TARA

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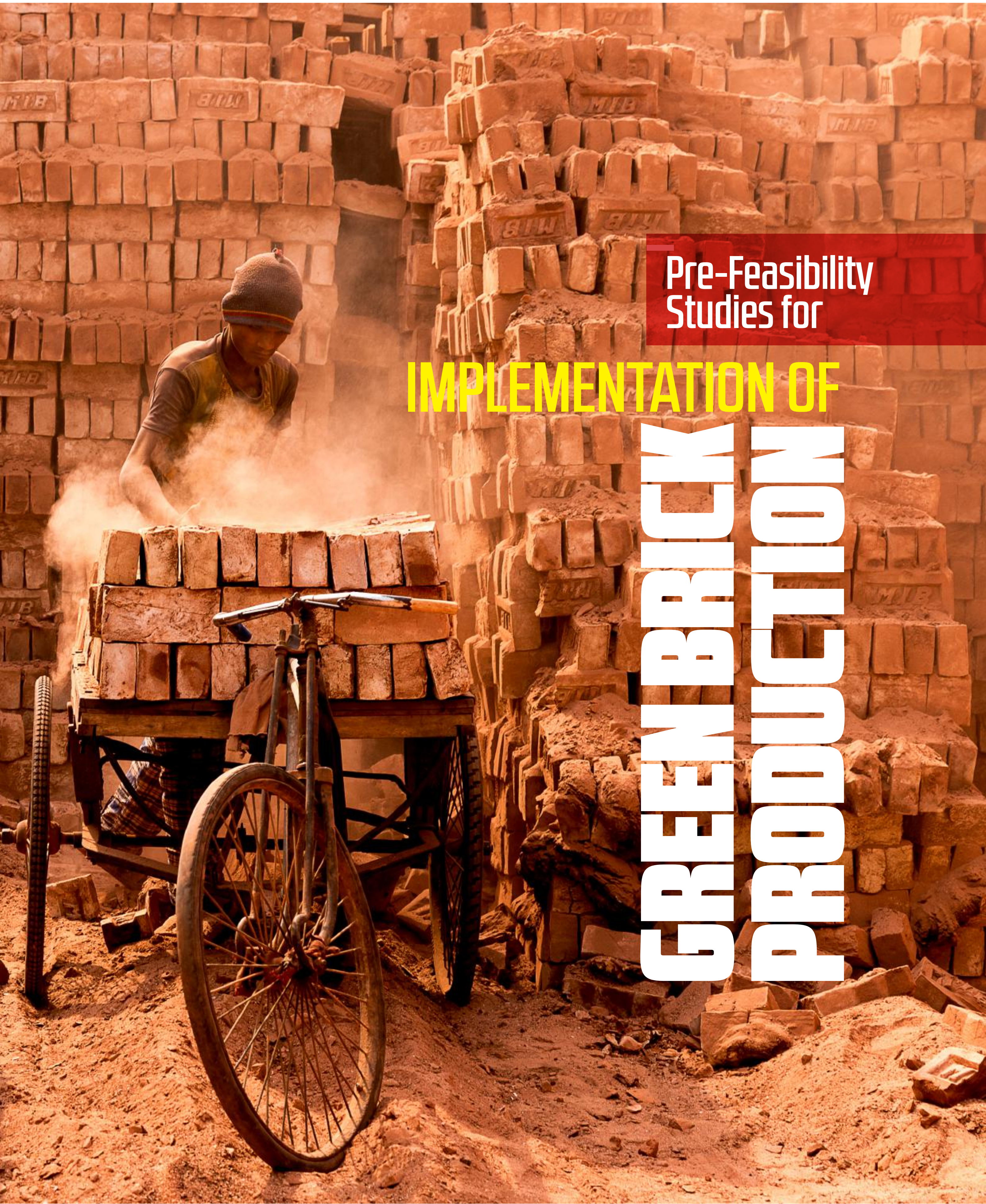
ACCMS



Pre-Feasibility Studies for IMPLEMENTATION OF GREEN BRICK PRODUCTION

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The team gratefully acknowledges the support from Pollution Control Board Assam for their interest shown in the pre-feasibility study. Their interest to take out time, compile and provide brick kiln data and discuss possible means of cooperation with the implementation team shows their keen interest and support for dissemination of the cleaner brick production technologies in Assam. Their constructive criticism of the results and feedback on future work to be done through discussions was extremely helpful.

