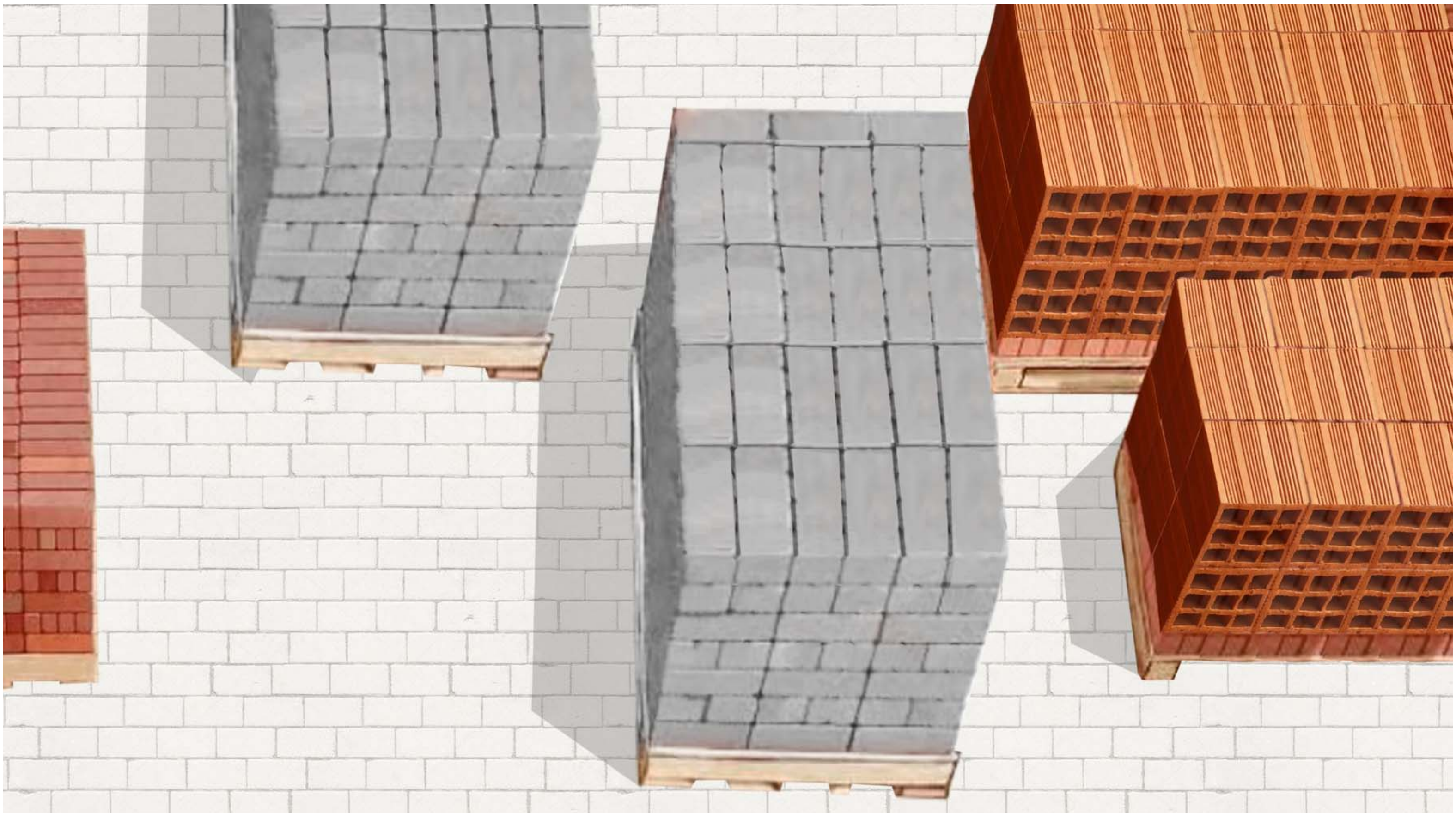

Roadmap for Promoting Resource Efficient Bricks in India:
A 2032 strategy

A win-win approach that promotes environment sustainability, quality housing, and sustainable livelihoods

Greentech Knowledge Solutions Pvt. Ltd

SHAKTI
SUSTAINABLE ENERGY FOUNDATION

Roadmap for Promoting Resource Efficient Bricks in India: A 2032 strategy

December 2017

Authors:

Sameer Maithel | Ananthakrishnan Ravi | Sonal Kumar

About Shakti Sustainable Energy Foundation

Shakti Sustainable Energy Foundation works to strengthen the energy security of the country by aiding the design and implementation of policies that encourage energy efficiency, renewable energy and sustainable transport solutions, with an emphasis on sub sectors with the most energy saving potential. Working together with policy makers, civil society, academia, industry and other partners, we take concerted action to help chart out a sustainable energy future for India (www.shaktifoundation.in).

About Greentech Knowledge Solutions Pvt. Ltd.

Greentech Knowledge Solutions Pvt. Ltd. (GKSPL) is a Clean Energy Research and Advisory firm which offers services across Renewable Energy, Energy Efficiency, and Green Buildings domains. GKSPL has been involved in providing technical support for design of several energy-efficient buildings, studies related with integration of renewable energy in buildings, conducting technical training programmes for building design professionals and undertaking policy studies in the field of energy-efficient/low carbon buildings.

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Preface

Construction of buildings require a variety of building materials, such as, sand, aggregates, brick, cement, steel, aluminum, timber, glass, ceramic tiles, etc. Building materials have a large environment footprint. Building materials manufacturing is already one of the largest contributor of GHG emissions, single largest user of mined raw materials and an important source of air pollution in India. This roadmap focuses on bricks.

Masonry construction using bricks is the main type of building construction technology used in the country. Among various types of bricks, solid burnt clay bricks are the most widely used bricks. In recent years, several new walling construction technologies and materials have been introduced, but in the foreseeable future, bricks are expected to retain its dominant position. Given the large anticipated growth in the building construction, the annual demand for bricks in India is expected to peak to 750–1000 billion standard billion bricks (SBUs) a year during 2032–37 from about 250 SBUs a year during 2012–17.

It is against this background of rising demand for bricks and growing concerns about the environment sustainability, this study was conducted by Greentech Knowledge Solutions with support from Shakti Sustainable Energy Foundation and presents a “Roadmap for Promoting Resource Efficient Bricks in India”.

The study covered a wide range of aspects:

a) It starts with presenting the status of brick sector in India, which includes an analysis of the market for bricks, manufacturing industry and the environment policy landscape. It highlights the unique features of the brick sector in India, be it pre-dominance of the small unorganized sector enterprises in manufacturing, large number of persons employed, regional differences in raw materials availability and markets, etc.
b) It then presents a resource efficiency framework and compares different types of bricks available in the Indian market – solid burnt clay brick, perforated burnt clay brick, hollow burnt clay brick, burnt clay fly ash brick, compressed stabilised earth block (CSEB), fly ash lime brick, fly ash cement brick, hollow concrete block, solid concrete block, autoclaved aerated concrete (AAC) block, and cellular light-weight concrete (CLC) block. This analysis leads to identifying options for resource efficient bricks (REBs) in the Indian context.

c) The last section of the report deals with the estimation of the future demand for bricks and presents a strategy and a roadmap for next 15 years to transform the brick sector and make it resource efficient.

We anticipate and welcome debates and discussions on the numbers and roadmap presented in this publication. Targeting policy makers, decision makers, and other important stakeholders of the brick industry, we strongly believe that this audience can shape and give direction to the future of the brick industry in the country and help the country in its quest for *environment sustainability, providing quality housing and sustainable livelihoods to all its citizens*.

Sameer Maithel

Acknowledgment

This study is continuation of work on improving environment performance of Indian brick industry, being supported by Shakti Sustainable Energy Foundation, since 2010. We gratefully acknowledge Shakti Sustainable Energy Foundation for their support.

We thank Dr. Veena Joshi for reviewing various project documents at different points of time and providing valuable feedback. We also thank the brick manufacturers and the building industry representatives who shared valuable information during field trips and survey. We thank all the participants, speakers and panelists who participated in the national stakeholder workshop organised at New Delhi on 7 June 2016 for their providing valuable inputs and sharing insights.

Last but not the least we would like to thank all our colleagues at Greentech Knowledge Solutions for providing support to the project team whenever required and Mr. K P Eashwar of Academic and Development Communication Services for editing the report.

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Abbreviations/Acronyms

AAC	autoclaved aerated concrete
BEE	Bureau of Energy Efficiency
BIS	Bureau of Indian Standards
BMTPC	Building Materials and Technology Promotion Council
BSPCB	Bihar State Pollution Control Board
C&D	construction and demolition
CAGR	compound annual growth rate
CEA	Central Electricity Authority
CLC	cellular light-weight concrete
CPCB	Central Pollution Control Board
CPWD	Central Public Works Department
CSEB	compressed stabilised earth block
CTO	consent to operate
DEAC	District Level Expert Appraisal Committee
DDA	Delhi Development Authority
DEIAA	District Level Environment Impact Assessment Authority
DIC	District Industry Centre
DST	Department of Science and Technology
EC	environment clearance
ECBC	Energy Conservation Building Code
EIA	Environmental impact assessment
EPCA	Environment Pollution (Prevention & Control) Authority

ESP	electrostatic precipitator
FCBTK	fixed chimney Bull's Trench Kiln
GFRG	glass fibre reinforced gypsum
GHG	greenhouse gas
IESS	India Energy Security Scenarios
INR	Indian National Rupee
LGSFS	light gauge steel framed structures
MCBTK	moving chimney Bull's Trench Kiln
MNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MoEFCC	Ministry of Environment, Forest and Climate Change
MoHUA	Ministry of Housing and Urban Affairs
MoMSME	Ministry of Micro Small and Medium Enterprises
MoUD	Ministry of Urban Development
NCR	National Capital Region
NGT	National Green Tribunal
NSDC	National Skill Development Council
PM	particulate matter
PSCST	Punjab State Council for Science and Technology
PWD	Public Works Department
RCC	reinforced cement concrete
REB	resource efficient brick
SBU	standard brick units
SEIAA	state environment impact assessment authority
SLCP	short-lived climate pollutant

SPCB	state pollution control boar
SPM	suspended particulate matter
TCPO	Town and Country Planning Organisation
TERI	The Energy and Resources Institute
ULB	urban local body
VSBK	vertical shaft brick kiln

1 Introduction

1.1 Growth in Building Construction

India's building floor space is growing rapidly, propelled by economic and population growth, and urbanisation. The number of houses increased from 25 crore to 33 crore, an increase of 33% between 2001 and 2011.[1] A study by McKinsey[2] estimated that the building floor space doubled from 4 billion m^2 to 8 billion m^2 during the period 1990–2005. The same study projected that the demand for building floor space will rise to 41 billion m^2 by 2030 (a 500% growth during 2005–30). A study by NITI Aayog has projected that India's building floor space will increase by about four times, i.e., from 14 billion m^2 to 64 billion m^2, during 2012–47 (Figure 1.1).[3] The enhanced focus of the Government of India on programmes such as 'Housing for All' and 'Smart Cities' is expected to increase the growth of building floor space in the immediate future.

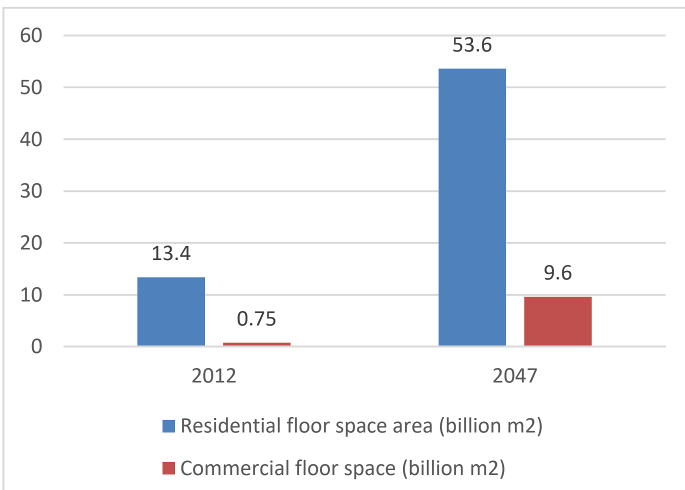

Figure 1.1. Building floor space (billion m^2): 2012 and 2047[4]

1.2 Growth in Building Materials Demand

Construction of buildings requires a variety of building materials such as sand, aggregates, cement, steel, aluminium, timber, glass, brick, and ceramic tiles. Growth in construction of new

[1] Census of India. 2011. <censusindia.gov.in/2011census/hlo/Data_sheet/India/00_2011_Housing_India.ppt> (accessed on 14 April 2017).
[2] McKinsey. 2009. Environment & Energy Sustainability: An Approach for India. Mumbai: McKinsey & Company Inc.
[3] Niti Aayog. 2015. India Energy Security Scenarios < http://www.indiaenergy.gov.in/ > (accessed on 14 April 2017)
[4] Niti Aayog. 2015. India Energy Security Scenarios < http://www.indiaenergy.gov.in/ > (estimates for 7.4% CAGR in GDP) (accessed on 14 April 2017)

buildings means an increase in the demand for building materials. For example, as per the McKinsey study, the annual demand for cement doubled from 60 million tonnes (MT) in 1990 to 127 MT in 2005; further, this is expected to grow to 860 MT by 2030. As per NITI Aayog, the annual demand for cement is projected to increase from about 230 MT in 2012 to over 1000 MT by 2047 (an increase of 400%) and that of steel, another material used widely in building construction, from about 90 MT in 2012 to 650 MT by 2047 (an increase of about 700%).[5]

1.3 Environmental Impacts of Building Materials

There are a variety of environmental impacts that take place during the life cycle of a building material and hence increased demand for building materials would have severe impacts on the environment. The life cycle of building materials essentially consists of five stages (Figure 1.2):

1. Extraction of raw-materials
2. Production
3. Transportation
4. Use in buildings
5. Demolition of building

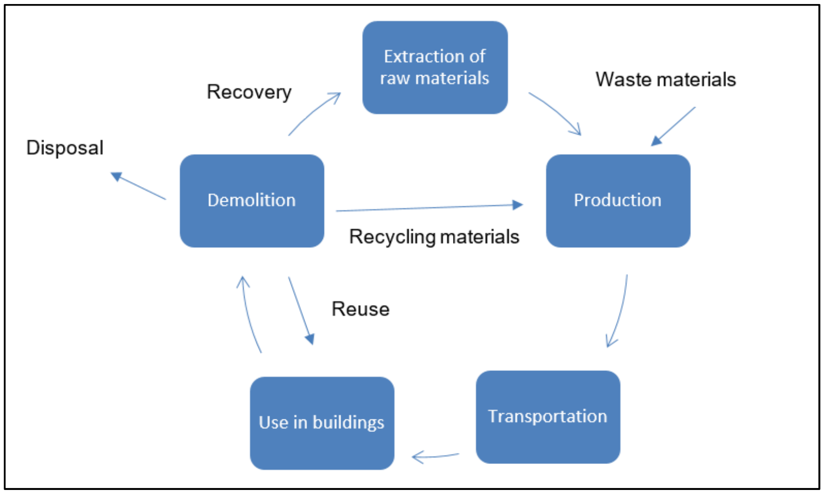

Figure 1.2. Stages in the life cycle of building materials

[5] Niti Aayog. 2015. India Energy Security Scenarios < http://www.indiaenergy.gov.in/ > (accessed on 14 April 2017)

Each of these stages and the main environmental impacts are described in the following paragraphs.

1. Extraction of raw materials: Large quantities of raw materials are required for the production of building materials. These include sand (used in concrete and mortar), common clay/brick earth (used for brick production), stone (used as blocks for wall construction or as aggregates used in concrete), limestone (used in cement production), and iron ore (used for steel production). Out of the total material consumption in India of 5.4 billion tonnes (BT) in 2013, about 2.3 BT (almost 43% of the total consumption)[6] was for industrial and construction minerals, a large part of it being attributed to building materials. During the past two decades, the construction sector has been the fastest growing sector with regard to increase in absolute material consumption.[7]

Figure 1.3. Clay mining

The extraction of raw materials for building materials has many negative environmental impacts. They range from land degradation, damage to forest eco-systems, damage to rivers, loss of agriculture top-soil, reduction in ground water recharge, air pollution, water pollution, noise pollution, etc. Also, the machinery for mining and transportation of raw material uses fossil fuels, which results in air pollution and carbon dioxide (CO_2) emissions.

2. Production: Production or manufacturing of building materials is energy intensive. Cement, iron and steel, aluminium, bricks, glass, and ceramic tiles are some of the largest energy consuming industries. Cement industry accounted for 38 MT and iron and steel industry combined accounted for 81 MT of raw coal consumption in India in 2014/15.[8] Burnt clay

[6] Vienna University of Economics and Business (WU).2014. Global Material Flows Database. < www.materialflows.net > (accessed on April 14. 2017)
[7] GIZ. 2016. Material Consumption Patterns in India – A Baseline Study of the Automotive & Construction Sectors. New Delhi: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
[8] Ministry of Statistics an Programme Implementation (MOSPI). 2015. Energy Statistics 2016.< http://mospiold.nic.in/Mospi_New/upload/Energy_statistics_2016.pdf> (accessed on 1 December 2017)

brick industry consumed about 31 MT of raw coal in 2014/15.[9] With the increase in the production of building materials, the consumption of energy (mostly fossil fuels) will also grow.

Figure 1.4. Smoke emission from a brick-kiln chimney

As per NITI Aayog, the annual energy demand for the cement industry is projected to increase from 250 TWh (terawatt-hour) in 2017 to 906 TWh in 2047 (an increase of 260%); and that of the iron and steel industry from 926 TWh in 2017 to 4192 TWh in 2047 (an increase of 350%).[10] The use of large amounts of energy, which is mostly derived from fossil fuels, gives rise to air pollution (particulate and gaseous pollutants) and CO_2 emissions.

3. Transportation: The construction sector accounts for 20%[11] of all materials demand and as this material needs to be transported in the form of raw materials and finished building material products, transportation of construction materials constitutes a large chunk of the freight transport. Most of the material is transported by road and some by rail and ships. All these modes of transport use fossil fuels causing air pollution and CO_2 emissions.

[9] Kumar S. 2016. TERI presentation titled "Options for Walling Materials and benefits of using REBs in building construction", organised by Punjab State Council for Science & Technology (PSCST) at Chandigarh on 24 May 2016.
[10] NITI Aayog. 2015. India Energy Security Scenarios excel tool "IESS_Version2.2". <http://indiaenergy.gov.in/iess/default.php> (accessed on 22 August 2017)
[11] Dittrich M. 2015. Global Material Flows database. < www.materialflows.net > (accessed on 14 April 2017)

Figure 1.5. Air pollution caused by truck transportation[12]

4. Operational energy in buildings: The operating energy of a building is the amount of energy that is consumed by a building to satisfy the demand for heating, cooling, ventilation, lighting, equipment, and appliances. The thermal properties of building materials influence the thermal properties of the building envelope, and hence the operation energy in buildings. For example, better thermal insulation property of walls helps in reducing the energy use for heating or cooling of the building and thereby, reducing the impact on the environment. The environmental impacts are in the form of use of fossil fuels, air pollution, and CO_2 emissions. Worldwide, buildings consume 30%–40% of primary energy in their construction, operation, and maintenance and are held responsible for emitting 40% of greenhouse gases (GHGs)[13]. In India, 24% of the primary energy and 30% of the electrical energy are consumed in buildings.[14]

[12] Image Source https://www.motorbeam.com/wp-content/uploads/2015-Polluting-Truck.jpg

[13] Asif M, Muneer T, and Kelley R. 2007. Life cycle assessment: a case study of a dwelling home in Scotland, *Building and Environment* 42: 1391–94.

[14] Bansal N K. 2007. Science, technology and society energy security for India. In: Jyotirmay Mathur, H J Wagner, N K Bansal (eds), *Energy Security, Climate Change and Sustainable Development,* pp. 15–23. New Delhi: Anamaya Publishers

Figure 1.6. Construction site of a building showing the use of steel, cement, and bricks

5. Demolition: At the end of the life of a building, the building is demolished. Construction and demolition (C&D) waste comprises building materials and debris and rubble resulting from construction, re-modeling, repair, and demolition of any civil structure.[15] There are various estimates regarding the quantum of generation of C&D waste. A study indicates that 14.5 MT[16] of construction waste is generated annually in India. Growth of population, increasing construction, and rising standards of living due to technological innovations have contributed to an increase in the quantity of C&D waste. Building materials differ in terms of reuse and recycling potential. The materials that have low potential for reuse and recycling or that are toxic have larger negative environment impact.

Figure 1.7. Construction and demolition (C&D) waste at a C&D waste brick manufacturing set-up

[15] Central Pollution Control Board (CPCB). 2016. Draft CPCB Guidelines on Environmental Management of C&D Waste Management in India. New Delhi: CPCB.
[16] Pappu, et al. 2007. Solid Wastes Generation in India and Their Recycling Potential in Building Materials. *Building and Environment* 42(6): 2311–20.

1.4 Concept of Resource Efficiency

Resource efficiency is defined as 'using the Earth's limited resources in a sustainable manner while minimizing impacts on the environment'.[17] There is a need to apply the concepts of resource efficiency to deal with the issue of environmental impacts of building materials. In this report, the definition of resources is limited to primary and secondary raw materials, and energy.

The concept of resource efficiency has been gaining ground, particularly in Europe, with the development of a 'Roadmap to a resource efficient Europe', which proposes ways to increase resource productivity and decouple economic growth from resource use and its environmental impact.[18]

India does not have an overarching policy framework on resource efficiency. However, there are several regulations pertaining to buildings and building materials, which directly or indirectly promote the concept of resource efficiency. Examples of such regulations are listed below.

- The National Building Code (NBC) advocates reuse of existing buildings, use of rapidly renewable materials, recycled materials to minimise the adverse impact of natural resource consumption in the manufacture of new building materials.[19] It also calls for promoting the use of local materials to assist the local economy and reduce the negative impact of transportation.
- The notification of the Ministry of Environment, Forest and Climate Change (MoEFCC) on fly ash utilisation[20] is aimed at promoting use of secondary raw materials such as fly ash, bottom ash or pond ash generated due to burning of coal in power plants, primarily for the production of construction materials and to conserve natural resources.
- Construction and Demolition Waste Management Rules, 2016,[21] by MoEFCC is another such regulation that is aimed at promoting recycling and reuse of C&D waste.

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[17] http://ec.europa.eu/environment/resource_efficiency/index_en.htm (accessed on 16 March 2017)
[18] http://ec.europa.eu/environment/resource_efficiency/about/roadmap/index_en.htm (accessed on 16 March 2017)
[19] Bureau of Indian Standards (BIS). 2016. National Building Code Part 11. Approach to Sustainability. New Delhi: BIS
[20] Ministry of Environment, Forest and Climate Change (MoEFCC). 2016. Amendment in fly ash regulation 2016. < http://www.moef.nic.in/sites/default/files/fly%20ash%20amendment%202016.pdf > (accessed on 12 May 2017).
[21] Ministry of Environment, Forest and Climate Change (MoEFCC). 2016. C&D waste notification. <http://www.moef.gov.in/sites/default/files/C%20&D%20rules%202016.pdf> (accessed on 12 May 2017).

- The MoEFCC emission standards[22] for brick kilns, cement kilns, and steel power plants aim at reducing the air pollution during the manufacturing of building materials and thus reducing the environmental impact of building material production.
- The Environment Impact Assessment notification for the mining of minor minerals[23] (e.g., sand, soil for brick making) is another regulation that tries to limit the environmental damage during the process of extraction of raw materials.
- The Energy Conservation Building Code (ECBC)[24] by the Bureau of Energy Efficiency (BEE) aims at reducing the operational energy in commercial buildings.

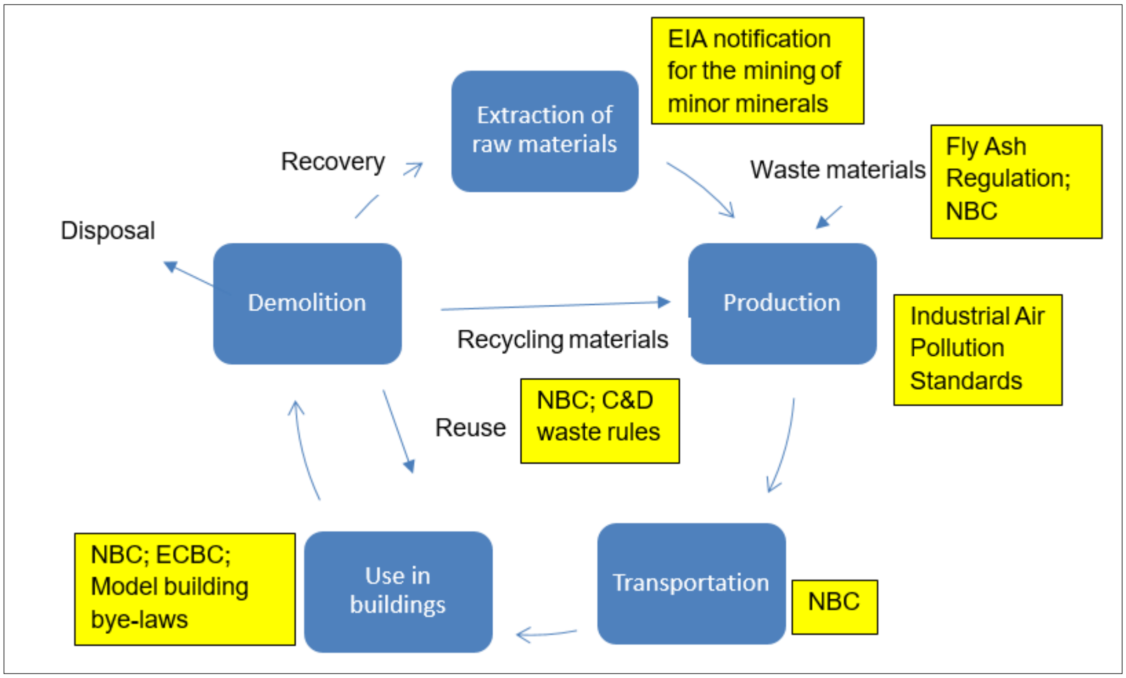

Figure 1.8. Existing environment regulations that promote resource efficiency in buildings and building materials

1.5 Scope of the Study: Resource Efficient Bricks

1.5.1 Definition of brick

Within the larger domain of building materials, this report focuses only on bricks.

A brick, in the context of this report, is defined as a building material primarily used to make walls but it can also be used for the construction of pavements, canals, drains and other elements in masonry construction. Traditionally, the term brick is referred to a unit

[22] Ministry of Environment, Forest and Climate Change (MoEFCC). 2009. Emission Standards for Brick Kiln Sector. < http://www.moef.nic.in/environmental_standards> (accessed on 12 May 2017).
[23] http://www.downtoearth.org.in/news/eia-notification-amended-to-bring-small-scale-mining-under-its-ambit-52628 (accessed on 1 June 2017)
[24] https://beeindia.gov.in/content/buildings (accessed on 1 December 2017)

composed of clay, but in the context of this report it is used to denote any rectangular unit laid in mortar.[25]

The largest application of bricks is for the construction of walls. It should be noted that apart from brick masonry construction, a variety of other materials and construction techniques exist for the construction of walls (Figure 1.9).

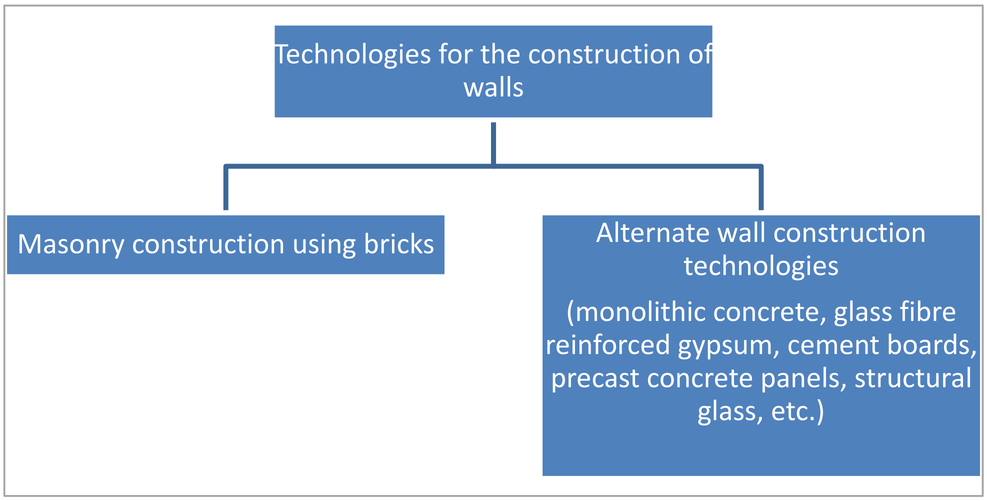

Figure 1.9. Technologies for the construction of walls

The Building Materials Technology Promotion Council (BMTPC) has published a 'Compendium of Prospective Emerging Technologies for Mass Housing', in which the following alternate wall construction technologies have been covered:

- Monolithic Concrete Construction System
- Expanded Polystyrene Core Panel System
- Industrialised 3-S System using Precast RCC Columns, Beams and Cellular Light Weight Concrete Precast RCC Slabs
- Speed Floor System
- Glass Fibre Reinforced Gypsum (GFRG) Panel Building System
- Factory Made Fast Track Modular Building System
- Light Gauge Steel Framed Structures (LGSFS)

In addition to the above-mentioned alternatives, materials such as structural glass, aluminum panels, and cement boards are also used for wall construction. The application of alternative wall construction technologies is mostly confined to the organised real estate sector. The

[25] Definition adapted from https://en.wikipedia.org/wiki/Brick (accessed on 14 June 2017)

organised real estate sector is estimated to construct about 0.1 billion m^2/year,[26] which is a small segment (~13%) of the total annual building construction in India. Thus, the overall market share of alternative technologies for the construction of walls is estimated to be small (less than 10%).

Construction carried out by the unorganised sector, which includes construction done by local masons, civil contractors, small builders as well as self-construction, is estimated at about 0.65 billion m^2/year[27] (~87%) making it the main mode of construction in the country (Figure 1.2). Within the unorganised sector, brick masonry construction is the most popular method for the construction of walls.

In the coming decades, the percentage shares of both the organised real estate sector and alternative technologies for wall construction are likely to increase. However, brick-based masonry construction is expected to remain the dominant form of wall construction in the near future, and hence this study focuses on bricks.

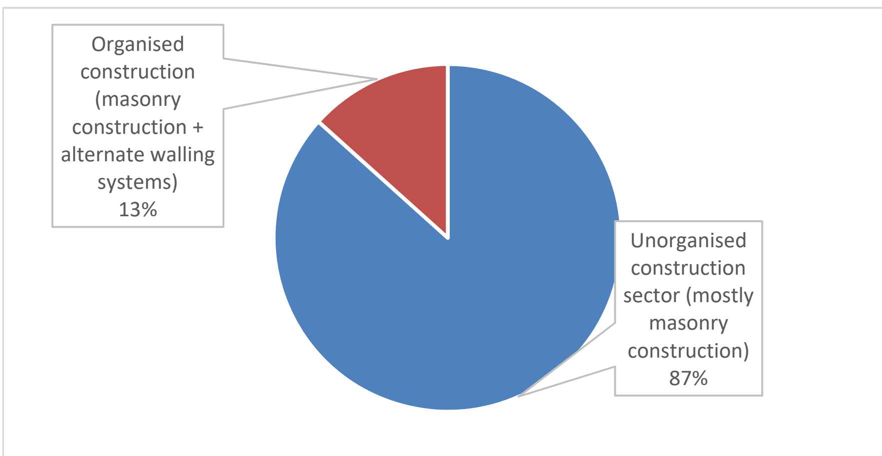

Figure 1.2. Most of the new construction in the country is masonry construction using different types of bricks

1.5.2 Types of bricks

The various types of bricks covered in this study are classified into three categories as per the Bureau of Indian Standards (BIS)[28].

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[26] Bain & Company, Inc. 2016. Residential real estate in India. <http://www.bain.com/Images/BAIN_REPORT_India_Real_Estate.pdf> (accessed on 01 June 2017)

[27] The total built-up area in India is estimated to be about 15 billion m^2 by NITI Aayog (IESS, 2047). If we take an annual growth rate of 5% increase in the building built-up area, the annual addition in the built-up area will be 0.75 billion m^2/year. The organised real estate constructs about 0.1 billion m^2/year, thus the remaining 0.65 billion m^2/year is assumed to be constructed by the unorganised construction sector. [NITI Aayog. 2015. India Energy Security Scenarios excel tool "IESS_Version2.2". <http://indiaenergy.gov.in/iess/default.php> (accessed on 22 August 2017)].

[28] Bureau of Indian Standards (BIS). 2005. National Building Code. New Delhi: BIS.

1. Clay and stabilised soil products: Common clay or soil is the predominant raw material used for the manufacturing of this set of products.
    - Solid, hollow, perforated burnt clay bricks, and clay-fly ash burnt bricks in the category are produced by firing of bricks in a kiln in which the bricks gain strength due to vitrification process.
    - In the case of compressed stabilised earth blocks (CSEB), the strength is achieved by mixing cement and its curing.
2. Building lime and gypsum products: Fly ash is the major constituent in pulverised fuel ash lime bricks, commonly known as FaL-G bricks. Lime reacts with silica from fly ash in the presence of moisture to form calcium silicate hydrate, which provides binding. The strength of this product is achieved by the process of curing.
3. Cement matrix products: Cement is the most important raw material used for the manufacturing of products in this category.
    - Products such as autoclaved aerated concrete (AAC) blocks and cellular light-weight concrete (CLC) blocks have lower density (lighter in weight) and are produced by introducing air voids inside the block body during manufacturing. AAC, CLC, and pulverised fuel ash (also known as fly ash) are the major constituent.
    - Pulverised fuel ash cement bricks have fly ash as their major constituent.
    - Solid/hollow concrete blocks have aggregates as their major constituent.

These set of products achieve their strength by the process of curing.[29] The curing is done naturally (in ambient conditions) in all the products except in AAC blocks where autoclaves are used. Figure 1.3 shows various kinds of bricks.

[29] The water causes the hardening of concrete through a process called hydration. Hydration is a chemical reaction in which the major compounds in cement form chemical bonds with water molecules and become hydrates or hydration products.

