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teri

(UNDP-GEF)

RESOURCE EFFICIENT BRICKS

Benefits of producing clay-fired REBs

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For more information

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About the Project "Energy Efficiency Improvements in Indian Brick Industry"

The UNDP-GEF intervention aims to address key barriers related to modernization of Indian brick sector. The project supports to reduce energy consumption and restrict GHG emissions by creating appropriate infrastructure for sustained adoption of new and improved technologies for production and use of resource-efficient bricks in India.

The project implementation includes the activities such as enhancing public sector awareness on resource-efficient products; access to finance for brick kiln entrepreneurs; improving knowledge on technology and marketing; availability of resource-efficient technology models, and improving capacity of brick kiln entrepreneurs.

The United Nations Development Programme (UNDP) is the GEF implementing agency for the project, the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India, is the executing agency, and The Energy and Resources Institute (TERI) is the responsible partner for project implementation.

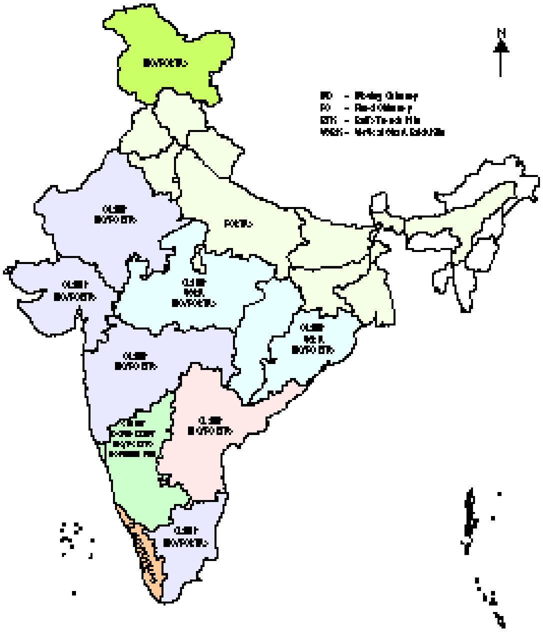
Introduction

The brick kiln entrepreneurs in India are switching over from manual processes to mechanization for clay preparation and green brick moulding. This provides an opportunity to produce clay-fired resource efficient bricks (REBs) like perforated bricks and hollow blocks in place of conventional handmade or extruded solid bricks. In order to motivate the brick kiln entrepreneurs to adopt production of clay-fired REBs, it is important to increase their awareness on benefits of producing REBs.

Under the UNDP-GEF brick project on 'Energy Efficiency Improvements in the Indian Brick Industry', TERI was entrusted with a study to carry out comprehensive resource audit of six brick kilns—2 brick kilns producing perforated bricks, 2 brick kilns producing hollow blocks, and 2 brick kilns producing conventional handmade solid bricks. This booklet presents the key results of the resource audit. The results clearly highlight the fact that it is economically beneficial for the brick kiln unit to produce REBs in place of conventional handmade solid bricks. It is expected that this booklet will help the brick kiln entrepreneurs in making an informed decision about production of REBs.

1.0 Background

Bricks are one of the oldest known building materials. Traditionally, the word 'brick' is exclusively associated with building units made of burnt clay. Bricks were the signature mark of the entire Indus cultural tradition, where mud bricks were used around 7000 BCE. It was discovered that most of the Indus Civilization's large cities, e.g. Harappa, Mohenjodaro, Kot Diji, Ganweriwala, Rakhigarhi, and Lothal, were constructed using both mud bricks and baked bricks. Bricks due to their enviable characteristics of pleasant aesthetic appearance, weathering resistance, thermal/acoustic insulating properties, and ease in handling/workability have maintained their position as a prominent walling material since the first use for building habitats. In spite of competition from a number of alternate building materials in the market, bricks are the preferred walling material in all climate regions of the world.



1.1 BRICK INDUSTRY IN INDIA

Brick manufacturing is one of the prominent industries positioned in the MSME (Micro, Small and Medium Enterprises) sector in India. Brick kilns are generally located in clusters that are spread throughout the country. The industry is seasonal and usually operates during November to June each year (avoiding rainy season). The industry is also labour intensive, and is typically characterized by use of inefficient manufacturing methods/technologies and has witnessed a limited level of mechanization.

Brick manufacturing being an unorganized activity, the industry-specific parameters such as size, production, energy consumption, turnover, etc., are not readily available for the sector. A national level study undertaken by TERI during 2000/01 had estimated that about 90,000 brick kilns were operating in the country during the period and were annually producing 144 billion bricks, using 24 million tonnes of coal and 3 million tonnes of biomass. A similar study was undertaken by TERI during 2013/15 and the results are provided in Table 1. Both the studies clearly ascertain that the brick industry in the country is quite energy-intensive and accounts for a sizeable share of coal consumption in the country.

The basic raw material for brick making is clay. Coal and locally available biomass are used as fuel. Bull's Trench Kilns (BTKs) and clamp kiln are the main brick firing technologies used for firing of bricks in the country. Use of BTK is more common in the northern and eastern parts of the country. This technology is also used in small pockets spread across various states in central, western and southern India. The clamp kiln technology is prevalent in the southern, central, and western parts of the country. Essentially, the entire brick production in the country is in the form of solid bricks, using top soil from the nearby agricultural fields.

Table 1: Brick production and resource consumption by Indian brick sector

Sr No.	Parameter	2013-15 study*
1	Number of brick kilns**	190,000- 280,000
	Clamp kiln	147,000 - 232,000
	BTK	42,000 - 47,000
	Others	500 -1000
2	Annual brick production (billion)	220 - 280
3	Annual coal consumption (million tonnes)	29 - 35
4	Annual biomass consumption (million tonnes)	12 - 16
5	Annual top soil consumption (million m^3)	400 - 500
6	Annual water consumption (million m^3)	200 - 235

Notes: * The results are based on joint analysis by TERI and PSCST
**The estimate of number of clamp kilns in operation can vary significantly depending upon the market demand. Clamp kilns are not registered and are not members of any industry associations.

2.0 Manufacturing process

The basic principles of brick manufacturing are fairly uniform throughout the country. It essentially consists of mixing ground clay with water, its formation into the desired shapes followed by drying, firing, and cooling. An individual unit may undertake certain variations to adjust to their particular raw material and method of operation. The general steps to produce fired brick are shown in Figure 1 and the brief description of each process is provided in the following section.