At the end and certainly not because they were the least important, TARA would like to highlight the crucial role played by brick manufacturers of Assam in helping us understand the current situation, identify key issues, estimate the immense potential for modernization of the brick sector and chart out the way forward. The openness and alacrity with which they shared information and ideas was truly remarkable.

We do hope that the feasibility study will encourage the introduction of Cleaner Brick Production Technologies in Assam to help in building up resilience to cope with climate change effects in future.

Technology and Action for Rural Advancement, 2022

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ACCMS	Assam Climate Change Management Society, Govt. of Assam
BEE	Bureau of Energy Efficiency
CBRI	Central Building Research Institute
CGTMSE	Credit Guarantee Trust for Micro and Small Enterprises
CLCS-TU	Credit Linked Capital Subsidy for Technology Upgradation
CO	Carbon monoxide
CO_2	Carbon dioxide
CTE	Consent to Establish
CTO	Consent to Operate
ECBC	Energy Conservation Building Code
FCBTK	Fixed Chimney Bull's Trench Kiln
GSDP	Gross State Domestic Product
GDP	Gross Domestic Product
GHG	Greenhouse gas
HD	High Draught
KVIC	Khadi and Village Industries Commission
LM	Lean manufacturing
MCs	Mini clusters
MFI	Micro Finance institutions
MSECDP	Micro and Small Enterprises- Cluster Development Programme
MSME	Micro, Small and Medium Enterprises
MT	Metric Ton
MUDRA	Micro Units Development & Refinance Agency Ltd.
MUNY	Mahila Udyam Nidhi Yojana
MioT	Million Ton
NBFCs	Non-banking finance corporations
NOx	Nitrogen oxide
OHS	Occupational health and safety
PMEGP	Pradhan Mantri Employment Guarantee Programmes
PPM	Parts Per Million
PCBA	Pollution Control Board Assam
RRB	Regional Rural Banks
SEC	Specific Energy Consumption
SIDBI	Small Industries Development Bank of India
SPM	Suspended Particulate Matter
SO_2	Sulphur dioxide
SDC	Swiss Agency for Development and Cooperation
UAM	Udyog Aadhar Memorandum
VSBK	Vertical Shaft Brick Kiln
ZED	Zero defect, zero effect

Executive Summary

The pre-feasibility study for green brick[1] production in Assam looked at the current brick production practices and trends across three demand centres in Assam - Guwahati, Silchar and Dibrugarh and assessed the prevailing challenges in adoption of green technologies across different stages of the construction sector value chain in the state. A holistic systems approach was selected as a framework for analysis. The recommendations derived from the on-ground analysis aim to serve as a guide for the different stakeholders involved in the construction and brick manufacturing sector of Assam.

In order to arrive at any climate resilient strategies or models, an accurate estimation of the number and types of brick producing units in the state along with a holistic picture of their emissions, pollutant sources, available resources, socio-economic and geographical landscape is crucial to assess the overall environmental impact of the sector. Although some data on the same exists with PCB Assam, the completeness and accuracy of the data needs to be verified through a ground-truthing exercise. Until and unless actual data is recorded, any conclusion remains an estimation only and will present an inaccurate picture of actual brick production in the state.

This pre-feasibility study was conducted using a three stage action research based approach using research tools such as documentation, field research, GIS-mapping and stakeholder consultations. A detailed socio-ecological profile relevant to the sector was prepared for Assam by conducting geological studies and soil studies and secondary research on various socio-economic parameters. In addition, an overview of the trends and practices in the brick production sector is also presented by analysing the production and consumption patterns, environmental impact, social conditions and economics, regulatory frameworks, and appropriate policy convergence. It highlights the prevalent technologies with respect to type of kilns, fuels, bricks in use and their implications for various climatic, social, economic, and ecological parameters.

As observed during this study, among the current practices observed on ground, kilns most in use are the Fixed Chimney Bull's Trench Kiln (FCBTK) type along with some instances of Zig Zag kilns. In the type of bricks observed, few Autoclaved Aerated Concrete (AAC) block making units were observed in Guwahati, while fly ash brick units were scarce due to unavailability of fly ash in the vicinity.