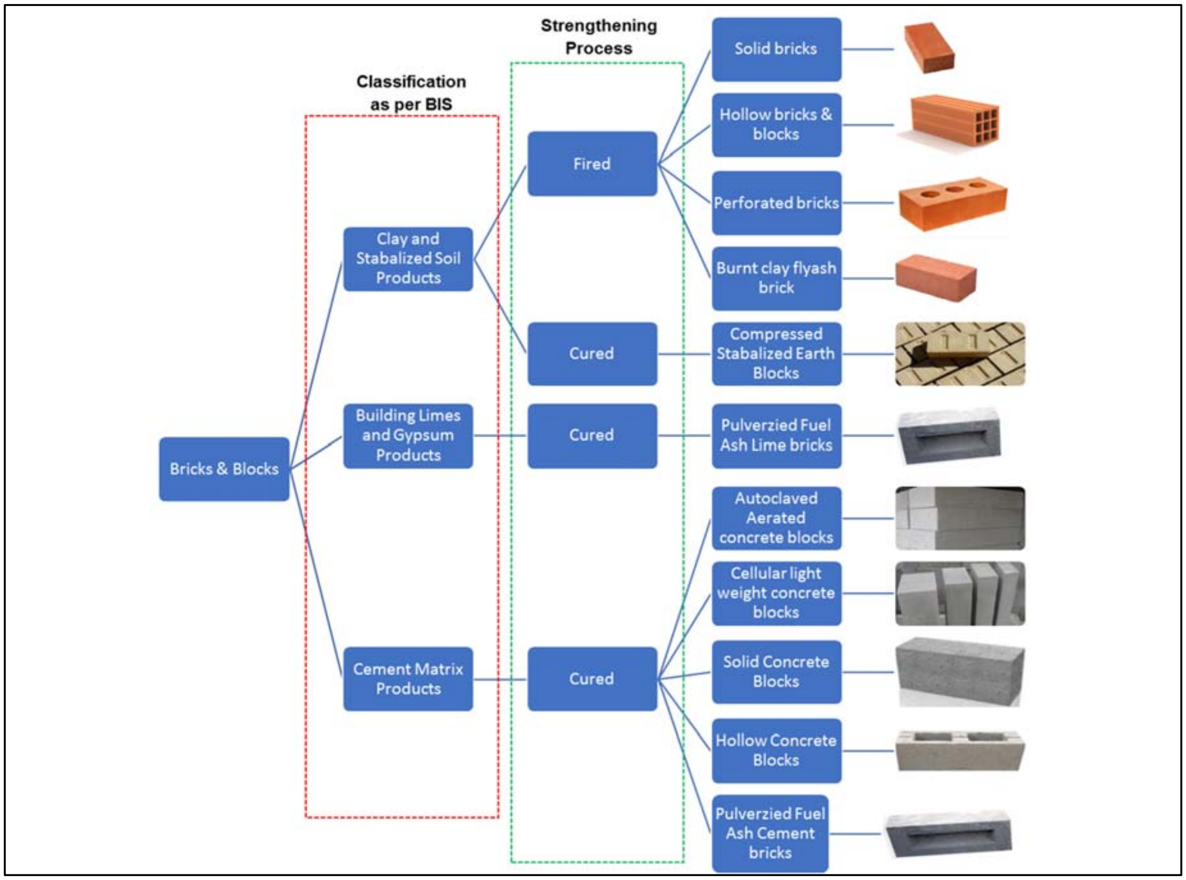

Figure 1.3. Various masonry products based on BIS classification

1.5.3 Census data on use of bricks in construction

As per the Census of India 2011[30], burnt clay bricks were the predominant material for wall construction in 47% households; but if we consider only the urban households this percentage was 64% (Figure 1.4). If we compare the number of households with burnt clay brick as walling material, the number of such households has more than doubled, from 5.2 crore in 1991 to 11.7 crore in 2011 (Figure 1.5).

[30] Census of India. 2011. http://censusindia.gov.in/Tables_Published/H-Series/houselist_main.html (accessed on 1 Dec 2017)

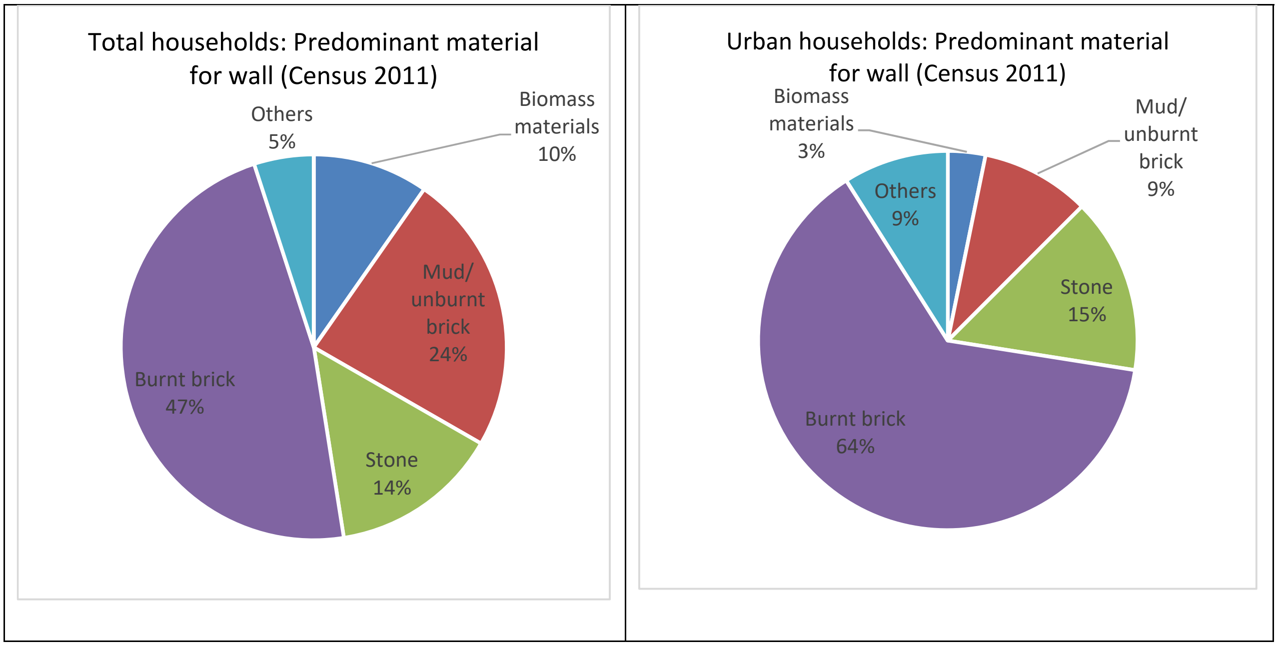

Figure 1.4. Census based walling material analysis based on households

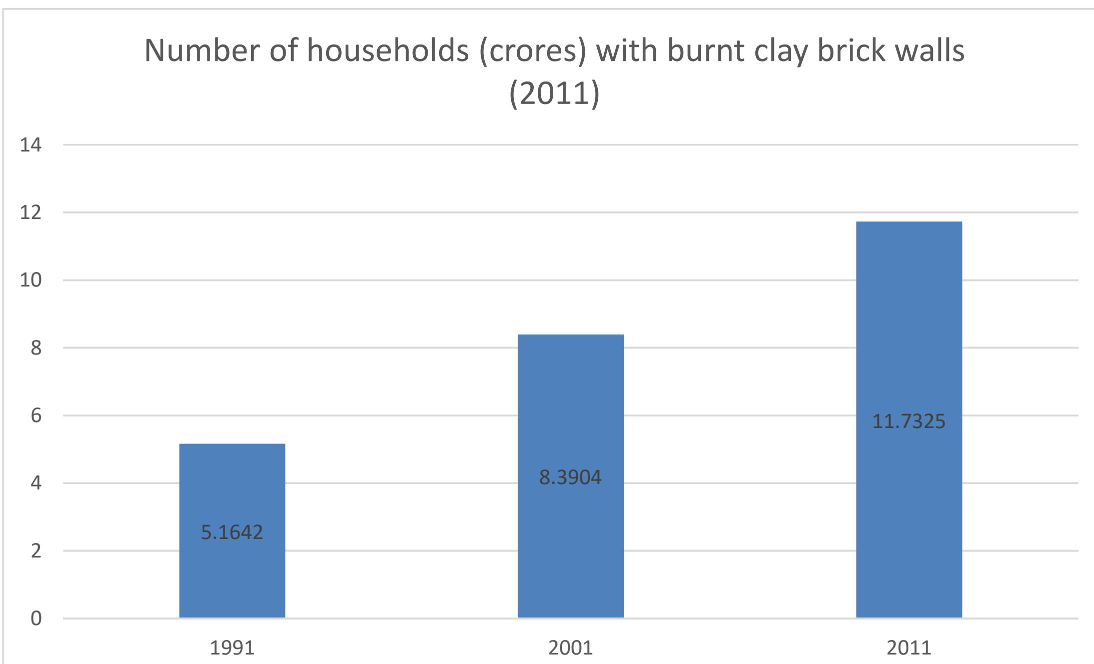

Figure 1.5. Decennial depiction of number of households with burnt clay bricks walls

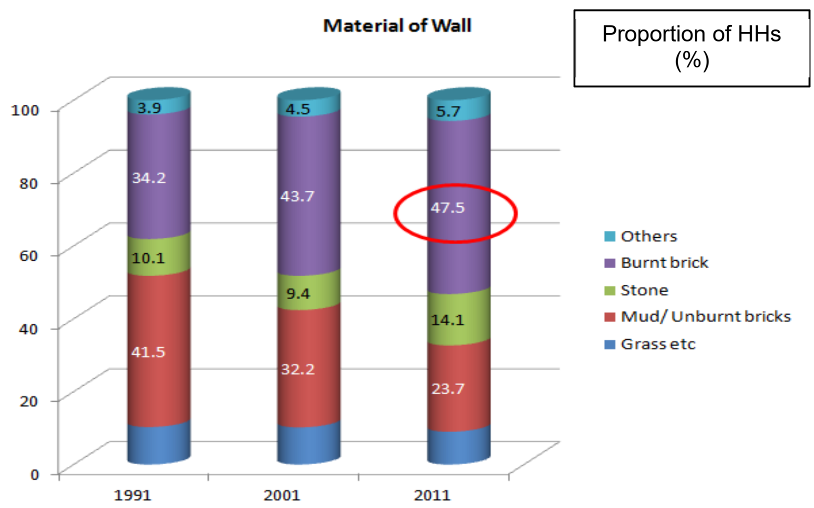

Figure 1.6. Bricks used for constructing walls in India (Census data for 1991, 2001 and 2011)[31]

The analysis of the census data shows that burnt clay brick is the main building material used for the construction of walls in the country. Overall, there is a strong trend of replacing the buildings constructed using traditional mud/unburnt brick with buildings made of burnt clay bricks.

1.6 Outline of the Report

Chapter 2 of this report provides details about the status of the brick sector in India in terms of manufacturing industry, market, and environment policies.

Chapter 3 presents the resource efficiency framework and performance of various types of bricks with respect to various resource efficiency parameters. Various brick types have been compared based on a resource efficiency framework presented in the chapter and a few resource efficient brick (REB) options are identified.

Chapter 4 presents a roadmap/strategy for transformation to an REB future. It presents the projected demand for bricks in the future and presents a policy roadmap for the transformation to REBs.

[31] Census of India. 2011. <censusindia.gov.in/2011census/hlo/Data_sheet/India/00_2011_Housing_India.ppt> (accessed on 14 April 2017)

2 Bricks: Status

2.1 Market

The market of bricks shows wide variations across the country. These variations are mainly influenced by:

- Geographical region (based primarily on raw material availability) and
- Type of building projects (urban/rural, intended use, scale, agency responsible for the construction, etc.).

2.1.1 Regional diversity based on raw material availability

Given the large quantities of raw materials required to produce bricks, utilisation of local raw materials (to reduce transportation) is a pre-requisite. In rural areas, bricks are usually produced adjacent to the location where the main (bulky) raw materials are available. Traditionally, brick enterprises around urban areas were located adjacent to the locations where main raw-materials were available. Now, several enterprises source their raw materials over longer distances, still this distance is usually less than 100 km.

Three main raw-materials to produce bricks are brick earth/clay, stone aggregates, and fly ash (Table 2.1).

Table 2.1. Main raw materials for the production of bricks

Type of bricks	**Main raw-material** (bulky, accounting for 55%–100% of the raw materials requirements)	**Other raw-materials**
Autoclaved Aerated Concrete blocks, Cellular Light Weight Concrete, Pulverised Fuel Ash-Lime bricks, Pulverised Fuel Ash-Cement bricks	Pulverised fuel ash (fly ash from thermal power plants)	Sand, cement, lime, gypsum, aluminium powder
Hollow Concrete blocks	Stone chips (coarse aggregate)	sand or stone-dust (fine aggregate), cement
Solid burnt clay, perforated burnt clay, hollow burnt clay blocks,	Brick earth/ clay	Coal as fuel (for burnt-clay products); Cement (CSEB)

Compressed stabilised earth blocks (CSEB)		

The distribution of these three raw materials is not uniform in the country. Based on the raw material availability for the manufacturing of bricks, the country can be divided into three regions:

1. Himalayan states and North-eastern States (except Assam and Tripura)
2. Indo-Gangetic plains, Assam, and Tripura
3. Peninsular, desert, and coastal India

The availability of the three main raw materials for making bricks is shown in Table 2.2; the three regions are marked on the map of India in Figure 2.7.

Table 2.2. Availability of main raw-materials for bricks in different regions

Region	**Stone for building/ stone aggregate**	**Brick earth**	**Fly ash**
Himalayan states and North-eastern States (except Assam and Tripura)	Good availability	Availability limited to valleys	No local availability, as there are no thermal power plants located in this region
Indo-Gangetic plains, Assam, and Tripura	No local availability in the region	Good quality brick making clay is abundantly available throughout the region	Availability limited to a few pockets near thermal power plants
Peninsular, desert, and coastal India	Good availability	Brick earth availability limited to delta regions, flood plains of rivers, ponds, and rice-cultivating areas	This region has 75% of the total thermal power generation capacity installed in the country. Due to large concentration of power plants, there are several places which have good availability of fly ash.

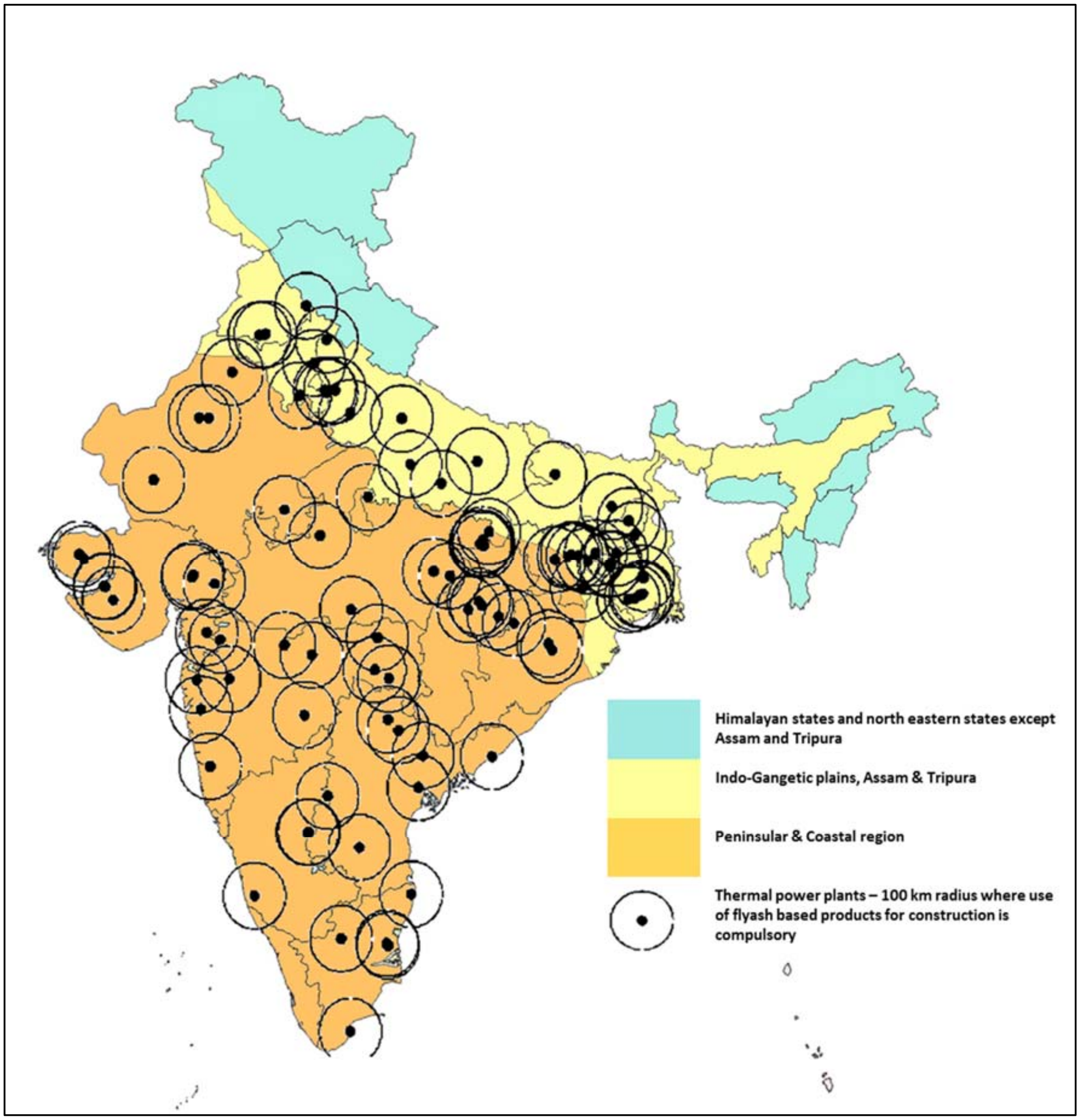

Figure 2.7. Main physiographic regions of Indian and locations of thermal power plants

An analysis of the Census 2011 data on walling material for house construction is presented in Table 2.3. The analysis shows that there is a broad agreement between the availability of raw material and the building material used for walling.

Table 2.3. Percentage distribution of household based on material used for wall construction (Census, 2011)[32]

% Distribution of households by predominant material of roof as per Census 2011							
	Indian States	Clay based			Concrete	Stone	Biomass and Others
		Burnt	Unburnt	Total			
Himalayan region and North eastern states except Assam & Tripura	Jammu & Kashmir	55.9	13.2	69.1	2.2	23.9	4.8
	Himachal Pradesh	44.1	18	62.1	1	34.7	2.2
	Uttarakhand	55.1	4.5	59.6	1.9	35.2	3.3
	Sikkim	24.6	10.7	35.3	13.8	7.5	43.4
	Manipur	11.8	54.1	65.9	1	1.3	31.8
	Nagaland	13.8	3.2	17	5.6	1	76.4
	Meghalaya	9.4	6.9	16.3	13	5.6	65.1
	Mizoram	7.2	0.2	7.4	10.2	0.5	81.9
	Arunachal Pradesh	5.6	1.9	7.5	8.1	5	79.4
Indo-Gangetic Plains, Assam & Tripura	Punjab	87.1	4.7	91.8	5.2	1.9	1.1
	Haryana	87.1	4.3	91.4	1.9	5.6	1.1
	NCT of Delhi #	86.3	2.2	88.5	5.5	4.8	1.2
	Uttar Pradesh	68.4	20	88.4	0.6	3.2	7.8
	Bihar	49.2	19	68.2	0.8	2.1	28.9
	Assam	21.2	3.6	24.8	2.9	2.2	70.1
	Tripura	12.2	50.4	62.6	0.5	1	35.9
	West Bengal	44.1	29.1	73.2	3.8	1.2	21.8
Peninsualar, Coastal and Desert Region	Jharkhand	36.2	58.5	94.7	0.8	2.1	2.4
	Odisha	36.7	47	83.7	1.6	7.1	7.6
	Chhattisgarh	27.8	66	93.8	0.7	3.5	2
	Madhya Pradesh	36.9	49.4	86.3	0.9	7.8	5
	Rajasthan	28.5	22.1	50.6	0.4	45.3	3.7
	Gujarat	61.3	18.2	79.5	3.6	10.4	6.5
	Andhra Pradesh	48.6	15.2	63.8	2	27.3	6.9
	Kerala	24.5	11.5	36	2.9	56.9	4.2
	Maharashtra	45.9	21.7	67.6	10.2	13.4	8.8
	Karnataka	33.9	21.7	55.6	6.9	32.1	5.4
	Goa	1.8	12	13.8	8.7	74.3	3.2
	Tamil Nadu	45.3	20.8	66.1	8.6	20.1	5.2

The analysis shows that

- Himalayan and North-eastern states (except Assam and Tripura): In the western Himalayan states of Jammu and Kashmir, Himachal Pradesh, and Uttarakhand, clay-based walling materials and stone are the main materials for masonry construction. In the North-eastern region, in a few states clay-based bricks are dominant, but other materials such as biomass (e.g., bamboo) and metal sheets are also used.
- Indo-Gangetic plains, Assam and Tripura: This region is dominated by the use of clay-based bricks.

[32] Census of India. 2011. http://www.censusindia.gov.in/2011census/Hlo-series/Hl-data/DDW-HH0702B-0000.xls (accessed on 14 April 2017)

- Peninsular, desert, and coastal India: In several states of this region, clay-based bricks dominate the existing buildings. After clay, stone is the second largest material in use along with concrete blocks.

2.1.2 Type of building projects

Rural

Residential construction in rural areas is mostly single-story or low-rise construction. Except for rural housing constructed by the government, most of the residential construction is self-constructed or self-supervised by the owner by hiring the services of masons. Usually traditional construction technologies (load-bearing masonry construction, concrete-framed construction with masonry in-fill, etc.) are used in this segment. The main types of bricks used for masonry construction in rural areas are given below.

- Himalayan and North-Eastern States (except Assam and Tripura): Clay-based (burnt and un-burnt) bricks and stone are the main materials used in masonry construction.
- Indo-Gangetic plains, Assam, and Tripura: Clay-based (burnt and un-burnt) bricks are the main materials used in masonry construction.
- Peninsular, desert, and coastal India: Clay-based (burnt and un-burnt) bricks and stone are the main materials used in masonry construction.

Urban

Construction in urban areas is varied in terms of intended use, scale, agency responsible for the construction, construction technology, etc. The main categories are given below.

<u>Large-scale housing projects</u>

Large-scale housing projects refer to projects where several hundreds or several thousands of houses are constructed as a part of a single project. In this segment, there is a growing preference for mid-/high-rise construction. Private sector builders dominate the market in new housing and new township developments; public sector involvement is limited to development of public sector housing and some affordable housing projects. The main trends in terms of brick use are listed below.

- Himalayan and North-eastern states (except Assam and Tripura): Solid burnt clay bricks are the main material for masonry construction. In some areas, concrete blocks are also used.

- Indo-Gangetic plains, Assam, and Tripura: Traditionally only solid burnt clay bricks were used and still maintain the top position. However, AAC blocks due to their lower weight, lower thermal conductivity, and faster construction have gained a significant part of the market in the National Capital Region (NCR) and Kolkata. These blocks have been introduced in other major urban centres in the region (Chandigarh, Lucknow, etc.) as well.
- Peninsular, desert, and coastal India: In this region, in most urban areas there is no single type of brick that is dominant. In most of the cities in this region, several types of bricks are being used, which may consist of solid burnt clay brick, AAC blocks, pulverised fuel ash bricks, and concrete blocks.

Table 2.4 gives the distribution of the type of bricks used in large-scale housing projects in major Indian cities.

Table 2.4. Type of waling materials being used in large-scale housing projects in Indian cities

Cities	**Region**	**Type of bricks used in large-scale housing projects**	**Other walling technologies**
Shimla, Dehra Dun, Dharmshala	Himalayan and North-eastern states (except Assam and Tripura)	**Solid burnt clay bricks,** AAC blocks being introduced	None
Ludhiana, Lucknow, Patna, Guwahati, Kolkata, Varanasi	Indo-Gangetic plains, Assam, and Tripura	**Solid burnt clay bricks**, AAC blocks being introduced	Monolithic concrete construction
Delhi, Gurgaon, Noida, Faridabad, Ghaziabad, Sonipat	Indo-Gangetic plains, Assam, and Tripura	**AAC blocks, solid burnt clay bricks**, pulverised fuel ash bricks	Monolithic concrete construction, pre-fabricated concrete panels
Jaipur, Indore, Ahmedabad, Bhopal	Peninsular, desert, and coastal India	**Solid burnt clay bricks, AAC blocks**, pulverized fuel ash bricks	Monolithic concrete construction
Mumbai, Pune, Thane	Peninsular, desert, and coastal India	**AAC blocks, pulverised fuel ash brick**, Solid burnt clay bricks	Monolithic concrete construction

Nagpur	Peninsular, desert, and coastal India	**Solid burnt clay-fly ash bricks, pulverised fuel ash bricks**	Monolithic concrete construction
Bengaluru	Peninsular, desert, and coastal India	**Solid concrete blocks**, solid burnt clay brick, hollow burnt clay brick, AAC blocks	Monolithic concrete construction
Hyderabad, Chennai	Peninsular, desert, and coastal India	**AAC blocks**, Concrete blocks, solid burnt clay brick, pulverised fuel ash bricks	Monolithic concrete construction
Vishakhapatnam	Peninsular, desert, and coastal India	**Pulverised fuel ash brick,** Solid burnt clay bricks, AAC blocks	None
Coimbatore, Madurai, Vijayawada	Peninsular, desert, and coastal India	**Solid burnt clay bricks**, Pulverised fuel ash brick, AAC blocks	None

Source: Field survey by GKSPL during 2015/16

In the high-rise construction, the preference is for lighter materials and materials/technologies, which allows for faster rate of construction and requires less skilled workers. The growing market for AAC blocks and monolithic construction is mainly explained based on this preference.

Low-rise housing

The housing on smaller plots of land, urban slums and urban villages are mostly low-rise and self-constructed. Usually traditional construction technologies and materials are used in this segment. Burnt clay bricks and in some areas pulverised fuel ash bricks are the main walling materials. The penetration of alternative materials is rather limited.

2.1.3 Market of bricks

The total production (2014/15) for different types of bricks is estimated to be 274 billion bricks/year (Table 2.5). As no agency in the country has good data on the market of bricks, the table has been prepared by compiling data from different studies. A short methodology and information on sources is provided in Annexure 4.

Table 2.5. Market of bricks (2014/15) estimates in billion standard bricks/year

Type of brick	**Annual consumption (2014/15)**	**Source**
Solid burnt clay bricks	243 billion bricks/year	Based on production data [Kamyotra J S. 2016][33] [Kumar S. 2016][34]
Hollow and perforated burnt clay bricks	0.2 billion bricks/year	Based on production data [GKSPL. 2016][35]
Pulverised fuel-ash lime/cement bricks	11.7 billion bricks/year	Based on fly-ash utilisation data of CEA [GKSPL. 2016][36]
Autoclaved aerated concrete blocks	4.4 billion bricks/year	Based on fly-ash utilisation data of CEA [GKSPL. 2016][37]
Concrete blocks	15 billion bricks/year	Explained in Point 4 of Annexure 4 in this report
Total	**274 billion bricks/year**	

The data shows that solid burnt clay bricks still retain ~89% of the market for bricks. The other bricks such as concrete blocks, pulverised fuel-ash lime/cement bricks, and hollow and perforated burnt clay bricks together make up for the rest of the market. The market for alternative bricks, particularly AAC blocks,[38] has grown during the last decade.

2.2 Manufacturing Industry

The manufacturing industry for the production of bricks is spread throughout the country. The total number of manufacturing units is estimated to range between 2,50,000 and 3,00,000. It

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[33] Kamyotra J S. 2016. CPCB presentation titled “Brick Kilns in India”, Presentation made at the workshop on “Roadmap for Brick Kiln Sector Challenges and Opportunities”, organized by Centre for Science & Environment at New Delhi on February 8, 2016.
[34] Kumar S. 2016. TERI presentation titled “Options for Walling Materials and benefits of using REBs in building construction”, organised by Punjab State Council for Science & Technology (PSCST) at Chandigarh on 24 May 2016
[35] Greentech Knowledge Solutions Pvt. Ltd (GKSPL).2016. Market assessment of burnt clay resource efficient bricks. Report prepared for UNDP-GEF-MoEFCC project on “Energy Efficiency Improvements in the Indian Brick Industry”.
[36] Greentech Knowledge Solutions Pvt. Ltd. (GKSPL). 2016.Assessment of fly ash based Walling Material Production Inventory in India, Report prepared for Climate Studies Program, Indian Institute of Technology, Bombay.
[37] Ibid.
[38] http://www.indiancementreview.com/News.aspx?nId=JTbWdUj6k4vECxF5gfuorg== (accessed on 1 July 2017)

is estimated that a majority of the units (>98% in number of units and contributing to >90% of the production) can be characterised as belonging to the unorganised industrial sector; within these a large number of units, particularly those producing solid burnt clay bricks, show several characteristics of informal sector.[39] For the definition of 'organised', 'unorganised' and 'informal', please refer to Box 1.

Box 1: What is meant by organised, unorganised, and informal sector?

Adapted from 'India Unincorporated', by R. Vaidyanathan

Organised sector: Enterprises that are registered or come under the purview of the Companies Act 2013 or Factories Act 1948 and maintain any annual report presenting the profit and loss account and balance sheet.

Unorganised sector: Partnership and proprietorship enterprises, which do not maintain any annual report presenting the profit and loss account and balance sheet.

Informal sector: It is a sub-set of the unorganised sector. From the point of view of mode of production or economic activity, the distinguishing features of the informal sector are as follows:

a) Low level of organisation; small in scale usually employing fewer than 10 workers and often from the immediate family;
b) Heterogeneity in activities;
c) Easier entry and exit than in the formal sector;
d) Usually minimal capital investment; little or no division between labour and capital;
e) Mostly labour-intensive work, requiring low-level skills; there is usually no formal training as workers learn on the job;
f) Labour relations based on casual employment and or social relationships as opposed to formal contracts; employer and employee relationship is often unwritten and informal with little or no rights;
g) Due to their isolation and invisibility, workers in the informal sector are often largely unaware of their rights, cannot organise them and have little negotiating power with their employers and intermediaries.

[39] Vaidyanathan R. 2014. India Unincorporated. Westland and Tranquebar Press. 372 pp

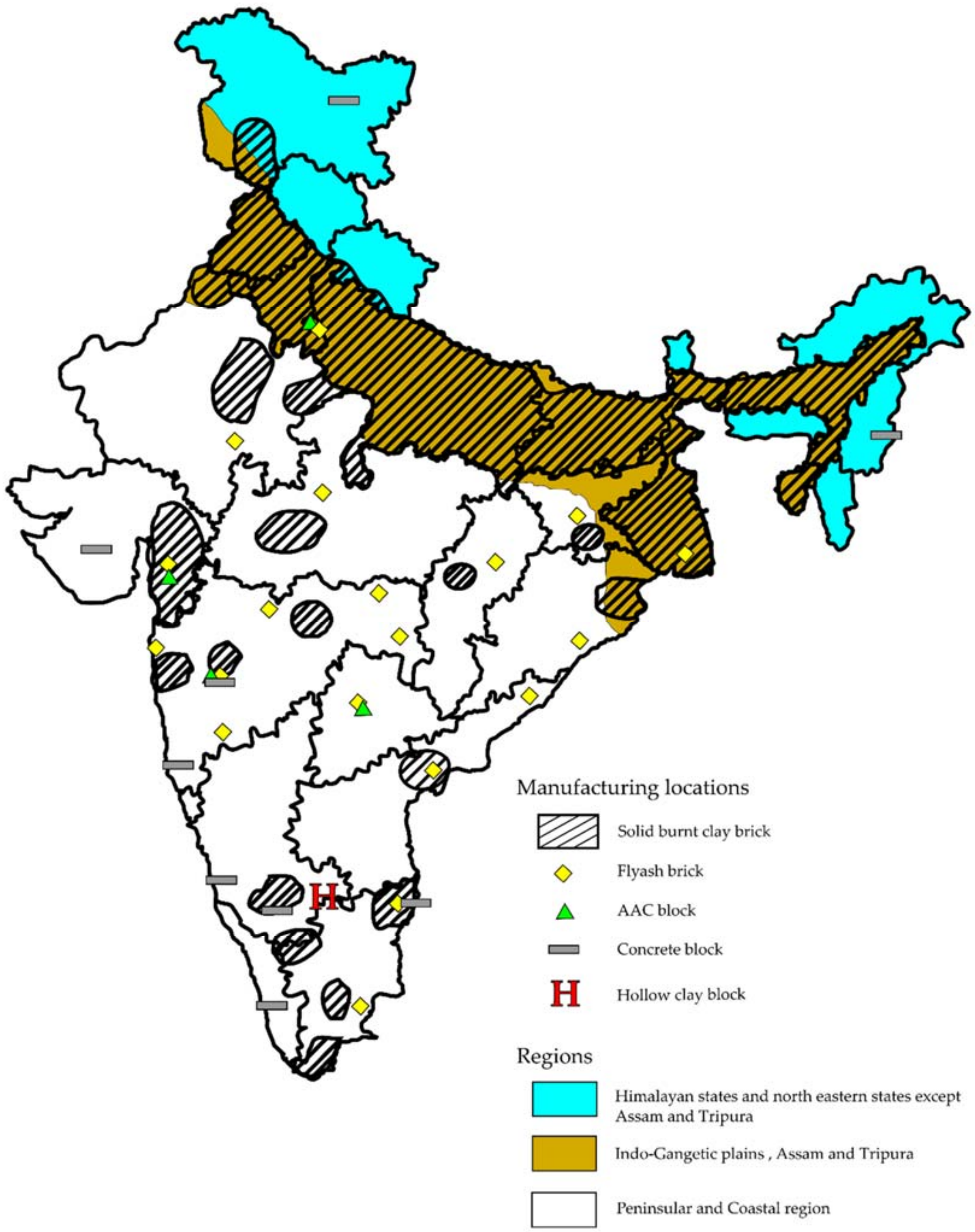

Figure 2.8. Geographical distribution of the brick manufacturing industry in India (Source: GKSPL Analysis)

Figure 2.8 depicts the geographical distribution of the brick manufacturing industry in India. In the following sections, an overview of brick industry classified according to the type of brick has been presented.