2.1 CLAY WINNING

The basic raw material for green brick preparation is clay[1] which is generally mined from the nearby agricultural field. Over the years, the local availability of clay has reduced, therefore, clay is transported to the green brick moulding site from a distance that ranges up to 10 kilometres. In some parts of the country, specifically in south India, the de-silted sand from lakes and ponds is also used for brick making. The conventional process of manual excavation is now being

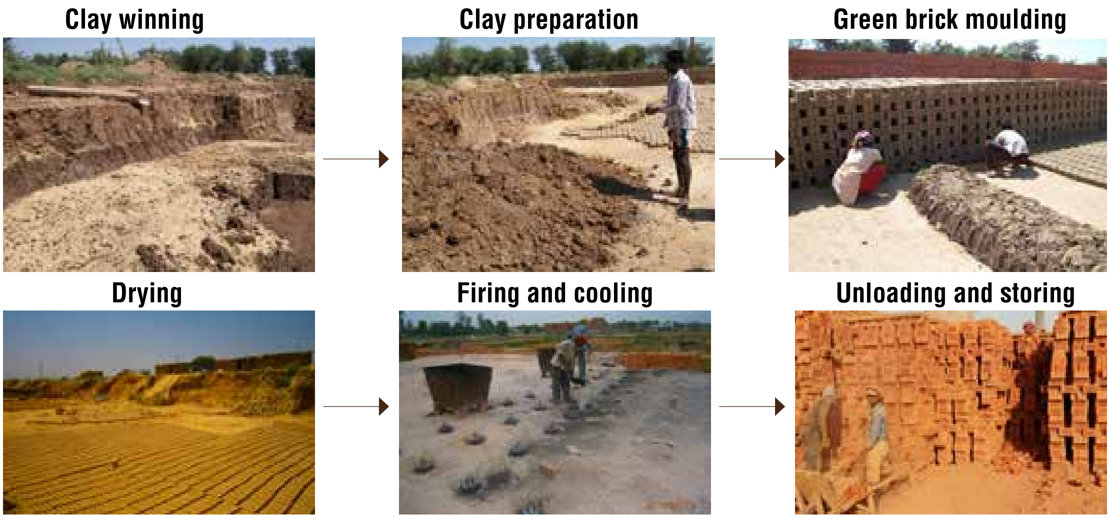


Figure 1: Brick making process

Source: TERI and PSCST

[1] Clay is hydrated alumino-silicate mineral having fine particle sizes, usually below 2 microns. Clay minerals have a layered structure and many a times, the aluminium is replaced partly or wholly by magnesium, iron, alkali or alkaline earth elements.

replaced by mechanical means of excavation. It is a common practice at the brick kiln site to store enough quantity of clay to ensure continuous operation for several days, regardless of the weather conditions.

2.2 CLAY PREPARATION

Clay preparation involves the processes that render the clay homogeneous, workable, and makes it suitable for shaping process. Clay is processed to free it from gravel, lime, kankar particles, and organic matter. It is then puddled, watered, and left (generally for 12–24 hours) for weathering and subsequent processing. This is followed by kneading of the homogenised clay with spade or other manual/mechanical equipments into a plastic mass.

2.3 GREEN BRICK MOULDING

Subsequent to pugging/kneading, plastic clay mass becomes ready for the forming or moulding step. Traditionally, bricks are moulded manually using metal or wooden mould. However, mechanized clay preparation and moulding processes are gaining popularity among the brick manufacturers, wherein the following three principal processes are used for brick moulding:

2.3.1 Soft-mud process

In this process, similar to hand moulding, clay is mixed with about 20–30% of water (by weight), followed by formation of the mould. For proper moulding of clay into brick, clay should be soft and at the same time, it should be firm enough to maintain its shape after its release from the mould. To enable the shaped clay mass to leave the mould readily, a lubricant generally in the form of sand is used.

2.3.2 Stiff-mud process

In stiff-mud/extrusion process, clay is mixed with about 12–15% by weight of water to make it plastic. After thorough mixing, tempered clay goes through a de-airing chamber in which a vacuum of 15–29 inch (375–725 mm) of mercury is maintained. The de-airing process removes air holes and bubbles and imparts increased workability and plasticity to the clay. Since a certain amount of water is evaporated during the passage of clay through the vacuum chamber, an allowance is often kept while adjusting the

Figure 2: Hand moulding

Figure 3: Brick extrusion

consistency of clay mix. After de-airing, clay is extruded through a die to produce a column of clay, which passes through an automatic cutter to make the final brick unit of desired size.

2.3.3 Dry press process

In this process, clay is mixed with a minimum quantity of water (upto 10% by weight), followed by forming in steel moulds, under pressure, using hydraulic or compressed air rams. This process is suitable for clays which have very low plasticity.

2.4 DRYING

The green moulded brick contains 7–30% moisture, contingent on the type of moulding. During the drying process, most of the moisture contained in the green brick is evaporated either through natural drying in open air (Figure 4) or in ventilated drying sheds (Figure 5). The natural drying method is the most common method of brick drying adopted in the country. The drying time of bricks usually varies from 24 to 120 hours depending upon clay type and weather conditions.

2.5 FIRING AND COOLING

The purpose of firing is to convert a fairly loosely compacted blend of different minerals into a strong, hard, and stable product—the fired brick. Firing is the most energy-intensive process in brick manufacturing. The firing process determines the properties of the fired brick—strength, porosity, stability against moisture, hardness, etc. Depending on the nature of clay, bricks are generally fired in a temperature range of 700–1100°C. During firing, several important changes occur in the physical and chemical properties of the clay body (Figure 6). The chemical reactions which take place during the firing process depend on the composition and nature of clay used. A brief description of the various processes that occur during clay firing is provided in the following section.

2.5.1 Removal of mechanical moisture

Depending upon the climatic conditions, about 4–12% of moisture still remains in the green

Figure 4: Natural drying

Figure 5: Shed drying

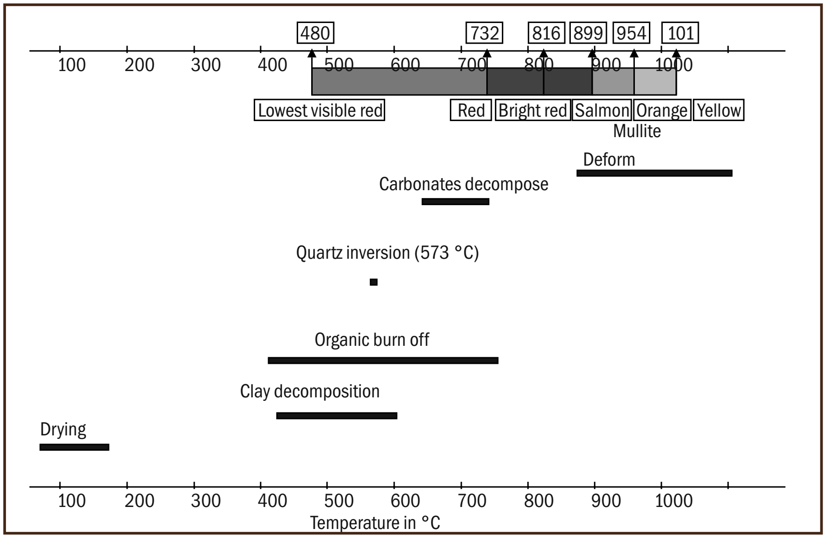


Figure 6: Action of heat on clay

bricks during its loading in the kiln for firing. The first stage of heating involves removal of this moisture. When the temperature of the bricks reaches about 150°C, almost all mechanically held water is evaporated.