Due to the inherent climatic conditions of Assam, the brick making period in the state is limited to around 6 months. The high humidity poses challenges for firing as bricks have high moisture content, demanding consumption of large amounts of fuel and energy in the firing process. There is also no scientific basis for brick production processes followed vis-a-vis soil selection, use of internal fuels, proper use of moulds, moulding process, drying process and even firing process. There are no standardised processes or protocols and the current entrepreneurs are largely ignorant of the technical advances in brick making, continuing their traditional, often outdated technologies. It is evident that the prevailing brick production technologies and processes being used by burnt brick manufacturers in Assam are highly energy-intensive, resource-depleting and pollute the environment. Although the state follows a 230mm x 110mm x 70mm standard brick size, the brick sizes actually produced vary widely. Due to inherent soil conditions, the quality of bricks being produced is excellent. However, there is an evident need for proper training, scientific inputs and technology diffusion amongst the brick producing community to improve the quality and profitability of bricks as well as mitigate the socio-environmental impacts of brick production.

As per data received from PCBA, around 1242 brick kilns are presently operational in Assam, producing an excess of 37,260 lakh bricks and consuming 670,680 tons of coal per year. The annual GHG emissions from the brick kilns in Assam is estimated to be approximately

1 Green Brick here refers to the brick production process which is low carbon, low emission and aims to be environmentally sustainable and 'green' in this respect.

20,69,357 (0.26 MioT) tCO_2/year. It is estimated that if business as usual continues, the total GHG emission from brick kilns will reach around 46.87 tons per year by 2030 and 193.60 tons per year by 2050. These insights into the resource consumption and emissions status of Assam assume significance in the backdrop of climate change resilience by identifying the extent of raw material extraction and different sources of pollution within the brick manufacturing sector. These figures serve as a wakeup call to move to more efficient methods of brick production to ensure conservation of natural resources and environmental protection while minimising the impact on human health and wealth.

Considering the factors discussed above, some alternative technology options have been recommended based on critical analysis of the economic and environmental feasibility of different types of kilns and fuels used in the production process. In this respect, it identifies two major intervention areas to integrate alternative technologies. The first proposes a strategy of process optimisation and improvement of existing technologies using better feeding and firing practices, or incorporating internal fuel in the brick making process. The alternative option could be adoption of new technologies by switching to more efficient kiln designs, such as zigzag or vertical shaft brick kilns (VSBK), or alternative masonry materials such as compressed earth blocks. The Ministry of Environment, Forest and Climate Change has in its recent notification also suggested the phasing out of FCTBK kilns while promoting zigzag or VSBK kiln type. A comparative analysis of projected GHG emissions from various technology options has been presented to compare their GHG emission reduction potential for assisting data-based decision making towards the choice of technologies. Further recommendations have also been made towards various financial instruments available for facilitating this transition and supporting entrepreneurs in the sector.

The way forward has been presented in the form of recommendations to streamline the adoption of green manufacturing practices in the brick sector of Assam including:

- GIS-based mapping, resource mapping of raw materials being used and detailed GHG inventorization and environmental impact assessment of brick kilns
- Technological improvement through pilot demonstration of alternate technologies, facilitated technology transfer, and training, capacity building and awareness generation among stakeholders
- Structural transformation through enhanced policy and institutional support, business and financial support, implementation support through ancillary service providers, contextualisation of technology, and human and social capital development

1

Introduction

1.1 Context

In light of the increasing economic activity and growing levels of urbanisation in the state of Assam, the demand for supporting housing and infrastructure has been rising steadily. This has given a boost to the state's construction sector, which recorded an impressive compound annual growth rate of 7.35% between 2011-12 and 2016-17. However, this rate of growth is still lower than the national average of 11.2%.

In keeping with the State's goals and projected vision for sustainable development, the construction sector has emerged as one of the biggest employment generators in Assam. This growth, however, has also caused this sector to become a major contributor to greenhouse gas emissions, causing carbon footprint to increase significantly throughout the building and material life cycle.

Unlike developed countries where the majority share of GHG emissions comes from the energy consumption during the built environment's operation and maintenance, in India the majority contribution (more than 80%) of the construction industry's emissions comes from consumption and production of materials like cement, steel and bricks.

