
	Hoffman	Coal	685	4.48	274	1.79
		Biomass	1051	1	420.45	0.4
	Chamber	Coal	457	3	183	1.2
		Biomass	701	0.67	280.3	0.27
	Tunnel	Coal	388.3	2.54	155.3	1.02
		Biomass	596	0.57	238	0.23
	VSBK	Coal	274	1.8	110	0.72
Sri Lanka	Wood-fired kiln (tile production)		487	0.36	183.77	0.14
Vietnam	Tunnel kiln (burnt brick)		92	3.1	40.9	1.38

*Source: *Rudramoorthy, 2002; Kumar, A., et. al., 1998.*

Solid Waste Generation

Most of solid waste in brick making industry is recycled. The clay strewed in the production process, substandard brick in the drying process and cinder are re-used as additives. Substandard bricks in the baking process and the rest of cinder are discharged to the lakes and pools around the industries.

In Sri Lanka, the brick producers are not much concerned in maintaining the correct firing conditions. Most factories use firewood, and the ash is dumped at the factory sites. Majority of the industries operate without the proper environmental license.

State-owned brick sectors in Vietnam, mostly use the modern technologies, which meets the state government's environmental regulations. Therefore its environmental pollution is lower than the sector benchmarks. However, the private owned brick sectors emit highly polluted air pollutants as they use traditional technologies

In general, very limited attention is paid to abate the pollution in brick/ceramic making industry of study countries. The causes for the pollution are accredited to the following:

- Poor quality of raw material;
- Burning of sulfur-rich and coal based fuel for energy generation;
- Lack of awareness towards the economical benefits gained through pollution abatement;
- Lack of state owned enterprises and their independence;
- Ignorance of general public on the importance of healthy environment and conservation of natural resources; and
- Non-availability of spare parts for pollution abatement equipment in local markets.

Chapter 5: CERAMIC PRODUCTION PROCESSES

This chapter discusses about the ceramic production processes, the trends in production technology developments and used technologies adopted in study countries.

Raw Materials

Raw materials used in the production of ceramics are inorganic and non-metallic crystalline solids, which are formed by complex geological processes. Kaolin, Ball clay, Quartz, Silica sand, Feldspar, Dolomite and Calcite are some of raw materials that are used in ceramic industry.

Chemicals like Zinc oxide, Barium carbonate, Sodium silicate, zircon, blue stain black stain and plaster of Paris are used during its production processes. Silicate and aluminum silicate materials form the backbone of high tonnage products of the ceramic industry. Even though the manufacture of bricks does not require extensive beneficiation of the raw materials, manufacture of fine ceramics requires the raw materials of higher quality, normally obtained through various beneficiation processes.

The required ceramic mixture should be a body with enough cohesion and plasticity. This is obtained by mixing an adequate amount of water with clay, at its natural state or mixed with other substances.

Production Processes

There are two essential processes for the production of ceramics, the treatment of materials and firing. Natural raw materials contain mixtures of various components. The quality of ceramic products will weaken if there is too much of iron and titanium.

Crushing

Forming and sintering properties vary according to the grain size of the raw materials. Hence, the ore is first crushed prior to screening to get the desired grain size.

Ball mill for grinding

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For detail figure refer to appendix E

Blending and Kneading

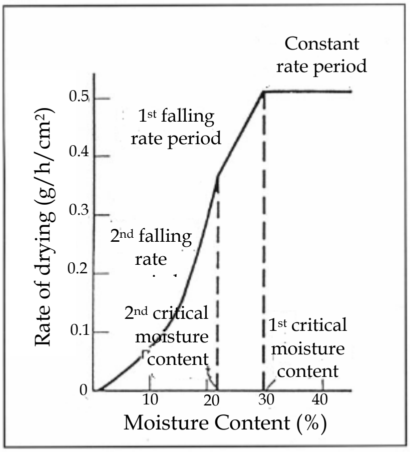
Technical know-how is very important in blending and kneading process. The blending process affects the yield, quality and workability. The major point in the kneading process is how to knead the material uniformly with water and how to mix various materials.

Forming

Since the ceramics shrinks, when fired, it requires mold to produce the desired shape. In most cases metal molds and plaster molds patterns are used for ceramic forming.

Drying

Drying is an important process and it is essential to know the appropriate conditions of temperature, humidity and time. Inappropriate drying may cause the products to be cut or broken.



Typical drying curve in Ceramic
Source: Ceramic Industry Data Book, (2002)

Firing

Changes in the physical and the chemical state takes place during the firing stage. This results in the progressive and continuous chemical reaction, which then fixes the kind of desired ceramics.

Ceramic products

After dehydrating, Clayware is made by firing the clay material at low temperature (1050 ^{0}C). The firing temperature range for Earthenware is from 1050^{0}C to 1150^{0}C.

Advanced gasification process is used in the production of Stoneware, which requires firing at 1150^{0}C to 1250^{0}C.

In the production of Porcelains, they are fired at the temperature of 1250^{0}C or higher, until the product becomes translucent with an increase in glass phase (MEMR & MPE, 1994).

Ceramic Making Technologies

Ball mills, blenders, compressors and intermittent type kilns are some of the basic machineries used in ceramic manufacturing process. However creative ceramics make uses of additional equipment such as filter press and cup machines.

Different types of kilns are used in the ceramic industry. Some of them are down draft kiln, chamber kiln, tunnel kiln, top hat kiln, vertical shaft kiln, and shuttle kiln.

Trends in Production and Process Improvements

Ceramics and porcelain sectors in the study countries are tuning themselves to the market demand with respect to design and production techniques. Their equipment are shipped from western countries for the sole purpose of meeting the latest design techniques and production capacities. The study countries are also cooperating with expert designers and consultants from the developed countries to train the manufacturers in quality production, décor paintings and special techniques involved in designing the products.

Philippines ceramics have made major breakthroughs in foreign markets through high quality products and distinctive craftsmanship. Its growth was influenced by the entry of foreign designers and consultants. The decorative ceramic industry can be considered as technologically advance, utilizing machinery and equipment such as high-speed mixers, roller machines, jiggering machines, ram press and high-fired kilns. The entry of foreign designers and consultants have fast tracked the growth of the industry, training key person from the private sector in production process and planning, model and figure making, kiln and firing technology and on glaze and decor painting.

In Sri Lanka, a Ceramics Cluster was formed one and a half years ago. The cluster includes manufacturers, component manufacturers, raw material and machinery suppliers and support service providers. It is not a protection-oriented but more of a forward-looking association. Ceramics Cluster is now working on new technologies and discovering unexplored areas in the field of ceramics, and overall development for the industry as a whole.

In Vietnam, the ceramic production is breathing new life into a century old tradition. With the involvement of German development agency (GTZ), Vietnam has developed more efficient and less environmental hazard Gas kiln technology in ceramic production. This GTZ gas kiln uses high-tech fiber mats, which is cheaper and more energy efficient and can be build locally. The Vietnamese government has tried to help factories by granting 'soft loans' to SMIs as an investment in energy efficient technologies. The government has also introduced regulations prohibiting the use of wood as an energy source in the new factories. In the next decade, the entire ceramic industry in Vietnam, comprising more than thousand factories, is expected to switch to gas technology.

CHAPTER 6: ENERGY ISSUES OF CERAMIC SECTOR

This chapter reviews the energy issues in ceramic sector in study countries.

The drying and firing processes in ceramic production use much energy. As in the brick making process, the energy consumption in firing depends on many factors such as temperature in the kiln, form of ceramic required, thickness and surface exposed for heat transfer, firing time, etc.

Sources Used for Supplying Energy in Ceramic Sector

Electricity, coal and LPG are the main energy sources used for ceramic industry in the study countries.

Sources for supplying energy in ceramic industry

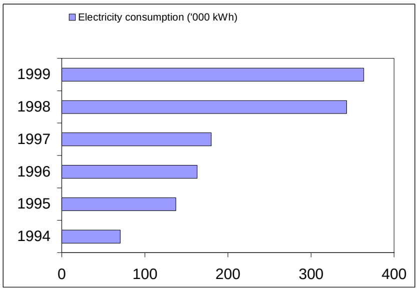
Country	Sources
Philippine	Electricity, LPG, Oil
Sri Lanka	Electricity, LPG, Kerosene
Vietnam	Coal oil, fired wood, rise husk, LPG

The factories heavily use electricity for raw material preparation. Electric motors are used for ball milling, filter press, pug mill, casting, jiggering, ram press, trimming, sponging, lights, and air-conditioning units and office equipment.