2.5.2 Combustion of carbonaceous matter

During excavation of clay, some amount of carbonaceous organic matter (plant material such as roots, leaves, etc.) comes along with the clay. During the clay preparation process, most of the organic matter is removed. However, some amount of organic matter still remains in the clay. In some parts of the country like Datia (Madhya Pradesh), Raigad (Maharashtra), and Kankia (Odisha), agricultural residues (wheat straw/rice husk) are also added to clay as internal fuel. During the firing process, combustion of the organic matter is initiated at about 400°C and this process is completed when the temperature reaches about 700°C.

2.5.3 Decomposition of clay molecule and release of combined water

The clay material consists of several chemical compounds; kaoline ($Al_2O_3.2SiO_2.2H_2O$) being the major component of clay. When clay is heated, it starts decomposing at a temperature range of 450–600°C, resulting in release of combined water. In two other significant clay minerals, Montmorillonite and Illite, removal of the combined water starts at a lower temperature compared to Kaolinite.

$$Al_2O_3.2SiO_2.2H_2O \rightarrow Al_2O_3 + 2SiO_2 + 2H_2O$$

When clay is heated to about 600°C, it does not remain plastic. Therefore, this is the minimum temperature to which the clay should be fired.

2.5.4 Quartz inversion

Quartz occurs as alpha-quartz in nature. During clay heating at a temperature of 573°C, alpha-quartz changes its form to beta-quartz instantaneously and this transformation is accompanied by an exothermic effect (i.e. release of heat) and an expansion of volume by about 2%. As a result, rapid heating of large alpha-quartz grains occurs, often causing the crystals to shatter. During cooling, beta to alpha change occurs. Therefore, heating and cooling rates near quartz inversion temperature have to be controlled for preventing crack formation in bricks.

2.5.5 Vitrification

Vitrification entails partial melting of clay particles at points of contact, to form a glassy bond, which binds the entire mass together and provides strength (Figure 7). Vitrification of clay commences at about 900°C. However, it may vary depending upon the type of clay used for brick preparation. As temperature increases, more melting of clay mass occurs. The extent to which a mass of clay is melted depends on the temperature of the clay mass, duration of firing, type of minerals constituting clay, including their proportion and particularly the amount of fluxing oxides (ferrous oxide, lime, magnesia, and potash) being produced during the firing process.

2.6 UNLOADING AND STORING

The fired bricks are allowed to cool in the kilns which are then unloaded, sorted, and stacked for sale. In the Indo-Gangetic belt, fired bricks are classified into different categories (For example, class-I, class-II, class-III, etc.) based on their quality. The fired brick quality at the brick kiln is judged by visual observation. The best quality bricks fetch a higher price than other categories of bricks in the market.

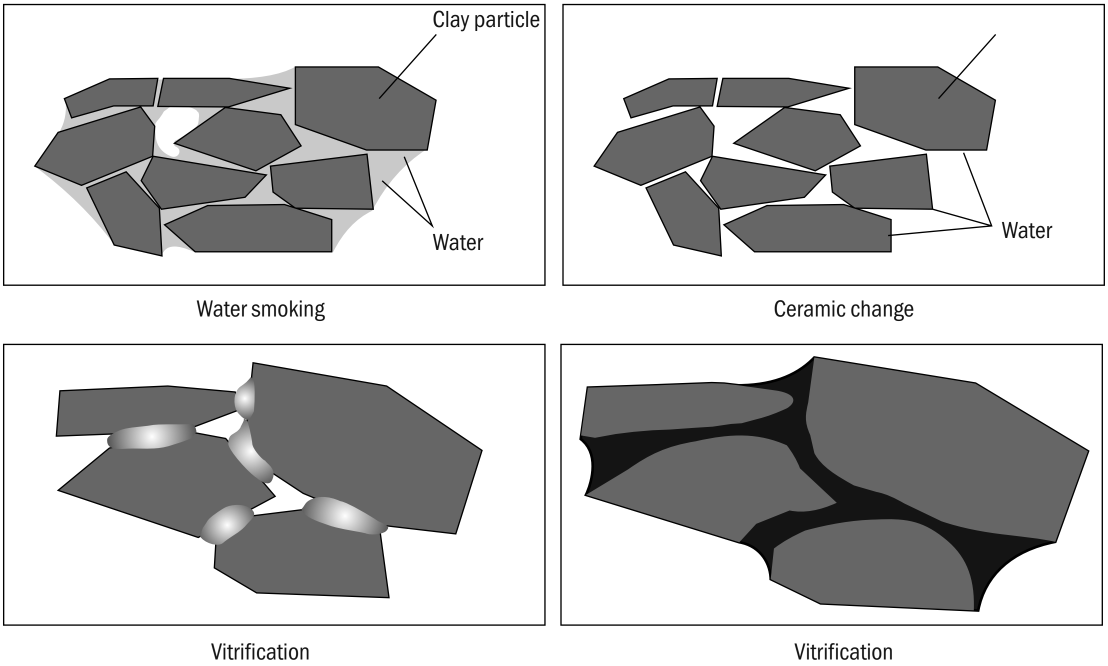


Figure 7: Vitrification of clay

3.0 Conventional handmade solid bricks

Majority of the brick production in India is in the form of hand moulded solid bricks. The Indian standard code related to hand moulded solid brick is IS 1077:1992 (Reaffirmed 2007) Common Burnt Clay Building Bricks Specifications. As per this code, general specifications for common burnt clay building bricks are described as follows:

3.1 CLASSIFICATION

Based on the compressive strength, the common burnt clay bricks are classified in 11 categories as enumerated in Table 2.

Table 2: Classes of common burnt clay bricks

Class Designation	Average Compressive Strength not less than	
	N/mm²	Kgf/cm² (approx.)
35	35.0	350
30	30.0	300
25	25.0	250
20	20.0	200
17.5	17.5	175
15	15.0	150
12.5	12.5	125
10	10.0	100
7.5	7.5	75
5	5.0	50
3.5	3.5	35

3.2 DIMENSIONS

The standard size of the common building bricks is provided in Table 3.

Table 3: Standard size of the common building bricks

Type of brick	Length (mm)	Width (mm)	Height (mm)
Modular	190	90	90
	190	90	40
Non-Modular	230	110	70
	230	110	30

3.3 COMPRESSIVE STRENGTH

The compressive strength of an individual brick shall not be less than the minimum compressive strength specified for the corresponding class of the brick by more than 15%.

3.4 WATER ABSORPTION

The water absorption in the bricks after immersion in cold water for 24 hours shall not be more than 20% by weight up to class 12.5 and 15% by weight for higher classes.