Within the construction sector, apart from the manufacture and use of cement, fired-brick production is the most polluting, both in terms of its emissions as well as its use of virgin resources. Despite being the predominant emissions' contributor, quantitative data on direct emissions from the brick industry in India has not yet been quantified in an integrated manner. Brick firing continues to use fossil fuels like coal. In addition, in its composition too, clay bricks utilise fertile top soil from agricultural lands. This adds to the climate challenges, as according to the 2022 edition of the National Footprint and Biocapacity Accounts[2], we are using an equivalent of 1.75 Earths to provide resources and absorb waste. This means it now takes the Earth one year and nine months to regenerate what we use within a year. Humanity uses more ecological resources and services than nature can regenerate due to ruthless overfishing and overharvesting of forests and emitting more carbon dioxide into the atmosphere than forests can sequester. With the increasing focus on resource efficiency in construction activities, one of the major challenges is to adopt strategies to facilitate a shift to greener building materials and practices while reducing the energy footprint of existing building materials and technologies.

In line with the conventional red brick making practices seen in the country, the Assam brick sector is not different in any way, both from the resource and the emission point of view. Till date there is no published data on the actual number of brick kilns in the state of Assam. As per PCBA's official figures, in 2012-2013 there were around 731 brick kilns in the state. These kilns produced around 5 billion bricks in a year and consumed around 15MioT of fertile soils on account of raw materials used for brick making with emissions of over 4.5 MioT of CO_2 in the firing process.

2 Global footprint network_ www.footprintnetwork.org/our-work/ecological-footprint/

1.2 Current challenges

The current practices for brick production in Assam are mostly based on the traditional Fixed Chimney Bull's Trench Kiln (FCBTK) design which has high energy consumption due to fossil fuel use and inefficient resource utilisation. Sporadic instances of alternate technologies such as high draught kilns and zigzag kilns have also been observed. However, these are limited in number and are yet to be adopted at a large scale. Further, limited instances of non-fired building materials were found, that too confined to hollow concrete blocks and bricks. Possible solutions in such a scenario may be explored through new material technologies which utilise secondary resources or alternate materials in the composition of bricks such as fly ash, agricultural waste, plastics etc. It may also be feasible to investigate process optimization strategies for redesigning kilns using improved models such as natural or induced draught zigzag kilns, vertical shaft brick kilns (VSBK), or improving the combustion process within the brick kiln using internal fuels.

In addition to the above, Assam's brick sector also faces other challenges. These are

1. Impacts of high GHG emissions
2. Use of virgin raw materials
3. Lack of awareness on new technologies and skills to implement the same
4. Lack of technology demonstration to build confidence amongst entrepreneurs on the viability
5. No inventory by the State on the number of brick kilns
6. Substantial number of unauthorised brick kilns operating in the state with no regulations or monitoring

1.3 Need for assessment

1.3.1 Climate change vulnerability of Assam

In this context, Assam is positioned to be a contributor as well as a victim of climate change. The climate change vulnerability of Assam arises from multiple factors. Chief among them is its location and geography within the North eastern Himalayas and the fact that the Brahmaputra river flowing through it is a perennial river. This places Assam at the risk of frequent floods, droughts and rainfalls which get exacerbated by climate change induced extreme weather events. These inevitably position brick manufacturing at the mercy of climate change since the raw materials and production processes of drying, firing, soil mixing etc get restricted due to these eventualities.

Other than the projected GHG emissions and pollution from its production and firing in kilns, the brick production sector and its related activities also add to natural resource depletion with vast swathes of fertile topsoil getting extracted for moulding into bricks. This has severe repercussions on agriculture, and the natural climate resilience provided by soil, since it aggravates the rate of soil erosion, soil and land degradation, groundwater levels and water retention in soil, making the land more prone to harmful impact of extreme weather events in the face of climate change events such as floods and droughts.

1.3.2 Long term impact and Climate Projections

According to the Assam State Action Plan on Climate Change (2015-2020), it is estimated that

- 86% of Assam's population thrives on agriculture and forest produce
- Since the last 60 years (1951-2010), the annual mean temperature in Assam has increased by 0.59 degree celcius and the annual rainfall has decreased by -2.96/mm per year
- Incidents of floods are projected to increase by more than 25%
- mean average temperature is likely to rise by +1.7-2.2 degree celsius by mid- century with respect to 1971-2000.(Table 1)

Table 1 below goes a step further and shows the district wise projected impact of climate change in terms of likely variations across the parameters of mean temperature, annual rainfall, extreme rainfall days, floods and drought weeks between the period of 2021-2050. These have a direct impact on the study areas of Silchar (Southern Assam), Dibrugarh (Northeast Assam) and Guwahati (Western Assam) which are estimated to be impacted by these parameters in the future.