In Philippines, LPG, diesel, kerosene, firewood, rice husk and fuel oil are used for drying and firing processes.

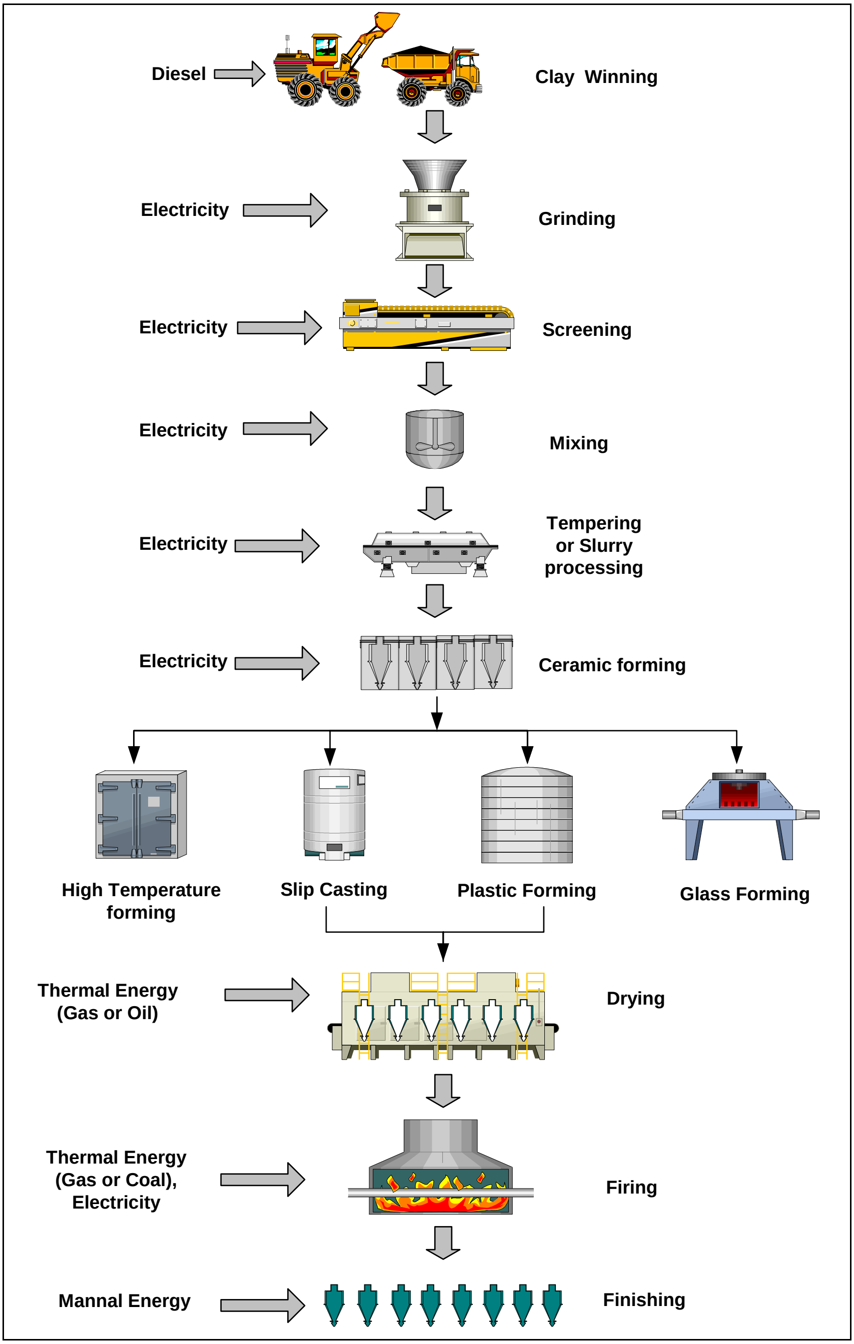
Only 25% of the heat supplied to the kilns is used in actual production, 75% is lost in the exhaust and losses due to improper combustion, radiation and convection from the kiln walls. Hence, the recent issue on energy in Philippine ceramics sector is the high LPG consumption used for kilns. The total energy consumption of ceramic industry in the Philippine consists of 88% of LPG and electricity.

Most ceramic factories in Sri Lanka heavily use electricity for raw material preparation and for thermal energy requirements.



Average electricity consumption in a ceramics factory, Sri Lanka (1994 – 1999)
Source: ISB, 2000b

The annual coal consumption in Vietnam within the year 1995–2000 is about 120,000–150,000 tons. In the southern part of Vietnam, most of the ceramic units use oil, fired wood and rice husk for firing. The annual energy consumption amounts to 50,000-60,000 tons of Furnace Oil (FO) and Diesel Oil (DO), in addition to a considerable quantity of wood used. At present,



Energy inputs in a typical ceramic process

40% of ceramic products are being baked in ceramic fiber-wool kiln in which LPG are used as the energy source.

Factors and Issues on Energy Use in Ceramic Making Process

Ceramic making is one of the energy intensive industries in study countries. Some issues related to energy use in this sector are discussed below.

Electricity and LPG are the main sources of energy for the ceramic manufacturing plants. Electricity is used in electric motors for ball milling, filter press, pug mill, casting, jiggering, ram press, trimming and sponging, among others. In addition, it is used for utilities including lighting, air-conditioning, and other office equipment for the production of decorative ceramics. For terra cotta production, electricity is similarly used in electric motors, thermic dryers, paints sprays, and other utilities. LPG is mainly used in firing (bisque, décor and glost) for decorative ceramics. On the other hand, LPG is used for brisk firing and dryers for terra cotta production.

LPG consumption in three typical ceramic industries in Philippine varies from a low value of 5.3 MJ/kg of product (Factory B- terra cotta, 13,439.84kg/d) to a high value of 147.2 MJ/kg of product (Factory A- Ceramic dinner wares, 2,400pcs/d). It is highlighted that factory's 'A' kiln contributes to many factors, such as: inefficient fuel combustion, defective insulation and low firing capacity.

Source: Herrera et. al., 2001

The energy consumption of ceramic making in Vietnam in 1997 is as follows,

- Northern provinces - 100,000 tons of ash coal
- Southern provinces- 1,300,000–1,500,000 ste of wood
- In the whole country - 330,000–360,000 tons of ash coal.

With the traditional handicraft technologies, specific energy consumption for ceramic making in Vietnam is very high.

In Sri Lanka, the energy cost is most ceramic industries accounts for 35% of the total production cost. In the same industry, 80% of the total energy cost

Comparison of fuel cost of traditional handicraft technologies in Vietnam with other technologies in Philippines and Sri Lanka

Country	Technology	Fuel Type	Fuel cost (%)
Sri Lanka	Handicraft kiln	Wood, biomass	20 – 30%
Philippines	LPG-fired kiln	LPG	20 – 25%
Vietnam	1960s Chinese kiln	Coal	35 – 40 %
	Traditional vertical kiln	Coal	45 – 50%

Sources: Quang, 1999; Thuong, 1999

is for heating alone. Even though there is a lot of enthusiasm and commitment in the ceramic industry regarding energy efficiency but implementation is lacking (the practical aspects such as strategic planning are weak in Sri Lanka).

Sri Lanka imports gas since it does not have the large oil and natural gas deposits. Energy costs are therefore high, but some of the cited cost disadvantage may be the result of poor energy management in individual companies (TCI, 2002).