4.0 Resource efficient bricks

Although conventional handmade solid bricks are mainly produced in India, yet since the last few years, clay-fired resource efficient bricks (REBs), like hollow blocks and perforated bricks, have also starting emerging in the market. Some of the reasons leading to emergence of this product in the market include:

- With less availability of space due to increasing population and demand, majority of the construction in cities and towns is taking place in the form of multi-storey buildings using RCC (Reinforced Concrete Cement) columns. In RCC column-based buildings, bricks are increasingly being used as filler material rather than load bearing walls. This scenario offers more importance to REBs as these products can be effectively used as a non-load bearing material in place of conventional solid bricks. Production of REBs results in less consumption of resources (clay, fuel like coal, biomass). Similarly, during their use as walling unit in buildings, REBs help in savings of cement (in mortar and plastering) and steel (due to reduced dead load).
- During the last few years, the market for walling materials in India is changing. The customers have started demanding niche products that are resource efficient during their use in buildings. The building norms (like ECBC) and rating systems[2] (GRIHA or LEED) also promote the usage of such walling materials that are resource efficient. Clay-fired REBs are most suitable materials that fit these criteria.
- The production of hand-moulded solid brick is a manpower-intensive process. Each brick kiln employs around 150 persons to produce

[2] GRIHA (Green Rating for Integrated Habitat Assessment) and LEED (Leadership and Energy and Environmental Design) are building rating systems that certifies a building based on the defined environmental performance and resource efficiency criteria's.

about 30,000 fired bricks per day. Majority is the manpower is used in green brick moulding process. A significant proportion of the labour employed on brick kilns is migratory. However, during the last few years due to various policy initiatives by the government, such as the Mahatama Gandhi National Rural Employment Guarantee Act (MNREGA), the migration of the workers, to look out for employment opportunities outside their village, has reduced. This has compelled the brick kiln entrepreneurs to look out for the options that reduce their dependence on labour. Adoption of mechanization/semi-mechanization for green brick preparation is one such viable option for brick kiln entrepreneurs. Use of mechanization for green brick production enables the brick kiln for production of REBs.

Different types of clay-fired REBs being produced in the Indian market are shown in Figure 8 and the increase in their production during the last few years is shown in Figures 9 and 10, respectively.

The Indian standard codes related to clay-fired REBs are:

- Perforated brick: IS 2222: 1991 (reaffirmed 2007)—Specification for burnt clay perforated building bricks
- Hollow block: IS 3952: 2013—Burnt clay hollow brick and blocks for walls and partitions

Figure 8: Different types of clay-fired REBs produced in India

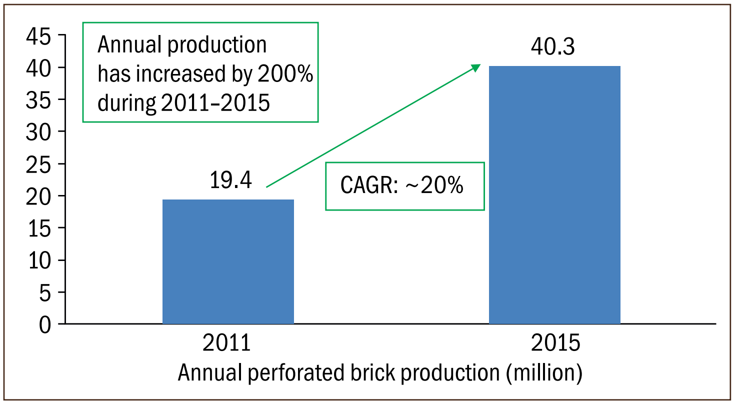


Figure 9: Increase in production of perforated bricks

Source: UNDP-GEF project on 'Energy Efficiency Improvements in Indian Brick Industry'

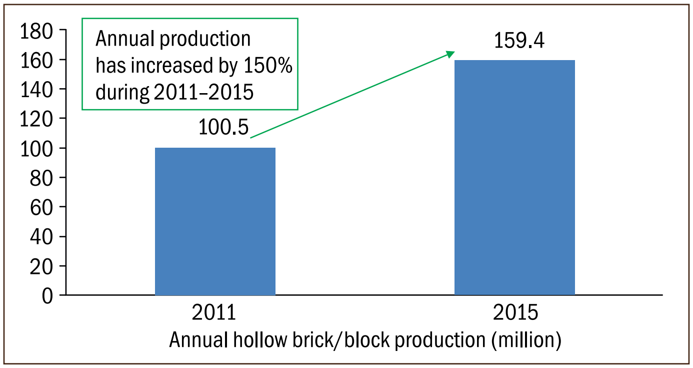


Figure 10: Increase in production of perforated bricks
Source: UNDP-GEF project on 'Energy Efficiency Improvements in Indian Brick Industry'

4.1 PERFORATED BRICKS

As per IS 2222: 1991 (reaffirmed 2007), the general specifications for burnt clay perforated building bricks include the following:

4.1.1 Dimensions of the brick

Type of brick	Length (mm)	Width (mm)	Height (mm)
Modular	190	90	90
Non-modular	230	110	70

4.1.2 Perforations

The area of perforations should be between 30% and 45% of the total area of the corresponding face of the brick.

The perforations should be uniformly distributed over the surface. The area of each perforation shall not exceed 500mm^2. The thickness of any shell shall not be less than 15 mm and that of any web shall not be less than 10 mm. The shorter side of the perforations shall be less than 20 mm in case of rectangular perforation and less than 25 mm diameter in case of circular perforations.

4.1.3 Compressive strength

The minimum average compressive strength of the brick should be 7 N/mm^2 on net area.

4.1.4 Water Absorption

The water absorption in the bricks immersion in cold water for 24 hours shall not be more than 20% by weight.

4.1.5 Warpage

The average warpage in the brick shall not exceed 3 percent.

4.2 HOLLOW BLOCKS

As per IS 3952: 2013, the general specifications for burnt clay hollow bricks and blocks for walls and partitions include the following:

4.2.1 Types

The brick/block shall be of the following types:

- **Type A**: Brick/block with both faces keyed for plastering or rendering
- **Type B**: Brick/block with both faces smooth and suitable for use without plastering or

rendering on either side

- **Type C**: Brick/blocks with one face keyed and one face smooth

4.2.2 Dimensions

Type of product	Length (mm)	Width (mm)	Height (mm)
Hollow bricks	190	190	90
	290	90	90
	290	140	90
Hollow blocks	400	200	200
	400	150	200
	400	100	200

4.2.3 Hollows

- The volume of holes passing through the brick/block shall be more than 25% of the total volume of the brick/block and holes shall not be small[3]
- The hollows may be right angle or parallel to the bearing surface
- The thickness of any shell shall not be less than 11 mm and that of any web not less than 8 mm

4.2.4 Crushing strength

The minimum average crushing strength of the bricks/blocks shall be 3.5 N/mm^2.