2.2.1 Solid Burnt clay bricks

The number of enterprises producing solid burnt clay bricks ranges from 1,40,000[40] to 2,10,000.[41] The estimated annual production varies from 236 billion[42] to 260 billion[43] bricks. Most of the enterprises are 'informal' enterprises, located in peri-urban and rural areas. Brick manufacturing industry shows different characteristics in the three zones:

1. Indo-Gangetic plains account for about 65% of total burnt clay brick production in the country. Uttar Pradesh, Bihar, West Bengal, Punjab, and Haryana are the major brick producing states in this region; owing to the easy availability of fertile alluvium soils. The typical production capacity of the enterprises ranges from 30 lakh to 80 lakh bricks ayear. The total number of enterprises is estimated to range between 40,000 and 50,000. The capital cost for the construction of a Fixed Chimney Bull's Trench Kiln (FCBTK), which can produce about 5 million bricks a year is about INR 30–50 lakh. FCBTK is the main brick kiln technology for firing of bricks. In recent years, 3000–4000 FCBTKs have been converted into more efficient zigzag kilns. In all cities of this region, brick kiln clusters are located just outside the municipal limits. Some of these are large and can have 300–500 kilns located together (e.g., Baghpat, Bahdurgarh [both in NCR], and Maner [outside Patna]).
2. Peninsular, coastal, and desert regions account for the remaining 35% of solid burnt clay brick production. The main raw material for making bricks (brick earth) is available only in small pockets and hence the industry is distributed. Gujarat, Rajasthan, and Tamil Nadu are important brick producing states. Leaving aside a few big burnt clay brick making clusters located around Nagpur, Chennai, Coimbatore, Madurai, Bengaluru, etc., which are using FCBTK technology, a majority of the brick manufacturing units are small (annual production <20 lakh bricks a year) and use clamps or other intermittent kilns for firing of bricks. The rate of adoption of mechanisation is higher in this region compared to the Indo-Gangetic plains.
3. The brick production in the Himalayan region is limited to valleys (e.g., Srinagar and Dehra Dun).

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[40] Kamyotra J S. 2016. CPCB presentation titled "Brick Kilns in India". Presentation made at the workshop on "Roadmap for Brick Kiln Sector Challenges and Opportunities", organised by the Centre for Science and Environment at New Delhi on 8 February 2016.
[41] Kumar S. 2016. TERI presentation titled "Options for Walling Materials and benefits of using REBs in building construction", organised by Punjab State Council for Science & Technology at Chandigarh on 24 May 2016.
[42] Ibid.
[43] Kamyotra J S. 2016. CPCB presentation titled "Brick Kilns in India". Presentation made at the workshop on "Roadmap for Brick Kiln Sector Challenges and Opportunities", organised by the Centre for Science and Environment at New Delhi on 8 February 2016.

Most of the brick kilns in India are non-mechanised or use basic level of mechanisation in the manufacturing process. This industry employs mainly hand-moulding methods for the shaping of green bricks. Surface soil excavated from agriculture fields and silt deposited from river and tanks are the main sources of clay supplies. These enterprises operate during the dry season (in most parts of the country this ranges from November to June) and are estimated to employ about 10 million workers (mostly seasonal migrant workers). The total annual turnover is estimated to be about INR 80,000 to 100,000 crore. Brick kilns consume about 31 million tonnes (MT)[44] of coal a year, making them the third largest industrial consumer of coal after the iron and steel industry, and cement industry.

Solid burnt clay brick industry is an old industry in India, with its history going back to the time of great river valley civilisations of Harappa. The industry has grown rapidly during last three decades, with its production increasing from 50 billion[45] in 1985 to 243 billion in 2015. This rapid expansion of brick making with only small improvements in its technology has given rise to many environmental concerns. The main environmental concerns associated with the production of common burnt clay bricks are mentioned below.

- Large CO_2 emissions: The production process involves baking of bricks up to a temperature of 800–1100 °C in brick kilns. To achieve this high temperature, fuel is burned in brick kilns. As indicated earlier, common burnt clay brick industry is one of the largest industrial consumers of coal in the country. The CO_2 emissions from the solid burnt clay brick industry are estimated to be 66–84 MT per year.[46]
- Air pollution: The combustion of fuel in brick kilns, which is often incomplete, gives rise to a variety of air pollutants such as $PM_{2.5}$, PM_{10}, sulphur dioxide (SO_2), carbon monoxide (CO), Hydrogen Fluoride (HF), and black carbon. The black carbon emissions from brick kilns in India are estimated at over 100,000 tonnes a year.[47] Recent research shows that large brick kiln clusters around urban areas, particularly those situated in the northern and eastern states, are an important source of air pollution in the cities. For example, the functioning of over1000 brick kilns around Delhi are considered a significant contributor to air pollution in Delhi and nearby urban areas.[48]

[44] Kumar S. 2016. TERI presentation titled “Options for Walling Materials and benefits of using REBs in building construction”, organised by Punjab State Council for Science & Technology at Chandigarh on 24 May 2016.
[45] Gandhi S. 1987. Brick industry in India: energy use, tradition and development. Doctoral thesis submitted to University of Cambridge
[46] The Energy and Resources Institute (TERI). 2016. Report on Resource Audit of Brick Kilns. New Delhi: TERI [Project Report No. 2015IE22].
[47] Cheryl Weyant, et al. 2014. Emissions from South Asian Brick Production. *Environ. Sci. Technol*., 48 (11): 6477–83.
[48] Guttikunda S K and Calori G. 2013. A GIS based emission inventory at 1 km x 1 km spatial resolution for air pollution analysis in Delhi, India. *Atmospheric Environment* 67: 101–111.

- Loss of agricultural top soil and land degradation: About 750 MT of clay is consumed per year to produce common burnt clay bricks. Part of this clay is river silt harvested from rivers in the delta regions as well as clay obtained from the desilting of ponds, water tanks, dams, etc. However, a large amount of clay is obtained by excavating agriculture fields up to a depth of 2 metres. The areas from where clay is mined and located around urban settlements get absorbed as the urban settlement expands. For instance, Vasant Kunj, which is now a large and prominent residential locality in Delhi, was an important brick making area 30–40 years ago. At several places in Indo-Gangetic plains where clay depths are large, the mined area is put under agriculture. However, unplanned mining of clay from agriculture fields is an environmental concern, particularly in peninsular India[49] and results in the loss of top soil and land degradation.

Another important issue concerning the traditional brick industry is the issue of poor working conditions and non-adherence to existing labour laws/regulations. On one hand, brick industry is a major source of livelihood for more than 10 million migrant rural workers, on the other hand, it is also known for practices such as paying advance through contractors to procure workers, bonded labour,[50] poor working conditions, and child labour.[51] Issues like availability of cheap labour, informal nature of the enterprises, lack of electricity have resulted in the slow pace of mechanisation in the industry and lack of innovation.

2.2.2 Hollow and perforated burnt clay bricks

Production of perforated and hollow burnt clay brick requires mechanisation of the brick shaping process using a machine called extruder. Compared to solid burnt clay bricks, perforated and hollow burnt clay bricks require controlled drying and careful handling. As a result, hollow and perforated bricks can only be manufactured in semi-mechanised or mechanised brick-making plants.

A recent study has estimated that there are about 400 brick manufacturing units in the country, which are equipped with extruders. These enterprises are mainly located in three southern states of Karnataka, Tamil Nadu, and Kerala; and in some other pockets like Balaghat (Madhya Pradesh), Manipur, and around Chandigarh. However, only 45 of these enterprises are producing perforated and hollow burnt clay bricks; rest of them are producing solid bricks

[49] Dominik Noll. 2015. Socio-ecological Impacts of Brick Kilns in the Western Ghats: A socio-metabolic Analysis of small-scale Brick Industries in the Mumbai Metropolitan Region, Maharashtra, India. <https://www.aau.at/wp-content/uploads/2016/11/working-paper-164-web.pdf> (accessed on 1 July 2017).
[50] https://www.equaltimes.org/the-horror-of-modern-day-slavery?lang=en#.WS_I3GiGPg8 (accessed on 1 July 2017)
[51] http://www.thehindu.com/news/national/telangana/Brick-kilns-continue-to-use-child-labour/article16835129.ece (accessed on 1 July 2017)

or roofing tiles. While perforated burnt clay bricks are mostly manufactured in north India (Punjab, Haryana), hollow burnt clay bricks are manufactured mainly around Bengaluru and Kerala. The total production of hollow and perforated bricks in the country is estimated at about 0.22 billion bricks a year in 2015. The production of perforated and hollow burnt clay bricks has increased at 16% CAGR during 2011–15.[52] While hollow burnt clay blocks are being mostly used in high-rise residential buildings and individual housing; perforated burnt clay bricks have their main market in institutional buildings followed by the individual housing. In both the cases, the market for perforated and hollow burnt clay bricks is predominantly urban.

Wienerberger India Private Limited, a part of the world's largest clay brick manufacturer Wienerberger AG, is the largest manufacturer of hollow burnt clay bricks in the country with an estimated production of 100 million standard bricks a year.[53] The company has established a modern hollow brick manufacturing facility at Kunigal near Bengaluru; the total investment in India by the company is estimated at INR 200 crore.[54]

All the other manufacturers of perforated and hollow bricks in the country are much smaller in size and are usually organised sector brick or roofing tile manufacturers who have diversified into perforated and hollow brick production. The typical capital investment on plant and machinery in these enterprises varies from INR 2 crore to 20 crore depending on the technology choice, degree of mechanisation, and scale of production.

The key issues in the growth of perforated and hollow brick manufacturing industries are briefly expalined below.

- Limited availability and high price: At present, manufacturing is limited only to certain regions in the country. For example, while the region around Bengaluru is the main market for hollow burnt clay blocks; perforated burnt clay bricks are mainly available in the NCR and parts of Punjab and Haryana. Even in these regions, due to limited production capacity and limited competition, the prices for these products are often high. Almost all the existing burnt clay brick manufacturing enterprises, manufacture hollow and perforated clay bricks as secondary products. For them, the primary product is usually common burnt clay solid brick or roofing tile. Thus, their manufacturing facilities are not optimised for hollow and perforated clay brick production, and none of the producers (except Wienerberger) possess an integrated production line. Because of lack

[52] Greentech Knowledge Solutions Pvt. Ltd (GKSPL) 2016. Market assessment of burnt clay resource efficient bricks. Report prepared for UNDP-GEF-MoEFCC project on "Energy Efficiency Improvements in the Indian Brick Industry".
[53] http://timesofindia.indiatimes.com/city/bengaluru/Bangalores-architects-and-builders-are-innovative/articleshow/28201029.cms (accessed on 1 July 2017)
[54] Ibid.

of assured market, and lack of any financial support/low-cost financing options to upgrade technology, the enterprises are hesitant to invest in integrated production lines.

- Shortage of trained manpower for construction: The products being new, there is limited understanding about the right methods for using these products. In the case of hollow blocks, the concerns range from laying of pipes and conduits to nailing. In the case of perforated bricks, the right method of application to ensure holes not getting filled with mortar is an issue. Shortage of trained manpower (masons and contractors) and right tools for application acts as barriers.

2.2.3 Autoclaved Aerated Concrete (AAC) Blocks

AAC block is a light-weight, precast building material. The raw materials for the production of AAC blocks are fly ash, gypsum, cement, lime, and aluminium powder. The AAC block manufacturing was introduced in India in 1970s but till 2008 the turnover of the industry was small. It is estimated that the turnover of the AAC block industry in 2008 was INR 50 crore, and in 2015 it is estimated to have grown to INR 2000 crore,[55] and it is expected that the industry turnover will rise to INR 5000 crore by 2020.[56]

It is estimated that in 2015, there were about 75 industrial units, all belonging to the organised sector, manufacturing AAC blocks in the country, with a total installed production capacity equivalent to about 6.3 billion standard size bricks a year (12 million m^3/year). AAC block manufacturing can be divided into two types of enterprises:

1. Enterprises that are part of an industrial house (e.g., cement manufacturers) or having multiple AAC manufacturing units; the combined installed capacity of these types of enterprises at the end of 2015 was around 2.6 billion bricks a year. These units are generally doing better business.
2. Individual/stand-alone manufacturing units. Several of these units have issues related to the quality of the product and are not doing well.

The top five states in terms of AAC production are Gujarat (main cluster around Surat), Maharashtra (main cluster around Pune), Haryana, Telangana (main cluster around Hyderabad), and West Bengal, contributing to 75% of the total installed production capacity. The typical production capacity of AAC plants is 0.1 million m^3 a year to 0.3 million m^3 a year. The typical investment for a plant having 0.1 million m^3 a year capacity is INR 15–20 crore.

[55] http://www.indiancementreview.com/News.aspx?nId=JTbWdUj6k4vECxF5gfuorg==, (accessed on 12 September 2016)
[56] Ibid.

The key issues concerning AAC block industry are mentioned below.

- An AAC manufacturing plant needs to be in the vicinity of thermal power plants for uninterrupted supply of key raw material—fly ash at low cost (transportation costs) as well as should be near to the large urban centres. AAC plants face competition from the cement industry in the procurement of fly ash. Given these requirements, AAC manufacturing is limited to only a few centres in the country.
- With increasing acceptance of the product in Indian construction activities, the AAC block manufacturers registered continuous growth in total operating income over past five years. However, on the contrary, profitability has shown declining trend due to significant increase in installed capacities of AAC block in a short span of time together with strong competition from cheaper clay bricks.
- In several of the markets, there are some concerns regarding crack formation, leakages, etc. in the walls made from AAC blocks, which indicates the need for better quality control during manufacturing and following right methods for application of the material.

2.2.4 Pulverised Fuel Ash Lime/Cement bricks

Broadly there are two types of pulverised fuel ash bricks

1. Pulverised fuel ash-lime bricks are produced from raw materials consisting of pulverised fuel ash as the major component with lime and an accelerator acting as a catalyst.
2. Pulverised fuel ash-cement bricks are made from raw materials consisting of pulverised fuel ash as the major component with cement acting as the binder.

As per CEA,[57] only about 12 MT or 6.5% of the total fly ash generated was utilised for brick making at the national level. In terms of scale and level of automation, the fly ash brick manufacturing enterprises can be divided into two categories:

1. Semi-mechanised small production: The production capacity of these enterprises usually ranges from 1000 to 10,000 bricks per day (annual production <20 lakh bricks/year). The number of micro and small fly ash enterprises in the country in 2015 is estimated at 18,000,[58] with a total installed capacity to produce 54 billion bricks a year.[59] These are semi-mechanised units in which most of the material handling is manual and the product

[57] Central Electricity Authority. 2015. Report on fly ash generation at coal/lignite based thermal power stations and its utilization in the country for the year 2014-15. New Delhi: Central Electricity Authority.
[58] Bhanumatidas N and Kalidas N. 2016. FaL-G the unique E4 technology. Presentation at the Stakeholder Workshop on Resource Efficient Walling Materials. Workshop organised by Greentech Knowledge Solutions, 7 June 2016. New Delhi.
[59] Ibid.

is cured by spraying water. The typical capital investment in plant and machinery for these enterprises is INR 15–20 lakh.

2. Mechanised large production: The production capacity of these enterprises can range from 25,000 to 200,000 bricks per day (annual production 50 lakh to 5 crore bricks). The exact number of such enterprises is not known, but most of such enterprises are located near or within the premises of power plants, several of them are owned by the thermal power plants themselves. The material handling in these enterprises are mechanised and in some cases the curing is done using steam.

If fly-ash utilisation is converted into equivalent number of standard bricks, and after accounting for fly ash consumption for AAC production, the annual production of pulverised fuel ash cement/lime bricks is estimated at 8.36 billion bricks. The top three states in terms of fly ash brick production are Maharashtra, Andhra Pradesh, and Tamil Nadu.

The key issues/barriers in the growth of fly ash brick industry are as follows:

- There is a large gap between the installed production capacity (about 60 billion bricks/year) and the actual annual production (about 8 billion bricks/year) of fly ash bricks, indicating the low utilisation of the installed capacity.
- The quality of bricks produced in semi-mechanised small enterprises is a big issue because of lack of control over raw material quality, lack of technical knowledge regarding the product chemistry among the owners/managers, reducing the period of curing to save cost or due to shortage of water.
- Many fly ash brick manufacturers have reported loss in production because of shortage of sand, due to ban on sand mining.[60] [61] According to several manufacturers, thermal power plants prefer supplying fly ash to large consumers like cement plants. The shortage of these two primary raw materials is one of the reasons for the low operating capacity of the fly ash brick enterprises.
- There is uncertainty regarding potential adverse health effects resulting from exposure to fly ash constituents and products made with it. Fly ash contains several components that pose risks to human health (e.g., radioactive elements), and there are several ways in which workers or the general public can get exposed (e.g., by handling fly ash at brick production facilities, inhabiting buildings constructed using fly ash bricks). However,

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60 http://www.dnaindia.com/locality/cuttack/ban-sand-mining-threatens-livelihood-fly-ash-bricks-manufacturers-labourers-cuttack-64899 (accessed on 12 September 2017)
61 http://www.business-standard.com/article/economy-policy/fly-ash-brick-production-drops-over-70-per-cent-in-ap-115071200776_1.html (accessed on 12 September 2017)

there is limited understanding of the magnitude of the potential health impacts associated with the production and use of fly ash bricks.[62]

2.2.5 Concrete Blocks

The basic raw materials for the manufacture of cement concrete blocks are cement, fine aggregate (sand), and coarse aggregate. Wastes generated by stone crushers, quarrying, and stone processing units can also be used as aggregates and have now become increasingly common. Many of the concrete brick manufacturing units are in the informal sector, i.e., they are either not registered or licensed to any official organisation. In terms of scale and level of automation, the concrete block manufacturing enterprises can be divided into two categories:

1. Semi-mechanised small production: The production capacity of these enterprises usually ranges from 100 to 2500 blocks per day (annual production <6 lakh blocks). In these units, most of the material handling is manual and the product is cured by spraying water. The typical capital investment in plant and machinery for these enterprises is INR 10–20 lakh.
2. Mechanised large production: The production capacity of these enterprises can range from 8000 to 32,000 blocks per day (annual production 24 lakh to 1 crore blocks). There are only a few such enterprises. The material handling in these enterprises are mechanised and in some cases the curing is done using steam.

Concrete blocks are manufactured throughout the country; but the usage is limited to a few applications such as boundary walls and commercial complexes. In a few cities in south India such as Chennai and Bangalore, these blocks are also used as infill material in the construction of high-rise residential buildings.

2.2.6 Key issues with the manufacturing enterprises

One of the key issues about the manufacturing enterprises engaged in the production of different types of bricks is that >90% of the production is contributed from enterprises belonging to the unorganised sector. The common issues of these enterprises are listed below.

- Technology obsolescence: In the case of unorganised burnt clay brick manufacturing enterprises, the basic process of forming is manual and the brick kiln technologies in use are at least 100 years old. In the case of other types of bricks, generally the forming process are semi-mechanised but material handling is usually manual.

[62] ABT Associates and TERI. 2016. Considerations on the Health Impacts of Coal Fly Ash Use in Brickmaking and Building Construction in India. Report prepared for The Climate and Health Research Network.

- Problems in the supply/procurement of raw materials: Clay brick enterprises in most parts of the country are facing problems in getting access to brick earth for making bricks as the arrangements for providing environment clearance for the mining of brick earth is still not fully operational. The problem in clay procurement is particularly severe in states like Kerala. On the other hand, fly ash enterprises have problems in procuring fly ash in several states due to various reasons such as earmarking of the entire fly ash supply for cement production and reluctance of power plants to supply fly ash to small producers. Both fly ash brick enterprises and concrete block enterprises face problems in the procurement of sand.
- Poor product quality: In the absence of an effective quality control and assurance system, the quality of bricks available in the market is often poor. Burnt clay bricks have issues related to efflorescence, high water absorption, and large variation in product size and shape. In the case of fly ash bricks and concrete blocks, inadequate strength and high-water absorption are often cited as problem areas.
- Poor working conditions: Burnt clay brick production is a seasonal industrial activity and relies on migrant workers. Often the working and living conditions for workers are poor. Similarly, in the case of fly ash brick production, there is inadequate protection for workers handling fly ash.
- Difficulty in understanding and complying with the complex environment regulations: Most of the owners of unorganised enterprises are not highly educated, also they do not have educated and professionally trained managers or supervisors. They find it difficult to understand complex environment regulations, e.g., environment clearance for the mining of brick earth. The opaqueness of the implementation process leads them into the hands of intermediaries to get necessary environment compliance. The issue of corruption in State Pollution Control Boards has been acknowledged by the MoEFCC and is a matter of concern[63]. In recent years, the number of litigations related with brick industry has increased manifold and cases related with brick industry forms significant part of the ongoing cases in the National Green Tribunal.
- Overcapacity and low profitability: There is significant over capacity for manufacturing of bricks in certain regions. In states like Punjab, the installed burnt clay brick production capacity is way above the required capacity, resulting in severe pressure on profitability. In the case of fly-ash brick production, though the number of enterprises that have been set up are estimated to be more than 20,000, the number of enterprises that are operational is 10,000 or lower.

[63] http://www.freepressjournal.in/india/environment-minister-wants-to-clean-corruption-in-pollution-control-offices/1092586 (accessed on March 11, 2018)

The enterprises in the unorganised sector all over the country are under pressure to transform into the organised sector and to comply with regulations on environment, mining, taxation, transportation, workers, etc.

2.3 Environmental Policy

The main policies covered under this section are related to air pollution from brick kilns, fly ash regulation, environment impact assessment for mining of minor minerals, and building regulations.

2.3.1 Abatement of Air Pollution from Brick Kilns

2.3.1.1 Emission Standards for Brick Kilns

The first emission standards for brick kilns were notified in 1996. The standards specified limiting particulate matter (PM) emission values in the stack gases of brick kilns. In addition, the standards also specified the minimum height of the chimney for the dispersion of pollutants for various types of kilns. A process to amend the emission standards for brick kilns was initiated by the CPCB in 2009; a draft amendment was circulated by MoEFCC for comments in 2015, but the revised standards are yet to be notified. While the existing standards are kiln technology specific,[64] i.e., ranging from 250 mg/Nm^3 to 1200 mg/Nm^3 (Table 2.6), it is expected that the new standards will be the same across main kiln categories and would be stricter (about 250 mg/Nm^3).

Table 2.6. Particulate matter emission standards for brick kilns

Type of brick kiln	Limiting concentration of particulate matter (mg/Nm^3)
Bull's Trench Kiln (Small)	1000
Bull's Trench Kiln (Medium and Large)	750
Down-draft kiln	1200
Vertical Shaft brick kiln	250

2.3.1.2 Directions under Section 18 (1) (b) of the Air Act, 1981 to State Pollution Control Board regarding Controlling Air Pollution from Brick Kilns

In December 2015, the CPCB, under Section 18 (1) (b) of the Air Act 1981, issued directions to State Pollution Control Boards (SPCBs) of states such as Haryana, Uttar Pradesh,

[64] Ministry of Environment, Forest and Climate Change (MoEFCC). 2009. Environment (Protection) Fourth Amendment Rules. <http://www.moef.nic.in/legis/ep/543_E.pdf> (accessed on 1 July 2017)

Rajasthan, Uttarakhand, and Punjab to take steps to control air pollution from brick kilns. These steps were proposed due to the worsening air quality in the NCR and other cities in the region. The directives asked for:

- To ensure that no unauthorised brick kiln is allowed to operate.
- The existing FCBTK brick kilns should shift to zigzag kilns.[65]

Several SPCBs had since then issued notifications to implement these directives. The Environmental Pollution (Prevention and Control) Authority (EPCA) has called for all brick kilns operating in Delhi-NCR, estimated to be about 4000 in number, to shift to a 'zigzag setting'.[66]

In a separate development, the Bihar SPCB directed all the brick kilns located in five blocks adjoining the city of Patna to shift to cleaner brick kiln technologies in 2016. Further, the same directive requires brick kilns throughout the state of Bihar to upgrade to cleaner brick production technologies by August 2017. The order has been implemented in the five blocks located around Patna and a summary of the experience is presented in Box 2.

Box 2: Implementation of directive to shift to cleaner brick kiln technologies in five blocks of Patna district

In February 2016, Bihar State Pollution Control Board (BSPCB) has directed all the brick kilns located in five blocks of Patna district, namely Patna Sadar, Fatuah, Danapur, Fulwarisharif, and Maner, to shift to cleaner brick production technologies before the commencement of next brick-making season. By early 2017, out of the 190 brick kilns in these five blocks, 92 brick kilns shifted to cleaner brick kiln technologies (71 to Natural draft zigzag kilns and 21 to induced draft zigzag kilns). The progress of the implementation of this directive was tracked continuously by Greentech Knowledge Solutions team, which also conducted awareness and training programmes to assist brick makers with this transition.

Out of the 92 kilns that shifted to cleaner brick kiln technologies, 70%–75% were able to undergo the shift quite well. A large majority among them reported satisfaction due to savings of more than 15% in coal consumption and improvement in brick quality. The flue gas analysis at some of the kilns showed considerable reduction in the CO emissions, indicating better/more complete combustion. However, around 25%–30% of the kilns struggled with the change in technology and the operation of the zigzag kilns. Most of these problems were related to the wrong design, construction, and operation advice given by the technology providers. Following are the learnings from this experience:

- The experience strongly indicates the need for training and certifying a large number (in hundreds) of technology providers in kiln construction and operation, if thousands of kilns were

[65] The initial directive issued on 26 December 2015 asked for conversion of natural draught kilns into induced draught kilns. Later the notices issued by SPCBs clarified that the conversion should be to zigzag kilns.

[66] http://www.downtoearth.org.in/news/epca-draws-roadmap-for-brick-kilns-in-delhi-ncr-57945 (accessed on 27 May 2017)

to be reconstructed over a short period of time. Preparation and distribution of audio-visual tools, training manuals, and guidance materials for brick kiln workers and staff to help them in operation and troubleshooting of brick kilns operating on cleaner technologies are also needed.

- The experience also indicated that as SPCBs have limited capacities, development of GIS map-based tools can help in monitoring and tracking compliance of the directive. Simple methodologies and low-cost tools for measuring emissions from large number of kilns are also needed.
- The state government should take initiative to make the processes of getting environment clearances/consent smooth and streamlined. For example, the District Environment Impact Assessment Authority (DEIAA), which is the designated authority to issue environment clearances (EC) to brick kilns, is not yet functional in most of the districts. And those kilns, which do not have prior EC or their application is pending, could not get their 'consent to operate' (CTO) certificate renewed from BSPCB. These kinds of discrepancies should be resolved.

2.3.1.3 Suggestions for emission standards for brick kilns

The indications given by CPCB and MoEFCC officials suggest that the revised emission standards are likely to reduce the limiting concentration of PM in stack gases to 250 mg/Nm^3. It also seems that to meet these standards the brick kilns are likely to adopt the simplest route, i.e., they will change over to zigzag kilns. This would be a good starting point, but it would help the industry, if like vehicles, the government can come up with a more ambitious roadmap for emission standards for brick kilns. Assuming that the revised emission standards for brick kilns will be notified in 2017, this would mean that a revision in the emission standards for brick kilns has taken almost 21 years (as the last emission standards were revised in 1996). Given that the Indian requirement for bricks will peak some time during 2032–37, there is a need to revise the emission standards at much shorter time duration (after every 5–8 years).

Some of the specific suggestions, which can be considered while revising emission standards (upcoming revision or future revision) for bricks kilns, are as follows:

- The standards for 'new' kilns (kilns established after a certain date) should be stricter compared to the standards for the 'existing' kilns. While 'existing' kilns should be allowed to operate after upgrading the technology, within a specified time period, to meet the emission standards, the 'new' kilns, which will have longer operational life of 20–30 years, should be based on technologies having stricter emission standards. The logic for this recommendation follows the emission standards for vehicles, where emission standards for new vehicles are stricter, which allows the replacement of the vehicular fleet with less polluting vehicular stock over a period of time. In China[67] and South Africa, separate emission standards are specified for 'existing' and 'new' brick kilns.

- Instead of having technology-specific PM emission standards that vary from 250 to 1200 mg/Nm^3), it is suggested that there should be one uniform standard of 250 mg/Nm^3 for all 'existing' brick kilns (except clamp kilns) and such kilns should reduce their PM emissions to 250 mg/Nm^3 and increase their stack height in a specified time period of 3 years. Therefore, it is possible for all existing kilns to adopt/retrofit to either natural or induced draught zigzag kiln, Vertical Shaft Brick Kiln (VSBK) or other kiln technologies (tunnel kiln, Hybrid Hoffmann Kiln, etc.) to meet the standard of 250 mg/Nm^3. More technological options can be added to this list after proper scientific evaluation.
- The standard for 'new' kilns (set up after a particular cut-off date, e.g., 1 January 2018) should be 100 mg/Nm^3. The standard of 100 mg/Nm^3 for 'new' kilns is achievable by using cleaner fuels (e.g., natural gas, producer gas, biogas; powdered coal as internal fuel) and adopting cleaner kiln technologies. More technological options can be added to this list after proper scientific evaluation. It should be noted that in South Africa[68] the emission standards for 'new' brick kilns (excluding clamp kilns) are at 50 mg/Nm^3, while for 'existing' brick kilns (excluding clamp kilns) are at 150 mg/Nm^3. Similarly, in China,[69] the proposed emission standards for 'new' brick kilns (drying and firing) are at 50 mg/Nm^3, while for 'existing' brick kilns (drying and firing) are at 100 mg/Nm^3.

2.3.2 Fly Ash Regulation

Most of the electricity production in India is based on coal. The combustion of coal in power plants generates about 170 MT of fly ash every year. Safe disposal of this large amount of fly ash is a major environmental challenge. The Government has been promoting its use for various applications, including those for the manufacturing of cement and building materials. The first regulation for fly ash utilisation was notified in 1999, which have subsequently been revised in 2003, 2009, and 2016. As per the revised 2016 notification:

- All brick manufacturing units within the 300-km radius of a thermal power plant are required to use fly ash for the manufacturing of bricks.

[67] http://www.sinoequipment.com/knowledge-detail.asp?Id=57&category=engineering (accessed on 17 November 2015).
[68] https://www.environment.gov.za/sites/default/files/gazetted_notices/nemaqa_listofactivities_g33064gon248.pdf (accessed on 17 November 2015).
[69] ESMAP. 2011. Introducing Energy-efficient Clean Technologies in the Brick Sector of Bangladesh. Report No. 60155-BD. Washington, DC: The International Bank for Reconstruction and Development /The World Bank Group Energy Sector Management Assistance Program (ESMAP).

- All cities having a population of more than 1 million to amend building bye-laws to make the use of fly ash bricks mandatory.
- Further the use of fly-ash-based bricks and products is made mandatory in all Government schemes or programmes such as Mahatma Gandhi National Rural Employment Guarantee Act, 2005 (MNREGA), Swach Bharat Abhiyan, Urban and Rural Housing Scheme, where the built-up area is more than 1000 square feet and in infrastructure construction including buildings in designated industrial Estates or Parks or Special Economic Zone.

Figure 2.9 shows the annual fly ash generation and utilisation. It is observed that in 2013, the total fly ash utilisation was about 60% of the annual fly ash generation. As a result of the regulation, the utilisation of fly ash has increased and cement industry has emerged as the largest user of fly ash in the country. The annual utilisation of fly ash for manufacturing of bricks is still small, only 7% (about 12 MT) of the annual fly ash generation. As pointed out earlier, the fly-ash-based bricks constitute only 3%–5% of the total brick production.

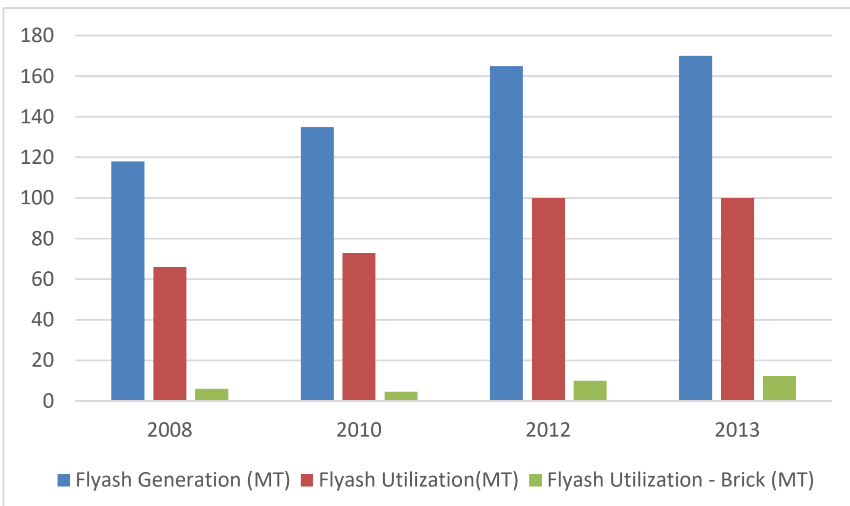


Figure 2.9. Fly ash generation and utilisation (MT/year)

The fly ash availability is highly skewed among states (Figure 2.10).[70] There are several states having almost no or very little amount of fly ash available for brick making; hence, the provision of making use of fly ash bricks mandatory throughout the country is not practical.

States like Andhra Pradesh, Telangana, Chhattisgarh, Uttar Pradesh, and Odisha have large quantities of unutilised fly ash. In these states, there is potential to push up utilisation of fly

[70] Ahmed, et al. 2016. Geographical spread of fly ash generation and residual potential for its utilization in India. *International Journal of Innovative Research and Review*, 4(1): 8–19.

ash for brick production. In states like Punjab, Rajasthan, and Tamil Nadu, the fly ash utilization is high; so these states have low scope for utilising fly ash for brick production.