Specific energy consumption for typical ceramics factories in Philippines

Energy	Factory/ Year		SEC	
			Per pieces	***MJ/kg of product)***
LPG (lit/pieces)	A	1996	0.948	80.23
		1997	1.105	93.52
		1998	1.739	147.18
	B	1999	0.940	5.30
	C	1999	0.608	13.19
Electricity (KWh/pcs)	A	1996	0.138	0.88
		1997	0.127	0.80
		1998	0.158	1.02
	B	1999	0.520	0.22
	C	1999	0.815	1.35

Note: Factory A and C are producers of decorative ceramics while factory B is a producer of terra cotta.
Source: Herrera et. al., 2001

Energy Costs of typical Ceramic Industries in Sri Lanka- (2000-2001)

Type of Product	Average raw material processed (MT/month)	Specific Electricity use in the entire factory (kWh/MT of RM)	Energy Cost* per MT of Raw material throughput (Rs/MT)	Energy Cost Share in the Total Production Cost
Porcelain Tableware	207.0	1232.8	40,081	37.4%
Porcelain tableware	270.0	2072.5*	34,531	21.2%
Floor Tiles	2135.3	228.2	5,978	36.3%
Floor Tiles	2206.8	239.3	4,803	25.5%

Source: The Competitiveness Initiative (TCI), Sri Lanka, 2002
**at November, 2001prices, Rs. Sri Lankan Rupee*

CHAPTER 7: ENVIRONMETAL IMPACTS AND ISSUES IN CERAMIC SECTOR

This chapter highlights the environmental impacts, namely air pollution, water pollution and solid waste management in the ceramic sector in the study countries. Air pollution is more predominant than water pollution and solid waste generation in the ceramic sector. The degree of pollution depends on the raw material, type of product and kiln used.

It is vital to identify and adequately address environmental issues in the ceramic industry in today's increasingly regulatory environment.

Therefore, beyond just the conservation of the natural environment by reducing pollution (atmospheric emissions, solid waste, aqueous discharges, noise pollution, etc.), the problem can be considered from economic and strategic points of view. From an economic viewpoint, financial savings can be brought about by a reduction in energy and raw materials consumption, a reduction in the cost of waste disposal or even, in many countries, a reduction in the tax on polluting activities. From a strategic viewpoint, benefits can be achieved through the positive image by a

Environmental Issues of the ceramic-making Industry

Process	Air Emission	Waste-water	Solid waste
Clay extraction	Dust	Exploited water	Waste soil
Mixing, crushing, extruding, cutting	Dust	Washing and filtered water	Sand, clay, sludge
Forming of ware	-	-	Substandard adobe
Drying	Dust, H_2O	-	
Casting	Dust	Waste water	Solid rejects
Biscuit firing (Biscuit kiln)	Dust, SO_2, CO, CO_2, H_2O, NO_x	-	Substandard product
Glaze mixture	Dust	Washing and filtered water	-
Glazing	VOC, benzene, oil	-	Solid rejects
Glaze firing	VOC, oil steam	-	-
Boiler and LPG kiln	Dust, SO_2, H_2O, CO_2, CO, NO_x	Washing water (CN^-, S^{2-}, phenol)	Cinder, sludge from washing, ESP

Specific Pollution Load of the ceramics sector in Philippine and Sri Lanka

Country	Production	Specific pollution load			
		(kg/'000 pieces)		*(kg/ton pieces)*	
		CO_2	SO_2	CO_2	SO_2
Philippines (*)	Dinner wares 2,400 pcs/day	1,823	N.A.	-	N.A.
	Terra cotta 13,439.84 kg/day	1,551	N.A.	184.86	N.A.
	Dinner wares, decorative vases etc. 2,400 pcs/day	1,003	N.A.	460.09	N.A.
Sri Lanka	Ceramic ware 1,500 kg /month	-	-	106.21	0.14
	Ornamental ceramic ware 2,500 kg/month	-	-	482.00	0.55

N.A. – Not available;
(*) – The results are estimated based on the LPG use.

company that is concerned with the environment (good corporate image).

Before the firing, majority of the materials can be recycled within the factory. However, in an average factory about 2% of the raw materials cannot be recovered and are discharged either as water-borne effluent or are reduced to solid and sent to dumping site.

Environmental Issues and Impacts

Air Pollution

The use of coal and LPG for drying and firing in ceramic industry releases, carbon dioxide and water vapor. Furthermore, the kiln stack is the main source for air pollution in the ceramic industry. The emissions vary with the type of fuel and kiln. The emissions from kiln mainly contain particulate matters, CO_2, SO_2, NO_x, fluorides, chlorides and vapors of some metals or compounds as pollutants.

Fluorine is present as an integral component in most types of clay and cannot be removed before use. It is released from the clay, primarily as gaseous hydrogen fluoride (HF), on firing above 750°C. Atmospheric hydrogen fluoride is now recognized as a health hazard and as a nuisance to the environment, particularly in urban areas where it causes the etching of window glasses. The concentration of HF emitted from the kiln chimneystack is influenced by number of factors, namely:

- the configuration of the ware loading in the kiln,
- the firing temperature profile,
- atmospheric conditions in the kiln, and
- kiln design.

Local compliance requirements on ground concentration of HF are met by increasing the height of the kiln stack. Hence, the emerging gases are dispersed over a larger area. However, this should be regarded as a short-term measure only since the main requirement is to minimize the amount (not the concentration) of HF released to the environment.

Volatile Organic Compounds (VOC) occurs in most forms of the materials used in decorative tableware. The VOC's are normally burned-off during the firing process when the combustion products are vented to atmosphere. There is however no reliable data on the quantities of VOC's that are emitted by the tableware industries.

Water Pollution

A significant part in the ceramic manufacturing process is the use of water. In ceramic making, liquid effluent is discharged in the form of wastewater from ball milling, pug mill, casting, molding, glazing, acid picking, wet grinding, washing of ball mills, molasses drum and finishing areas.

Treatment and recycling of wastewater is practiced in some industries but the majority discharge their effluent with minimum treatment that is needed to comply with the relevant environmental legislation.

The body and glaze suspensions are prepared with solids contents of approximately 46% by weight. Thus for each ton of finished product, approximately 1 ton of water must be extracted by filter pressing and in ware dryers. Traditionally, water from the ware dryer is vented to atmosphere as steam, wasting both water and heat. Water recovered from filter press is contaminated with mineral particles and dissolved chemicals and must be filtered and chemically cleaned before reuse.

The use of decoration by decals and transfers also requires the use of relatively low quantities of water in the process. However, the levels of contamination by heavy metals and VOC's are high. Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Heavy metals (Pb, Cd, Cr, Zn, Ni, Fe etc), oil and grease are some of pollutants in the discharged wastewater. This water must also be treated before disposal or reuse. The wastewater that comes from the cleaning of buckets can be reused for holding the casting materials and the cleaning of rugs, used in the finishing process. The wastewater from the cleaning of pails contains solid particles and excess paints.

Solid Waste Generation

Solid waste is generated in several stages in the ceramic industry. This consist of dust particles, mainly from ball milling, waste clay materials from the filter press and pug mill, sponges from the sponging process and biscuit rejects from bisque firing, and decoration firing. Some rejected clay materials from the ram press, jiggering, casting, trimming, and polishing are being recycled in Philippine, Sri Lanka and Vietnam. Solid wastes in the form of breakages occur during firing and handling.

Damaged fired products cannot be recycled and are thrown as solid waste The fired biscuit pieces are also not recycled, and are dumped at low-lying areas within or near the industry. The ash from kilns are dumped in open dumping sites or sold for construction activities. These are considered as non-hazardous waste.

Glaze materials, despite having much higher value, are frequently wasted to a greater degree. It is not uncommon for 10% of the glaze materials purchased to be discharged as aqueous effluent or landfill. Many colored glazes and decoration materials contain toxic heavy metals, such as Zn, Cd, Pb, Cr and Fe salts etc., which triggers an additional environmental hazard. Therefore those wastes should not be disposed at normal dumpsites. While some industries treat to hazardous waste in proper manner, others dispose them as solid wastes in the dumpsites.