4.2.5 Water absorption

The average water absorption of the bricks/ blocks shall not be more than 20% by weight.

Type of Brick	Relevant IS Code
Conventional Solid Brick	IS 1077:1992 (Reaffirmed 2007)-Common Burnt Clay Building Bricks
Perforated Brick	IS 2222: 1991 (reaffirmed 2007)—Specification for burnt clay perforated building bricks
Hollow Block	IS 3952: 2013—Burnt clay hollow brick and blocks for walls and partitions

[3] A small hole is one having width less than 20 mm and area less than 500mm^2 (IS 2248:1192- Glossary of terms relating to clay products for buildings)

5.0 Resource efficient brick production

In order to ensure REB production, the green brick production process has to be mechanized. The first steps in manufacturing clay-fired REBs include preparation of proper raw-mix and production of green products. The commonly employed mechanical method of green brick/ block manufacturing is the extrusion process. The clay from the agricultural fields is excavated manually or mechanically and is transported and stored at the green brick making sites. The clay is left for weathering and the weathered clay is thereafter passed through set of equipment's to produce green bricks.

5.1 EQUIPMENT USED FOR CLAY PREPARATION AND MOULDING

General equipment that will be used in a brick kiln for clay preparation and green brick moulding are summarized in the following sections:

5.1.1 Box Feeder

Box feeder consists of rectangular chamber of one or more compartments fitted with an intermittently moving conveyor. The speed of the moving base can be adjusted as per the output requirements.

5.1.2 Crushing Roller

Crushing Roller has a pair of smooth rollers mounted on horizontal spindles. The clay particles are broken down between the rollers by pressure. The rolls move in opposite directions and sometimes at different speeds to increase the shear.

Depending upon the characteristics of clay, additional equipment, such as clay-mixer or another set of rollers, may be required to improve the workability of clay.

5.1.3 Extrusion

Most structural clay products, including REBs, are manufactured by the extrusion process. The shapes of the structural clay products made by this process are precise and uniform. Machinery required for extrusion process is adaptable to automation and high speed production. The clay after preparation is fed to the extrusion machine to prepare the product of desired size and shape. The clay mass is mixed with about 12%–15% (by weight) of water to make it plastic. The plastic clay passing through an extrusion machine contain air. For better quality of product, it is important to remove this air (especially when the clay has low plasticity). The trapped air is removed through a de-airing process wherein the tempered clay mass is passed through the de-airing chamber in which a vacuum of 15–29 inch (375–725 mm) of mercury is maintained. The de-airing process removes air holes and bubbles and improves the workability and plasticity of clay. After de-airing, the clay is extruded through die. The shape and construction of die depends upon the article to be made. After coming out of die, the clay column is cut into desired size by using an automatic/ manually operated cutter on a cutting table.

5.2 INVESTMENT IN PLANT AND MACHINERY

For REB production, a mechanized clay preparation and green brick production unit is required. The total investment on plant and machinery depends upon the desired output (number of bricks per day) of the brick kiln. The details of investment for a typical brick kiln unit producing 5000 bricks per hour are provided in Table 4.

5.2.1 Additional operating expenses

Due to adoption of mechanization, certain additional expenses have to be incurred by the brick kiln. The major recurring expense is on power/diesel for operation of various machines. Other expenses include some additional manpower, for instance, a marketing representative, computer operator, guard, etc.; these expenses are enumerated in Table 5.

Table 5: Additional operating expenses

S.No	Particulars	Amount (INR in Lakhs)
1	Power/Diesel	16.4
2	Extra Labour	4.9
3	Repair and Maintenance	4.3
	Total	25.6

Table 4: Investment in plant and machinery for producing 5000 bricks per hour

S.No.	Particulars	Amount (INR in Lakhs)
Plant & Machinery		
1	Boxfeeder (14)’	13.6
2	Fine roller (800 x 600)	9.6
3	Clay Mixer (3.5’ x2’)	8.3
4	De-airing Pugmill (18”)	17.5
5	Vacuum Pump	1.3
6	Automatic Brick cutter	7.5
7	Belt Conveyor 30 metre (3@10m)	4.5
8	Electric Motors 159 HP (10 nos.)	6.5
9	Electrification charges including labour, control panel, wiring	8.0
10	Battery car 3 wheel type (8 nos.)	12.0
11	Foundation, Erection and Commissioning	5.0
12	Generator 200 kVA	12.0
	Total	105.8
Building		
1	Machinery shed (6000 sqft)	12.0
2	Drying shed (50,000 sqft)	50.0
3	Office building	5.0
	Total	67.0
Pre-operative expenses		
1	Electricity connection	15.0
2	Legal expenses	1.0
3	Testing, etc.	1.0
	Total	17.0
Others		
1	Miscellaneous Fixed assets (Lump-sum)	3.0
	Total	3.0
Grand Total		192.7

6.0 Energy consumption for REB production

Since the last few years, many brick kilns have started manufacturing REBs in addition to conventional solid bricks. To establish the benefits of producing REBs in place of conventional solid bricks, a comprehensive study was undertaken by TERI. In the study, resource auditing of six brick kilns operating in different geographical locations of the country was carried out. Four brick kilns were using BTK technology and two brick kilns were using Hoffman technology for firing of green bricks. In the study, two types of REBs were monitored. The key findings of the study are highlighted in the following section.

Figure 11: Type of perforated brick manufactured

6.1 KILN 1

The brick kiln is using semi-mechanized process for green brick preparation and BTK technology for firing of bricks. The brick kiln produces perforated bricks with 8% perforations. The production capacity of the kiln is about 13 lakh bricks per circuit. For operation of the kiln, about 80 persons are employed. The type of bricks produced in the kiln is shown in Figure 11 and the details are provided in Table 6.

Table 6: Details of bricks produced

Type of perforations	3 holes
Percentage perforation	8%
Diameter of hole (mm)	30
Size of green brick (mm)	234× 114 × 75
Weight of green brick (kg)	3.55
Size of fired brick (mm)	230 × 114 × 73
Weight of fired brick (kg)	3.48

6.1.1 Energy consumption

The kiln has installed an extrusion machine of Chinese-make. The production capacity of extrusion machine is 6500 bricks per hour and is operated for about 8 hours per day. The average production by the machine during the monitoring period was 5588 bricks per hour

(86% of installed capacity). The average power consumption of the machinery installed at the kiln was 106 kW. The brick kiln uses coal as fuel for firing of bricks. The overall specific energy consumption (SEC) of the unit is 1.09 MJ per kg fired brick, which is predominantly thermal energy. The SEC of the unit is provided in Table 7.