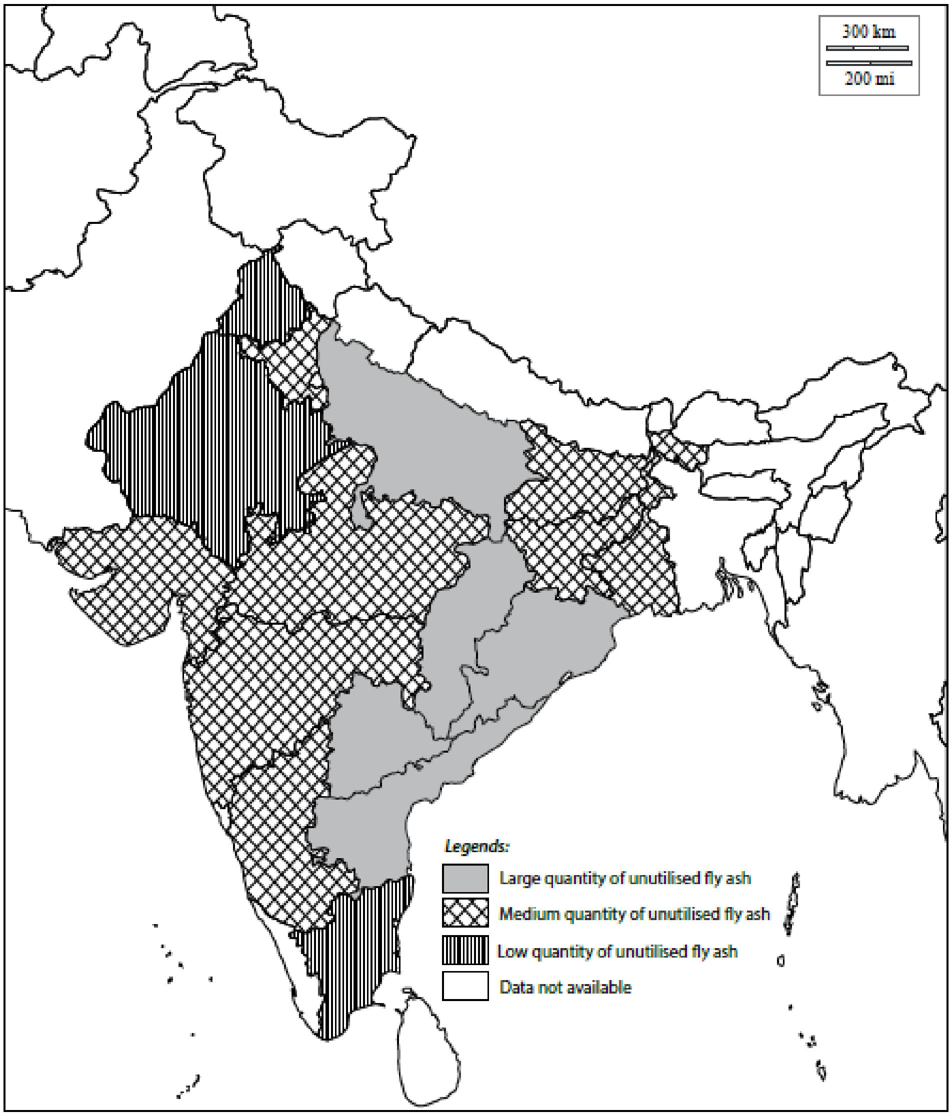


Figure 2.10. Fly ash availability in the country

2.3.2.1 Issues with the fly ash regulation

There are two primary issues related with the fly ash regulation as far as brick production is concerned.

1. The fly ash regulation has been framed as a national regulation but has not considered the regional differences in the availability of fly ash. Given that in a large part of the country, almost no or very little amount of fly ash is available for brick making, the provision of

making the use of fly ash bricks mandatory in all cities having population in excess of 1 million or mandatory use of fly ash bricks for government construction throughout the country does not seem practical. The fly ash regulation makes it mandatory for coal-based thermal power plants to supply at least 20% of dry ESP fly ash free of charge to units manufacturing fly ash or clay-fly ash bricks, blocks, and tiles on a priority basis over other users. Most of the power plants at present are not meeting this requirement. Even if in the best-case scenario all the thermal power plants are able to supply 20% dry ESP fly ash for brick production, the total quantity of fly ash available for brick production will be about 35 MT a year, which will be sufficient for making 25–35 billion bricks per year or meet only 10% of the total current annual requirement for bricks. Thus, mandating only fly ash bricks for construction is not the solution.

Without considering these facts, some of the states have issued notifications based on the 2016 fly ash notification. This has resulted in uncertainty/insecurity over planned investments to manufacture other types of REBs such as burnt clay hollow and perforated bricks.

2. The other issue with the fly ash regulation is the difficulty in implementing it, because of the multiplicity of agencies responsible for its implementation (Figure 2.11).

<table>
<tr><td rowspan="2">Central Monitoring Committee
Convener: MoEFCC
Members: Ministry of Coal, Ministry of Mines, Ministry of Power, CPCB, Central Electricity Authority (CEA), Department of Science and Technology, Building Materials Technology Promotion Council</td><td>Collecting reports on implementation from states: CPCB and Regional offices of MoEFCC</td></tr>
<tr><td>CPWD and other public builders for the use of fly ash bricks in the public construction
NTPC for supply of fly ash from thermal power generation</td></tr>
</table>

<table>
<tr><td rowspan="2">State Monitoring Committee
Convener: DoEF
Members: Department of Mines, Department of Power, SPCB, Road and Building Construction.</td><td>Collecting reports on implementation: SPCB</td></tr>
<tr><td>State thermal power generation companies (e.g., Mahagenco in Maharashtra) for supply of fly ash from thermal power generation</td></tr>
</table>

Department of Urban Development, Town and Country Planning, Municipal Corporations, Development Authorities for the **implementation of revision in building bye-laws and their implementation**	State Pollution Control Boards for **ensuring fly ash utilisation in brick manufacturing units**
	State PWDs, Rural Development, Housing departments for **the use of fly ash bricks in the public construction**

Figure 2.11. Implementation mechanism for fly ash regulation

The notification relies to a great extent on the revision of building bye-laws for making mandatory the use of fly ash bricks. If this is to be implemented, better coordination with the Ministry of Urban Development and Town and Country Planning Office as well as municipal authorities (who play an important role in revision of building bye-laws) is required. In the present implementation structure, they are not represented in the central committee and similar state- and municipal-level organisations are not represented in the state-level committee.

3. The fly ash regulation needs to be reworked taking into account the issues of availability of fly ash and demand for building products. It also needs simplification for easy implementation.

Box 3: The Fly Ash Brick Industry in Bihar

Excerpts from "*The Fly Ash Brick Industry in Bihar"* by Shakti Sustainable Energy Foundation, Bihar State Pollution Control Board and Development Alternatives.

Field study conducted in Bihar to understand the present scenario of the fly ash brick industry indicates that the sector has seen an upsurge of fly ash brick production units since 2012. The number of fly ash brick enterprises in the state has grown from 25 in 2014 to 129 in 2016. Analysis from the survey reveal that only 46 out of the 129 fly ash brick enterprises remained functional (currently in operation) while the rest of the units were either non-functional or shut down due to lack of market demand.

Fly ash brick makers face several barriers to entry, including a lack of market demand, negative mindset regarding fly ash bricks, lack of fiscal incentives, problems with fly ash sourcing, and lack of regulation, leading to market uncertainty and awareness.

2.3.3 Environment Impact Assessment for Mining of Brick Earth

Through a notification issued in 2012 by the MoEFCC, the excavation of brick earth for the production of burnt clay bricks is permissible only after prior environment clearance from the respective State Environment Impact Assessment Authorities (SEIAA). Through a notification issued in January 2016, the MoEFCC has instructed the formation of District-level Environment Impact Assessment Authority (DEIAA) for grant of environmental clearance for Category 'B2' Projects for mining of minor minerals (applicable to brick earth). For the purposes of assisting DEIAA, the notification also instructs constitution of the District-level Expert Appraisal Committee for all the districts of the country (DEAC for the district). Before the January 2016 notification, several SEIAAs had started granting environment clearances for brick enterprises. However, the process of providing clearances has slowed since then, as the formation DEIAA and DEAC is still in progress. Several environmentalists have raised issues regarding the composition of the DEIAA and the DEAC, particularly on the lack of environment expertise and hence their inadequacy to protect the environmental requirements of ecosystems in granting clearances for mining of minor minerals.[71]

The provisions of environment clearance limit the depth of clay mining to a maximum of 3 m; they also do not allow two mining locations to be within a distance of 500 m. It also puts the onus of rehabilitation of the mined land on the agency involved in mining. As in most of the cases, the environment clearance is being given based on an affidavit by the brick kiln owners to follow best practices, it is yet to be seen whether the brick makers would follow the best practices on mining and rehabilitation after getting the necessary environment clearance.

Once again just like fly ash regulation, the intent of having environment impact assessment for mining of brick earth is for the benefit of the environment, but lack of institutional capacities at the district level and the way in which it is being implemented has raised a question mark on its effectiveness. Also, the complex paperwork for getting environment clearance means that brick kilns must hire the services of consultants for the paperwork and bear substantial additional expenditure. The number of cases in the NGT regarding brick kilns has gone up significantly, adding further regulatory risks for new investment in the modernisation of the sector.

[71] http://indianexpress.com/article/india/india-news-india/ngt-notice-to-moef-on-decentralisation-of-ec-for-sand-mining-3053156/ (accessed on 1 April 2017)

2.3.4 Model building bye-laws

The model building bye-laws issued by the Town and Country Planning Office (TCPO), Ministry of Urban Development in section 10.2.6, which is titled as "Sustainability of Building Materials", states that:

"*Sustainability of natural resources for building materials shall be ensured through conservation of available natural resources and use of supplementary materials such as industrial/agricultural by-products, renewable resources, factory made building components and recycled construction and demolition waste. Supplementary building materials (derived or processed waste) shall be suitably used in combination with conventional resources offers dual advantages in purview of health & environmental benefits.*

Use of Factory made pre-fab/pre-cast and recycled components with Green benefits: a) Panels, hollow slabs, hollow blocks, etc. - conservation of materials, less water requirement. b) Fly Ash bricks, Portland Pozzolana cement, Fly ash concrete, phosphogypsum based walling & roofing panels, particle wood – recycled use of industrial/ agricultural by-products. c) Fly ash/ AAC (Autoclaved aerated light weight concrete) panels/ CLC (Cellular light weight concrete) panels- ensures thermal comfort (significant reduction in air conditioning requirement) d) Use of bamboo & rapidly growing plantation timbers - environmental benefits.

Local materials are generally suitable for prevailing geo-climatic conditions & have advantage of low transportation cost & time. Sustainable use of building materials shall be encouraged which may combine certain mandatory provisions and incentives."

These bye-laws refer to the fly ash notification of the MoEFCC and make use of fly-ash-based bricks mandatory in all buildings having built-up area >20,000 m^2.

2.3.5 Other programmes and policies

MoEFCC-UNDP-GEF project on Energy Efficiency Improvements in Indian Brick Industry: The project, which operated from 2009 to 2016, was aimed at promoting the manufacturing and use of perforated and hollow burnt-clay bricks, which can result in 20%–50% reduction in the quantity of clay as well as fuel and have better insulation properties. The project worked on creating awareness about the benefits of perforated and hollow burnt-clay bricks as well as worked with about 20 brick-making units involved in the manufacturing of perforated and hollow burnt-clay bricks.

BEE programme for improving energy efficiency in MSME clusters: The programme aims at taking demonstration, pilot dissemination activities to promote energy efficiency in MSME clusters. One of the identified clusters is Varanasi brick kiln cluster, in which BEE supporting 10 brick kilns to change over from FCBTK to zigzag firing. The progress of the project has been very slow and its reach is miniscule considering the large number of bricks kilns.

State-level policies promoting production of alternate walling materials: Some of the states, such as Bihar and Odisha, are providing incentives for setting up of manufacturing units for the production of fly-ash-based walling materials. Odisha has about 1000 fly ash brick-making units. The fly ash brick manufacturing units come under green category and are exempted from environmental clearance.[72] Since 2012, fly ash bricks have been included in the Schedule of Rates of the state Public Works Department (PWD), which makes the procurement of fly ash bricks for Government construction possible. Further, the state government had decided that fly ash bricks conforming to relevant BIS (Bureau of Indian Standards) specifications will be used in the construction of all government buildings located within a radius of 100 km of fly ash generating units. The District Industry Centres in the state are providing technical support and helping industries to access bank finance. The Bihar government is providing 20% subsidy for setting up fly-ash-based brick manufacturing plants to promote utilisation of fly ash in walling material production. There are about 100 fly ash brick-making units that have been set up in the state.

Housing for All

Urban: The urban scheme aims at constructing 2 crore houses by 2022.[73] The scheme is being coordinated by the Ministry of Housing and Urban Poverty Alleviation (MHUPA) and has provision for undertaking construction of mass housing projects through public and private builders/agencies as well as providing financial assistance to beneficiary-led individual house construction or enhancement. A Technology Sub-mission has been set up (being coordinated by Building Material Technology Promotion Council [BMTPC]) to facilitate the adoption of modern, innovative, and green technologies and building material for faster and quality construction of houses for the mass housing segment. The technology sub-mission is expected to coordinate with various regulatory and administrative bodies for mainstreaming and upscaling deployment of modern construction technologies and materials in place of conventional construction. Going through the minutes of the first few meetings of the technology sub-mission,[74] it seems that the focus of the sub-mission is on new industrial

[72] http://www.newindianexpress.com/states/odisha/Fly-Ash-Brick-Units-Earn-Good-Returns/2016/04/11/article3374129.ece (accessed on 1 April 2017)
[73] http://www.pmindia.gov.in/en/news_updates/housing-for-all-by-2022-mission-national-mission-for-urban-housing/ (accessed on 14 June 2017)
[74] http://mhupa.gov.in/writereaddata/csmc03-231115.pdf

technologies for construction (including walling) of mass housing. Some of these are listed below.

- Monolithic concrete construction system
- Expanded polystyrene core panel system
- Industrialised 3-S System using precast RCC columns, beams and cellular light-weight concrete precast RCC slabs
- Glass Fibre Reinforced Gypsum (GFRG) panel building system
- Factory-made fast-track modular building system
- Light Gauge Steel Framed Structures (LGSF)

Masonry construction using REBs does not seem to figure on the agenda of the technology sub-mission. An analysis of nine mass housing projects taken by Rajkot Municipal Corporation (RMC)[75] shows that only one project is using the new industrial technology (monolithic concrete construction) and the remaining eight are using masonry brick construction mainly using AAC blocks. This points out to the need for more focus on REBs in the Technology Sub-mission.

Rural: The rural scheme is being coordinated by the Ministry of Rural Development and aims at providing financial assistance to 1 crore households for the construction of *pucca* houses under the project during the period from 2016/17 to 2018/19.[76] Unlike the urban scheme, this scheme aims at using locally available building materials. It promotes the use of compressed stabilised earth blocks and fly ash bricks produced under MGNREGA. No information is available on the use of these bricks in the programme.

Green Building Rating System

Use of the green walling materials is one of the parameters promoted by the Green Building rating systems such as IGBC and GRIHA. However, there is no agreement on the definition of 'green' walling materials and in practice the main parameter to define these 'green' materials seem to be solely based on the content of waste/recycled material, such as fly ash.

2.3.6 Conclusions on policy framework

The above discussion shows that there are a variety of gaps that exist in the existing policy framework. These gaps coupled with the absence of a national policy framework for REBs

[75] Ashok B Lall Architects and GKSPL. 2017. Position paper on resource efficient low carbon affordable housing. Paper supported by the Swiss Agency for Development and Cooperation.
[76] http://www.pmindia.gov.in/en/news_updates/implementation-of-the-rural-housing-scheme-of-pradhan-mantri-awaas-yojana-gramin-to-achieve-housing-for-all-by-2022/ (accessed on 1 May 2017)).

make the task of moving towards an REB future uncertain and slow. The main gaps in the policy framework are as follows:

a) Lack of a comprehensive view on REBs: The policy lacks a comprehensive view on REBs. In practice, the policy is only aiming at parts; for example, reduction in air pollution (emission from brick kilns) or promoting use of fly ash in brick making. It lacks a common understanding of REBs and a clear and strong link between the policy for the production of REBs and the policy for developing a market for the same.

   An analysis of the policy framework in China (refer Box 3 for details), which seems to have made progress in introducing new walling materials and in reducing specific energy consumption and emissions from its brick industry, indicates a clear link between production of REBs (supply side) and energy-efficient building construction (demand side) from the beginning and a multi-pronged policy approach covering aspects such as finance, R&D, and energy and environment standards. It also indicates that the transformation in the brick industry is a long-term process. In China, the process started in 1992 and is still ongoing.

b) Complex and difficult to implement regulations: As pointed out in the case of fly ash regulation, it seems that the regulation was framed without taking into account either the regional differences in raw material availability or the institutional arrangements/capacities for its implementation in the states. Devolution of environment impact assessment for the mining of minor minerals to the district level does not take into account the issue of scarce implementation capacities at the district level. Experience suggests that complex implementation arrangements lead to inefficiencies and give rise to corrupt practices. There is a need for broader consultations with experts as well as with representatives from states and districts during policy formulation, to result in simpler and easy-to-implement policies and regulations.

c) Long delay in the formulation of regulations/policies: As explained, the process of revision of emission standards for brick kilns has taken over eight years and the revised emission norms are yet to be notified. In the meantime, the worsening air quality problem in northern India has resulted in *ad hoc* decisions by SPCBs to control air pollution from brick kilns. A timely revision of the emission standards could have avoided the confusion and the need for taking *ad hoc* decisions by SPCBs.

d) Lack of coherence between policies: There is lack of coordination between and among different ministries involved in the framing of regulations, particularly those related with building regulations. This is explained by a few examples below:

   - The fly ash utilization policy, 2016, calls for ‘all cities having a population of more than 1 million to amend building bye-laws to make the use of fly ash bricks mandatory’, presumably for all types of buildings. The model building bye-laws, 2016, proposes making use of fly ash bricks mandatory only for large building projects having a built-up area of >20,000 m^2.

- The fly ash regulation makes the use of fly ash bricks mandatory in all Government rural and urban housing projects having a built-up area of >1000 m^2. A notification by MoUD,[77] has made it mandatory for Central Public Works Department (CPWD), Delhi Development Authority (DDA), and National Building Construction Corporation (NBCC) to use monolithic concrete construction or industrialised 3-S system using cellular light-weight concrete slabs and precast columns in all projects (presumably including mass housing projects) having construction value of more than INR 100 crore.

e) Lack of capacities at the state-/district-levels to implement environment policies and regulations: This aspect has been explained while discussing emission standards (inadequate capacities at SPCBs) and environment impact assessment for mining (at district level).

f) Absence of key elements in the government policies: Three elements that stand out are listed below:

- Though brick manufacturing employs more than 10 million workers, and the industry is expected to both expand and modernise in the coming decades, brick manufacturing does not seem to be a part of the National Skills Development Mission.
- Absence of dedicated financing facility for the modernisation of brick industry. Unlike several other large industrial sectors like Technology Upgradation Fund for textile industry, no such fund or financing scheme exists for the brick sector.
- Absence of a dedicated technical assistance programme for making available technical assistance and technical training to brick manufacturing enterprises as well as training on application of REBs.
- Absence of R&D programme on brick manufacturing technologies or development of REBs.

[77] http://www.bmtpc.org/DataFiles/CMS/file/PDF_Files/MOUD_OM_Emerging_Technologies.pdf (accessed on 7 June 2017).

Box 4: Chinese policy framework for walling materials[78] [79]

China is the largest producer of bricks in the world. In 2004, Chinese brick production was estimated at 900 billion bricks a year. The solid burnt clay brick is the main walling material in China, like in India. In 2004, it was estimated that solid burnt clay bricks made up for 65% of the brick production. China has been promoting new types of bricks such as hollow burnt clay bricks, fly ash bricks, and AAC blocks and is aiming to raise the contribution of these new bricks to 60% by 2030. The Chinese policy on bricks has several aspects and has evolved over a period of time:

1992: Circular GF [1992] No 66: First policy statement on the need to accelerate transition to new walling materials and promote energy efficient buildings. This was followed by several policy actions:
- Policy on restriction of solid burnt clay bricks in identified regions and urban areas
- Preferential tax policies for new walling materials
- Strengthening of institutions for R&D and for providing technical support to brick industry
- Emission standards for brick kilns
- Policy on phasing out of kilns based on outdated technologies
- Energy consumption standards for brick kilns

2007: 11th Five-year plan on brick and tile industry in China
2010: Aim to have 40% of the total walling materials as new walling materials

Several ministries and departments have played a key role in policy formulation and implementation, which includes Ministry of Construction, Ministry of Agriculture, National Development and Reform Commission, State Economic and Trade Commission, Ministry of Finance, Ministry of Science and Technology, State Administration of Taxation, State Bureau of Quality and Technical Supervision, Construction Material Bureau, etc.

2.4 Conclusion

The main conclusions that can be drawn regarding the status of market, manufacturing industry, and policy framework for bricks are as follows:

1. The market of bricks shows wide variations across the country. These variations are mainly influenced by geographical region (based primarily on raw material availability) and within a geographical region by factors such as type of building projects (urban/rural, intended use, scale, agency responsible for the construction, etc.). The country can be divided into three geographical regions in terms of brick market:

[78] ESMAP. 2011. Introducing Energy Efficient Clean Technologies in the Brick Sector of Bangladesh. https://openknowledge.worldbank.org/bitstream/handle/10986/2797/601550ESW0P1110e00201100Color0FINAL.pdf (accessed on 10 August 2017)
[79] Heierli and Maithel S. 2008. Brick by Brick: The Herculean Task of Cleaning Up the Asian Brick Industry. Berne: Swiss Agency for Development and Cooperation.

- Himalayan and North-eastern states (except Assam and Tripura): Burnt clay bricks dominate the market in the western Himalayan region bordering the Indo-Gangetic plains. In the North-eastern states, concrete blocks also have significant market share.
- Indo-Gangetic plains, Assam and Tripura: Burnt clay bricks are the predominant brick type. AAC blocks, fly ash bricks, and concrete blocks are used in smaller quantities mainly in urban centres.
- Peninsular, desert, and coastal India: This is a diverse region, in which in some areas burnt clay bricks dominate the market (e.g., north Rajasthan, Madurai) but then there are pockets where solid concrete blocks (e.g., Karnataka), AAC blocks (e.g., Pune, Surat) and fly ash bricks (e.g., parts of Maharashtra and Andhra Pradesh) have large market shares.

2. The total production of bricks (2014/15) of different types is estimated to be 274 billion bricks a year. Solid burnt clay bricks have the largest production share (~89%); other alternative bricks such as concrete blocks, pulverised fuel-ash lime/cement bricks, and hollow and perforated burnt clay bricks together make up for the rest of the market. The market for alternative bricks, particularly AAC blocks, has grown during the past decade.
3. The manufacturing industry for the production of bricks is spread throughout the country. The total number of manufacturing enterprises is estimated to range between 2,50,000 and 3,00,000. Majority of the enterprises (>98% in number of units and contributing to >90% of the production) can be characterised as belonging to the unorganised industrial sector. The unorganised sector enterprises face issues of:
    - Low level of mechanisation and technology obsolescence
    - Uncertainty/problems in the supply/procurement of raw materials such as brick earth, fly ash, and sand
    - Poor product quality
    - Labour relations based on casual employment and/or social relationships as opposed to formal contracts and poor working conditions, reliance on migrant workers, bonded and child labour
    - Difficulty in understanding and complying with the complex environment regulations and a large number of ongoing litigations.
    - Overcapacity and low profitability: There is significant over-capacity for manufacturing of bricks in certain regions. In states like Punjab, the installed burnt clay brick production capacity is way above the required capacity, resulting in severe pressure on profitability. In the case of fly-ash brick production, though the number of enterprises is estimated to be over 20,000, only about 10,000 are operational.

4. The main policies that relate to the environmental impact of the brick industry are air pollution regulation for brick kilns, fly ash regulation, environment impact assessment for mining of minor minerals, and building regulations/building bye-laws. There are a variety of gaps that exist in the existing policy framework. These gaps coupled with the absence of a national policy framework for REBs portray an uncertain and slow future for REBs. The main gaps in the policy framework are as follows:
    - Lack of a comprehensive view on REBs
    - Complex and difficult to implement regulations
    - Incompatibility/lack of coherence between policies
    - Lack of capacities at the states/districts to implement environment policies and regulations
    - Absence of policy interventions in the areas of skill development, financing, technical assistance, R&D, and training.

The next chapter deals with defining resource efficiency in bricks and comparing various types of brick on resource efficiency parameters.

3 Resource Efficient Bricks

3.1 Parameters to define Resource Efficiency

Till now environment policy and regulation has been piecemeal, guided by a specific environment objective, be it air pollution or fly ash utilisation. To develop a comprehensive environment policy on bricks, a more integrated understanding of various environment issues is required. The resource efficiency framework developed in this study is an attempt to develop such an understanding.

Resource efficiency is defined as 'using the earth's limited resources in a sustainable manner while minimizing impacts on the environment.'[80] The resource efficiency framework for bricks in this study covers various stages of the life cycle of bricks and comprises four quantifiable parameters.

1. *Primary material consumption* is the quantity of virgin material (kg/m^3 of bricks) used for the manufacturing of bricks
2. *Primary energy* (MJ/m^3 of bricks) used in the manufacturing of bricks
3. *Carbon dioxide emission* (tCO_2/m^3 of bricks) during the manufacturing of bricks
4. *Air pollution* caused in the form of particulate matter emissions (g/m^3 of bricks) during the manufacturing of bricks

Resource efficiency parameters have been computed for different types of bricks. For burnt clay bricks, the data has been collected by monitoring of manufacturing units, while for other types of bricks it is based on data reported in literature and provided by the industries.

The chosen parameters have high relevance in the Indian context, given the large scale of construction likely to take place in the immediate future. Also, for all these parameters, data is available to quantify them. However, there is scope to further enlarge the resource efficiency framework by incorporating aspects such as the ones listed below.

- *Thermal conductivity* (W/m-K) of the brick, which has an influence on the heat gain or loss through the external walls of a building and hence on the energy use for cooling or heating of the building.
- *Transport requirement* – when brick manufacturing units are located at a place where the raw material can be obtained locally, and the building construction site is not far away, it

[80] http://ec.europa.eu/environment/resource_efficiency/index_en.htm (accessed on 16 March 2017)

reduces the requirement of transportation, which has an influence on the fuel consumption

- *Reusability*
- *Recyclability*, etc.

The parameters that are covered in this study and those that need to be further incorporated in future have been indicated in the life cycle diagram in Figure 3.12.

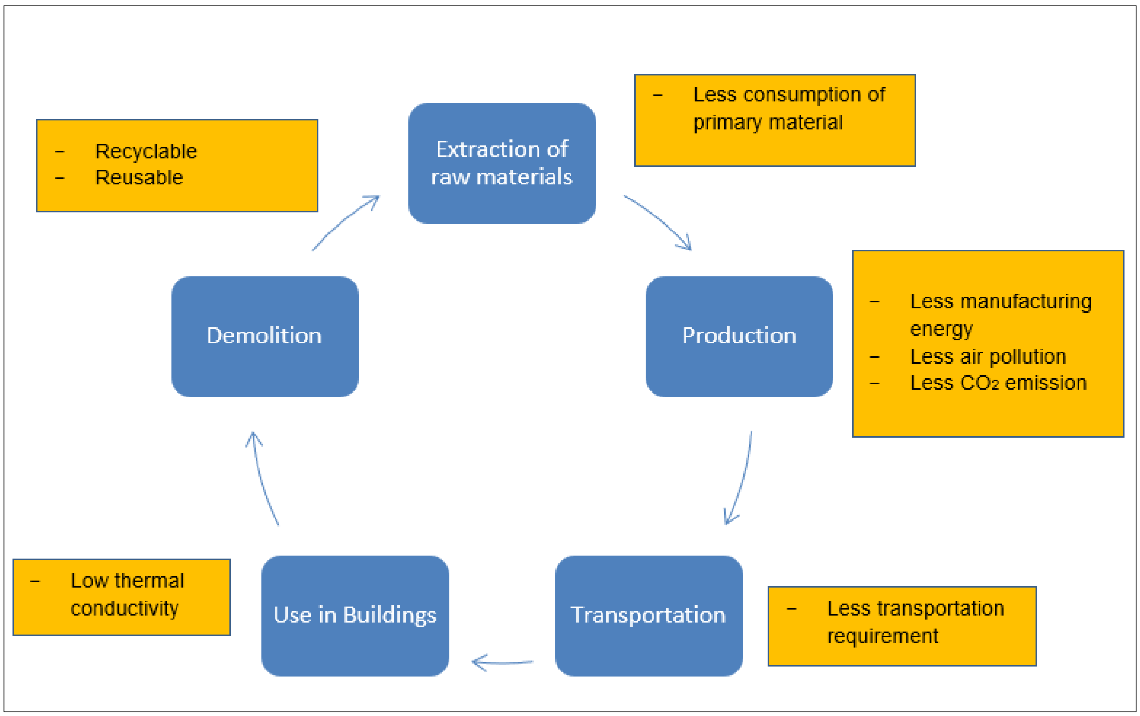


Figure 3.12. Parameter chart of resource efficient bricks

3.1.1 Methodology for walling material comparison on resource efficiency parameters

In the following sections, each of the resource efficiency parameter covered in this study has been discussed. In each section, various types of bricks have been compared on each of the resource efficiency parameter. The numerical values are presented in tabular forms. The values provided in these tables are indicative numbers, based on field survey/monitoring carried by the project team or are taken from literature.

The values are colour coded: the values that lie above the resource efficiency benchmark value have been marked red and the values that lie below the benchmark have been marked green. The resource efficiency benchmark values and their rationale are given in Table 3.7. Further, it is proposed that *all bricks that meet the resource efficiency benchmark values can be defined as REBs.*

Table 3.7. Resource efficiency benchmark values

Parameter	**Resource efficiency benchmark**	**Rationale**
Mined raw material	1320 kg/m^3	25% reduction from baseline value
Primary energy (manufacturing)	1560 MJ/m^3	25% reduction from baseline value
CO_2 emission (manufacturing)	0.14 tCO_2/m^3	25% reduction from baseline value
PM emission (manufacturing)	828 g/m^3	Corresponding to the SPM concentration of 250 mg/Nm^3 in stack gases as proposed in the draft revised national emission standards for brick kilns

3.1.2 Primary material consumption

The extraction of natural resources has negative environmental impacts in the form of depletion of non-renewable resources, degradation of land, rivers, forests, etc. Also, the machinery for mining and transportation of raw materials use fossil fuels, resulting in air pollution and CO_2 emissions. Thus, less primary material requirement is one of the criteria that defines an REB. While computing primary material requirement, the quantity of waste material has been deducted from the total material requirement.

The values for mined raw materials for different materials are tabulated in Table 3.8. It is observed that the highest primary material requirement is for solid concrete block (2153 kg/m^3) while the lowest is almost 1/10th for AAC blocks (224 kg/m^3). Bricks such as AAC blocks, CLC blocks, and burnt clay hollow blocks, which are low in density; and bricks that use waste materials such as pulverized fuel ash (Fly ash); are examples of bricks requiring less primary material.

Table 3.8. Primary material consumption of different bricks

Resource Efficiency Parameters	
Parameters	**Mined raw material**
Units	**kg/m^3**
Solid burnt clay- FCBTK (Baseline)	1760
Solid burnt clay fly ash - FCBTK	1009
Solid burnt clay - Zigzag kiln	1760
Perforated burnt clay - Zigzag kiln	1584
Hollow clay blocks - Tunnel kiln	815
Autoclaved aerated concrete blocks	224
Cellular light-weight concrete	338
Pulverised fuel ash-lime bricks	450
Pulverised fuel ash-cement bricks	711
Solid concrete blocks	2153
Hollow concrete blocks	1615
Compressed stabilised earth blocks	1976
Construction and demolition waste bricks	540

3.1.3 Primary energy used in manufacturing

Burnt-clay bricks consume fuels such as coal, pet coke, and biomass for the firing process of bricks in brick kilns. Similarly, cement used for manufacturing bricks/blocks uses fuel and electricity for its production. Bricks that consume less energy (fuel and/or electricity) in their manufacturing process fulfill one of the criteria for REBs. Table 3.9 provides the estimates for manufacturing energy consumption for different bricks/blocks.

Solid burnt clay bricks fired in FCBTK has the highest primary energy consumption (2080 MJ/m^3), while hollow concrete blocks (581 MJ/m^3) and CSEB (653 MJ/m^3) consume 1/3rd the primary energy and perform best amongst all the bricks on this parameter.

Table 3.9. Primary energy consumption for manufacturing of different bricks

Resource Efficiency Parameters	
Parameters	**Primary energy – manufacturing**
Units	**MJ/m^3**
Solid burnt clay- FCBTK (Baseline)	2080
Solid burnt clay fly ash - FCBTK	1558
Solid burnt clay - Zigzag kiln	1680
Perforated burnt clay - Zigzag kiln	1512
Hollow clay blocks - Tunnel kiln	1275
Autoclaved aerated concrete blocks	1276
Cellular light-weight concrete	1003
Pulverised fuel ash-lime bricks	1025
Pulverised fuel ash-cement bricks	811
Solid concrete blocks	774
Hollow concrete blocks	581
Compressed stabilised earth blocks	653
Construction and demolition waste bricks	1533

3.1.4 CO_2 emissions

Fossil fuels such as coal and pet coke, and electricity generated using fossil fuels (coal, natural gas, diesel) are used for manufacturing bricks. All these fuels emit CO_2 during combustion due to the presence of carbon in them. CO_2 is a greenhouse gas (GHG) – one of the major causes of global warming – that creates significant negative impact to the environment. Bricks that consume less amount of fossil fuels and/or electricity fulfills one of the important criteria of resource efficiency. Table 3.10 provides the estimates for CO_2 emissions during manufacturing of different bricks/blocks.

Solid burnt clay bricks (0.19 tCO_2/m^3) have the highest CO_2 emissions, while pulverised fuel ash-lime bricks (0.08 tCO_2/m^3) and solid concrete blocks have the lowest CO_2 emissions perform the best amongst all the bricks on this parameter.

Table 3.10. CO_2 emission during manufacturing of different bricks

Resource Efficiency Parameters	
Parameters	**CO_2 emission - manufacturing**
Units	**tCO_2/m^3**
Solid burnt clay- FCBTK (Baseline)	0.19
Solid burnt clay fly ash - FCBTK	0.14
Solid burnt clay- Zigzag kiln	0.15
Perforated burnt clay - Zigzag kiln	0.14
Hollow clay blocks - Tunnel kiln	0.12
Autoclaved aerated concrete blocks	0.14
Cellular light-weight concrete	0.15
Pulverised fuel ash-lime bricks	0.08
Pulverised fuel ash-cement bricks	0.12
Solid concrete blocks	0.12
Hollow concrete blocks	0.09
Compressed stabilised earth blocks	0.10
Construction and demolition waste bricks	0.24

3.1.5 Stack Air Pollution (Particulate Material Emissions)

Traditional brick kilns consume large amount of fuel; burning of these fuels, gives rise to air pollution in the form of sulphur dioxide (SO_2), carbon monoxide (CO), particulate matter, etc. The air pollution has negative impact on human health. Inefficient combustion produces higher air pollution. Bricks that produce less air pollution during manufacturing fulfills one of the criteria of REBs. Table 3.11 provides the estimates for PM emissions for different bricks/blocks. Pulverised fuel ash-lime bricks perform the best amongst all the building materials in this parameter. It is to be noted that this parameter has been evaluated based only on the air pollution measured in stack and does not consider fugitive emissions, which could be significant in all types of brick production.