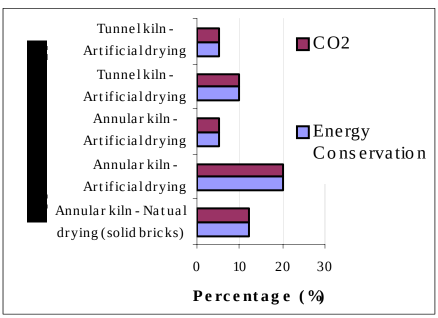
CHAPTER 8: ENERGY EFFICIENT AND ENVIRONMENTALLY SOUND TECHNOLOGICAL (E3ST) OPTIONS FOR THE BRICK AND CERAMIC SECTORS

This chapter highlights the energy efficient and environmentally sound technological (E3ST) options for brick and ceramic sectors in study countries and in Thailand. SMIs in developing countries do not use energy efficiently, and contributes to pollution generation.

Overview of E3ST in Brick and Ceramic Sectors

China

In China, 90% of bricks are produced with higher energy consumption, Greenhouse Gases (GHG) emissions and high raw material consumption. It is estimated that solid brick making capacity in China can be upgraded up to 30% by using energy efficient technologies. Furthermore, there are possibilities to reduce energy consumption by 12 million tce and about a million ton of CO_2 emission.



Potential of energy saving and CO_2 reduction in China (%tce/10,000pieces)
Source: CESTT, 2000

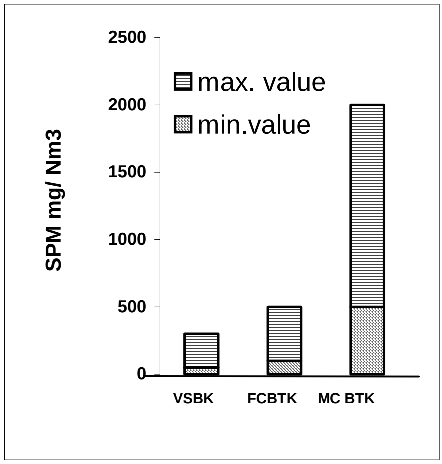
India

In India, the VSBK technology is promoted after several studies on air pollution in kiln stacks, heat loss to the ground, and heat loss from the kiln surface of existing brick industries. This technology has been shown to be energy efficient, environment friendly and economically viable to produce quality bricks.

Studied factories in India, showed that the drying time can be reduced from 39 to 31 hours by improving the air mixing and reducing the depth of charge during the drying process. Furthermore, by establishing a buffer zone between the clay extruder and drying kiln, the drying process can be operated continuously.

VSBK only needs about 25 to 30% of the land required by BTKs. VSBK is easy to operate and does not require electricity for functioning. VSBK technology results in energy saving of about 50% as compared to clamps and 20 to 30% as compared to BTKs.

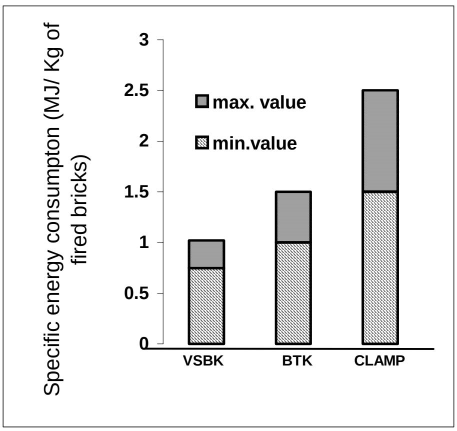
Vertical Shaft Brick Kiln (VSBK)



Comparison of SPM concentration in stack gases
Source: TERI, 2001

Even though the construction cost of VSBK is higher compared to other traditional technologies, it also reduces the production cost.

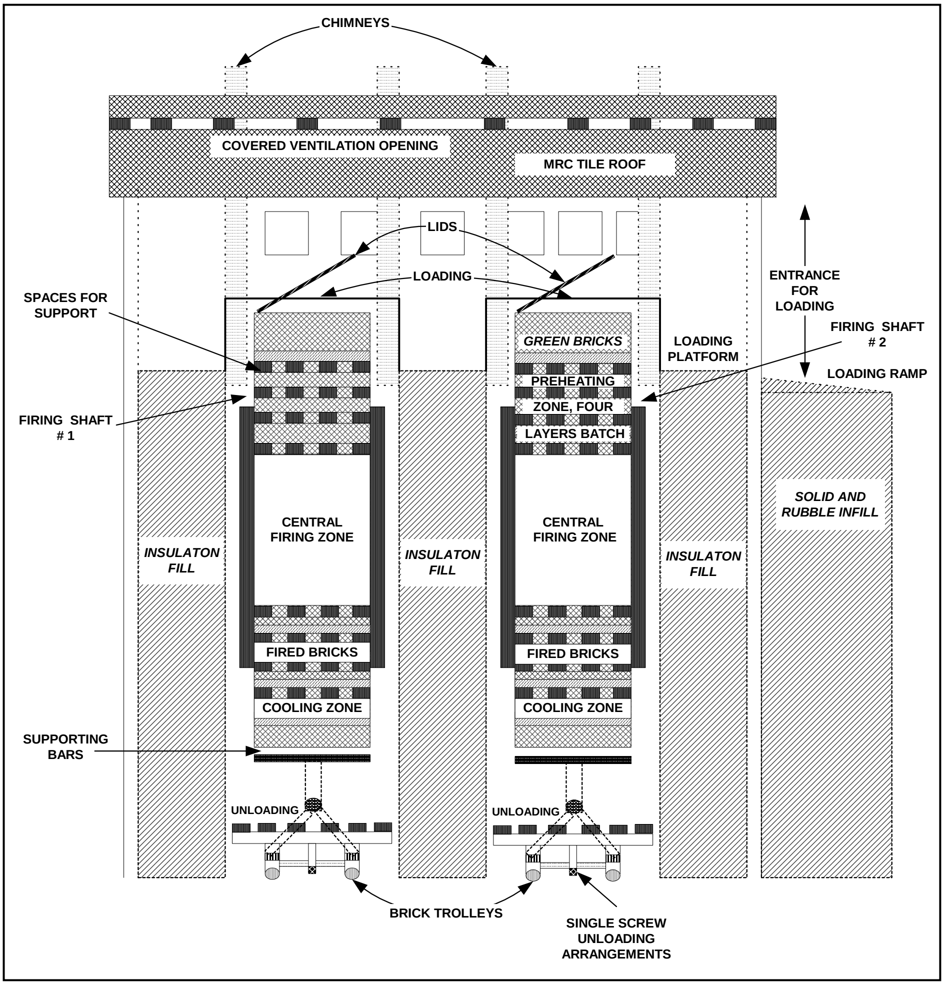
In addition it is not affected by variations in weather unlike other brick kilns that can be operated only 5 to 6 months in a year.



Specific energy consumption of brick kilns in India
Source: TERI, 2001

Philippines

Studies carried out in three ceramic factories in the Philippines showed two energy efficient and environmentally sound technologies being used. These are LPG-fired model kiln and thermic dyer.



Schematic drawing of VSBK
Source: Adapted from Kumar et al, 1998

Performance of LPG-fired model kiln

Type of kiln: Batch type, downdraft,
Temperature rating: 1300^{0}C
External dimension: 2.03x1.84x2.23m
Internal dimension: 1.66x1.48x1.54m
Setting volume: 2.6 m3
Furnace insulation: Composite construction using ceramic fiber blanket and calcium silicate block insulation
Type of burners: Atmospheric
Rating of burner: 13.6kW@600 mbar
Firing time: 5 h@ 10500C;
7h @ 13000C
Product load: 150–300 kg green ware
Energy consumption: 25–30kg of LPG

Thermic Dryer is basically a tunnel kiln dryer. In order to control the conditions throughout the tunnel dryer accurately, a number of control zones are created internally. Each zone is designed according to the evaporation rate from the products. These are operated at different temperature set points and relative humidity. Air volumes and speeds are also increased throughout the length of the tunnel in order to protect the ware from damage in early stages of the cycle. Then, it increases the rate of drying towards the end of the tunnel on a "time and motion" basis. Thermic dryer, has three heating or conditioning zones and a cooling zone at the exit.

***Zone 1**:*

The primary purpose of Zone 1 is to stabilize the ware and ensure the thorough heating of the body with a strict controlled rate of evaporation from the ware. Delicate cast pieces, which enter the dryer at up to 19% moisture content, are heated slowly in high humidity condition, which effectively retards the drying so that as little as 30% of the total water to be removed is evaporated in 45-50% of the overall cycle time.