Table 7: Specific energy consumption of kiln

Type of fuel used	Coal
GCV of coal (MJ/kg)	33.3
SEC - Thermal (MJ/kg-fired brick)	1.06
SEC – Electrical (kWh/kg-fired brick)	0.006
SEC – Overall (MJ/kg-fired brick)	1.09

The total energy consumption of the kiln is 1064 MJ per tonnes of fired brick. The distribution of energy consumption across various areas in the kiln is shown in Figure 12.

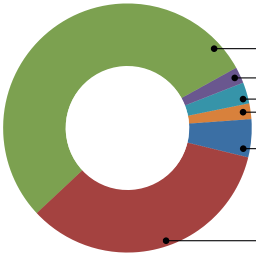


Figure 12: Energy balance of the kiln

6.2 KILN 2

The brick kiln is using manual hand-moulding process for green brick preparation and BTK technology for firing of bricks. The kiln is producing solid bricks. The production capacity of the kiln is about 13 lakh bricks per circuit. For operation of the kiln, about 170 persons are employed. The type of brick produced in the kiln

Figure 13: Type of bricks manufactured

is shown in Figure 13 and the details are provided in Table 8.

Table 8: Details of bricks produced

Percentage perforation	-N.A.-
Type of perforations	-N.A.-
Diameter of hole (mm)	-N.A.-
Size of green brick (mm)	234×117×76
Weight of green brick (kg)	3.68
Size of fired brick (mm)	232×114×76
Weight of fired brick (kg)	3.41

6.2.1 Energy consumption

The brick kiln uses coal for firing of bricks. The overall SEC of the unit is 1.12 MJ per kg fired brick, which is predominantly thermal energy. The SEC of the unit is provided in Table 9.

Table 9: Specific energy consumption of kiln

Type of fuel used	Coal
GCV of coal (MJ/kg)	32.9
SEC - Thermal (MJ/kg-fired brick)	1.12
SEC – Electrical (kWh/kg-fired brick)	-N.A.-
SEC – Overall (MJ/kg-fired brick)	1.12

The total energy consumption of the kiln is 1116 MJ per tonne of fired brick. The distribution of energy consumption across various areas in the kiln is shown in Figure 14.

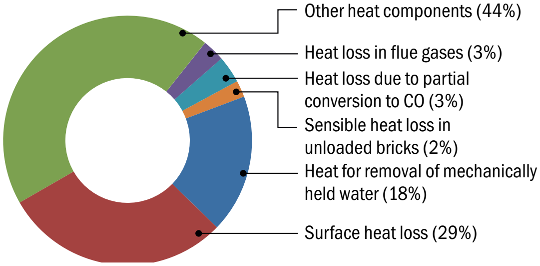


Figure 14: Energy balance of the kiln

6.3 KILN 3

The brick kiln is using semi-mechanized process for green brick preparation and BTK technology for firing of bricks. The brick kiln produces perforated bricks with 8% perforations. The production capacity of the kiln is about 14 lakh bricks per circuit. For operation of the kiln, about 70 persons are employed. The type of brick produced in the kiln is provided in Table 10 and is shown in Figure 15.

Table 10: Details of bricks produced	
Percentage perforation	8%
Type of perforations	3 holes
Diameter of hole (mm)	30
Size of green brick (mm)	230×113×69
Weight of green brick (kg)	3.27
Size of fired brick (mm)	228×109×68
Weight of fired brick (kg)	3.0

6.3.1 Energy consumption

The brick kiln uses coal for firing of bricks. The kiln has installed an extrusion machine of Chinese-make. The production capacity of extrusion machine is 9500 bricks per hour and is operated

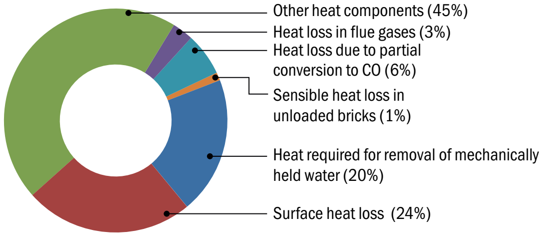


Figure 15: Type of brick manufactured

for about 8 hours per day. The average power consumption of the machinery installed at the kiln was 140 kW. The overall SEC of the unit, provided in Table 11, is 1.18 MJ per kg fired brick, which is predominantly thermal energy.

Table 11: Specific energy consumption of kiln	
Type of fuel used	Coal
GCV of coal (MJ/kg)	33.2
SEC - Thermal (MJ/kg-fired brick)	1.16
SEC – Electrical (kWh/kg-fired brick)	0.006
SEC – Overall (MJ/kg-fired brick)	1.18

The total energy consumption of the kiln is 1162 MJ per tonne of fired brick. The distribution of energy consumption across various areas in the kiln is shown in Figure 16.

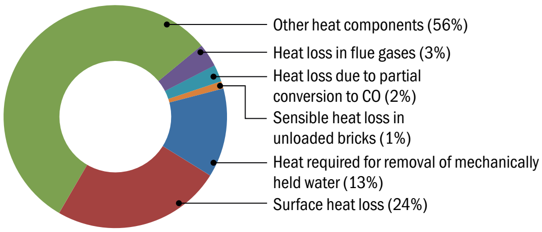


Figure 16: Energy balance of the kiln

6.4 KILN 4

The brick kiln is using manual hand-moulding process for green brick preparation and BTK technology for firing of bricks. The kiln is producing solid bricks. The production capacity of the kiln is about 14 lakh bricks per circuit. For operation of the kiln about 190 persons are employed. The type of the brick produced in the kiln is shown in figure 17 and the details are provided in Table 12.

Figure 17: Type of brick manufactured

Table 12: Details of bricks produced	
Percentage perforation	-N.A.-
Type of perforations	-N.A.-
Diameter of hole (mm)	-N.A.
Size of green brick (mm)	224×111×71
Weight of green brick (kg)	3.05
Size of fired brick (mm)	224×109×68
Weight of fired brick (kg)	2.87

6.4.1 Energy consumption

The brick kiln uses coal for firing of bricks. The overall SEC of the unit is 1.21 MJ per kg fired brick, which is predominantly thermal energy. The SEC of the unit is provided in Table 13.

Table 13: Specific energy consumption (SEC) of kiln	
Type of fuel used	Coal
GCV of coal (MJ/kg)	33.2
SEC - Thermal (MJ/kg-fired brick)	1.21
SEC – Electrical (kWh/kg-fired brick)	-N.A.-
SEC – Overall (MJ/kg-fired brick)	1.21

The total energy consumption of the kiln is 1214 MJ per tonne of fired brick. The distribution of energy consumption across various areas in the kiln is shown in Figure 18.