Table 3.11. Particulate matter emission during manufacturing of different bricks

Resource Efficiency Parameters	
Parameters	**PM emission - manufacturing**
Units	**g/m^3**
Solid burnt clay- FCBTK (Baseline)	1888
Solid burnt clay fly ash - FCBTK	1547
Solid burnt clay- Zigzag kiln	368
Perforated burnt clay - Zigzag kiln	331
Hollow clay blocks - Tunnel kiln	178
Autoclaved aerated concrete blocks	151
Cellular light-weight concrete	210
Pulverised fuel ash-lime bricks	83
Pulverised fuel ash-cement bricks	161
Solid concrete blocks	167
Hollow concrete blocks	125
Compressed stabilised earth blocks	139
Construction and demolition waste bricks	327

3.2 Conclusions

A comparison of various types of bricks on resource efficiency parameters is presented in Table 3.12. The main conclusions that can be drawn are as follows:

- There are several types of bricks, which can be classified as REBs. AAC block, fly ash brick, and hollow burnt clay block meet all four resource efficiency parameters and can be taken as examples of REBs.
- Solid burnt clay fly ash brick, perforated burnt clay brick, CLC block, hollow concrete block, and CSEB meet several criteria and with improvements in the production process can become options of REBs.
- Solid burnt clay bricks perform poorly on most of the resource efficiency parameters. However, moving away from the production of solid burnt clay bricks in traditional kilns to hollow and perforated burnt clay bricks fired in efficient kilns results in significant improvements in resource efficiency parameters.

Table 3.12. Resource efficiency comparison table

Resource Efficiency Parameters				
Parameters	**Mined raw material**	**Primary energy manufacturing**	**CO_2 emission manufacturing**	**PM emission manufacturing**
Units	**kg/m^3**	**MJ/m^3**	**tCO_2/m^3**	**g/m^3**
Solid burnt clay- FCBTK (Baseline)	1760	2080	0.19	1888
Solid burnt clay fly ash - FCBTK	1009	1558	0.14	1547
Solid burnt clay - Zigzag kiln	1760	1680	0.15	368
Perforated burnt clay - Zigzag kiln	1584	1512	0.14	331
Hollow clay blocks - Tunnel kiln	815	1275	0.12	178
Autoclaved aerated concrete blocks	224	1276	0.14	151
Cellular light-weight concrete	338	1003	0.15	210
Pulverised fuel ash-lime bricks	450	1025	0.08	83
Pulverised fuel ash-cement bricks	711	811	0.12	161
Solid concrete blocks	2153	774	0.12	167
Hollow concrete blocks	1615	581	0.09	125
Compressed stabilised earth blocks	1976	653	0.10	139
Construction and demolition waste bricks	540	1533	0.24	327

4 Roadmap to Resource Efficient Brick future

4.1 Future Demand

The projection of demand for brick till 2047 has been carried out. The framework used in NITI Aayog's India Energy Security Scenarios to project future building stock is used as the basis for making the projections.

4.1.1 Methodology

The methodology for estimating the future demand is shown in Figure 3.13 and explained in the subsequent paragraphs.

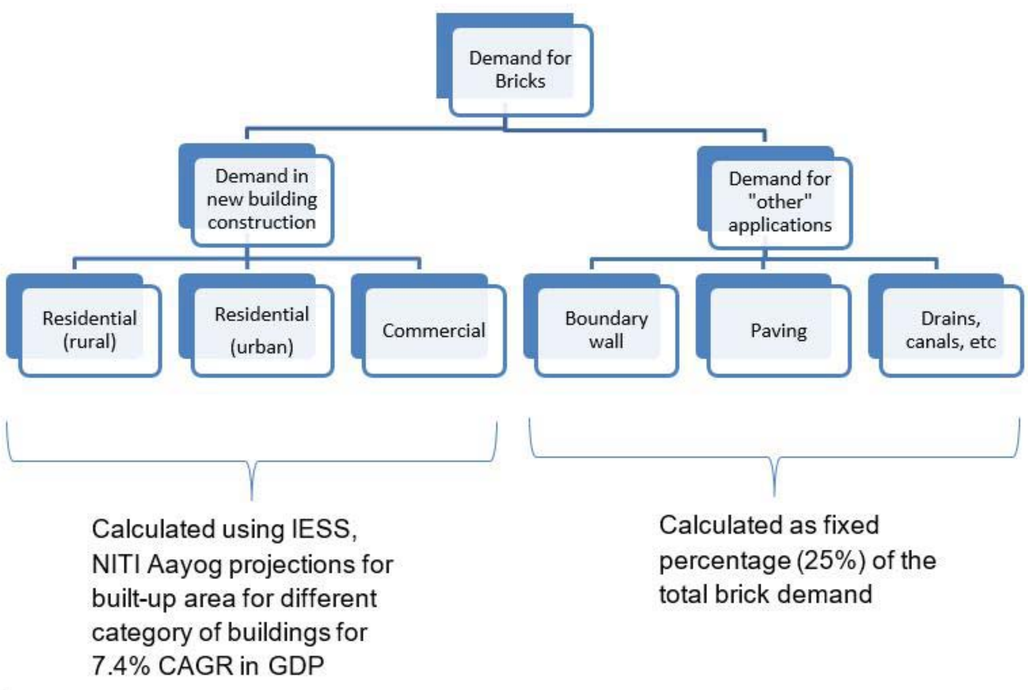


Figure 3.13. Methodology for estimating future demand for bricks

The total brick demand is assumed to be composed of two main categories:

1. Demand of bricks for construction of walls in the new construction of buildings (urban residential buildings, rural residential buildings, and commercial buildings)

2. Demand for bricks for 'other' applications (paving, flooring, boundary walls, construction of dams and sewers, lining of canals, etc.)

$$Brick\ Demand\ (Total) = Brick\ Demand\ (Building\ walling) + Brick\ Demand\ (Others)$$

The demand of bricks for the construction of buildings has been estimated by

1. First estimating the built-up area requirement for residential urban, residential rural, and commercial buildings, for 7.4% CAGR of GDP option using NITI Aayog's India Energy Security Scenarios. The built-up area has been calculated for the block of five years starting from 2012–17 to 2042–47.
2. The built-up area calculated above has been multiplied by 360 bricks/m^2 to get the brick requirement. The average requirement of 360 standard size bricks per m^2 of floor space area has been based on the calculations of the volume of walls (external and internal walls) for different types of house construction mentioned in the census (refer Annexure 2). Though these calculations are for residential construction, the same number has been used for the commercial buildings as well.

$$Brick\ Demand\ (Building\ walling) = 360 * Built\ up\ Area\ (New\ Buildings\ in\ m2)$$

The demand for bricks for 'other' applications has been estimated as follows:

Demand of bricks for other forms of construction includes use of bricks for applications such as paving, flooring, construction of dams and sewers, boundary walls, and lining of canals. An earlier study by Building Materials and Technology Promotion Council (BMTPC) and Centre for Symbiosis of Technology, Environment and Management (STEM)[81] has estimated the brick demand for other forms of construction at 37%. Considering that in recent years, many new materials are being used for other construction, particularly use of concrete has increased for applications like paving, canal and drain construction, in this study the brick demand for other forms of construction is assumed as 25% of the total brick demand for the entire period till 2047.

$$Brick\ Demand(Others) = 0.25 * Brick\ Demand\ (Total)$$

[81] BMPTC and STEM. 2000. Housing & Key Building Materials in India: A Long-Term Perspective: 1991-2011.New Delhi: BMTPC and STEM

4.1.2 Projected demand for bricks

The results of the analysis in the form of projected brick demand (billion bricks/year) for different end-use applications are shown in Figure 4.14. The main conclusions of the analysis are as follows:

1. The average annual demand for bricks during 2012–17 is estimated at 294 billion bricks a year. It is to be noted that the calculated demand (based on data on construction and economic growth) is higher compared to the estimated production (based on data on production from brick enterprises) of 274 billion bricks per year for all types of bricks and blocks. This should be considered a good agreement given the fact that 40% of the rural residential housing requirement during 2012–17 is met by kuccha and semi-pucca houses, as per the IESS data given by NITI Aayog, using materials such as biomass and stones. The average annual demand for bricks is estimated to increase and reach to a peak of about 1000 billion bricks a year during the 2032–37 period. This would be 250% increase over the demand for 2012–17 period. After 2032–37 period, the average annual demand for bricks will reduce and is estimated to decline to 760 billion bricks a year for 2042–47 period. The expected rapid increase and peaking of demand in 2032–37 underlines the need for immediate action to regulate new manufacturing capacities to be resource efficient.
2. During 2012–17, rural residential demand accounts for 38% of the total demand for bricks; this is going to decrease to around 25% by 2032–37 and less than 10% by 2042–47. Overall, if a major part of the brick demand for 'other' category is assigned to the rural sector, it can be concluded that at present the rural:urban demand is roughly 50:50. By 2032–37, the demand will be predominantly urban, and the ratio of rural:urban demand is expected to change to roughly 30:70, and would have an impact on the market for REBs as the choice of REBs may differ between rural and urban areas.

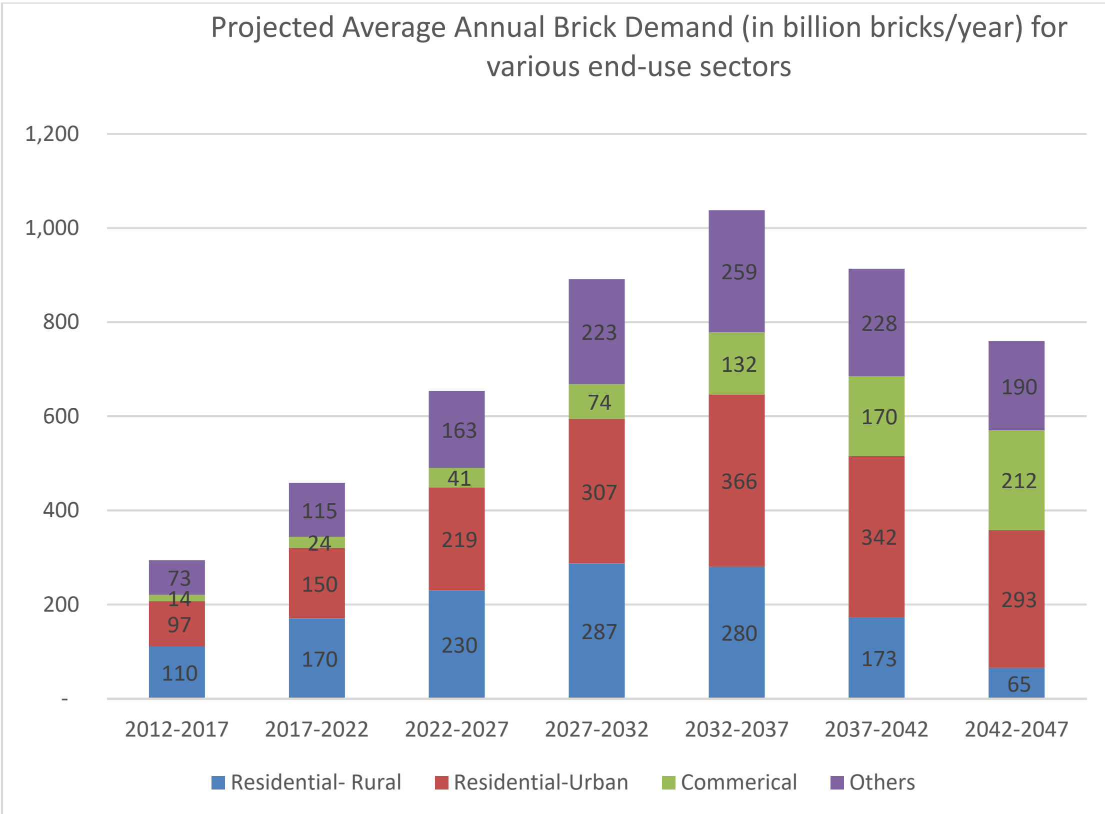


Figure 4.14 Projected annual average demand for bricks (billion brick/year) for 2012–47

4.1.3 Projected demand for bricks: Rural and urban by state

The analysis done in the previous section provides us information on demand of bricks for residential construction in urban and rural areas at the national level. As IESS data by NITI Aayog, does not give a break-up of the residential built-up area at the state level, we have used population projections for 2026[82] to get a break up of urban and rural demand at the state level. The analysis shows that:

- Urban brick demand: Five states – Maharashtra, Uttar Pradesh, Tamil Nadu, Gujarat, and West Bengal constitute more than 50% of the urban brick demand.
- Rural brick demand: Five states – Uttar Pradesh, Bihar, West Bengal, Andhra Pradesh and Telangana combined, and Rajasthan constitute more than 50% of the rural brick demand.

[82] Census of India. 2001. Population projections for India and states 2001-2026. < https://nrhm-mis.nic.in/Part%20B%20Demographic%20and%20Vital%20Indicators/Population%20Projection%20Report%202006%20by%20RGI.pdf> (accessed on 1 April 2017)

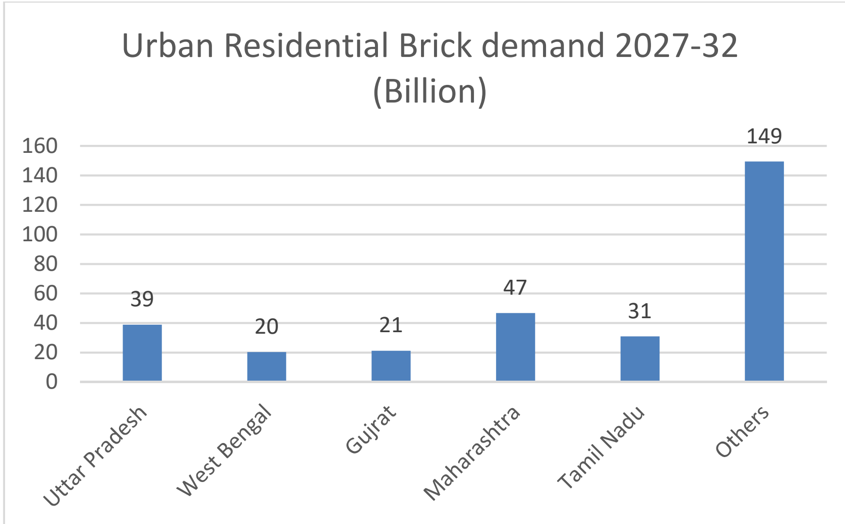


Figure 4.15. Urban residential brick demand 2027–32 (billion)

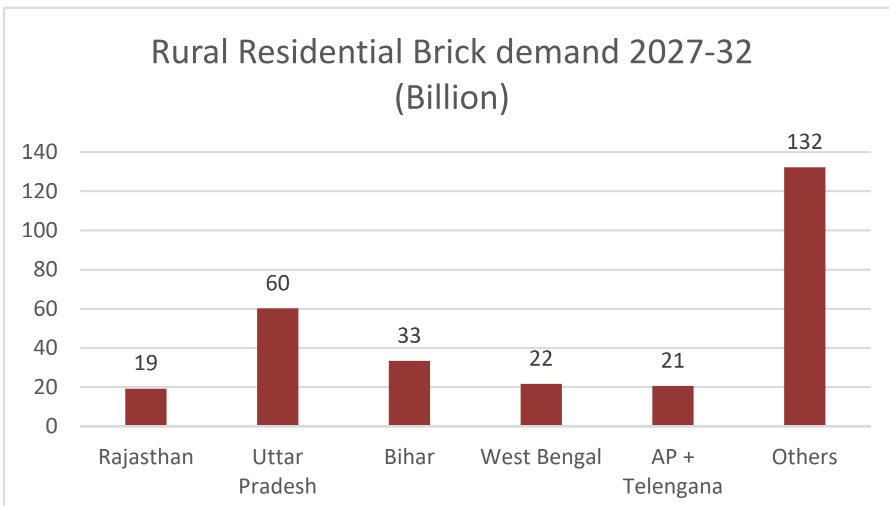


Figure 4.16. Rural residential brick demand 2027–32 (billion)

4.2 Potential Pathways for Transformation

4.2.1 Resource efficient brick pathways

The resource efficient brick pathways differ for different regions as well as for urban and rural areas within a region. The potential REB solutions for the three regions are shown in Table 4.13, Figure 4.17, and Figure 4.18.

Table 4.13. Resource efficient brick (REB) choices for the three regions

Himalayan states and North-eastern states (except Assam and Tripura)		**Indo- Gangetic plains, Assam and Tripura**		**Peninsular, desert and coastal India**	
Rural	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**
Baseline (2016)					
- Solid burnt clay bricks fired in traditional kilns. **- Stone** - Solid concrete blocks	**- Solid burnt clay bricks fired in traditional kilns** - Solid concrete blocks - AAC blocks - Stone	**- Solid burnt clay bricks fired in traditional kilns**	**- Solid burnt clay bricks fired in traditional kilns** - AAC & CLC blocks	**- Solid burnt clay bricks fired in traditional kilns.** **- Stone** **- Solid concrete blocks** **- Pulverised fuel ash-cement or lime bricks**	- AAC and CLC blocks - Solid and hollow concrete blocks - Pulverised Fuel ash-cement or lime bricks - Solid burnt clay bricks
Potential REB choices					
- Hollow concrete blocks **- Perforated burnt clay bricks** **- Solid burnt clay bricks fired in cleaner kilns** - CSEB	**- Hollow concrete blocks** - AAC blocks - Perforated and hollow burnt clay bricks	**- Solid burnt clay bricks fired in cleaner kilns** **- Pulverised fuel ash-cement or lime bricks** - Perforated burnt clay bricks - CSEB	**- Perforated and hollow burnt clay bricks** **- AAC and CLC blocks** - Pulverised fuel ash-cement or lime bricks	**- Pulverised fuel ash-cement or lime bricks** **- Hollow concrete blocks** - Solid burnt clay bricks fired in cleaner kilns - Perforated burnt clay bricks. - CSEB	**- AAC and CLC blocks** **- Hollow concrete blocks** **- Pulverised fuel ash-cement or lime bricks** - Perforated and hollow burnt clay bricks

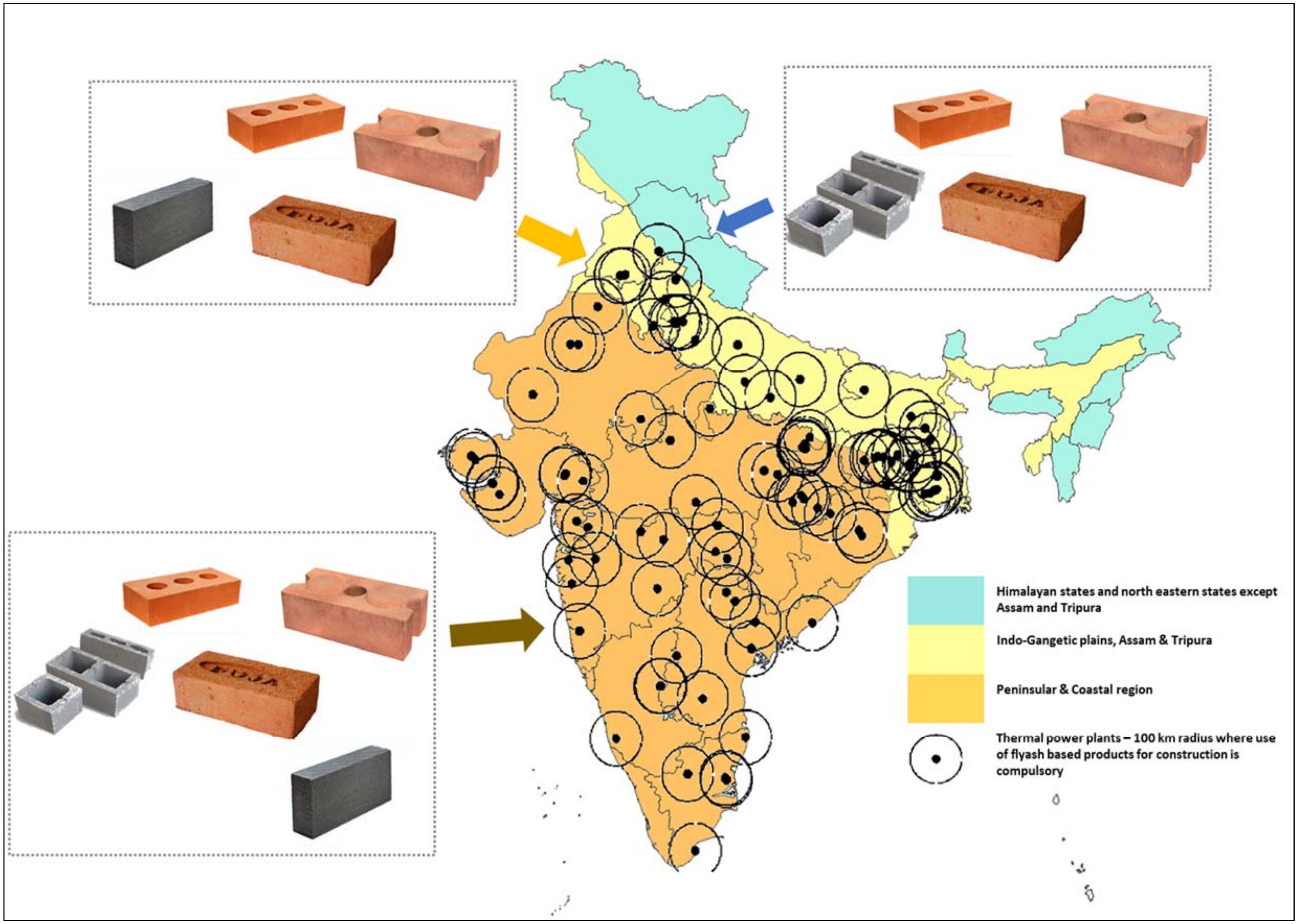


Figure 4.17. Resource efficient brick choices for rural areas

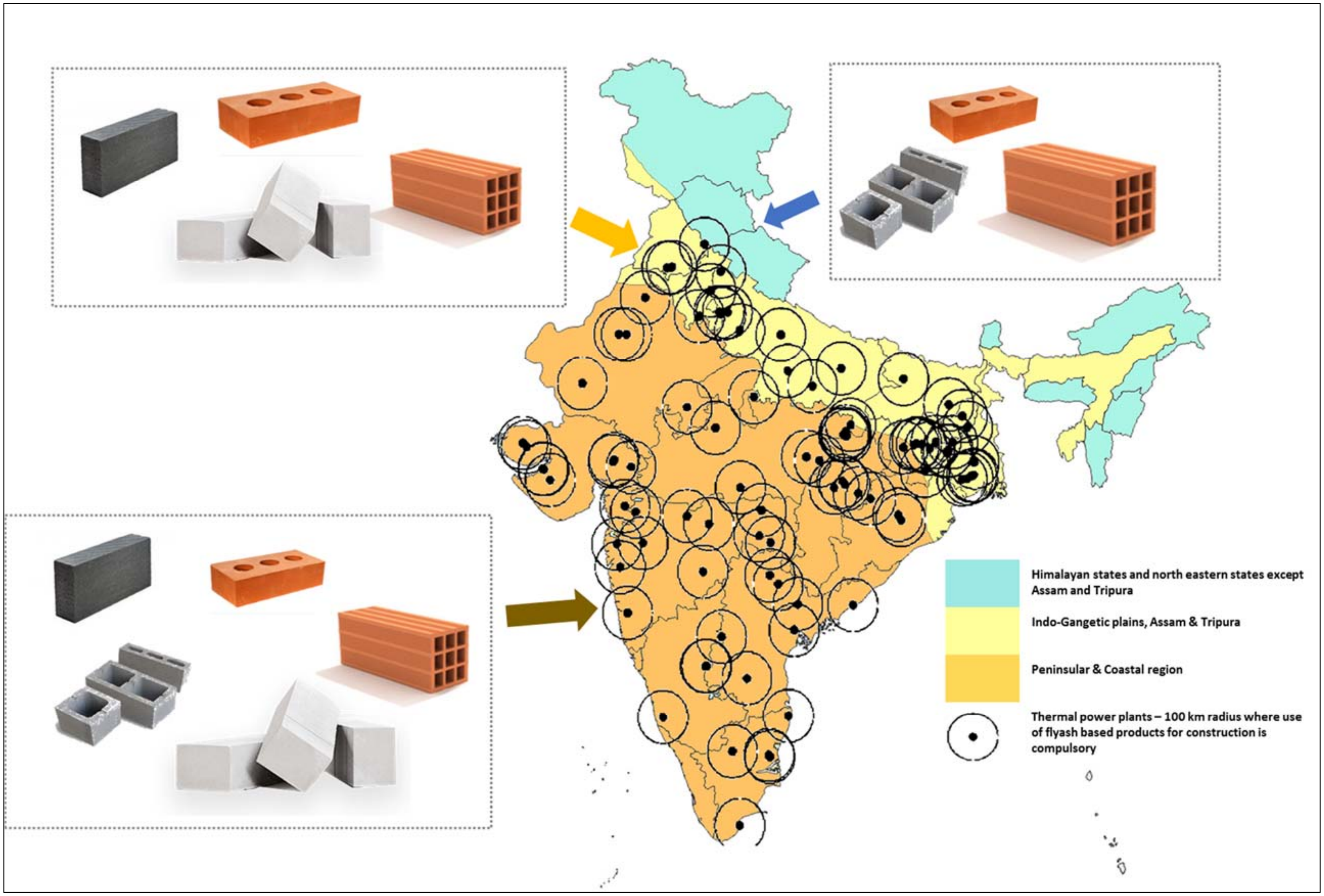


Figure 4.18. Resource efficient brick choices for urban areas

The REB choices for the urban area are influenced by the following factors:

a) The dominating building typology in the urban markets will be mid- and high-rise construction. Lighter density bricks will be preferred. Also, large block size will be preferred as that helps in faster rate of construction.
b) It is expected that compared to rural areas, the transformation of the brick industry from unorganised to organised will be faster in and around urban areas. This transformation to organised industry will move the industry towards mechanisation, consolidation of the industry, larger production, and larger investment (>INR 5 crore). These enterprises will be more suitable to produce lighter density bricks such as AAC blocks, hollow burnt clay bricks, and hollow concrete blocks.

The REB choices for the rural areas are influenced by the following factors:

a) The dominating building typology in the rural markets will be low-rise construction, with a preference towards solid brick products because of factors such as preference for load-bearing construction in some regions, safety, and security issues.
b) The enterprises in the rural areas will be relatively smaller production capacity, will use semi-mechanised process, and will require lower initial investment (INR 10 lakh to 2 crore).

4.2.2 Future Scenarios

Two scenarios have been developed for the future development of the brick sector in India. The first scenario is the ***reference scenario,*** which assumes that no fresh policy initiatives are taken to promote REBs and there is no change in the existing environment policies and implementation structure. According to this scenario (Figure 4.19), solid burnt clay bricks will retain more than 70% of the market in 2032 and the share of the new walling construction technologies and REBs will be about 25%.

The other scenario is the ***resource efficient scenario***. Under this scenario, it is assumed that new policy initiatives will be taken up for promoting REBs. These initiatives will take into account the regional differences in raw material availability and requirements of different segments of the building construction industry*. According to this scenario* (Figure 4.20*), the share of solid burnt clay bricks will reduce to 27% and the share of the new walling construction technologies and REBs will increase to about 70%.*

The methodology for estimating the distribution of brick market in the '*reference scenario*' and the '*resource efficient scenario'* has been provided in Annexure 6.

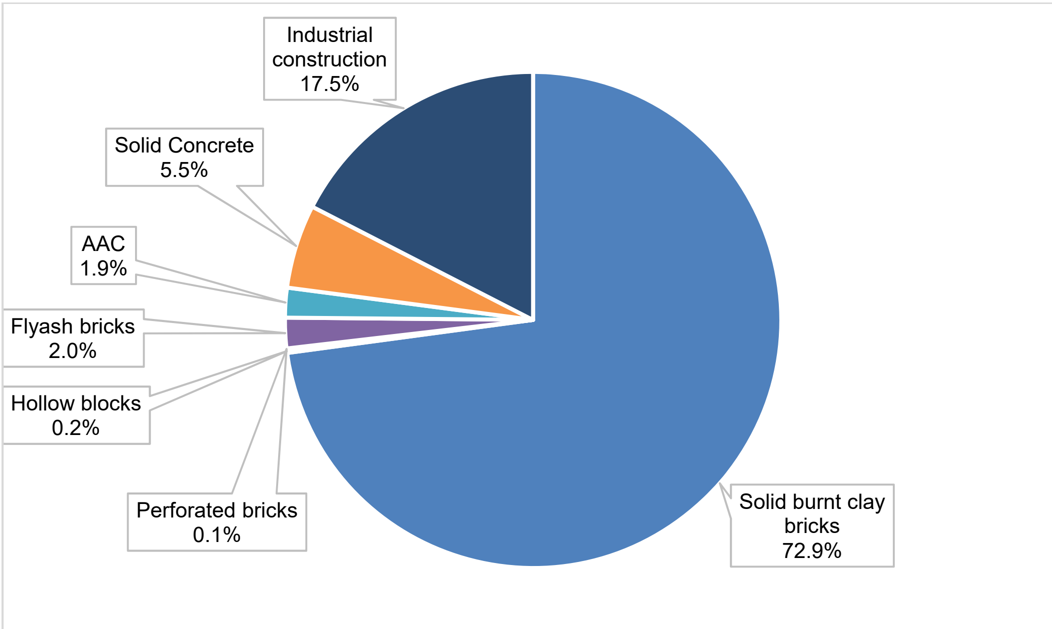


Figure 4.19. Brick market distribution in 2032 under 'Reference Scenario'

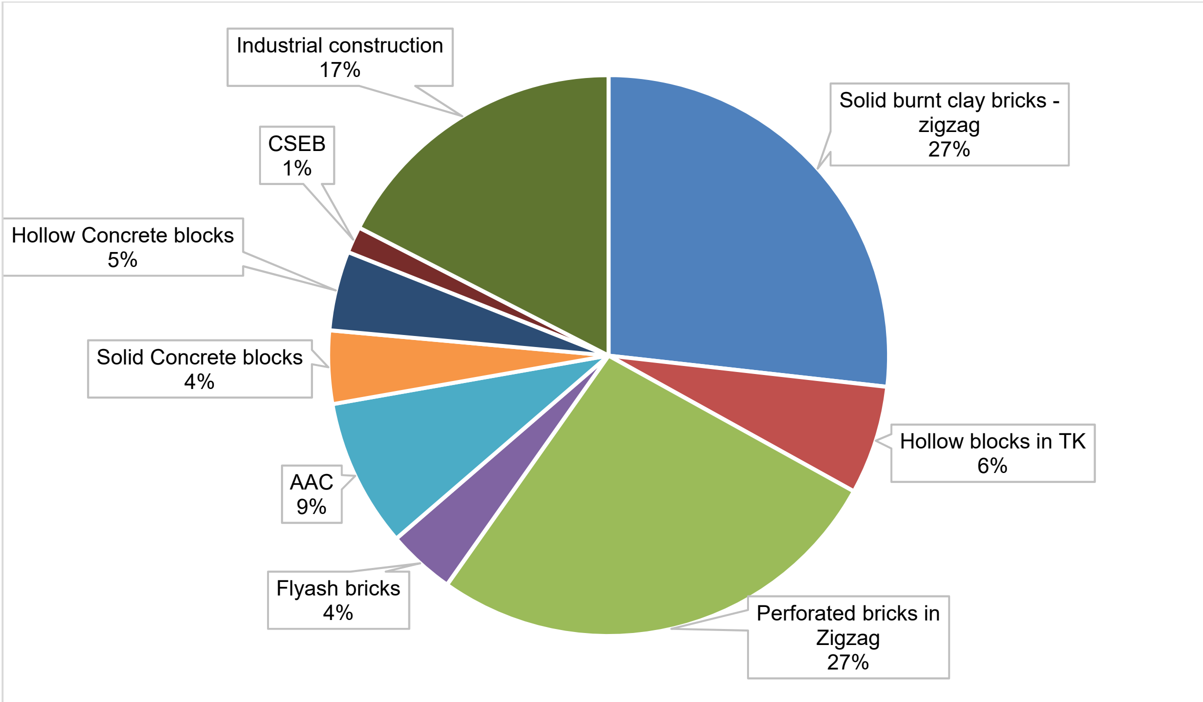


Figure 4.20. Brick market distribution in 2032 under 'Resource Efficient Scenario'

Based on the brick market distribution for the two scenarios, it is projected that there will be 18% saving in the ***resource efficient scenario*** over the ***reference scenario*** in cumulative clay consumption for the period of 2017–32 (Figure 4.21). Similarly, 35% saving in coal consumption (Figure 4.22) and 31% reduction in CO_2 (Figure 4.23) emission can be achieved by moving towards resource efficient scenario.[83]

[83] Section 4.1.1 explains the methodology for the projection of annual brick demand. Annexure 6 explains the methodology of brick distribution in future scenarios. Combining the two projections and the resource efficiency framework explained in Section 3.1.1, cumulative savings of clay, energy, coal and CO_2 have been estimated.