At the end of the first zone shrinkage, which has been controlled throughout the zone, will cease. This allows the body to accept far higher temperatures and greatly reduced humidity levels later in the cycle, in the succeeding control zones.

As it is dangerous to rely solely on evaporation of water from the clay body to attain the desired level of relative humidity at this stage, a "Steam Injection Humidifier " or water spray atomizer is incorporated to raise RH levels artificially and help retain moisture in the ware.

Also in the Zone 1 of the dryer, air circulation is at its least intense, and sufficient enough to distribute the conditioned air, thoroughly around the product setting.

Zone 2:

As shrinkage has now ceased, drying can take place more readily at a higher temperature and under constant humidity level. During this second phase of the drying cycle evaporation is so fast that almost 50% of the total water can be removed within around 30% of the drying cycle.

Air Circulation rates are increased in accordance with this fast speed and internal humidity levels are generated solely by evaporation from the ware without the need for steam injection.

Zone 3:

In this zone the remaining water is removed under the most intense rate of air circulation. The final percentage of water left (15-20 %) could take 2 hours, i.e. 25% of the drying cycle.

Sri Lanka

As far as the thermal energy is concerned, some ceramic manufacturers in Sri Lanka have increased the thickness of the kiln to minimize the heat dissipation.

Some of them are equipped with the waste-heat recovery systems connected to kilns. The recovered heat is supplied to some of the dyers in the casting and to forming sections of the factories.

A study was conducted and later, implemented by 'National Engineering Research and Development Center' to recover waste heat from the Glost kiln and the Biscuit kiln. This recovered heat was used in the dryer for casting and forming sections. The Glost kiln supplies hot exhaust at 200°C from the firing zone via a blower driven by a 11 kW electric motor, and hot exhaust at 144°C from the cooling zone by means of a blower driven by a 15 kW motor. In addition, supplementary blowers have been installed to make-up for the pressure drops in the ducting system connecting the Glost kiln and the dryers. Similarly, the Biscuit kiln supplies hot exhaust at 78°C from the firing zone via a blower driven by a 5.5 KW electric motor and hot exhaust at 78°C from the cooling zone through a blower driven by a 7.5 kW motor (TCI, 2002).

Some factories have implemented the following measures to improve the efficient use of electricity;

- Fixing polished aluminum reflectors to light fittings in the office;
- Fixing hanging switches to most light fittings: *Working staff were observed, switching off lights when leaving their workstations for meal breaks;*
- The factory was designed to maximize the use of daylighting through transparent roofing materials.

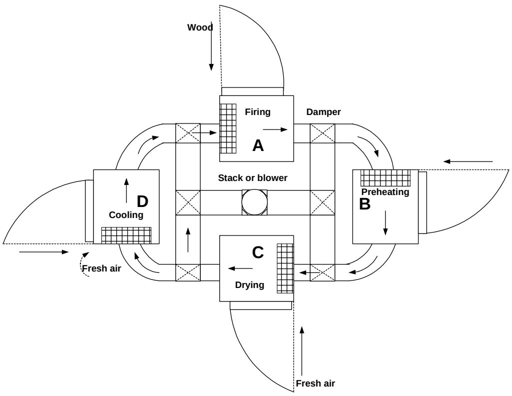
Most ceramic factories in Sri Lanka have opted to use the Ceylon Electricity Board's (CEBs) time of tariff. The economic advantage of this tariff is more than the CEB's regular tariff.

On the other hand, to manage electricity demand during peak hours, some factories switched off the electric kilns for few hours.

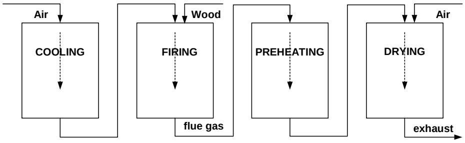
Thailand

A four-chambered downdraft kiln was developed for the brick industry of Thailand in 1997. The prototype kiln had capacity of 2,200 bricks and consumed 2.71 MJ/kg of bricks. The external size of the kiln was approximately (5x5x2) m; the internal effective volume was about (1.6x2x2) m. The system consists of cooling, firing, preheating and drying processes, which simultaneously occurs in the four chambers. The simulation covers the four processes in series and involves heat transfer, mass transfer and combustion of firewood.

The four kilns are connected by ducts, which convey fresh air for cooling and hot gas for preheating and drying of the brick. This system can be stand-alone (four) downdraft batch-type kilns or cooperative continuous kiln to serve the fluctuation of the brick market. The system is not completely continuous and the batch characteristic of each chamber introduces the transient behavior to the process.



The cooling process in the preceding chamber preheats the combustion air for firing chamber. The exhaust gas from the firing chamber is channeled to preheat and dry the brick in the next two chambers.



The four chambers of downdraft kiln
Source: Prasertsan and Theppaya, 1995

Economic Advantage of the Time-of-Day Tariff in a typical ceramic factory in Sri Lanka – 2001

Tariff	Maximum Demand (kVA)	Rate (Rs)	Off-peak Use (kWh)	Rate (Rs/kWh)	Peak-time Use (kWh)	Rate (Rs/kWh)	Monthly Bill (Rs)
Time of Day	1393	360.00	473,028	6.10	42,335	14.00	3,979,670
Regular	1393	380.00	473,028	7.00	42,335	7.00	4,136,912
Monthly Saving							157,242

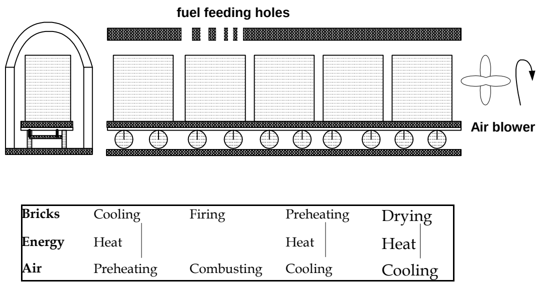
Note: Maximum demand and energy figures are monthly averages for year 2001; Rs. – Sri Lanka Rupee
Source: The Competitiveness Initiatives, Sri Lanka, 2002

Bricks produced by this system consumes about 1200 KJ/kg brick which is substantially lower than that produced by the conventional updraft kiln. At the same time the production rate was increased to 2.5 times (Prasertsan and Theppaya, 1995). Other advantages of four-chamber downdraft kiln are as follow:

- Both the brick and the combustion air are preheated, resulting in low fuel consumption in the firing process;
- Pilot tests have shown that the energy efficiency of this kiln was about 62%;
- Compared to the conventional open top Thailand updraft kiln, the fuel consumption was about 60% less and required area was four times less; and
- The firing time was 8.5 hours compared to traditional kilns.

On the other hand, the kiln operation is quite complicated and special training may be needed for the operators.

There is yet another energy efficient technology, namely tunnel kiln that is widely used in USA, Europe and higher capacity brick making industries in China, Indonesia, and Vietnam etc. The kiln is heated by burning coal or natural gas in the middle section. The combustion gases moves forward, towards the car entrance where they are removed through a series of exhaust ports in the sidewall. As the combustion products pass down the kiln, they preheat the green bricks placed on the cars traveling towards the fired bricks. The heated air passes to the firing zone for combustion purposes. At intervals, cars of fired bricks are withdrawn from the kiln and these are replaced by pushing the green bricks cars into the kiln at the opposite end.



Schematic diagram of tunnel kiln
Source: Prasertsan et al., 1995

The combustion temperature in this kiln is about $1,100^0C$. The temperature of exhaust gas and cooling air leaving the kilns are in the ranges of $100 - 145^0C$ respectively.

The advantages of tunnel kiln are,

- The capacity of tunnel kiln is about 50,000 - 150,000 bricks per day. It requires less labor than other kilns if compared
- The new generation of tunnel kiln has a specific energy consumption of about 0.94 MJ/kg of fired bricks.

Vietnam

A case study done in one of the ceramic factories in Vietnam reveals that it is possible to increase the production capacity, minimize the energy consumption and lessen the firing time even after replacing a thinner fire-wall.