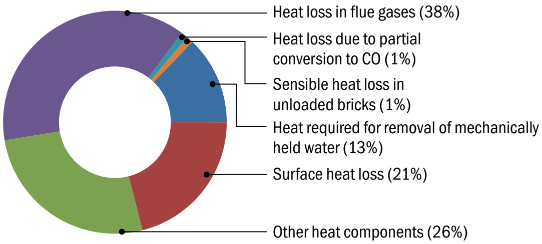


Figure 18: Energy balance of the kiln

6.5 KILN 5

The brick kiln is using semi-mechanized process for green brick preparation and Hoffman technology for firing of bricks. The kiln is producing hollow blocks and tiles. For operation of the kiln, about 60 persons are employed. The production capacity of the kiln is about 230 tonnes per circuit. The brick kiln is producing different types of clay-fired blocks. During the monitoring period, the kiln was producing blocks with 48% perforations. The details of the block produced at the kiln during the monitoring period are provided in Table 14 and the type of the block is shown in Figure 19.

Figure 19: Type of hollow block manufactured

Table 14: Details of blocks produced	
Percentage perforation	48%
Number of blocks in each chamber	1200
Total numbers of chambers in kiln	31
Number of chambers fired per day	3
Average Size of green block (mm)	383×202×100
Average Weight of green block (kg)	6.88
Average Size of fired block (mm)	377×198×98
Average Weight of fired block (kg)	6.24

6.5.1 Energy consumption

The brick kiln uses coal for firing of bricks. Two extrusion machines of Indian make are installed for production of blocks. The kiln is involved in production of various types of hollow blocks and tiles. The average power consumption of the machinery installed at the kiln was 90 kW. The overall SEC of the unit is 2.05 MJ per kg fired block, is predominantly thermal energy. The SEC of the unit is provided in Table 15.

Table 15: Specific energy consumption of kiln	
Type of fuel used	Coal
GCV of coal (MJ/kg)	15.3
SEC - Thermal (MJ/kg-fired brick)	1.945
SEC – Electrical (kWh/kg-fired brick)	0.028
SEC – Overall (MJ/kg-fired brick)	2.05

The total energy consumption of the kiln is 1944 MJ per tonne of fired block. The distribution of energy consumption across various areas in the kiln is shown in Figure 20.

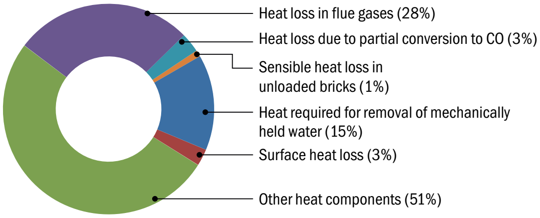


Figure 20: Energy balance of the kiln

6.6 KILN 6

The brick kiln is using a semi-mechanized process for green brick preparation and Hoffman technology for firing of bricks. The kiln is producing hollow blocks and tiles. The production capacity of the kiln is about 200 tonnes per circuit. The brick kiln is producing different types of clay-fired blocks. During the monitoring period, the kiln was producing blocks with 52% perforations. The details of the block produced at the kiln during the monitoring period are provided in Table 16 and the type of block is shown in Figure 21.

Table 16: Details of blocks produced

Average perforations (%)	52
Number of blocks in each chamber	1000
Total numbers of chambers in kiln	36
Number of chambers fired per day	5
Average Size of green block (mm)	385×213×156
Average Weight of green block (kg)	10.63
Average Size of fired block (mm)	381×209×154
Average Weight of fired block (kg)	9.47

6.6.1 Energy consumption

The brick kiln uses coal for firing of bricks. The kiln has installed a European-make extrusion machine. The average power consumption of the machinery installed at the kiln was 98 kW. The overall specific energy consumption (SEC) of the unit is 2.05 MJ per kg fired block, which is predominantly thermal energy. The SEC of the unit is provided in Table 17.

Table 17: Specific energy consumption of kiln

Type of fuel used	Wood
GCV of coal (MJ/kg)	14.5
SEC - Thermal (MJ/kg-fired brick)	2.12
SEC – Electrical (kWh/kg-fired brick)	0.017
SEC – Overall (MJ/kg-fired brick)	2.18

The total energy consumption of the kiln is 2116 MJ per tonne of fired block. The distribution of energy consumption across various areas in the kiln is shown in Figure 22.

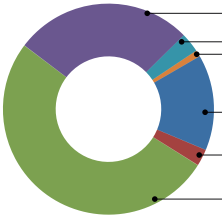


Figure 22: Energy balance of the kiln

Figure 21: Type of hollow block manufactured

7.0 Benefits of REBs production

The study conducted by TERI focussed on acquiring knowledge about three types of bricks, namely, conventional solid bricks, perforated bricks with 8% perforations, and hollow blocks with large perforations (48% to 52%). However, for a more representative analysis of the different types of clay-fired products being manufactured in the country, following additional types of bricks were also considered in the analysis:[4]

- Extruded solid bricks
- Perforated bricks with 10% perforations
- Perforated bricks with 15% perforations

The major benefits of producing REBs include savings in clay, fuel, reduction in manpower requirements, and production cost. These benefits are highlighted in detail in the following sections.

7.1 CLAY SAVINGS

Clay is the major raw material used for brick manufacturing. For a typical one cubic meter ($1m^3$) wall section, the clay savings with production of REBs in place of conventional hand moulded solid brick and extruded solid bricks, are highlighted in Tables 18 and 19, respectively. It can be seen that clay savings are directly proportional to perforations or hollowness of the REBs.

Table 18: Clay savings: REBs (perforated bricks and hollow blocks) vis-à-vis conventional hand-moulded solid bricks

Parameter	Perforated brick			Hollow block	
Perforation (%)	8	15	30	48	52
Clay saving (kg)	upto 55	167 to 408	419 to 635	788 to 876	868 to 957
Clay saving (%)	upto 3	10 to 24	26 to 37	48 to 51	53 to 55

[3] A few parameters like dimensions and weight of the perforated bricks (10% and 15% perforations) were measured in the field and have been used in the analysis. The parameters of extruded solid bricks are derived from perforated bricks with 8% perforations.

Table 19: Clay savings: REBs vis-à-vis extruded solid bricks						
Parameter	Conventional hand-moulded solid brick	Perforated brick			Hollow block	
Perforation (%)	–	8	15	30	48	52
Clay saving (kg)	94 to 249	84 to 215	349 to 568	602 to 795	970 to 1036	1050 to 1117
Clay saving (%)	5 to 13	5 to 11	19 to 30	33 to 42	53 to 55	58 to 59

The summary of clay savings are shown in Figure 23.

7.2 ENERGY SAVINGS

Coal and wood were used as fuel in brick kilns monitored during the study. For a typical one cubic meter ($1m^3$) wall section, the energy savings with production of REBs in place of conventional hand moulded solid brick and extruded solid bricks are highlighted in Tables 20 and 21, respectively.