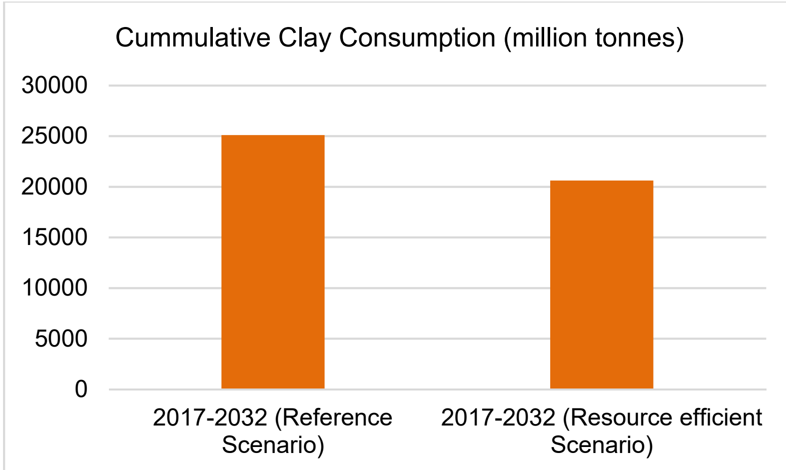


Figure 4.21. Cumulative clay consumption (2017–32) for future scenarios

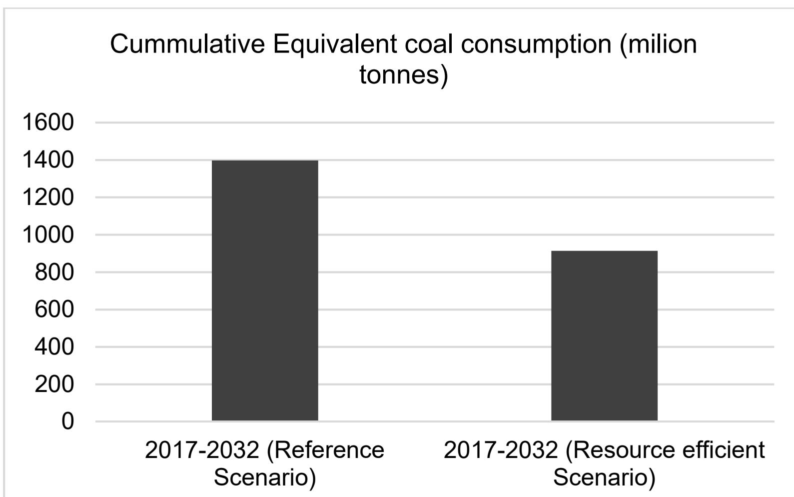


Figure 4.22. Cumulative equivalent coal consumption (2017–32) for future scenarios

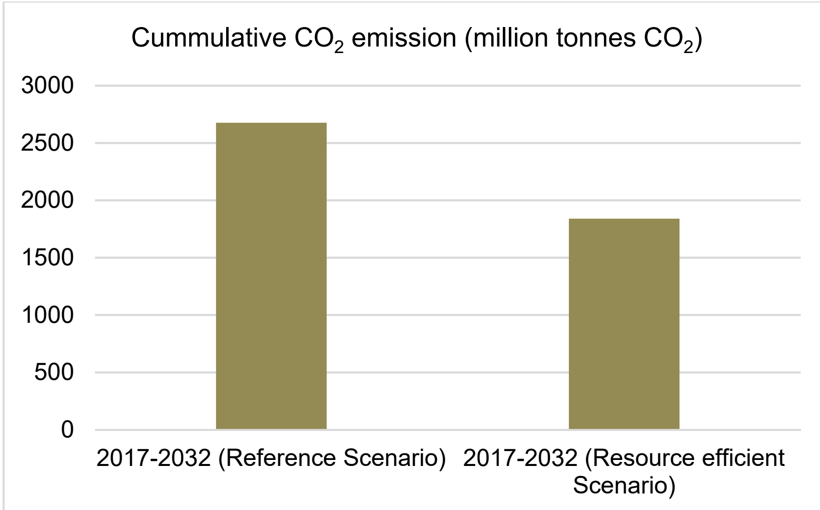


Figure 4.23. Cumulative CO_2 emission (2017–32) for future scenarios

4.2.3 Example of resource efficiency pathway for burnt clay brick industry

The techno-economics and the environmental benefits of transformation to REBs is shown in Table 4.14 and

Table 4.15, taking a case of burnt clay brick industry. The baseline case is taken as manually moulded solid bricks fired in an FCBTK kiln. Three cases have been considered

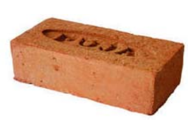
a) The FCBTK kiln is replaced with and efficient kiln (zigzag) but no other changes in the manufacturing process are made, the final product remains manually moulded solid burnt clay brick.
b) The manual moulding is replaced with an extruder and clay preparation machinery, which makes it possible to produce extruded perforated bricks, the bricks after extrusion are dried under shed and they are fired in an efficient zigzag kiln. The final product is a perforated brick with at least 20% perforation.
c) More clay preparation machinery is added and a good quality extruder is used to produce hollow clay blocks. The blocks are dried in a tunnel drier and fired in a tunnel kiln. The entire brick handling system is mechanised. The final product is a hollow burnt clay block.

As shown in Table 4.14, it should be noted that a move from FCBTK to zigzag kiln requires relatively lower investment (maximum INR 40 lakh) and has a high IRR of 100–250% due to substantial savings in coal and improvement in brick quality. This step-in transformation is a win-

win for all concerned and hence, as being seen, with a policy and regulatory push can easily be achieved.

However, the next steps in the transition from manually moulded solid brick to perforated or hollow burnt clay brick requires 7–30 times higher investment. This also involves risks related with new technology, creating market for new products, uncertainty in raw material supply, etc. If one can manage these risks, the IRR for these investments is still attractive. The main issue here is having a window to provide finance and a strategy to reduce risks in the transformation.

Table 4.14. Brick production technology economics compared to the baseline of traditional Fixed Chimney Bull's Trench Kiln

Product specification	**Type of product**	**New zigzag kiln producing solid bricks**	**New zigzag kiln and extruder producing perforated bricks**	**Tunnel kiln, tunnel dryer, and extruder producing hollow blocks**
	Dimension (mm)	230 x 115 x 75	230 x 115 x 75	400 x 200 x 200
	Weight (kg per brick/block)	3 kg/brick	2.4 kg/brick	11 kg/block
				
Life of brick manufacturing system	Year	20	20	25
Production capacity	cubic metre per year	8600	13,000	86,000
Capital cost	INR (lakh)	40	300	1300
Coal savings per year	tonne/year	160	430	3700
Coal savings over the lifetime	tonne over the lifetime	3200	8600	92,500
Coal savings per year	INR lakh/year	13	34.5	300
Coal savings over the lifetime	INR lakh	250	680	7400

Projected IRR		100%–250%	30%–50%	30%–60%

Note:

a) Capital cost does not include the cost of land.

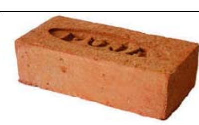
b) The fuel savings are in reference to the baseline performance of 'FCBTK' technology.

c) Average cost of coal (gross calorific value of 5000 kcal/kg) delivered at brick kiln site assumes INR 7500 /tonne.

d) A range has been provided for the projected IRR to account for the variations in the production and selling prices in different markets across India.

Table 4.15 tabulates some of the environment benefits. It is observed that the reductions in CO_2, black carbon, and PM emissions are high and the cost per tonne for the reduction in CO_2 emissions is attractive.

Table 4.15. Brick production technology emissions

Product specification	**Type of product**	**New zigzag kiln producing solid bricks**	**New zigzag kiln and extruder producing perforated bricks**	**Tunnel kiln, tunnel dryer, and extruder producing hollow blocks**
	Dimension (mm)	230 x 115 x 75	230 x 115 x 75	400 x 200 x 200
	Weight (kg per brick/block)	3 kg/brick	2.4 kg/brick	11 kg/block
				
CO_2 emissions compared to traditional FCBTK kiln baseline				
Specific CO_2 emissions savings	kg/cubic metre	159	127	114
CO_2 emission savings over the brick plant lifetime	Tonne	6,700	18,460	180,600

Cost per metric tonne of CO_2 avoided	INR/tonne		700	1600	720
Particulate matter (PM) emissions (FCBTK is 1.18 g/kg brick)					
PM stack emissions	g/kg brick		0.24	0.24	0.24
PM savings over brick plant lifetime	Tonne		244	292	1421
Black carbon (BC) emissions (FCBTK is 0.13 g/kg brick)					
BC stack emissions	g/kg brick		0.02	0.02	0
BC savings over brick plant lifetime	Tonne		29	34	197
BC savings per plant lifetime	CO_2 eq. tonnes[84]	GWP_{100} GWP_{20}	26,100 92,800	30,600 108,800	177,300 630,400

4.2.4 Risk analysis of future transformation

WEFT (Water Energy Food Transitions) Research undertook a short exploratory study in technical partnership with Greentech Knowledge Solutions in 2017, to understand the risks in the Indian clay bricks sector, mitigation possibilities, and financing needs. The overall framework for risks analysis is based on standard templates employed by credit rating agencies and financial institutions, which were populated based on review of literature and consultations with experts. Table 4.16 presents a few risks and the possible mitigants.

Table 4.16. Examples of risks in transformation of Indian clay brick industry

Risk category	Remarks	Possible mitigants
Technology risk (as some of the technologies have not been adequately	• Contractual arrangements between the supplier and the brick enterprise may be weak due to informal nature of the technology adopter (brick industry)	• Develop and promote standard contracts between the suppliers and brick industry.

[84] GHG savings derived from UNFCCC's 5AR of GWP_{100} of 900 and GWP_{20} of 3200 in CO_2 eq.

tested in India, there is a possibility that the technology is not able to perform at the desired levels)	• Several of the technology providers are also small enterprises providing a specific machinery, and not the entire manufacturing line and may not offer good after-sales service. • To reduce cost, there is a tendency to opt for critical machinery (e.g., extruders) from established technology providers and locally manufacture/assemble other machinery (e.g., box feeder). This has the potential to reduce the efficiency of the complete manufacturing line. • Due to informal nature of the industry, skilled manpower may not be available for the proper operation and maintenance of the machinery.	• Facilitating formalisation of the brick industry • Training and skill upgradation on new technologies • Insurance/guarantees to mitigate risk • Capacity building of technology integrators.
Compliance risk – environmental	• There are various types of compliances that are required related to air emissions, fly ash utilisation, and mining. • Complexity and vagueness of regulations • Weak implementation capacities of the regulatory bodies • Large number of ongoing litigations • Leakages and corruption issues	• Simplifying regulations for ease of implementation • Single window clearance • Strengthening capacities of the regulatory bodies

4.3 National Policy Roadmap for a 'Mission on Resource-Efficient Bricks' (2017–32)

This section provides an outline of the national policy framework for a mission on REBs.

The roadmap for resource efficient scenario should not only address the issue of environment sustainability but should also address the issues of providing affordable and good quality building materials for housing as well as in creating sustainable livelihood opportunities (Figure 4.24).

These policy goals address several key national priorities and can galvanise political and social support for an REB initiative.

These goals are enumerated below.

Environmental Goal:

- To help India in reducing air pollution, reducing wastage of energy and in meeting India's obligations under international agreements, such as Paris Agreement on Climate Change.

Developmental Goal:

- To meet demand for high-quality bricks at affordable prices for 'housing for all' and other building and infrastructure requirements of the country.
- To promote local entrepreneurship and provide sustainable livelihoods to skilled workforce engaged in brick production.

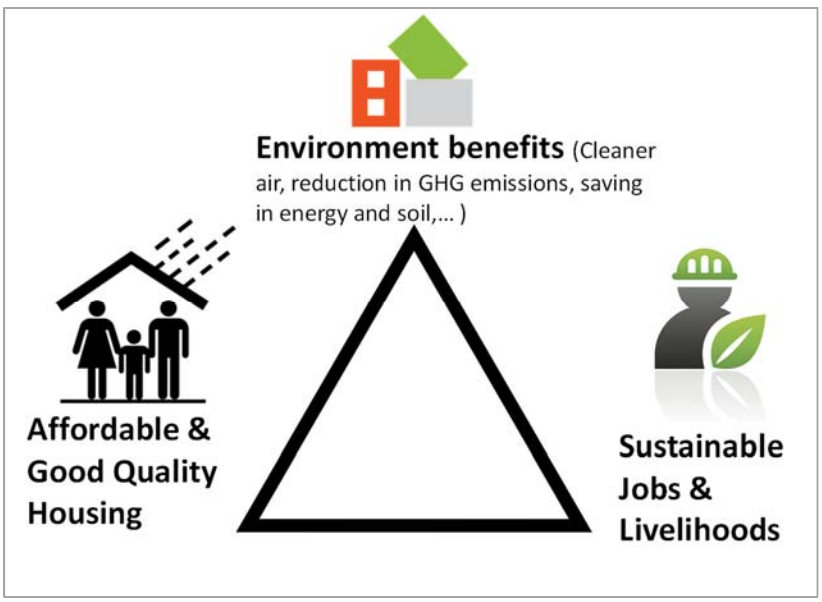


Figure 4.24. Key policy objectives of resource efficient brick initiative

4.3.1 Key Policy Principles

The key policy principles are as follows:

a) Minimising negative environmental impacts during the entire life-cycle of bricks
b) Making available high-quality bricks at affordable prices
c) Promotion of local enterprises/entrepreneurship
d) Utilisation of local raw-material resources
e) Creation of a large number of sustainable livelihoods
f) Skilled workforce for the production and construction using REBs
g) Decent working conditions for workers involved in the production of bricks
h) Helping India in meeting its obligations under the Paris Agreement on Climate Change and UN Sustainable Development Goals

4.3.2 Targets

Based on the resource efficient scenario, following targets are being proposed:

a) Achieving savings of 30% (or 800 million tonnes [MT]) in cumulative CO_2 emissions during 2017–-32 period compared to the reference scenario.
b) Achieving savings of 35% (or 500 MT) in cumulative coal consumption during 2017–32 period compared to the reference scenario.
c) 200% increase in annual fly ash consumption in brick making compared to the reference scenario by 2032.
d) Mobilise investment of about INR 60,000 crore by 2022 and INR 1,80,000 crore by 2032 in the upgradation/expansion of REB production.
e) To train and provide employment to 1 lakh skilled technical personnel in the production and application of REBs by 2022 and 5 lakh by 2032.

4.3.3 Policy Roadmap: Key Action Points

The main objective of the policy roadmap is to put in place a conducive policy environment to take the brick sector in the country towards a resource efficient path. Key policy action points (Figure 4.25) are elaborated in the following sections.

Figure 4.25. Key policy action

4.3.3.1 National policy on Resource Efficient Bricks

Piecemeal environment policies and regulations combined with poor implementation have not led to any substantial changes in the sector. A recent study on financing has found that one of the main barriers in attracting new finance to the sector is the presence of regulatory risks (e.g., uncertainty over mining of raw materials). Achieving transformation of the brick sector is not possible through environment policies and regulations alone. Complementary policies and actions are needed in the areas of financing and technical assistance for technology upgradation, market development for resource efficient products, R&D, and skill development and training. These are lacking at present. Thus, there is a need to develop a policy that is transformative in nature, so that the sector can respond to the larger environmental challenges and opportunities. Developing the national policy will require taking an integrated view of various policies shown in Figure 4.26 and involving all concerned ministries and departments. As this task involves multiple ministries, NITI Aayog seems to be better equipped to undertake the task of developing this policy.

As there has been a general lack of understanding about the importance of the brick sector and need for a policy to transform the sector, a concerted policy advocacy effort will be required by various stakeholders to reach out to NITI Aayog and other government agencies so that they can be convinced to initiate action to formulate a policy for REBs.

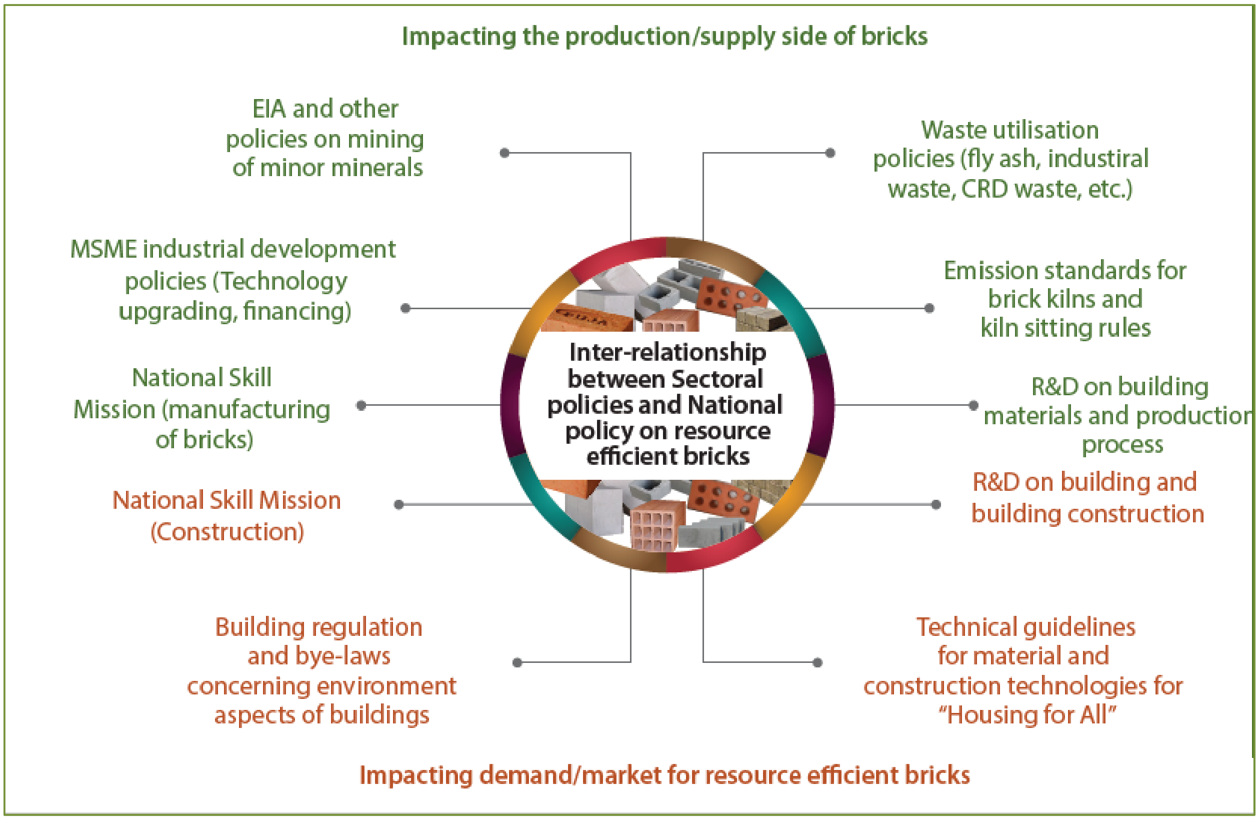


Figure 4.26. Various policies that needs to be considered while developing the national policy on resource efficient bricks

In line with the national policy on REBs, amendments would be needed in the existing environment policies and regulations to make them consistent, easy to implement, and effective. Some of the policies and regulations that can be taken up for amendments are listed below.

Table 4.17. Amendment required in existing policies

Existing policies/ regulations	Agency	Amendments required
Model building bye-laws 2016	Town and Country Planning Organisation (TCPO), Ministry of Housing and Urban Affairs (MoHUA)	1. Chapter 14 'Climate resilient construction – integration of environmental clearance with sanction' mandates use of fly ash bricks for building plan (> 20,000 m^2 built-up area). The fly ash bricks can be replaced with REBs and a definition/list of REBs can be added. Such a provision

		will provide a level playing field for different types of REBs. 2. Chapter 14 should also add a provision for the thermal quality of the envelope to reduce heat gains from the walls. Such a provision will encourage the production of REBs having low thermal conductivity.
Fly ash regulation	Ministry of Environment, Forests and Climate Change (MoEFCC)	1. The fly ash regulation covers only the fly ash generated from coal- or lignite-based thermal power plants. Apart from fly ash there are several other types of industrial and mining wastes are available (coal mine waste, lime stone waste, blast furnace slag, iron ore tailings, marble dust, etc). There is a need for a regulation that covers utilisation of other major types of industrial and mine wastes. 2. The two critical agencies for implementation of fly ash regulations are the State Pollution Control Boards to ensure that the specified quantity of fly ash is being used in the manufacture of bricks and the Urban Local Bodies (ULBs) to modify and implement building bye-laws to make mandatory the use of fy ash bricks. Given the large number (several lakhs of producers) and even larger number of building projects that need to be monitored, simple guidelines for compliance need to be developed.
Emission standards for brick kilns	MoEFCC, Central Pollution Control Board (CPCB)	1. The current emission standards do not cover all types of kiln technologies, e.g., clamps as well as modern kiln

		technologies like tunnel kiln. The emission standards should cover all types of kilns. Much better way would be to have 'uniform' (technology neutral) standards. 2. The standards can distinguish between the 'existing' and 'new' kilns. For 'new' kilns (kilns established after a certain cut-off date) the standards could be more stringent. 3. The current standards are only for SPM, the future standards can cover other pollutants e.g. sulphur dioxide, hydrogen fluoride, besides SPM. 4. The revision of the standards should take place at frequent intervals (e.g., 5 years). 5. As in several of the brick kilns, the feeding of fuel is intermittent, the emissions show periodic variation. The emission standards should include the methodology so that the sample collected cover both fuel charging and non-charging durations and similar other issues specific to brick kilns.

To implement the national policy on REBs, putting in place a national resource efficient brick mission/programme could be the next logical step. The mission can be tasked to coordinate actions across different central government departments and ministries. Some of the key action points for such a programme/mission could be as follows:

- Developing synergies with the 'Pradhan Mantri Awas Yojana' being coordinated by the Ministry of Housing and Urban Affairs (MoHUA) to create sustainable demand for REBs.

- Work on the issue of facilitating financing industries for REB production. This may lead to establishing a 'Brick Industry Financing Facility' to make available finance for establishing new or for upgrading existing brick enterprises.
- Update/new standards for different kinds of REBs to be done by the Bureau of Indian Standards (BIS).
- Inclusion of different types of REBs in the schedule of rates of different government construction agencies by the Central Public Works Department (CPWD). The schedule of rates already includes AAC block, fly ash brick masonry, other types of REBs such as perforated and hollow burnt clay bricks needs to be included.
- Programme on R&D and technology transfer in the area of REB production by the Department of Science and Technology (DST). Synergies with existing DST programmes on R&D in energy efficient buildings and waste management need to be explored.
- Labelling or certification of REBs under the eco-labelling scheme of MoEFCC or other similar labelling programme.
- Establishing a sector skill council for brick industry and start country-wide skilling initiative on both production and application of REBs by the National Skill Development Council (NSDC).
- Technology upgradation scheme for REB production by the Ministry of Micro Small and Medium Enterprises (MSME).

4.3.3.2 State Resource Efficient Brick Programmes

The responsibility of implementing the various national policies on REBs lies with states, district administrations, and urban local bodies. Also, the brick industry plays an important role in the political economy of a state as can be shown by the statistics on brick industry in Uttar Pradesh (UP) (Table 4.18). Given the large-scale socio-economic-environment-political implications, it will be in the interest of state governments to take a lead in developing their own programmes to promote REB production and use.

Table 4.18. Brick industry in Uttar Pradesh

Total number of enterprises	20,000
Total annual production	50 billion bricks/year
Industry turnover	INR 25,000 crore
Contribution to state GDP	2%
Employment	2–3 million

Tax revenue from mining	INR 200 crore

The resource efficiency pathway for each state and in some cases for different regions within a state will be different. While in the case of UP, located in the Indo-Gangetic plains, with good availability of clay for brick making throughout the state and several power plants, the resource efficiency pathway would consist of resource efficient burnt clay bricks and fly-ash-based bricks. On the other hand, for Maharashtra having large variations in raw material availability and market demand amongst six administrative regions, the pathway will differ from region to region. For instance, the Konkan region, which has limited clay and fly ash resources, the solution may lie in moving towards resource efficient concrete blocks; Nagpur and Amravati have higher availability of fly ash and hence resource efficient fly ash bricks can play an important role; the remaining three regions of Aurangabad, Nashik, and Pune do not have good availability of fly ash and hence the solution may lie in promoting resource efficient clay and concrete bricks.

Following sequence of steps is suggested for initiating action at the level of states:

- Background study on raw-material resource mapping, demand assessment, and developing a pathway for REB production for the state.
- Setting up of an inter-departmental committee, to develop the state policy/action plan, and oversee its implementation. The committee may be chaired by the Chief Secretary.
- The specific actions by various state departments may include:
  - Making available necessary infrastructure such roads, electricity or development of special zones for brick production
  - Streamlining mining, collection, and distribution of raw materials for making bricks, e.g., silt, sand, and fly ash.
  - Strengthening the state pollution control boards, mining departments, etc. for the enforcement of the environment regulations.
  - Inclusion of different types of REBs in the PWD schedule of rates.
  - Technical support programme for REB production through District Industries Centres (DICs).
  - Amending building bye-laws and development control rules by urban local bodies (ULBs) and development authorities for making use of REBs mandatory for building construction.
  - Skill development by state-level skill development missions

- Developing state-level technical capacities for performance monitoring, technical consulting, quality testing, etc.

4.4 Summary and Next Action Points

- Masonry construction using bricks is the main type of building construction technology used in the country.
- It is expected that in the next 15 years, masonry construction will retain its dominant position and the average annual demand for bricks will increase from about 250 billion Standard Brick Units (SBUs)/year during 2012–17, to a peak of 750–1000 billion SBUs/year during 2032–37.
- Brick manufacturing is resource intensive and brick sector has a large environmental footprint as it consumes about 800 MT of raw material per year, 40 MT of solid fuel (coal and biomass) per year and is an important source of CO_2, $PM_{2.5}$ and black carbon emissions.
- REBs such as perforated and hollow burnt clay bricks, clay-fly ash bricks, AAC blocks, and fly ash bricks have multiple environment benefits in the form of: lower primary material consumption, consumption of less energy for manufacturing, lower CO_2 and air pollution emissions during manufacturing.
- A programme to bring about a transformation in the brick industry and make it resource efficient by 2032 is being proposed. The programme will have multiple environmental and socio-economic benefits:
  - Achieving more than 25% savings in the primary raw materials compared to the reference scenario by 2032
  - Achieving savings of 30% in CO_2 emissions compared to the reference scenario by 2032.
  - Achieving savings of 35% in coal consumption compared to the reference scenario by 2032.
  - Substantial increase in the utilisation of industrial and other wastes for brick making, e.g., 200% increase in annual fly ash consumption in brick making compared to the reference scenario by 2032.
  - Making available good quality bricks for the construction of housing.
  - Assist in the transformation of large 'informal' small-scale brick manufacturing sector consisting of 250,000–300,000 enterprises into the 'formal' small-scale sector and in the process generating/transforming millions of seasonal jobs into 'round the year green jobs'.
- The next action points to bring about the transformation in brick industry are:

- Concerted efforts by a network of institutions for carrying out advocacy for a national initiative on REBs.
- Development of an overarching national policy/strategy on REBs.
- Revision of existing environment policies, e.g., fly ash regulation, environment standards for brick kilns, and make them coherent with the national policy/strategy on REBs.
- To implement the national policy on REBs, putting in place a national resource efficient brick mission/programme which covers actions on financing and technical assistance for technology upgradation, market development for resource efficient products, R&D, and skill development and training.
- Development of state-level resource efficiency programmes for brick industry taking into account the raw material availability, demand for bricks, and socio-economic development priorities of the state.

Annexure 1: Brief description on types of bricks

Solid Burnt Clay Bricks

The primary material used in the production of burnt clay bricks is clay. The various steps involved in the production process of burnt clay bricks are mining of clay, preparation of clay-mix, moulding of bricks, drying of green bricks, and firing in brick kiln. The energy consumption and air emissions during the production of bricks primarily depend on the brick kiln technology employed and the fuel used. Several types of kilns are used for firing bricks.

In India, Fixed Chimney Bull's Trench Kiln (FCBTK) and Clamp Kilns are the main technology used for firing bricks (also referred as traditional kiln technology); efficient kiln technologies include Zigzag Kilns, Vertical Shaft Brick Kiln (VSBK), and Tunnel Kiln.

Solid burnt clay bricks are not only one of the oldest but also the most extensively used building material in construction work. They are extensively used as both load-bearing and non-load-bearing masonry products. There exist considerable variations in the quality of raw material. the process of manufacture and the quality of the finished product.

The various BIS standards applicable to manufacturing of solid burnt clay bricks are:

1. IS-1077 (1992) Common Burnt Clay Building Bricks
2. IS-2117 (1991): Guide for manufacture of hand-made common burnt-clay building bricks
3. IS-11650 (1991): Guide for manufacture of common burnt clay building bricks by semi-mechanised process

Figure A1.27. Solid burnt clay brick

Hollow Burnt Clay Bricks/Blocks

The primary material used in the production of these blocks is clay. Hollow clay blocks are manufactured in factory set-ups, which mainly includes extruders for brick moulding, artificial dryers, and tunnel kilns for the firing the blocks. The manufacturing process and the machinery involved is provided in Figure A1.36.

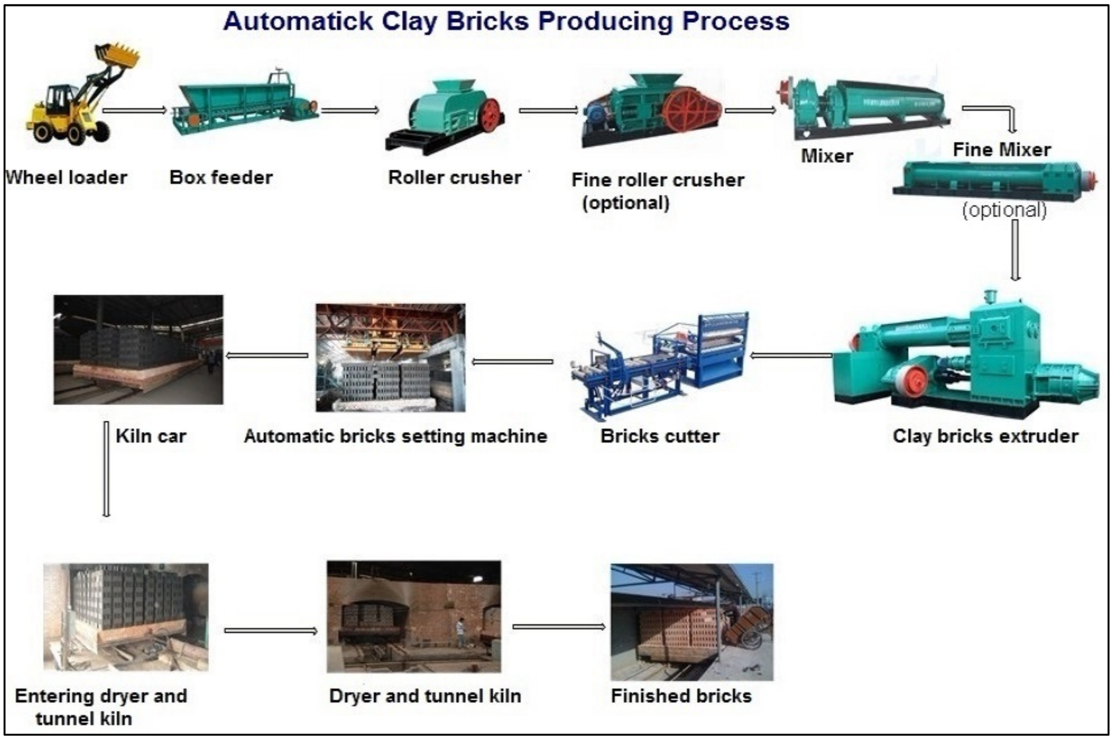


Figure A1.28. Manufacturing process of hollow/perforated clay bricks[85]

Volume of perforations are greater than 25% of the gross block volume, where the perforations are laid in the horizontal direction (Figure A1.29). These blocks are light in weight, have low thermal conductivity and precise in size and surface (avoids the need of plastering).

[85] Image source: http://www.cbecl.com/p/auto-bricks-manufacturing-plant.html (accessed on 1 August 2017)

Figure A1.29. Hollow clay block

Geographically, the current market for these blocks is concentrated in three southern states – Karnataka, Tamil Nadu, and Kerala. Hollow clay blocks are mostly used for two building types: (a) High-rise MIG/HIG housing in metro cities and (b) Individual HIG housing in metro cities and smaller cities. These are suitable for construction of non-load-bearing walls only. The BIS standard applicable to manufacturing of hollow clay blocks is IS-3952 (2013) Burnt Clay Hollow Bricks and Blocks for Walls and Partitions.

Perforated Burnt Clay Products

The primary material used in the production of these blocks is clay. Manufacturing of perforated bricks mainly require setting up of an extruder for brick moulding. In India, zigzag kilns and Hoffman kilns are the main technologies used for firing perforated clay bricks.

In practice, perforated bricks, usually having 3 to 10 holes, have perforations ranging from 7% to 22%. Bricks having higher volume of perforation are lighter in weight in comparison to solid burnt clay bricks and consume less fuel and energy for production.

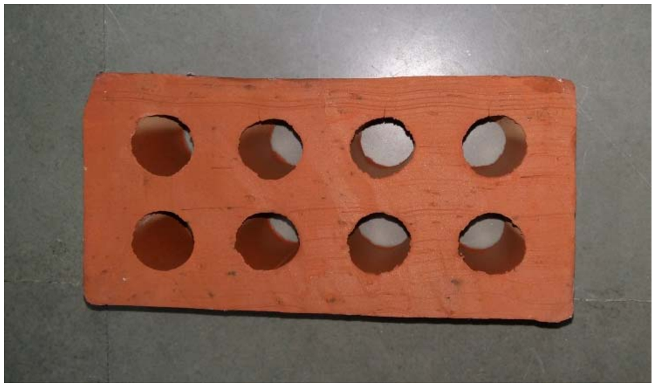


Figure A1.30. Eight-hole perforated brick

Geographically, the current market for perforated bricks is concentrated in the NCR, Punjab, and Haryana. Institutional buildings are one of the main buyers of perforated bricks as several of these buildings opt for exposed brick façade. Perforated bricks have also been used in affordable mass housing load-bearing construction and as sewer bricks due to high compressive strength and low water absorption properties.

The BIS standard applicable to manufacturing of perforated clay brick is IS-2222 (1991) - Burnt Clay Perforated Bricks.

Hollow and Solid Concrete Blocks

These are manufactured by controlled mechanical compaction of a mixture of cement, sand (fine aggregates), and stone chips (coarse aggregates) in a mould. Usually the blocks are cured by water only. Manufacturing units are usually small-scale units using concrete mixer, hydraulic or vibro-press block making machines (Figure A1.31).

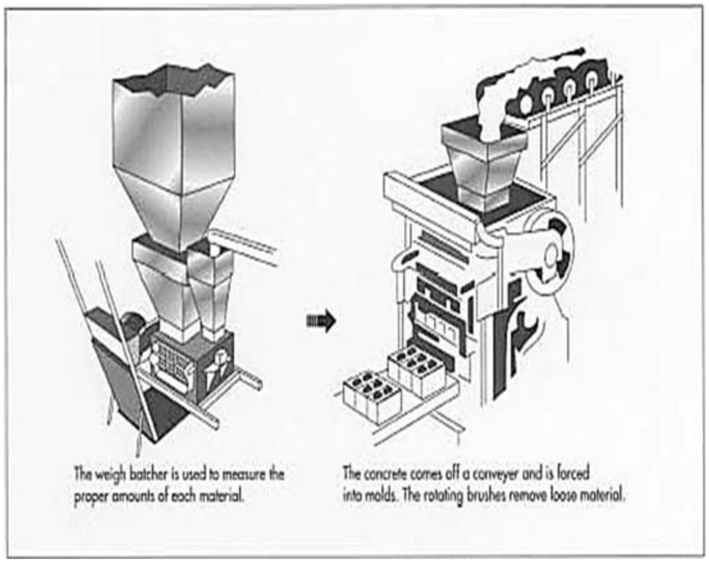


Figure A1.31. Manufacturing machinery for hollow/solid concrete blocks[86]

A hollow concrete block has one or more large holes or cavities, which either pass through the block (open cavity) or do not effectively pass through the block (closed cavity) and has the solid material between 50% and 75% of the total volume of the block.