As per Thuong (1999), there are more potential to save energy in both brick and ceramic industries in Vietnam.

Short term
Reasonable management in manufacturing, fuel/material use and kiln operation - 15 – 20%

Medium term
Improvement of firing kilns, anti-heat measures, waste heat recycling, step by-step replacement of annular kilns in order to recover heat - 20 – 25%

Long term
- Use annular kilns and tunnel kilns in brick making - 30 – 40%
- Use new LPG-fired kiln in ceramic making – 50%

Improvements after replacing a fire-wall" in a ceramic factory in Vietnam

	Before adding fire-wall	**After adding firewall**
Capacity (pieces/batch)	980	1,400
Firing time (hours)	60	55
Coal consumption (kg coal/pieces)	650	450
Share of fuel coal in total product's cost (%)	35 - 40	20 – 30
Investment for new "firing-bag" (US$)	-	300,000
Coal saving in 1997 (tons)	-	3,000
Payback period (years)	-	2

Source: NSTC, 1998.

National Policies to Promote E3ST of Brick/Ceramic Sectors

China

- Energy conservation and environmental protection were promoted by rules and regulations before economic reforms;
- Irrational energy prices have hindered the efforts to increase energy efficiency, to create an environmental pollution and ecological degradation. Valuable resources were unduly wasted;
- Energy conservation and environmental protection are promoted by market mechanisms (price increases, waste discharge fee, etc.) in addition to rules and regulations;
- Lack of independence of enterprises retards the process of E3ST.

India

- The functions of legislations, regulations, administration and the control are being performed by the state itself.
- Most energy sources are controlled by monopoly state corporations, hence they are inferior in quality;

Philippines

- Government policies and institutional support play a crucial role in the promotion of E3ST;
- The domestic market is shielded from international competition by high import tariffs (no more tariff due to WTO globalization policy).

Sri Lanka

- National productivity is one of the lowest in Asia;
- Too stringent labor laws;
- Facilitation roles played by certain state organizations gradually tend to decline with time.

Vietnam

- Most activities are controlled and performed by the state;
- National energy policy identifies coal, hydro, oil /gas, as the primary energy sources to meet national energy demands;
- The energy policy measure ensures a continuous enlargement of multiform and multilateral energy market (taking into account the development investment constraint of Vietnam);
- National energy policy highly appreciates the role of the peoples thriving in the rural/ mountainous region. Therefore, considers the gradual meeting of rural and mountains energy requirements.

Cross country comparison of regulatory bodies and NGOs at glance

Country	Regulatory Body	NGOs
China	- Promotes energy efficiency and environmental protection by economic, legal and administrative means; - Promotes cleaner production; - Preferential policies, tax exemptions, concessionaire loans, etc; - Enforcement tools, fines, orders to cease operations, fines for the top management, etc.; - Lack of public awareness.	- NGOs with limited state involvement do exist.
India	- Regulating bodies are very rigid in performing their duties; - Do not have means or desire to assist industries in overcoming their environmental problems; - The action is either to impose penalties or to order closure of manufacturing facilities.	- There are NGOs active in environmental protection activities.
Philippines	- Technological support to industries is provided; - Environmental regulatory strategy applied is mainly environment-based rather than technology-based; - Fines levied for non-compliance does not reflect cost of pollution prevention and management; - No regulations for energy efficiency improvements.	- There are NGOs activities in the environmental protection; - Activities of PCAPI are commendable.
Sri Lanka	- Central Environmental Authority (CEA) plays only a regulating role; - CEA has opted for most stringent standards practiced by the developed world; - No regulations for energy efficiency improvements.	- There are NGOs activities in the environmental protection.
Vietnam	- Ensure an efficient energy demand side management (DSM) by a system of "hard tolls" (legislation, regulation, rationing, load shedding, etc.) and "soft tool" (pricing, taxing, financial incentives, improving devices and appliances, technology transfers, training, etc.) especially by two principal DSM programs: energy conservation and energy audit in buildings and industries; - Environmental impact assessment (EIA) is considered as a major part of all energy development projects.	- NGOs with limited state involvement do exist.

Comparison of Institutional structure and interaction on energy issues in study countries

	China	India	Philippines	Sri Lanka	Vietnam
Institutional structure and interaction					
- Information dissemination and education	✓	✓	✓	✓	✓
- Research and development of efficient technologies	✓	✓	✓	✓	✓
- Energy conservation / audit	✓	✓	✓	✓	✓
- Financing efficient technology	✓	✓	✓	✓	✓
- Setting/ reviewing efficiency standards	✓	✓	✓	x	✓
- Monitoring and enforcement of regulations	✓	✓	x	x	x
- Co-operation between institutions	✓	✓	✓	✓	x
Energy and environmental regulatory measures					
- Energy law	✓	x	✓	x	✓
- Energy efficiency standards	✓	✓	x	x	x
- Fuel use limitation	x	x	x	x	x
- Time-of-use electricity tariff	x	x	x	x	✓
- Obligation of timely energy consumption reports	x	✓	✓	x	✓
- Obligation of timely reports on energy conservation	x	✓	✓	x	✓
- Obligation employment of energy manager	✓	x	✓	x	x
- Obligation of caring energy label on appliances	x	x	x	x	x
Command and Control approach					
- Energy efficiency standards	✓	✓	x	x	x
- Monitoring - Spot monitoring	✓	x	x	x	x
- Self monitoring	x	x	x	x	x
- Enforcement - Fines	x	x	x	x	x
- Imprisonment	x	x	x	x	x
- Temporary closure of factory	x	x	x	x	x

Source: Mohanthy and Visvanathan, 1997; Jansen and Thuong, 1998.
Note: ✓ - exist; x - not-existing

Comparison of Institutional structure and interaction on environmental issues in study countries

	China	India	Philippines	Sri Lanka	Vietnam
Institutional structure and interaction					
- Information dissemination and education	✓	✓	✓	✓	✓
- Research and development of clean technologies	✓	✓	✓	✓	✓
- Environmental management	✓	✓	✓	✓	✓
- Financing clean technologies	✓	✓	✓	✓	✓
- Setting/reviewing environmental standard	✓	✓	✓	✓	✓
- Monitoring and enforcement of regulation	✓	✓	✓	✓	✓
- Co-operation between institutions	✓	✓	✓	✓	✓
Environmental regulatory measures					
- Environmental law	✓	✓	✓	✓	✓
- Environmental standard					
- Ambient standards	✓	✓	✓	✓	✓
- Performance standards	✓	✓	✓	✓	✓
- Technology standards	✓	x	x	x	x
- Obligation of EIA reports	✓	✓	✓	✓	✓
- Obligation of environmental performance report	x	✓	✓	✓	x
- Right of public participation	x	x	x	x	x
Command and Control approach					
- Environmental standards	✓	✓	✓	✓	✓
- Monitoring - Spot monitoring	✓	✓	✓	✓	✓
- Self monitoring	x	✓	✓	✓	x
- Remote monitoring	x	x	x	x	x
- Enforcement: - Fines	✓	✓	✓	✓	✓
- Imprisonment	x	✓	x	✓	x
- Disapproval license based on EIA	✓	✓	✓	✓	✓
- Temporary closure of factory	✓	✓	✓	✓	✓

Source: Mohanthy and Visvanathan, 1997; Jansen and Thuong, 1998.
Note: ✓ - exist; x - not-existing

National environmental standards related to brick/ceramics sector
(Air pollution in different conditions in study countries)

Condition	Average time	*Pollutant*	China	Vietnam	India	Philippines	Sri Lanka	WHO
Workplace (mg/m³)		NOx	1,700	2,500	6,000	-	-	-
		SO_2	1,200	1,500	5,000	-	-	-
		SPM	-	600	-	-	-	-
		CO	-	-	40	-	-	-
Ambient condition (mg/m³, average time)	1 h	NOx	0.30	0.40	-	0.30	0.25	0.4
		SO_2	0.70	0.50	-	0.85	0.20	0.35
		SPM	-	0.30	-		0.50	-
		CO	2.00	40.00	-	85.00	30.00	30.00
	8 h	NOx	-	-	-	-	0.15	-
		SO_2	-	-	-	-	0.12	-
		SPM	-	-	-	-	0.35	-
		CO	-	10.00	-	10.00	10.00	10.00
	24 h	NOx	0.15	0.10	0.08	0.19	0.10	0.15
		SO_2	0.25	0.30	0.08	0.37	0.08	0.10 – 0.15
		SPM	0.25	0.20	0.20	0.18	0.30	0.15 – 0.23
		CO	6.00	5.00	4.00	-	-	-
	Annual average	NOx	0.10	-	0.06	-	-	-
		SO_2	0.10	-	0.06	-	-	0.04 – 0.06
		SPM	0.15	-	0.14	-	0.10	0.06 – 0.09
		CO	-	-	2.0	-	-	-

Source: Kumar, A. et al. , 1998.