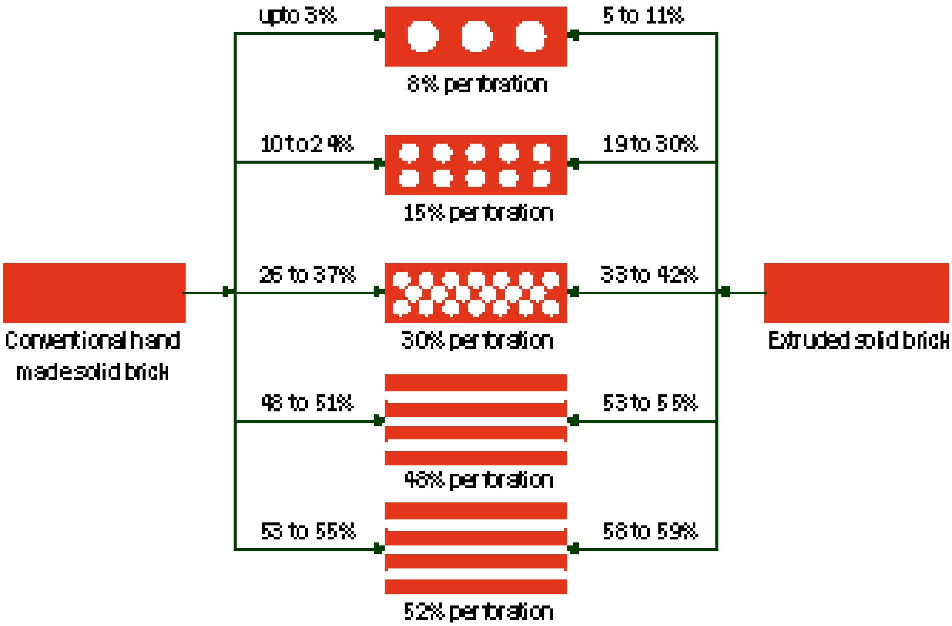


Figure 23: Clay savings due to REB production

Table 20: Fuel savings: REBs (perforated bricks and hollow blocks) vis-à-vis conventional hand-moulded solid brick					
Parameter	Perforated brick			Hollow block	
Perforation (%)	8	15	30	48	52
Fuel Saving (kg)	upto 2	6 to 15	14 to 23	26 to 32	29 to 35
Fuel Saving (%)	upto 3	10 to 24	26 to 37	48 to 51	53 to 55

Table 21: Fuel savings: REBs vis-à-vis extruded solid brick						
Parameter	Conventional hand-moulded solid brick	Perforated brick			Hollow block	
Perforation (%)	–	8	15	30	48	52
Fuel saving (kg)	6 to 9	5 to 8	15 to 21	24 to 29	37	40
Fuel Saving (%)	8 to 13	8 to 11	22 to 30	35 to 42	55	59

The summary of energy savings due to production of REBs is shown in Figure 24.

7.3 REDUCTION IN MANPOWER REQUIREMENTS

Machine moulding leads to a substantial reduction in manpower requirement for clay preparation and green brick moulding process, besides ensuring better quality of moulded bricks. The requisite manpower reduction with machine moulding process is provided in Table 22.

Table 22: Manpower used in moulding process	
Process for clay preparation and green brick moulding	Persons employed
Machine moulding	25–35
Hand moulding	120–150

7.4 COST SAVINGS DUE TO REB PRODUCTION

The monetary savings due to REB production (considering perforated bricks with 20 holes;

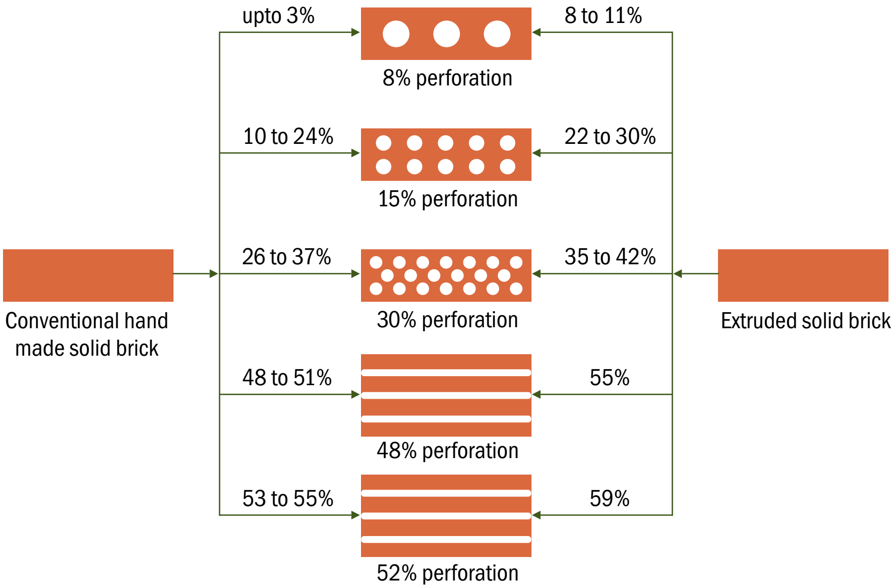


Figure 24: Energy savings due to REB production

about 15% perforations) are highlighted in Table 23.

Table 23: Details of revenue through savings		
S.No.	Particulars	Amount (Rs.)
1	Raw Material – clay and coal	7,77,600
2	Raw brick wastage due to occasional rain	8,64,000
3	Manpower savings	17,28,000
4	Improved quality of fired bricks	52,70,400
	Total	86,40,000

Payback period: The payback period on the total investment, estimated purely on savings, is about 3 years.

Thus, REBs offer significant potential for resource savings (fuel, clay, and manpower) as compared to conventional hand-moulded and extruded solid bricks. The potential of resource savings are dependent on the type of REBs produced in the brick manufacturing unit. For example, perforated bricks with 15% perforations offer better energy and clay savings as compared to perforated bricks with 8% perforations. Due to increased perforations/hollowness, the production of hollow blocks offers maximum resource savings.

Therefore, with brick kiln units shifting toward semi-mechanization that involve significant investment on machinery and related infrastructure, it would be worthwhile to adopt production of REBs. It would help the industry in conserving various resources such as clay, water, fuel, and manpower, besides ensuring better quality walling unit is available in the market.

Abbreviations

BTK	Bull's Trench Kiln
ECBC	Energy Conservation Building Code
GRIHA	Green Rating for Integrated Habitat Assessment
HP	Horse Power
LEEDS	Leadership and Energy and Environmental Design
Kg	Kilogram
kW	Kilo watt
m	meter
MJ	Mega Joule
MoEFCC	Ministry of Environment, Forests & Climate Change
no.	Number
REB	Resource Efficient Brick
SEC	Specific Energy Consumption
Sq. ft	Square feet
UNDP	United Nations Development Programme

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TERI report on 'Technical Assessment of Operating Extruders' prepared under the UNDP-GEF project on 'Energy Efficiency Improvements in Indian Brick Industry'.

TERI report on 'Resource Audit of Brick Kilns' prepared under the UNDP-GEF project on 'Energy Efficiency Improvements in Indian Brick Industry'.

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