Figure A1.32. Hollow concrete block

Figure A1.33. Solid concrete block

These blocks are manufactured throughout the country; but the usage is limited to few applications such as boundary walls, commercial complexes, etc. In a few cities in south India

[86] Image source: www.madehow.com (accessed on 2 August 2017)

such as Chennai and Bengaluru, these blocks are also used in the construction of high-rise residential buildings.

The BIS standards applicable to manufacturing of hollow/solid concrete blocks are:

- IS-2185-1- (2005)-Hollow and Solid Concrete Blocks
- IS-2185-2-(1996)-Concrete Masonry Light Weight Blocks Hollow and Solid

Autoclaved Aerated Concrete (AAC)

It is a lightweight, precast building material that is produced by mixing silica rich material fly ash/sand, cement, lime, gypsum, aluminum powder/paste, and water. The manufacturing set-up requires a complete mechanised production line (Figure A1.34) and high investment.

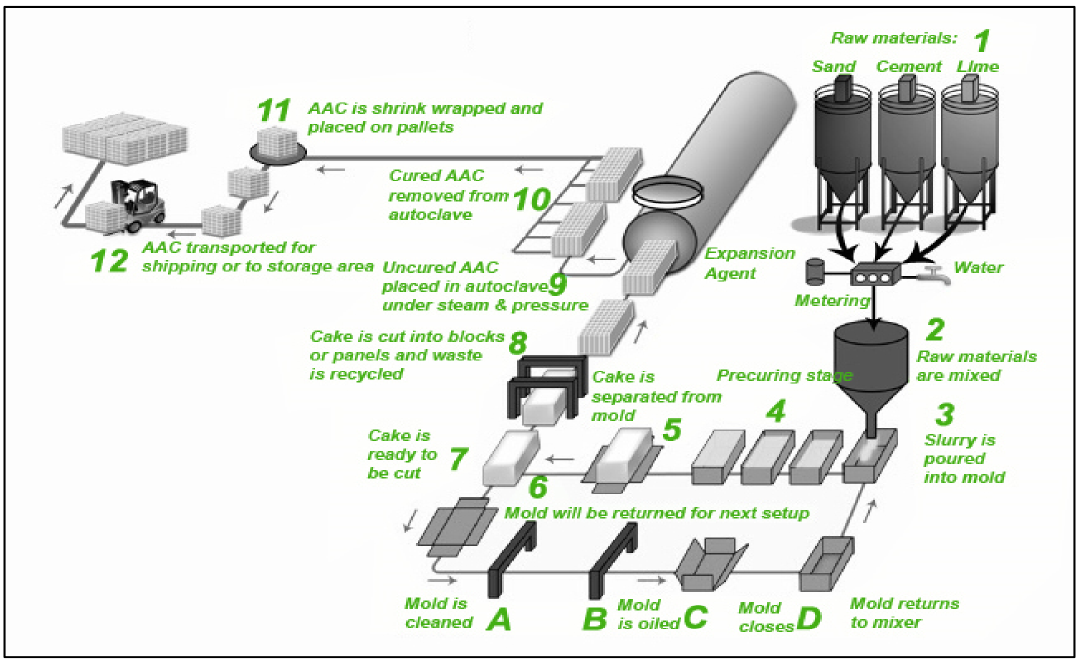


Figure A1.34. AAC block manufacturing line[87]

AAC blocks are large (in size), light in weight, and have low thermal conductivity. Use of AAC blocks results in reduction of deadweight of the structure, which, in turn, leads to reduction in use of steel and cement. Large block sizes ensure rapid construction so that more wall area can be laid per man-hour than in conventional brick wall constructions.

[87] Image source: http://www.greencon.my/img/production-map.jpg (3 August 2017)

Manufacturing of AAC Blocks is centered around large cities but supply network is spread across all cities. Gujrat, Maharashtra, Haryana, Telengana, and West Bengal are the leading producers of AAC Blocks in India. The blocks are predominantly being used in multi-storey high-rise construction sector.

BIS standards applicable to manufacturing of AAC Blocks is IS-2185-3-(1984)-concrete masonry units, Autoclaved cellular Aerated Concrete Blocks.

Figure A1.35. AAC blocks

Cellular Light-weight concrete (CLC)

It is a lightweight concrete that is produced by making a slurry of cement, fly ash, sand and water, which is further mixed with stable foam, in a concrete mixer, under ambient conditions (Figure A1.36). The manufacturing set-up requires low-cost machinery and relatively low investment.

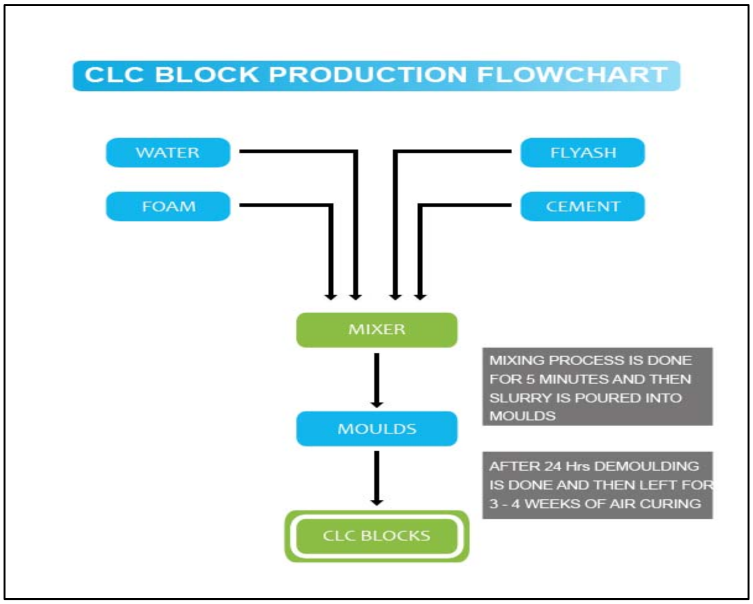


Figure A1.36. CLC production process[88]

CLC blocks are large (in size), light in weight and have low thermal conductivity. Use of CLC blocks results in reduction of deadweight of the structure; which in turn leads to reduction in use of steel and cement. Large block sizes ensure rapid construction so that more wall area can be laid per man-hour than in conventional brick wall constructions.

The manufacturing is generally done at the building construction site.

BIS standards applicable to manufacturing of CLC Blocks is IS-2185-4- (2008): Concrete masonry units, Part 4: Preformed foam cellular concrete blocks.

[88] Image source: http://www.iyantra.com/ (accessed on 1 August 2017)

Figure A1.37. CLC block

Construction and Demolition Waste bricks

These are dense solid block produced by compacting a mixture of cement (20%–25%), crushed demolition waste (65%–70%), admixture (5%–15%), and water. As of now these bricks use special admixtures in their manufacturing, which reduces their curing time. C&D waste bricks are still in a nascent phase of product development. The challenge lies in optimizing the compressive strength vis-à-vis density to achieve cost efficiency. The manufacturing process has been depicted in Figure A1.38.

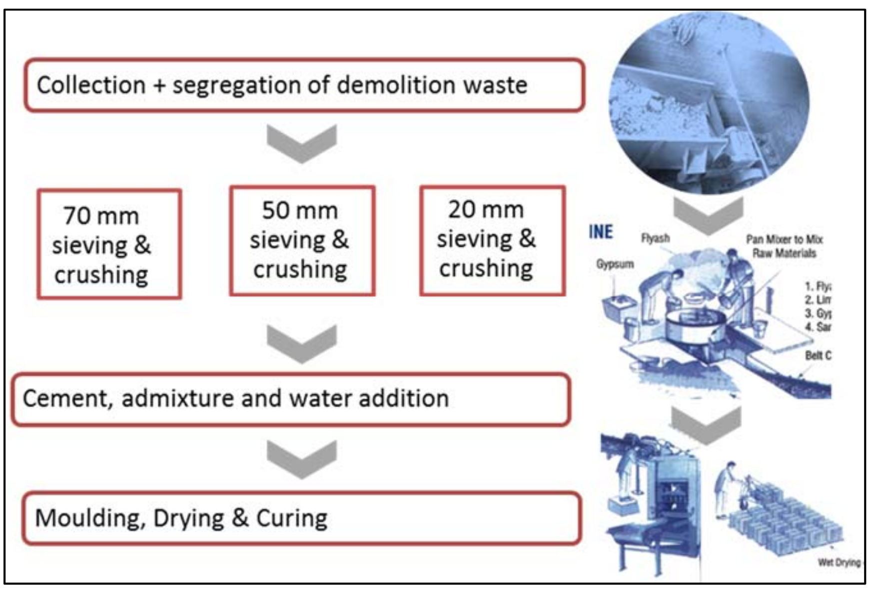


Figure A1.38. C&D waste brick production process

C&D waste bricks are not suitable for light-weight construction. At present, it is being used as an infill walling material. At present, there are only a few C&D waste brick manufacturing units, set up in and around the NCR region.

Figure A1.39. C&D waste bricks

Compressed Stabilised Earth Blocks (CSEB)

It is a dense solid block produced by compacting a mixture of soil, sand, stabiliser (cement/lime) and water using press machine. CSEB production is done on the site through soil excavated from the project sites or from nearby location which saves the transportation and fuel costs. Equipment for making CSEB is available in manual or mechanised models ranging from village to semi-industrial scale. The manufacturing process has been depicted in the Figure A1.40.

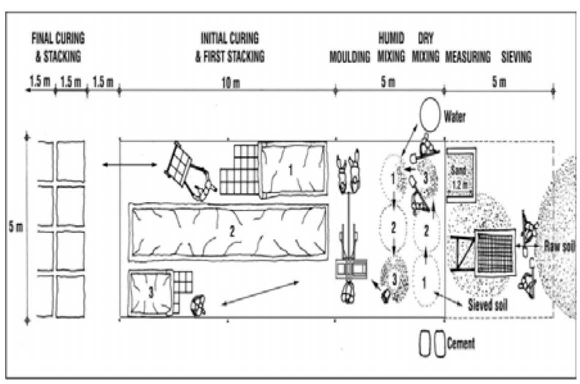


Figure A1.40. CSEB manufacturing process[89]

[89] Image source: http://www.earth-auroville.com/compressed_stabilised_earth_block_en.php (accessed on 1 August 2017)

CSEBs can be used in load-bearing construction up to two floors and in non-load-bearing construction, as infill. The blocks have negligible market share at present and are manufactured on site. The production of blocks requires technical expertise to assess soil characteristics and the appropriate mix of cement. This has been a barrier for its adoption.

The BIS standard applicable to manufacturing of CSEB is IS 1725 (1982): Soil based blocks used in general building construction.

Figure A1.41. Compressed stabilised earth blocks

Pulverised Fuel Ash Lime/Cement bricks

Pulverised fuel ash-lime bricks are produced from materials consisting of pulverised fuel ash in major quantity, lime and an accelerator acting as a catalyst. Pulverised fuel ash-cement bricks are made from materials consisting of pulverised fuel ash in major quantity, cement and admixtures. These bricks are generally manufactured by blending various raw materials which are then moulded into bricks and subjected to curing. The manufacturing process has been depicted in the Figure A1.42.

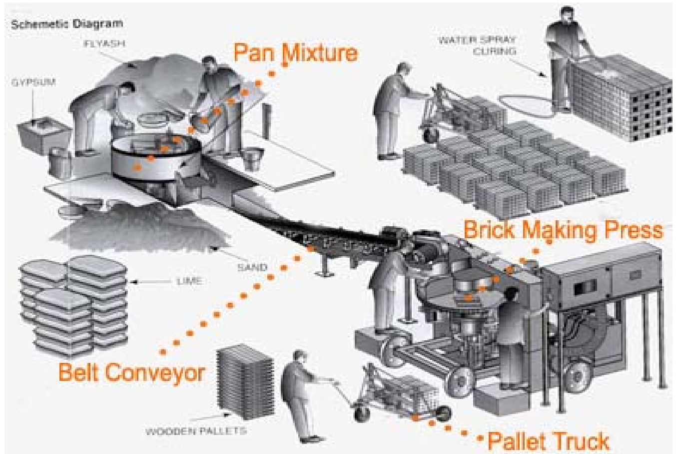


Figure A1.42. Fly ash brick manufacturing process[90]

Pulverised Fuel Ash Lime/Cement bricks, also known as fly ash bricks, are being manufactured primarily by small-scale producers in the regions, around thermal power plants. At present, fly ash bricks are being primarily used for low-rise construction and a few high-rise construction buildings. As per CEA data, Maharashtra, Andhra Pradesh, Tamil Nadu, Gujarat, and Rajasthan account for almost 70% of the fly ash utilisation for brick and tile manufacturing.

The BIS standards applicable to manufacturing of Fly ash bricks are:

- IS 12894 (2002): Pulverized Fuel Ash-Lime Bricks
- Draft IS for Pulverized Fuel Ash-Cement Bricks

[90] Image source: http://www.exportersindia.com/ (accessed on 1 August 2017)

Annexure 2: Calculation of brick requirement per m^2 of floor space construction

1. Step 1 – Design of various combinations

   Firstly, size and number of bedrooms, kitchens and toilets are assumed for various types of dwelling houses (as per census). The assumed floor area for a room is 15 m^2.

   As there are several possible combinations for five and six room dwellings, walling area is estimated according the ratio of walling area with floor area of other dwellings.

	No exclusive room	One room	Two rooms	Three rooms	Four rooms	Five rooms	Six rooms & above
Bedroom (3m*5m=15 sqm)	1	1	2	3	4	5	6
Kitchen (2m*2.5m=5 sqm)	0	1	1	1	2	2	2
Toilet (2m*2.5m=5 sqm)	1	1	1	2	3	4	4
Total(sqm)	20	25	40	60	85	105	120

The plan view of various combinations of dwelling units are shown in the next page.

2. Step 2 - Assumption

   The external walls are of 10” thickness; constructed by standard size bricks of 230 x 115 x 75 mm (98 bricks per m^2 of wall)

   The internal walls are of 5” thickness; constructed by standard size bricks of 230 x 115 x 75 mm (49 bricks per m^2 of wall)

3. Step 3 - Estimation

	No exclusive	1 room	2 rooms	3 rooms	4 rooms	5 rooms	6 rooms
Avg. total wall length of various combination (m)	23	26	38	56	73	88	97
Height of wall (m)	3.8	3.8	3.8	3.8	3.8	3.8	3.8

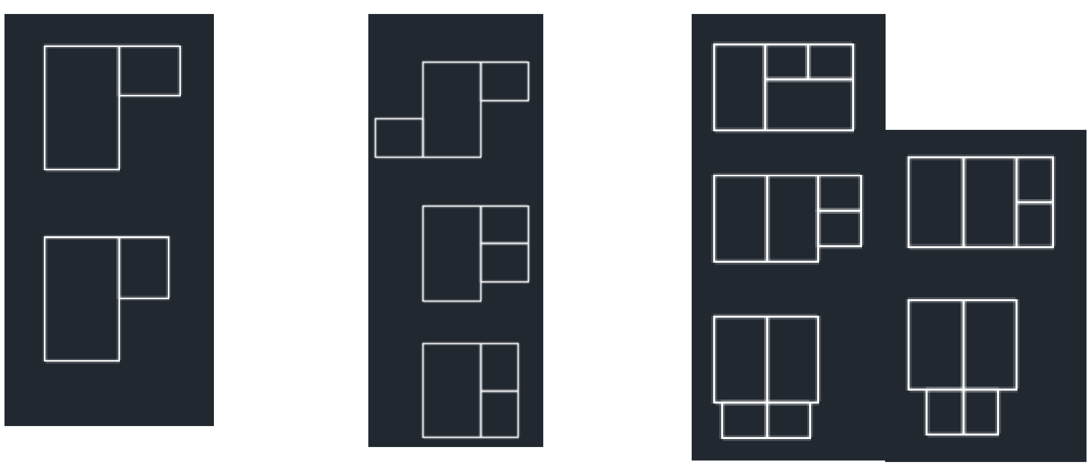
Total wall area (m^2)	87.4	98.8	144.4	212.8	277.4	334.4	368.6
Internal wall area (m^2)	9.5	22.8	43.7	76	110.2	140.6	155.8
Internal wall area without doors and windows (m^2)	7.9	21.2	40.1	68.8	97.9	124.7	137.9
External wall area (m^2)	77.9	76	100.7	136.8	167.2	193.8	212.8
External wall area without doors and windows(m^2)	73.6	70.95	94.9	128.7	158.3	182.6	200.1
Bricks for external walls	7212	6953	9300	12612	15513	17894	19609
Bricks for internal walls	387	1039	1965	3371	4797	6110	6757
Total bricks	7600	7992	11265	15984	20311	24005	26367
Total floor space area (m^2)	20	25	40	60	85	105	120
Bricks per m^2 of floor space area	380	320	282	266	239	229	220
Average of bricks per m^2 floor space area	276						

An additional 30% of bricks is accounted for the bricks consumed in constructing foundation, boundary walls, brick soling and drains of the house.

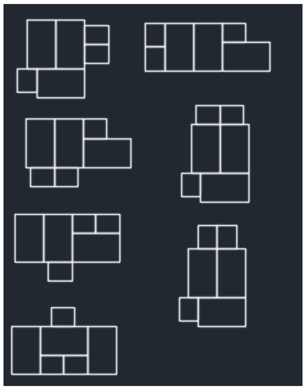
The average requirement of standard size bricks per m^2 of floor space is 360 bricks (~ 276 x 1.3).

Various Combinations of houses

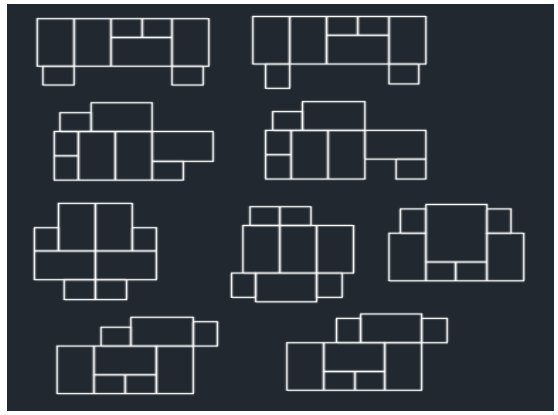
No exclusive room One room Two room



Three room



Four rooms



Annexure 3: Sample Calculation - Manufacturing energy consumption of a walling material

Embodied Energy of Raw Materials			
Raw material	**Embodied energy**	**Units**	**Source of data**
Lime	5.63	MJ/kg	Reddy BVV and Jagadish KS. 2003.[91]
Cement	3.99	MJ/kg	Madlool, et al. 2011.[92]
Aluminium	150.69	MJ/kg	Praseeda, et al. 2015.[93]
Electricity	11.22	MJ/kWh	Praseeda, et al. 2015. [94]
Flyash	0	MJ/kg	Recycled material
Gypsum	0.04	MJ/kg	<http://www.gib.co.nz/assets/Winstone-Wallboards/Environment/GBMAGyp-Sustainability-090522.pdf> (accessed on 1 July 2017)
Other data			
Density of diesel	820	kg/kl	Society of Indian Automobile
Calorific value of diesel	43.3	MJ/Kg	2006 IPCC Guidelines on National GHG Inventories: Table 1.2- Default NCV of Chapter 1 of Vol 2. Default value at the upper limit of the uncertainty at 95% confidence intervals is taken as conservative approach.
	35.5	MJ/l	Density of Diesel in kg/kl x Calorific value of Diesel in MJ/kg / 1000
Calorific value of petcoke	35.2	MJ/kg	Lab results

[91] Reddy BVV and Jagadish KS. 2003. Embodied energy of common and alternative building materials and technologies. *Energy and Buildings*. 35 (2), 129-137
[92] Madlool, et al. 2011. A critical review on energy use and savings in the cement industries. *Renewable and Sustainable Energy Reviews.* 15(4), 2042-2060
[93] Praseeda, et al. 2015. Embodied energy assessment of building materials in India using process and input–output analysis. *Energy and Buildings* 86, 677-686
[94] Ibid.

Autoclaved Aerated Concrete blocks (AAC blocks)

Material	Unit per m³ (A)[95]	% by wt. (B)	Embodied energy factor (C)	Embodied energy for AAC blocks MJ/m³ (D) = (A) x (C)
Raw materials				
Fly ash (kg)	458.0	75.3%	0.0	0.0
Lime (kg)	47.2	7.8%	5.63	265.7
Cement (kg)	100.0	16.5%	3.99	398.7
Gypsum (kg)	2.5	0.4%	0.04	0.1
Aluminium powder (kg)	0.35	0.06%	150.7	52.7
			Subtotal	717.2
Fuel and energy				
Petcoke (kg)	12		35.2	422.4
Diesel (l)	0.39		35.5	13.7
Electricity (kWh)	10.94		11.22	122.7
Total Manufacturing Energy Consumption				**1276**

Source: Raw material composition, fuel and energy consumption data taken from a prominent AAC manufacturing plant in Haryana.

[95] Units consumed in production of 1m³ of walling material

Annexure 4: Estimation of brick market in India

1. **Solid burnt clay bricks:** For this estimation, annual solid burnt clay brick production figures have been taken from two studies -
   a) Kamyotra J S. 2016.[96] **240 – 260 billion bricks per annum**
   b) Kumar S. 2016.[97] – **236 billion bricks per annum**

   The methodology used by both these studies is

   a) Estimate the number of brick enterprises by states (through information available with the state governments as well as through information available with the state level brick makers' associations and some field surveys)
   b) Estimate the average annual production capacity per enterprise for a state (through interviews with the state level brick makers' association and some field surveys)

$$National\ level\ brick\ production\ as\ per\ Study\ 1 = \sum Individual\ State\ level\ brick\ production$$

$$State\ level\ brick\ production = \left(\sum No.of\ brick\ kilns\right)\ x\ (Avg.brick\ kiln\ production\ capacity)$$

$$National\ level\ brick\ production = Average\ of\ National\ level\ brick\ production\ as\ per\ 'Study\ 1'\ \&\ 'Study\ 2'$$

   If we take an average of the production figures given in the two studies the brick production is estimated at **243 billion bricks per annum.**

   It should be noted that this type of estimation has large uncertainties, which are explained below:

   a) While the estimation of enterprises using FCBTK or zigzag kilns (bigger in size) is relatively better, the estimation of number of small rural (clamp based) enterprises is very difficult.

[96] Kamyotra J S. 2016. CPCB presentation titled "Brick Kilns in India", Presentation made at the workshop on "Roadmap for Brick Kiln Sector Challenges and Opportunities", organized by Centre for Science & Environment at New Delhi on February 8, 2016.
[97] Kumar S. 2016. TERI presentation titled "Options for Walling Materials and benefits of using REBs in building construction", organised by Punjab State Council for Science & Technology (PSCST) at Chandigarh on 24 May 2016

b) The number of operating brick enterprises fluctuates every year. This depends on the market demand, weather, workers' availability, etc. In the method used above, it is assumed that 100% of the brick enterprises are operational.
c) The annual average production capacity of brick enterprises can vary significantly in a state. Usually enterprises closer to the urban areas produce more bricks, compared to individual enterprise in a rural area. The capacity may also vary from region to region within a state e.g. a typical brick enterprise in western UP produces 50-75 lakh bricks/ year on the other hand a brick enterprise in eastern UP produces 30-50 lakh bricks. As the data is not available at the district level, assuming an average production capacity at the state level can bring in significant error.

However, given the absence of official data on brick kilns, this was perhaps the only way to estimate the production of burnt clay bricks. In recent years, several of the states have started preparing GIS maps of bricks kilns (e.g. Bihar and NCR) for either compliance with the environment norms or to improve the collection of mining revenue. It is expected that in coming years, there will be an improvement in data on number of brick kilns.

2. **Hollow and perforated burnt clay bricks**: The report on "Market Assessment for Burnt Clay Resource Efficient Bricks, 2016" prepared by Greentech Knowledge Solutions, for UNDP-GEF provides the status of burnt clay REB production (Hollow and perforated burnt clay bricks) in India.

In this report, information on both the number of resource efficient brick producing enterprises as well as their annual production was collected through interviews with brick makers, web search, reports and information available with the UNDP-GEF project, and suppliers of machines to these enterprises. The summary of the production data is as follows -

a) "The total annual production of burnt clay hollow bricks during 2015 is estimated at around **180 million** standard size bricks, out of which almost 87% are produced in Karnataka".
b) "The total annual production of perforated burnt clay bricks during 2015 is estimated at around **37 million** standard size bricks, out of which almost 80% are produced in north India -- Punjab, Haryana and NCR region".
c) The final figure for production of Hollow and perforated burnt clay brick industry is the cumulative of the above two figures – **0.22 billion bricks per annum.**

3. **<u>Pulverized fuel-ash lime/cement bricks and AAC Blocks</u>**: The report [GKSPL.2016][98] discusses on fly ash bricks production and AAC Blocks annual production. The amount of fly ash utilized for AAC block production was subtracted from the total annual fly ash utilization from brick making and the remaining amount was assigned to the production of pulverized fuel ash bricks. It was assumed that 1.0 kg of fly ash is used per bricks. This value was then used to calculate the number of flyash bricks that were produced. The following table briefly displays the important steps and results of the estimation. The methodology of the steps are provided after Table A4.19.

Table A4.19. Steps and results of fly-ash-based brick production estimation

Parameters	Quantity	Methodology (given below)
Fly ash utilised for brick making as per [CEA.2015][99]	12.36 million tonnes	[A]
AAC block production	4.4 billion bricks / year	[B]
Fly ash brick production as per CEA	8.36 billion bricks / year	[C]
Fly ash utilised in “Other” as per CEA (13%)	13.39 million tonnes	
Fly ash bricks manufactured from “Other” fly ash sources	3.35 billion bricks /year	[D]
Fly ash bricks production as per GKSPL based on CEA data	<u>11.7 billion bricks/year</u>	[E]
Fly ash bricks installed capacity as per INSWAREB	54 billion bricks/year	[F]
Fly ash bricks production at 50% PUF	27 billion bricks/ year	[G]

The methodology used for obtaining the figures presented in the above table is as follows:

A. CEA data for fly ash utilisation for brick making in a particular year. It was assumed that the amount of fly ash utilisation for brick making covers both pulverised fuel ash bricks as well as AAC blocks.

[98] Greentech Knowledge Solutions Pvt. Ltd. (GKSPL). 2016.Assessment of fly ash based Walling Material Production Inventory in India, Report prepared for Climate Studies Program, Indian Institute of Technology, Bombay.
[99] Central Electricity Authority. 2015. Report on fly ash generation at coal/lignite based thermal power stations and its utilization in the country for the year 2014-15. New Delhi: Central Electricity Authority

B. The data on annual AAC blocks production was calculated by collecting information on AAC production units as well as their annual production capacity. This data was used to calculate the annual production. It should be noted that a plant capacity utilisation factor was assumed while calculating the annual production.
C. The amount of fly ash utilised for AAC block production was subtracted from the total annual fly ash utilisation from brick making and the remaining amount was assigned to the production of pulverised fuel ash bricks. It was assumed that 1.0 kg of fly ash is used per bricks. This value was then used to calculate the number of fly ash bricks that were produced.
D. A part of fly ash utilisation in "others" also goes for brick making (as several of the small producers do not get fly ash directly from power plants). The amount of fly ash utilised in "Others" is 13.39 million tonnes (MT) (13% of 103 MT). Assuming that 25% of this quantity goes for manufacturing bricks, further 3.5 MT of fly ash is utilised in manufacturing fly ash bricks.
E. The figure of fly ash brick production as per GKSPL based on CEA data is the cumulation of figures obtained in steps C and D.
F. Vishakhapatnam-based NGO, Institute for Solid Waste Research & Ecological Balance (INSWAREB), which is involved in the promotion of fly ash bricks, has estimated that there are 18,000 fly ash brick production units in the country with a total installed capacity to produce 54 billion bricks/year.[100]
G. Five states – Andhra Pradesh, Maharashtra, Tamil Nadu, Gujarat and Telangana – that show high fly ash utilisation for brick making as per CEA data were selected for conducting rapid field surveys. Survey team consisting of 2-3 team members[101], visited these states during March to June 2016. During the visit, the survey team members met fly ash brick manufacturers, suppliers of fly ash manufacturing machinery, a few builders/building sector professionals and in some cases, a few government officials and power plant officials. Average percentage utilisation factor of the installed capacity at the time of survey varied from 25% to 75% (highest in Tamil Nadu and lowest in Gujarat). Assuming an average 50% plant utilisation factor, production figures can be obtained using INSWAREB's data on installed capacity.

[100] Bhanumatidas N and Kalidas N. 2016. FaL-G the unique E4 technology. Presentation at the Stakeholder Workshop on Resource Efficient Walling Materials. Workshop organized by Greentech Knowledge Solutions, June 7, 2016. New Delhi.
[101] The survey was conducted jointly by a team consisting of Bhagwat Technologies and Energy Conservation Pvt. Ltd and Greentech Knowledge Solitions Pvt. Ltd.

- It is difficult to estimate the exact national-level production figures for fly ash bricks. Also, there is a huge gap in the figures derived from CEA data and INSWAREB.
- The summary of the production data for year 2014/15, based on the report is as follows:
    - Fly ash bricks: 12 – 27 billion standard sized bricks / year (for the national brick consumption estimation, 11.7 billion bricks have been used)
    - AAC blocks: 4.4 billion standard sized bricks / year

4. **Concrete Blocks**: As many concrete brick units are in the unorganised sector, i.e. they are either not registered or licensed to any official organisation, so there is no record at any level how much these bricks are produced annually.

To assess the inventory data from CENSUS OF INDIA-2011, HOUSES HOUSEHOLD AMENITIES AND ASSETS and the same of 2001 has been analysed to get the annual consumption of the concrete bricks in India. To note, only households are considered in this study.

Distribution of households by predominant material of wall - HLO Indicators - Census 2011 and 2001

State Code	India/ State/ Union Territory #	Distribution of households by predominant material of Wall											
		Total No. of Households (Excluding institutional households)	Grass, Thatch, Bamboo etc.	Plastic, Polythene	Mud, Unburnt brick	Wood	Stone			G.I.,Metal,Asbestos sheets	Burnt brick	Concrete	Any other material
							Total	Not packed with mortar	Packed with mortar				
1	2	3	4	5	6	7	8	9	10	11	12	13	14
00	INDIA	246,692,667	9.0	0.3	23.7	0.7	14.1	3.4	10.8	0.6	47.5	3.5	0.6

Figure A4.43. Distribution of households by predominant material of wall

Distribution of households by number of dwelling rooms-HLO Indicators- Census 2011 and 2001

State Code	India/ State/ Union Territory #	Distribution of households by number of dwelling rooms							
		Total No. of Households (Excluding institutional households)	No exclusive room	One room	Two rooms	Three rooms	Four rooms	Five rooms	Six rooms & above
1	2	3	4	5	6	7	8	9	10
00	INDIA	246,692,667	3.9	37.1	31.7	14.5	7.5	2.6	2.8

Figure A4.44. Distribution of households by number of dwelling rooms

STEPS FOR ESTIMATION

1
- Create possible arrangements of -no. of dwelling rooms households considering kitchen and toilets also.

2
- Calculate the wall area of external and internal walls
- Reductions are to be done for doors and windows.

3
- Calculate number of bricks (230mm*115mm*75mm) in (x) no. for various dwelling household

4
- Calculate % Concrete Bricks State-wise from Census Data 2001 and 2011.
- Calculate no. of households dwelling wise for Concrete Bricks using above % obtained from census data 2001 and 2011.

5
- Calculate the difference in no. of households statewise between 2011 and 2001 census datas and estimate the no of households made of concrete brick for 10years.

6
- Calculation CAGR for 10 years, an estimate of consumption for the year 2011 is obtained

According to this study, the concrete block production for the year 2011 is estimated to be about 6.36 billion bricks per annum in residential sector and about 7.5 billion bricks per annum for 2014/15. As through the census data only the number of blocks used in the construction of residential buildings is calculated, in practice, a large number of concrete blocks are used for boundary wall construction as well as for the construction of other types of buildings. To account for these uses, a factor of '2' (i.e. concrete block use for boundary walls and other buildings is equal to the concrete block use in the residential buildings) has been used to calculate the total number of concrete blocks produced. Hence, the concrete block production for the year 2014/15, can be estimated at about 15 billion bricks per annum.

Annexure 5: Resource Efficient Bricks Pathways for Maharashtra

Maharashtra is a state in western region of India and it is India's second most populous state; with a population of 112 million.[102] It is one of the most developed states in India, contributing 25% of the country's industrial output and 23.2% of its GDP.[103]

Maharashtra is divided into 36 districts, which are grouped into six administrative divisions.[104]

1. Amravati Division
2. Aurangabad Division
3. Konkan Division
4. Nagpur Division
5. Nashik Division
6. Pune Division

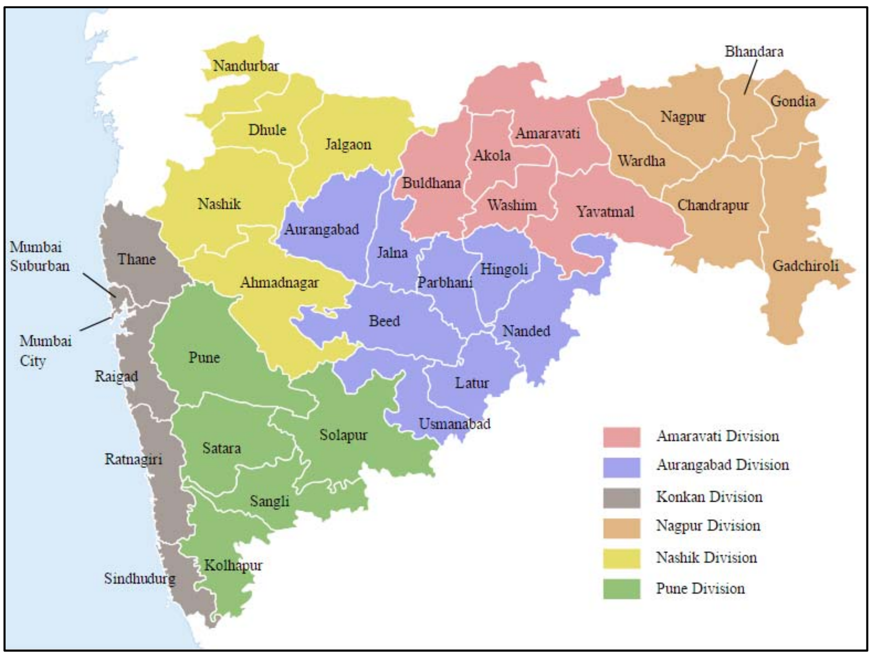


Figure A5.45. Districts and divisions of Maharashtra (without Palghar district)

[102] https://www.census2011.co.in/census/state/maharashtra.html (accessed on 5 August 2017)
[103] http://www.rediff.com/money/slide-show/slide-show-1-top-25-states-with-highest-gdp/20120223.htm (accessed on 4 August 2017)
[104] Image Source: https://en.wikipedia.org/wiki/List_of_districts_of_Maharashtra#/media/File:Maharashtra_Divisions_Eng.svg (accessed on 1 September 2017)

As per the projections by McKinsey Global Institute, Maharashtra will be one of the five states that will have more urban population as compared to rural population, by 2030. In 2008, the rate of urbanisation was 44% with an urban population of 47.9 million. It is projected, that the rate of urbanisation will be 58% with an urban population of 78.1 million by 2030.[105] With the current housing shortage coupled with required housing units for increasing population, the state of Maharashtra faces a housing need of 10.4 million houses by 2022.[106] (5.5 million in urban and 5 million in rural). The state is expected to show a sharp increase in the demand for building materials. Construction of buildings at such a scale would require a variety of building materials such as sand, aggregates, cement, steel, aluminium, timber, glass, brick, and ceramic tiles.