During the last decade, the study countries developed standards for regulating emission from various industries and set emission standards for all polluting industries. Some countries have included permissible limits for SPM and SO_2 in most of the air quality emission standards. But there are no specified standards for NO_x and CO.

Barriers related to promotion of E3ST in brick/ceramic sector

Financial Barriers

Many SMIs in study countries in general do not have the capital investments needed for the adoption of energy efficient and environmental sound technologies. Though most energy efficiency activities require low investments, they do not generate a separate revenue stream that could help industries pay-off ensuing loans from financing institutions. For most SMI, short-term profits are usually preferred over long-term gains. This makes it difficult to sell the 'business' argument that greater efficiency and higher material recovery leads to improved profits in the long run. Lack of finances also results in purchase of inferior technology or second-hand, low quality and inefficient devices or equipment. Uncertainty of energy prices, especially in the short term, often lead to higher perceived risks, and therefore to more stringent investment criteria and hence offer a higher hurdle rate in adopting energy efficient technologies (AIT, 2002).

Information and Technical Barriers

In developing countries, only few of the brick and ceramic manufacturing units are located near urban areas. The majority of the industries are located in the rural areas. Therefore, they have slow and difficult access to new technology and market information.

Regarding the labour awareness, it is necessary to promote activities in terms of environment protection, and energy conservation for the staff. This will not only upgrade the factories to save production cost but also reduce pollution load and improve labor safety.

The existing facilities in most of the brick/ceramics making plants are outdated with low thermal efficiency of the kiln. Some of the plants lacked proper equipment and facilities to produce high quality products.

To overcome information and technology barriers, it is possible,

- To add new equipment including extruders, high speed rollers, automatic coal feeders, decorative facing brick molds and automatic control system for the drying room and annular kiln;
- To renovate annular kilns for better thermal efficiency
- To import advanced designs for high-efficiency annular kiln and appropriate kiln building materials.
- To establish and improve information service

Policy and Law Barriers

The presence of national standards and benchmarks can, in one way or other, create awareness among industries on how they perform compared to the rest of the industry players (in terms of energy use and environmental management).

- The government should develop all kinds of energy saving standards and rules for industries and intensify the enforcement of these rules and standards;

- The measures has been like levy of 30% investment orientation tax on solid bricks factories, tax exemption for hollow block factories should be strictly performed;

- Increase the tax for resources; It should increase the cost of plant, and limit the development of outdated plants, producing low quality production. In this manner, it can widen the market of high quality brick and new production including perforated brick and hollow block.

Market Barriers

To overcome market barriers, it is possible,

- As housing arrangements being commercialized, the people should gradually pay more attention to energy saving standards and rules for buildings. As the government intensifies publicity on energy saving standards, each consumer should get to know it and consider it as a decisive factor when making the housing arrangements so that consumers should become the promoters of energy saving buildings.
- The government should intensify the enforcement of these rules and closely monitor the development of energy saving building industry.

The Way Forward to Implement E3ST in Brick and Ceramic Sectors

The following measures can be implemented to improve E3ST in both brick and ceramic sectors in study countries,

- Technical and managerial measures;
- Policy measures;
- Educational measures;
- Economic and financial measures and
- Environmental measures.

Technical and Management Measures

It is possible to improve the energy efficiency of the equipment by minor modifications of the existing production lines. The other possibilities are;

- Improvement of equipment towards energy saving and decreasing the firing time. Which will minimize the pollutions.
- Using modern equipments to increase plant availability and to increase its efficiency factor through more efficient transmission systems.
- Installation of dust collection system: Installation of cyclone for the large dust particles and electrostatic precipitators, bag filters or wet scrubbers for the finer ones.
- Careful control of excess air in kiln is necessary to keep the SO_2 at minimum.
- The factories should install devices, to measure and control material and energy consumption.

Policy Measures

It is necessary to promote and encourage the market demand for new products through policy mechanism and economic incentives. Incentives can be provided in form of rebates, tax and duty exemptions.

Development of sector guidelines, environmental quality criteria and standards for reducing environmental impacts in cost effective manners are also another important policy measure that needs to be implemented.

It is possible to set guidelines for encouraging banks to incorporate environmental criteria in lending practices.

It is necessary to ensure better enforcement and monitoring of legislation by developing effective institutional frameworks and promotion of wider participation in regulatory framework development.

Educational Measures

The case studies highlight that there is a great need to develop and conduct in-house training courses and awareness programs for all staff. These trainings will equip the SMI staff with necessary skills in order to enhance the marketability of their products through better quality and strength.

Economic and Financial Measures

SMIs often lack financial and human resources in order to renew their technologies. External assistance such as consultancy of technical expert, fund, information should be provided to SMIs.

Environmental Measures

It is possible to use environmental friendly technologies such as the use of soil-cement bricks or stabilized soil bricks as alternative walling materials.

Using alternative fuel for burning brick, such as agricultural and industrial waste in urban areas (e.g. boiler waste, used oil, etc.) is another environmental measure that can be implemented.

There are possibilities to use alternative raw materials in the production of bricks such as, those made from sand and lime or from fly ash and sand lime by pressing or steam curing.

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APPENDIX A: DRAWBACKS OF CURRENT TECHNOLOGIES IN BRICK/CERAMIC SECTOR

	China	Vietnam	India	Philippine	Sri Lanka
Repairing and maintaining equipment are inactive, inadequate	✓	✓	✓	✓	✓
Use tunnel kiln but its structure is unreasonable, cause much heat losses	x	✓	✓	x	✓
Heat from flue gas exhaust are not recovered	x	x	x	✓	✓
Insensitiveness of new technology, quality and some government policy	x	x	x	x	✓
Simple and outdated equipment, consume more energy	✓	✓	✓	✓	✓
Lack of knowledge or low education of employees and managers	✓	✓	✓	x	x
Lack of financing	x	✓	x	✓	✓
Lack of standard/benchmark	✓	✓	x	✓	✓
Lack of monitoring on energy use	✓	✓	✓	✓	✓
Insensitiveness of market of product	✓	✓	✓	x	✓

Note : ✓ – exist; x : not-existing

APPENDIX B: LIST OF WEB SITES RELATED TO THE BRICK AND CERAMIC SECTORS

General

A forum for information exchange; the latest technological advancements on ceramic sector.
http://www.ceramicindustry.com/

A list of online materials on experiments in ceramic production.-
http://members.tripod.com/%7Eandavall/CeramicDir.html

Ceramic Pots, Vases & Decorations From Vietnam
http://www.vvg-vietnam.com/ceramics_vietnam.htm

The ceramic production process.
http://www.comecsrl.it/products.htm

General information on Ceramic sector
http://www.ceramic-tile.com/

Ceramic Industry in Italy
http://www.ceramics-online.it/en/index.cfm

America's Largest Domestic Porcelain Stone Tile Manufacturer,
http://www.crossville-ceramics.com/

The Brick Industry Association.
http://www.bia.org/index.html

VBSK- India
http://www.vsbkindia.com/index.htm

Dedicated to ceramics, industrial minerals, and related raw materials and equipment.
http://www.ceramics.com/

Equipment Suppliers

L & L Kiln Mfg. Inc. : This site features L&L Kiln Mfg., Inc., a manufacturer of electric kilns for ceramic production.
http://www.hotkilns.com/

The products, which designs and builds high temperature furnaces, ovens, kilns, quench tanks and heat treating systems, including special products for ceramic production.
http://www.hotfurnace.com/products.htm

Ceramic engineering and equipment, a supplier of ceramic machinery and equipment.
http://www.lexkiln.com/

Publications

Books, Videos, CDs on Ceramic Sectors .
http://www.ceramic-tile.com/pubbooks.html

Publications on brick industry
http://www.bia.org/pdfs/biacatalogm.xprs.pdf

Ceramic Technology Newsletter
http://www.ceramics.nist.gov/pubs/pubs.htm

Reference Guide that contain helpful information on the processes and problems encountered in everyday manufacturing situations.
http://www.ceramicindustry.com/FILES/HTML/ReferenceIndex/0,2796,,00.html

Journal of the European Ceramic Society
http://www.elsevier.nl/inca/publications/store/4/0/5/9/3/5/index.htt?menu=cont.astc09552219.1

Industrial Associations/ Organizations

The members of International Ceramic Federation in Asia, and Central and South America.
http://www.ceramic.or.jp/%7Eicf/otheraddresses.html

European Ceramic Society
http://www.chem.tue.nl/ecers/

National Institute of Standards and Technology - Ceramics Division
http://www.ceramics.nist.gov/

Spanish Ceramic Tile Manufacturers' Association
http://www.ascer.es

The American Ceramic Society
http://www.acers.org

Association of American Ceramic Component Manufacturers
http://www.aaccm.org

Brazilian Association of Ceramic Tiles Manufacturers
http://www.anfacer.org.br

Italian Association that promotes Faenza Ceramics
http://www.ceramichedifaenza.it/consorzio

Italian Association of Artistic Ceramics Manufacturer from the Veneto
http://www.ceramicaveneta.it

Italian Association of the manufacturers of ceramic glazes and metallic oxides
http://ceramicolor.federchimica.it

International association of distributors, manufacturers and allied professionals of ceramic tile and related products.
http://www.ctdahome.org

Ceramic Tile Contractors & Industry Association of British Columbia
http://www.ctcia.com

Ceramics Artists Association of Israel
http://www.israelceramics.org

Ceramic Arts Association of Western Australia
http://www.ceramicartswa.asn.au

Association of Clay & Glass Artists of California
http://www.acga.net

American Art Pottery Association
http://www.amartpot.org

ECerS European Ceramic Society
http://www.chem.tue.nl/ecers

Ceramic Export Manufacturer's Association, Inc.
http://www.dti.gov.ph/bdtp/trade_vol1/crema.htm

Academic/Training/Research Institutions

Belgian Ceramic Research Centre
http://www.bcrc.be

Center for Technology Transfers in Ceramics: research organization involved in technical ceramics
http://www.ceramic-center.com

Professional Training Association for the Ceramic Industry
http://www.cerform.it

Non-profit organization with the goal of encouraging cultural cooperation among ceramic artists throughout the world
http://www.karaart.com/academy

Ceramic Technical Industrial French Center
http://www.ceramique.fr

Swedish Ceramic Institute
http://www.keram.se/index.htm

The National Council on Education for the Ceramic Arts
http://nceca.net

APPENDIX C: GLOSSARY

{The initials q.v. (quod vide) after a word indicate that it is also explained in the glossary.}

Ball clay	Fine-grained clay consisting of 49-60% disordered kaolinite, 18-33% illite, 7-22% quartz, and 1-4% carbonaceous material.
Biscuit	Porcelain (q.v.) or other pottery that has been fired but not glazed (q.v.).
Blending	The mixing of clay with coal powder, water or other additives.
China Clay	Primary clay, or kaolin, that is white, refractory, and not very plastic.
Cream ware	Earthenware (q.v.) covered with a cream coloured glaze (q.v.).
Decals	An image or design printed with ceramic material on a special paper so that it can be transferred to bisque ware or glazes surface and fired to permanency.
Die	A pattern made of steel, acrylic, or wood for cutting or stamping clay, or pressing it through an extruder (q.v.) in order to produce the desired form.
Drying	The process by which the moisture content of the green bricks (q.v.) is reduced before being subjected to baking.
Earthenware	Pottery that has been fired at low temperature and is porous and relatively soft.
Extruder	A mechanical aid for forming (q.v.) moist clay by pressing it through a die (q.v) that causes the clay to take the shape of the die.
Extruding	The process by which semisolid paste of clay, coal or other additives are pressed and extracted out to form a continuous block that is cut to obtain individual green bricks. It is done in a machine known as extruding machine.
Firing zone	The zone in the kiln where the actual baking of the bricks takes place. The temperature is highest in this zone and a reducing atmosphere is maintained for clay transformation and vitirfication.
Firing Chamber	The chamber between the firebox and the chimney to hold the ware, contained in a muffle for firing. Also termed as the ware chamber.
Flash Glaze	The phenomena caused by fly ash alighting upon clay surfaces within the kiln and combining with silica therein to form a glaze

	(q.v).
Fly ash	The product residue resulting from the cleaning gases from incineration process.
Forming	Shaping clay into bricks.
Glaze	Any vitreous coating that has been melted onto a clay surface by the use of heat. Made of fine-ground materials that, when fired to a certain temperature, fuses into a glassy coating.
Green bricks	Newly cast, wet but firm bricks, which are put into a drying shed or hack to harden up before being transferred to the kiln (q.v).
Greenhouse Gases (GHG)	Gases that absorb heat in the atmosphere, responsible for enhancing the earth's greenhouse effect. *Eg.* CO_2, CH_4, NO_x, *etc.*
Hollow ware	Pots, jugs, mugs, bowls, made on a potter's wheel.
Intermittent Kiln	A kiln (q.v) where the firing cycle starts and ends at ambient temperature.
Intermittent operation	When the kilns (q.v.) are operated for batch production it is called intermittent operation. The kiln is heated up before the green bricks are filled and cooled before the bricks are drawn out.
Jiggering	A method of forming multiples rapidly. Soft clay is placed in a mold, pressed into or onto the mold walls either mechanically or by hand, and then trimmed to size by hand or with a jolley.
Kaolin	A white-firing natural clay that withstands high temperatures. An essential ingredient in porcelain (q.v.), also called as china clay
Kiln	A furnace or oven built of heat-resistant materials for firing pottery or sculpture
Kneading	The process by which the dry clay mixture is mixed with water; when done manually the process is commonly known as kneading
Particulate matter	Refers to all airborne finely divided solid or liquid material with an aerodynamic diameter smaller than 100 microns.
Plasticity (plastic clay)	The ability of a damp clay body to yield under pressure without cracking and to retain the formed shape after the pressure is released.
Porcelain	Porcelain is a combination of Kaolin (a pure, white, primary clay), silica and feldspar.

Primary Clay	Clay found in nature that was formed in place rather than transported by the action of water. Also called residual clay.
Primary Energy Consumption	Primary energy consumption is the amount of site consumption, plus losses that occur in the generation, transmission, and distribution of energy.
Specific Electrical Energy Consumption	The amount of electrical energy used to produce a unit quantity of brick/ceramic as kWh/kg or pieces.
Specific Energy Consumption	The amount of total energy used to produce unit quantity (usually kg or pieces) of brick/ceramic, expressed as kWh/kg or pieces.
Specific Thermal Energy Consumption	The amount of thermal energy used to produce unit quantity (usually kg or pieces) of brick/ceramic, expressed as kWh/kg or pieces.
Specific Pollution Load	The amount of pollutant generated per unit quantity of the product expressed as mg/kg, g/kg, kg/kg, or L/kg.
Stoneware	A type of clay body fired to a temperature at which the body becomes vitrified, dense, and non-absorptive, but not translucent. Natural stoneware clay is usually brownish in color because of the presence of iron. Usually matures at temperatures above 2192°F/1200°C.
Suspended particles	Solid or liquid particles in the atmosphere (With diameters around 0.3 to 10 microns) such as dust, lampblack, metallic particles, cement, pollen, organic compounds, etc.
Terra cotta	A brownish-orange earthenware clay body commonly used for ceramic sculpture.
Total Suspended Solids (TSS)	The portion of solids in water that is retained by filter when the sample is filtered.