Brick Market – Status

The market of bricks shows wide variations across the state; and these variations are mainly influenced by Geographical region and type of building projects.

Regional diversity based on raw material availability

Maharashtra state has traditionally been abundant in aggregates, stones and clay deposits. The main raw materials used to produce bricks are brick earth, aggregates, fly ash and natural stones.

The distribution of these main raw-materials is not uniform in the state. The state's division wise-availability of the main raw materials for making bricks is shown in Table A5.20.

Table A5.20. Maharashtra's division-wise raw material availability

Availability of Raw Materials					
Divisions	**Fly ash**	**Clay**	**Coarse aggregates**	**Natural stone**	**Sand**
Amravati			Yes	No	Yes
Aurangabad			Yes	No	Yes
Konkan			Yes	Yes	No
Nagpur			Yes	No	Yes
Nashik			Yes	No	Yes
Pune			Yes	No	Yes

[105] McKinsey Global Institute (MGI).2010. India's Urban awakening: Building Inclusive cities, sustaining economic growth. Mumbai: McKinsey Global Institute
[106] KPMG. 2014. Decoding Housing for all by 2022. <https://assets.kpmg.com/content/dam/kpmg/pdf/2014/09/Decoding-Housing-for-all-2022.pdf> (accessed on 1 July 2017)

Assumptions and basis for colour coding

Colour coding definitions for fly ash availability

Green	Distance of TPP[107] < 100 km and fly ash available
Yellow	Distance of TPP < 300 km and fly ash available
Red	None of the above

Fly ash is assumed "not available to meet additional future demand for the production of fly ash based products" in TPP, when the present utilisation percentage is greater than 98%.

Colour Coding definitions for clay availability

Green	Clay is abundantly available, with thick clay deposits suitable for brick making
Yellow	Clay is available in small pockets normally near rivers, water bodies, etc.
Red	Clay is scarce

[107] Thermal Power Plant

Fly ash availability in Maharashtra as per CEA[108] data

Table A5.21. Fly ash utilisation (%) of Maharashtra's thermal power plants

	Name of TPS	Power utility and state	Utilisation (%)
1	TIRORA	ADANI POWER Ltd.	60.5
2	MIHAN	AMNEPL (No Generation)	-
3	AMARAVATI TPS	RattanIndia (formerly Indiabulls Power Ltd.)	49.6
4	BELA TPS	IDEAL ENERGY PROJECTS Ltd. (No Generation)	-
5	RATNAGIRI	JSW Energy Ltd	100.4
6	BHUSAWAL	M.S.P.G.C.L.	69.0
7	CHANDRAPUR	M.S.P.G.C.L.	46.4
8	KHAPARKHEDA	M.S.P.G.C.L.	86.4
9	KHAPARKHEDA (EXT)	M.S.P.G.C.L.	2.5
10	KORADI	M.S.P.G.C.L.	58.7
11	NASIK	M.S.P.G.C.L.	98.0
12	PARLI	M.S.P.G.C.L.	226.7
13	PARAS	M.S.P.G.C.L.	96.0
14	MOUDA TPS	N.T.P.C.LTD	80.8
15	DAHANU	RELIANCE INFRASTRUCTURE Ltd.	116.9
16	TROMBAY	T.P.CO.	99.8
17	SAI WARDHA POWER Ltd., WARORA	WPCL	124.3
18	GMR WAROARA ENERGY Ltd.	GMR WAROARA ENERGY Ltd.	87.3
19	DHARIWAL INFRASTRUCTURE Ltd.	Dhariwal Infrastructure Ltd.	86.7
20	GEPL TPP	GUPTA ENERGY Pvt. Ltd. (No Generation)	-

The analysis of CEA data shows that out of installed 20 thermal power plants in the state of Maharashtra, 6 of them have close to (or more than) 100% fly ash utilisation. The net available

[108] Central Electricity Authority. 2016. Report on fly ash generation at coal/lignite based thermal power stations and its utilization in the country for the year 2015-16. New Delhi: Central Electricity Authority.

fly ash for utilisation in the state is 5.6 million tonnes fly ash.[109] With the rising brick demand and increasing consumption of fly ash by cement industry, the available quantity of fly ash is inadequate, to fulfil the brick demand in future by itself (2027–32).

Type of building projects

Division-wise distribution of predominant form of construction for the state of Maharashtra has been provided in the Table A5.22.

Table A5.22. Maharashtra's division-wise form of construction

Divisions	Rural population distribution (%) based on Census 2011	Predominant form of construction		Major cities
		Urban	**Rural**	
Amravati	72%	RCC[110]	RCC, Load bearing	Akola, Amravati
Aurangabad	73%	RCC	RCC, Load bearing	Aurangabad, Latur
Konkan	22%	RCC, MCC[111]	Load bearing	Mumbai, Thane
Nagpur	58%	RCC	RCC, Load bearing	Nagpur
Nashik	69%	RCC	RCC, Load bearing	Nashik, Jalgaon
Pune	59%	RCC, MCC	RCC, Load bearing	Pune, Kolhapur, Solapur

Rural

Residential construction in rural areas is mostly single-story or low-rise construction. Except for rural housing constructed by the government, most of the residential construction is self-constructed or self-supervised by the owner by hiring the services of masons. Usually traditional construction technologies (load bearing masonry construction, concrete framed construction with masonry in-fill, etc.) are used in this segment.

Urban

[109] Availability of Pond ash from a TPP has not been considered in this study
[110] Reinforced Concrete Construction
[111] Monolithic Concrete Construction

Construction in urban areas is varied in terms of intended use, scale, agency responsible for the construction, construction technology, etc. The main categories are:

Large-scale housing projects (Urban)

Large-scale housing projects refers to projects where several hundred or several thousands of houses are constructed as a part of a single project. In this segment, there is a growing preference for medium and high-rise construction. In most of the cities in this region, AAC blocks and pulverized fuel ash bricks are being used for high rise construction. In places such as Pune and Mumbai, there is move towards Monolithic Concrete Construction for high-rise buildings.

Low-rise housing (Urban)

The housing on smaller plots of land, urban slums and urban villages are mostly low-rise and self-constructed. Usually traditional construction technologies and materials are used in this segment. Burnt clay bricks and pulverised fuel ash bricks are the main walling materials. The penetration of alternate materials is rather limited.

Market of bricks

The estimated market of bricks (2014/15) in the state of Maharashtra, for different types of bricks is presented in table below. As no agency in the country has good data on the market of bricks, the table has been prepared by compiling data from different studies.

Table A5.23. Market of bricks (2014/15) estimates in billion standard bricks/year

Type of brick	**Annual consumption (billion bricks)**	**Source**
Solid burnt clay bricks	17[112] billion bricks	Based on figures of no. of kilns from [Kumar S.2016][113] & avg. production capacity of Clamps from [Kumbhar S.2014[114]

[112] There are 16,663 brick kilns in Maharashtra; out of which approximately around 200 are FCBTK with an avg, production capacity of 5 million bricks per annum and the remaining kilns are Clamp kilns, with an avg. production capacity of 1 million bricks per annum.
[113] Kumar S. 2016. TERI presentation titled "Options for Walling Materials and benefits of using REBs in building construction", organised by Punjab State Council for Science & Technology (PSCST) at Chandigarh on 24 May 2016.
[114] Kumbhar, et al. 2014. Environmental Life Cycle Assessment of Traditional Bricks in Western Maharashtra, India *Energy Procedia.* 54: 260–269.

Pulverised fuel-ash lime/cement bricks	3.6 billion bricks	Based on fly ash utilisation data of CEA [GKSPL.2016][115]
AAC blocks	1.2 billion bricks	Based on fly-ash utilisation data of CEA [GKSPL.2016][116]
Concrete blocks	3 billion bricks	Based on Census data for 2001 and 2011 regarding walling materials [GKSPL.2015][117]
Total	25 billion bricks	

The data shows that solid burnt clay bricks still retains ~68% of the market for bricks. The other alternate bricks like concrete blocks, pulverised fuel-ash lime/cement bricks and AAC blocks together make up for the rest of the market. The market for alternate bricks, particularly AAC blocks, has grown during the last decade.

Manufacturing Industry

The manufacturing industry to produce bricks is spread throughout the states. The total number of manufacturing units is around 22,000. Majority of the units are micro and small enterprises and a large number of them show characteristics of informal sector. The number of manufacturing enterprises of important masonry products have been provided in the Table A5.24.

Table A5.24. Brick manufacturing Industry (2014/15) no. of enterprises

Type of brick	**Manufacturing units**	**Source**
Solid burnt clay bricks	16,663	Based on production data [TERI,2016][118]

[115] Greentech Knowledge Solutions Pvt. Ltd. (GKSPL). 2016.Assessment of fly ash based Walling Material Production Inventory in India, Report prepared for Climate Studies Program, Indian Institute of Technology, Bombay.
[116] Ibid.
[117] Discussed in Point 4 of Annexure 4.
[118] Kumar S. 2016. TERI presentation titled “Options for Walling Materials and benefits of using REBs in building construction”, organised by Punjab State Council for Science & Technology (PSCST) at Chandigarh on 24 May 2016.

Pulverised fuel-ash lime/cement bricks	~3000	Based on fly ash utilisation data of CEA [GKSPL,2016][119]
AAC blocks	14	Based on fly ash utilisation data of CEA [GKSPL, 2016][120]
Concrete blocks	1500-2500	Based on Census data for 2001 and 2011 regarding walling materials [GKSPL, 2015][121]
Total	~22,000	

Figure A5.46. **Manufacturing clusters of masonry products in Maharashtra** depicts the geographical distribution of the brick manufacturing industry in Maharashtra.

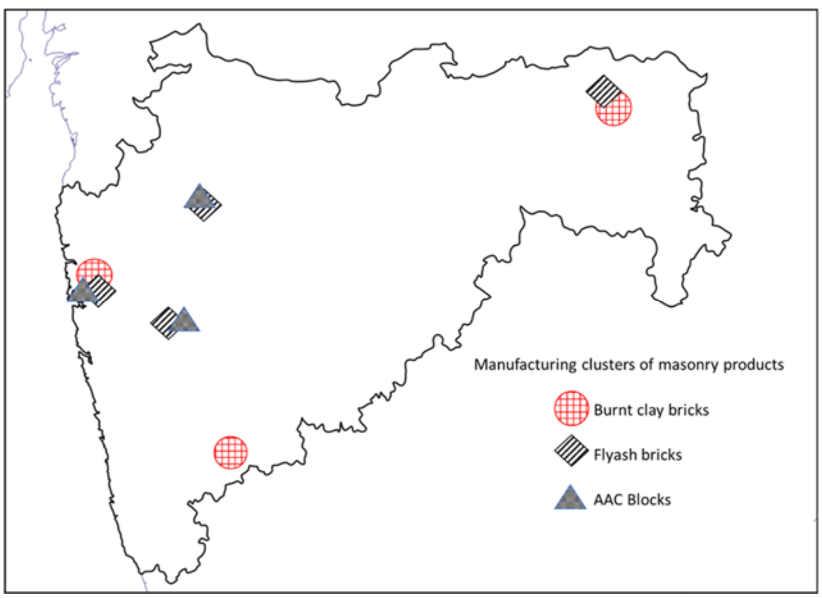


Figure A5.46. Manufacturing clusters of masonry products in Maharashtra

[119] Greentech Knowledge Solutions Pvt. Ltd. (GKSPL). 2016.Assessment of fly ash based Walling Material Production Inventory in India, Report prepared for Climate Studies Program, Indian Institute of Technology, Bombay.
[120] Ibid
[121] Discussed in Point 4 of Annexure 4

Policy and Regulations

- Clamp Siting Criteria, 2016
- Environment Clearance (EC) by State Environment Impact Assessment Authority (SEIAA)
- Consent to Establish' and 'Consent to Operate' by State Pollution Control Board
- Mining regulations - Mining permit and royalty
- Maharashtra state Fly ash Utilization Policy, 2016

Projected annual demand for bricks for Maharashtra for 2027–32

- Urban residential brick demand: 35 billion bricks
- Rural residential brick demand: 13 billion bricks

The overall projected annual brick demand for the state of Maharashtra for 2027–32 is about 71 billion; which is almost three times the current demand.

Resource efficient brick pathways for transformation

The resource efficient brick pathways differ for different regions as well as differ for urban and rural areas within a region. The potential resource efficient brick solutions for the six divisions are shown in Table A5.25.

Table A5.25. Maharashtra's division-wise potential resource efficient brick solutions

Baseline 2016		
Divisions	Rural	Urban
Amravati	Solid Burnt clay bricks (clamps)	Solid Burnt clay bricks (clamps), Fly ash bricks, AAC blocks
Aurangabad	Solid Burnt clay bricks (clamps)	Solid Burnt clay bricks (clamps), Fly ash bricks, AAC blocks
Konkan	Laterite Blocks	Solid Burnt clay bricks (Clamps), Monolithic Concrete Construction
Nagpur	Solid Burnt clay fly ash bricks (BTKs)	Solid Burnt clay bricks (clamps), Fly ash bricks, AAC blocks
Nashik	Solid Burnt clay fly ash bricks (Clamps + a few BTKs)	Solid Burnt clay bricks (clamps), Fly ash bricks, AAC blocks
Pune	Solid Burnt clay fly ash bricks (BTKs), Fly ash bricks	Solid Burnt clay bricks (clamps), Fly ash bricks, AAC blocks

Potential resource efficient brick solutions		
Divisions	Rural	Urban
Amravati	Pulverized Fuel Ash Cement/ lime bricks, Solid Burnt Clay bricks (Efficient kilns), Perforated burnt clay bricks, CSEB, Hollow Concrete blocks	AAC & CLC blocks, Pulverized Fuel Ash Cement/ lime bricks, Perforated and Hollow burnt clay bricks, Hollow Concrete blocks
Aurangabad	Perforated burnt clay bricks, Solid Burnt Clay bricks (Efficient kilns), Pulverised Fuel Ash Cement/ lime bricks, CSEB, Hollow Concrete blocks	Pulverised Fuel Ash Cement/ lime bricks, Perforated and Hollow burnt clay bricks, Hollow Concrete blocks
Konkan	Hollow Concrete blocks	Hollow Concrete blocks
Nagpur	Pulverised Fuel Ash Cement/ lime bricks, Solid Burnt Clay bricks (Efficient kilns), Perforated burnt clay bricks, CSEB, Hollow Concrete blocks	AAC & CLC blocks, Pulverised Fuel Ash Cement/ lime bricks, Perforated and Hollow burnt clay bricks, Hollow Concrete blocks
Nashik	Perforated burnt clay bricks, Solid Burnt Clay bricks (Efficient kilns), Pulverised Fuel Ash Cement/ lime bricks, CSEB, Hollow Concrete blocks	Pulverised Fuel Ash Cement/ lime bricks, Perforated and Hollow burnt clay bricks, Hollow Concrete blocks
Pune	Solid Burnt Clay bricks (Efficient kilns), Perforated burnt clay bricks, CSEB, Hollow Concrete blocks	Perforated and Hollow burnt clay bricks, Hollow Concrete blocks

Urban:

- Enterprises: Relatively larger investment (>INR 5 crore) with large degree of mechanisation/ automation
- Market: For mid- and high-rise construction, a product having lighter density and large block size is preferred.

Rural:

Relatively smaller production capacity with lower initial investment (INR 10 lakh to 2 crore), semi-mechanised process.

Market: Mostly low-rise construction with a preference towards solid brick products because of factors, such as, preference for load-bearing construction in some regions, safety and security issues.

Annexure 6: Projection methodology for market distribution of bricks for future scenarios

Two scenarios have been developed for the future development of the brick sector in India. The first scenario is the ***reference scenario*** which assumes that no fresh policy initiatives are taken to promote resource efficient bricks and there is no change in the existing environment policies and implementation structure. The other scenario is the ***resource efficient scenario***. It is assumed that under this scenario new policy initiatives will be undertaken for promoting resource efficient bricks. Further, these initiatives will consider the regional differences in availability of raw materials for producing bricks as well as requirements of different segments of the building construction industry.

The 2032 brick demand projection is the average of the 2027–32 and 2032–37 brick demand projections as explained in Section 4.1.

Assumptions made in the ***reference scenario.***

1. **Fly ash bricks and AAC blocks**:

- Quantity of fly ash generated per unit electricity produced is calculated by dividing the coal-based electricity generated in 2015[122], by fly ash generated from the CEA fly ash utilisation report for 2014-15.[123]

$$Quantity\ of\ flyash\ generated\ per\ unit\ electricity = \frac{Coal\ based\ electricity\ generated\ in\ 2015}{Fly\ ash\ generated\ in\ 2014-15} \ldots\ldots\ \textbf{\textit{(1)}}$$

- Projected coal-based electricity generated in 2032 is taken from IESS,2047 for Determined effort scenario (Level-2) ………. (**2**)
- Projection of fly ash generated in 2032 = (**1**) x (**2**)
- % of Fly ash utilisation has been assumed as 55% (the average % of utilisation over from the year 2006/07 to 2015/16). The % fly ash utilised in bricks and the % fly ash utilised in others have been taken as the same of 2014/15; i.e., 11.7% and 6.7%, respectively.

[122] http://www.cea.nic.in/reports/annual/thermalreview/thermal_review-2014.pdf (accessed on 1 July 2017)
[123] Central Electricity Authority. 2015. Report on fly ash generation at coal/lignite based thermal power stations and its utilization in the country for the year 2014-15. New Delhi: Central Electricity Authority

- It is assumed that in the year 2032, 40% of fly ash (of the fly ash utilised in bricks) will be used for manufacturing AAC blocks and the remaining for the manufacture of fly ash bricks. In 2015 it is estimated that 24% of fly ash used in bricks is used in manufacturing AAC blocks.

2. **Perforated and hollow burnt clay bricks/blocks**

- CAGR available for the period 2011 to 2015 have been assumed to remain unchanged till 2032.[124] It has been assumed that perforated bricks are produced only in Region-2 and hollow blocks Region-3

3. **Concrete blocks:**

- Region-wise CAGR between 2001 and 2011 of concrete block has estimated from Step 4 of Annexure 4. The same region-wise CAGR is assumed to remain unchanged at the same level till 2032.

4. **Industrial construction**

- This includes monolithic concrete construction, prefabricated concrete panels, etc. It is assumed that 50% of the urban construction will be industrial construction by 2032.[125]

5. **Kutcha Housing materials**

- This analysis is restricted only to “pucca” houses.

6. **Solid burnt clay bricks**

$$\begin{aligned} \textit{Solid burnt clay bricks} \\ &= \textit{Total brick requirement}\ ^{126} - \textit{Projections of}\ (\textit{AAC block}\ \&\ \textit{Flyash brick} \\ &+ \textit{Perforated}\ \&\ \textit{Hollow blocks} + \textit{Concrete blocks} + \textit{Industrial construction}) \end{aligned}$$

- It has been assumed that the remaining brick requirement, which is the total brick requirement minus the projected brick productions estimated in above Steps 1,2,3 and 4, will be fulfilled by the solid burnt clay bricks. It has also been assumed that in this scenario, 50% of these bricks will be manufactured using Zigzag kiln technology and the remaining 50% in conventional FCBTKs.

[124] Greentech Knowledge Solutions Pvt. Ltd (GKSPL) 2016. Market assessment of burnt clay resource efficient bricks. Report prepared for UNDP-GEF-MoEFCC project on “Energy Efficiency Improvements in the Indian Brick Industry”.
[125] It is assumed that by 2032, a large part of the building construction industry will become organized and the penetration of the industrial construction technologies will increase. Under Housing for all, BMTPC has released compendium of emerging technologies, which consists of several modes of industrial construction.
[126] Explained in section 4.1 of this document

<u>Assumptions made in the ***resource efficient scenario.***</u>

The steps for projecting distribution of bricks and their demands are –

1. Defining regions and regional markets
2. Estimating regional market demands using IESS data
3. Estimating AAC and fly ash brick production and demand for industrial construction
4. Distributing various walling materials across regional markets

Step – 1: For this scenario, the manufacturing regions of walling material have been further divided into the regional markets.

Table A6.26. Distribution of regions into regional markets

Regions	Regional markets
Himalayan and North-eastern states, except Assam and Tripura	1. Urban Horizontal development[127] 2. Urban Others[128] 3. Rural 4. Rural Others
Indo-Gangetic plains, Assam, and Tripura	1. Urban High-rise construction[129] 2. Urban Horizontal development 3. Urban Others 4. Rural 5. Rural Others
Peninsular, desert, and coastal regions	1. Urban High-rise construction 2. Urban Horizontal development 3. Urban Others 4. Rural 5. Rural Others

[127] Based on Horizontal development as defined in IESS,2047 [NITI Aayog. 2015. India Energy Security Scenarios excel tool "IESS_Version2.2". <http://indiaenergy.gov.in/iess/default.php> (accessed on 22 August 2017)]
[128] Considering that in recent years, many new materials are being used for applications like paving, canal, drain construction etc. In this study, the brick demand for other forms of construction is assumed as 25% of the urban and rural brick demand for the entire period till 2047
[129] Cumulative of High rise construction and affordable construction – based on the definitions of IESS,2047 [NITI Aayog. 2015. India Energy Security Scenarios excel tool "IESS_Version2.2". <http://indiaenergy.gov.in/iess/default.php> (accessed on 22 August 2017)]

Step – 2: The methodology for estimating brick demand for the regional markets in 2032, has been explained in the flow chart (Figure A6.47) below.

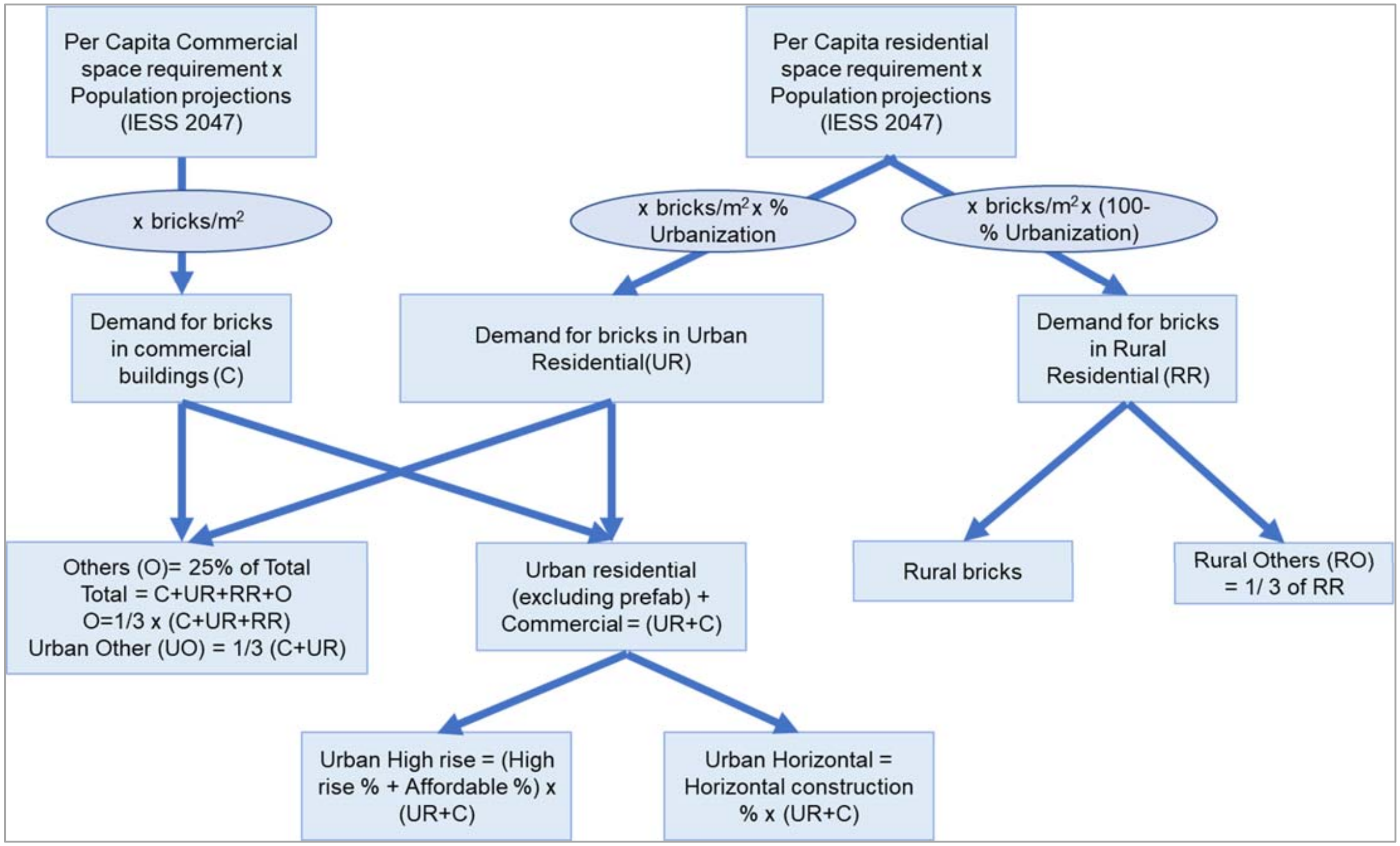


Figure A6.47. Flowchart for estimating regional market brick distribution

Note - IESS 2047, provides High rise%, Affordable % and Horizontal development for residential space requirement only. For our projections, the same % has been assumed for commercial buildings.

Step – 3: The assumptions for estimating the total production of AAC blocks and fly ash bricks has been described below.

- Quantity of fly ash generated per unit electricity produced is calculated by dividing the coal-based electricity generated in 2015,[130] by fly ash generated from the CEA fly ash utilisation report for 2014/15.[131]

$$Quantity\ of\ flyash\ generated\ per\ unit\ electricity = \frac{Coal\ based\ electricity\ generated\ in\ 2015^{132}}{Fly\ ash\ generated\ in\ 2014-15} \ldots\ldots. \textbf{\textit{(1)}}$$

- Projected coal-based electricity generated in 2032 is taken from IESS, 2047 for Determined effort scenario (Level-2) ………. (**2**)
- Projection of fly ash generated in 2032 = (**1**) x (**2**)
- It has been assumed that 100% of annual fly ash generated in 2032 will be utilised, out of which 20% will be utilised in bricks.
- It is assumed that 60% of fly ash (of the fly ash utilised in bricks) will be utilised for AAC and the remaining 40% in fly ash bricks in the year 2032.

In case of Industrial construction such as Monolithic concrete construction (MCC), prefabricated concrete panels, it is assumed that 50% of the urban construction will Industrial by 2032.

Step – 4: The distribution of various bricks across regional markets has been shown in the table below –

[130] http://www.cea.nic.in/reports/annual/thermalreview/thermal_review-2014.pdf (accessed on 1 July 2017)
[131] Central Electricity Authority. 2015. Report on fly ash generation at coal/lignite based thermal power stations and its utilization in the country for the year 2014-15. New Delhi: Central Electricity Authority
[132] http://www.cea.nic.in/reports/annual/thermalreview/thermal_review-2014.pdf (accessed on 1 July 2017)

Table A6.27. The distribution of various bricks across regional markets for 'resource efficient scenario'

		Solid burnt clay bricks - zigzag	Burnt clay Hollow blocks	Perforated bricks	Fly ash bricks	AAC	Solid concrete blocks	Hollow concrete blocks	CSEB
Himalayan and NE states except Assam and Tripura (Region-1)	Urban - Horizontal	0	0	50 % of (Urban Horizontal total - AAC)	0	AAC production data	0	50 % of (Urban Horizontal Total - AAC)	0
	Urban - Others	0	0	50%	0	0	25%	25%	0
	Rural	50%	0	0	0	0	40%	0	10%
	Rural Others	50%	0	0	0	0	50%	0	0
Indo-Gangetic plains and Assam and Tripura (Region-2)	Urban - High rise	0	Urban high-rise minus AAC Blocks	0	0	AAC production data	0%	0	0%
	Urban - Horizontal	0	0	Bricks minus flyash bricks minus hollow concrete	assumed 60% of region-2	0	0	3.2% total brick production in region-2.[133]	0
	Urban - Others	50%(Total-FA)	0	50%(Total-FA)	assumed 20% of region-2	0	0	0	0
	Rural	50%(Total-FA-CSEB)	0	50%(Total-FA-CSEB)	assumed 10% of region-2	0	0	0	5%
	Rural Others	Total-FA	0	0	assumed 10% of region-2	0	0	0	0
Peninsular, desert, and coastal Region (region-3)	Urban - High rise	0	50%(Total-AAC)	0	0	AAC production data	0	50% (Total-AAC)	0
	Urban - Horizontal	33%(Total-FA-HCB)	33%(Total-FA-HCB)	33%(Total-FA-HCB)	assumed 60% of region-3	0	0	6.3% total brick production in region-3.	0
	Urban - Others	50%(Total-FA-SCB)	0	50%(Total-FA-SCB)	assumed 20% of region-3	0	assumed 25% of urban others	0	0
	Rural	50%(Total-FA-SCB-CSEB)	0	50%(Total-FA-SCB-CSEB)	assumed 10% of region-3	0	assumed 10% of rural	0	5%
	Rural Others	50%(Total-FA-SCB)	0	50%(Total-FA-SCB)	assumed 10% of region-3	0	assumed 25% of rural others	0	0

Note: FA – flyash bricks, HCB – hollow concrete blocks, SCB – solid concrete block

[133] Same as 2015.

Annexure 7. Speakers, Panellists and Participants of the Stakeholder

Workshop (New Delhi, 7 June 2016)

S. No	Name	Organization
1	Megha Nikam	IIT Bombay, Mumbai
2	Dara Singh	Jindal Mechno Bricks P. Ltd., New Delhi
3	Vivek Taneja	Thermax Ltd, Pune
4	Anand Damle	DeBoer Damle, Pune
5	Shailesh Modi	Fourth Vision, Ahmedabad
6	N Kalidas	INSWAREB, Vishakhapatnam
7	Arshpreet Kalsi	Shakti Sustainable Energy Foundation
8	Kunal Sharma	Shakti Sustainable Energy Foundation
9	Pritpal Singh	Punjab State Council for Science and Technology
10	Ashok B Lall	Ashok Lall Architects
11	Satpal Jindal	Jindal Mechno Bricks P. Ltd.
12	Divya Jindal	Jindal Mechno Bricks P. Ltd.,
13	Anup Sharma	Jindal Mechno Bricks P. Ltd.,
14	Mr Pankaj Sampat	Gift City
15	Parveen Kumar	MDF Eco Panel
16	J Barooah	Jolly Barooah Associates
17	Ramesh Shrivastav	PCLRA, Ahmedabad
18	Mr O P Badlani	Prayag Clay Products Pvt Ltd
19	Ravi Kapoor	Independent Energy Consultant
20	Simrandeep Kaur	HSMI, HUDCO
21	Veni Nath	JK Lakshmi Cement, Jhajjar
22	Arvind Varshney	Confederation of Construction Products and Services
23	Sonia Dhull	TERI
24	Pradeep Kumar	GRIHA/TERI
25	Nakul Chaturvedi	HSMI -HUDCO
26	Apurva	HSMI -HUDCO
27	SMH Adil	GEED India
28	Ashok Tewari	Bengal Brick Field Owners Association
29	Sanjay Singh	Bengal Brick Field Owners Association
30	Promod Adlakha	Adlakha & Associates
31	Surabhi Shikha	Centre for Environment & Energy Development(CEED)
32	Sumana Bhattacharya	IORA Ecological Solutions

33	Rahul Kumar	Centre for Science and Environment
34	Deependra Prashad	Architect
35	Priyanka Kochhar	GBCI
36	Daniel Ziegrer	Embassy of Switzerland
37	Jessika Seddon	OKAPI
38	T P Sankar	TERI
39	Naman Mirajkar	Indian Institute of Technology, Roorkee
40	Harman Singh	Jolly Barooah Associates
41	Anand Shukla	Embassy of Switzerland
42	Veena Joshi	Independent Expert
43	Sandeep Ahuja	Prayag Kiln Technologies Varanasi
44	Surendra Kumar	HSMI-HUDCO, Lodhi Road
45	Satyendra Rana	Greentech Knowledge Solutions
46	Mukesh Kumar	J K Laxmi Cement
47	Anil Kumar	BTECON
48	Vinod Rai Chandani	Mahalaxmi & co.
49	Shweta Pandey	IORA Ecological Solutions
50	Yatin Choudhary	TERI
51	Kundan Dighe	Wiener Berger India Pvt. Ltd.
52	Ziaur Rehman	GEED India
53	Yogesh Aggarwal	Bengal Brick Field owners association
54	Ashok Ghosh	Bengal Brick Field owners association
55	Rajdeep Chowdhury	Biltech
56	Swati Sharma	WBCSD
57	Tanmay Tathagat	Environment Design Solutions
58	Rohith	GBCI
59	Sameer Maithel	Greentech Knowledge Solutions
60	Sonal Kumar	Greentech Knowledge Solutions
61	Saswati Chetia	Greentech Knowledge Solutions
62	Prashant Bhanware	Greentech Knowledge Solutions
63	Bharat Reddy	Greentech Knowledge Solutions
64	Ananthakrishnan Ravi	Greentech Knowledge Solutions
65	Vernica Prakash	Greentech Knowledge Solutions
66	Vinay Sharma	Greentech Knowledge Solutions
67	V S Kothari	Greentech Knowledge Solutions
68	K P Eashwar	ADCS
69	P Vignesh Raja	ADCS
70	Smita Chandiwala	Independent experts
71	Dr Satish Kumar	Alliance for Energy Efficient Economy (AEEE)