Table 1: District level climate projections of Assam for 2021-2050

	2021-2050 wrt BL	Remarks
Mean Temperature	l .7-2.0°C	All across Assam
Annual Rain fall	-5 to 5%	North western districts
	5-10%	North Eastern districts
	10-25%	Central, South Eastern Districts
Extreme rainfall days	38%	Rainfall >25 to 150 mm
Drought weeks	-25% to >75%	Southern districts show marginal reduction in drought weeks but rest of the district show an increase by more than 75% wrt BL
Floods	Stream flow <10% to >25%	Min in North East and Max in Southern part of the State

Note: Adapted from ***Assam State Action Plan on Climate Change, 2015-2020, (51)*** *by Department of Environment and Forest, Government of Assam, India*

In view of the above figures, it is clear that the intensity and frequency of climate change induced extreme weather events will only increase in Assam over the next few decades. This threatens the economic viability of any technological upgrades and therefore calls for climate resilient strategies to be integrated into all development plans at state, district and local level, across all the various sectors.

1.3.3 Way forward

To facilitate the shift to cleaner and greener brick production, it is crucial to study the current status and practices of the industry and identify potential focus areas for reform. Alternate materials and technologies may then be proposed with a clear assessment of expected benefits across environmental, social, and economic parameters along with future pathways and anticipated financial and regulatory mechanisms required for enabling a smooth transition to the new technologies.

1.4 Project objectives

The major objectives of the project were to:

- Evaluate the geographical extent of existing practices in burnt clay brick sector in and around the three largest cities of Assam, namely Guwahati, Silchar and Dibrugarh (termed as demand centres)
- Calculate the emissions and topsoil impacted due to current practices along with a projection based on current rates of population growth in planned infrastructure till 2030
- Carry out pre-feasibility studies to identify potential of shifts to cleaner production methods and technologies in sites (around the identified demand centres) in the state
- Identify 'Greener' fuel alternatives (available in the state) that can potentially replace wood or coal to fire the brick production process and indicate savings in emissions
- Make recommendations with respect to identified technologies, and fuel mix for cleaner production and finance requirements for this shift
- Proposal development for three units and handholding to access any clean funds to set-up green industry

2

Research design and methodology

The research strategy for the project was designed with an action research-based approach structured in three phases as shown in the figure below. The three phases have been further described in this section. Geographically the research was centred around three primary brick demand centres namely Guwahati, Silchar, and Dibrugarh.

PHASE I – Inception

- **Conducting Meeting** with ACCMS for realigning project expectations and finalising work plan
- **Baseline assessment framework** development for assessing the multidimensional impact of existing brick production technology in Assam
- **Development of Impact Assessment Matrix** to identify criteria for overall suitability of technologies.

PHASE II – Research & Analysis

- **Baseline assessment** to establish the parameters of current brick production in Assam and identify available alternatives
- **Field Data Collection** for identified technology options as per Impact Assessment matrix
- **Action Research** for testing field potential of internal fuel technology
- **Developing techno- economic model** for assessing economic feasibility, policy market features

PHASE III – Consultation & Documentation

- Stakeholder workshop for discussion on Draft Report and incorporating recommendations in final report.

2.1 Phase I: Inception

The foundation for the project was laid down in this phase. Orientation meetings were held with ACCMS to define the scope and expectations from the project and finalise the work plan as per defined project activities and deliverables. Post the initial discussions; a Baseline Assessment Framework was developed to establish the boundary conditions and critical criteria for assessing the current status of the brick industry in the state. Further, an **Impact Assessment Matrix** was developed to identify desired criteria for comparative analysis of alternate technologies that would be proposed to replace current brick production practices. The Baseline Assessment Framework and Impact Assessment Matrix have been attached as Annexure 1 and Annexure 2 respectively.

2.2 Phase II: Research and Analysis

This phase was initiated with desk research and review of secondary literature including various government and institutional research reports, technical papers, guideline documents, presentations, etc. An overall socio-ecological profiling of Assam was developed through this exercise as well as a preliminary overview of the brick industry in the state. Available resources and some alternative technologies were identified through desk research.

This was followed by **field research** for which a research team visited brick kilns producing fired red bricks in the three demand centres and collected data using a questionnaire developed on the basis of the Baseline Assessment Framework. Brick kilns were selected using a **representative sampling** approach based on identification of kiln clusters through visual surveying on Google maps. Physical surveys in the regions were conducted to compile information on the actual number of brick kilns operating in identified clusters and then semi-structured interviews were carried out at kilns for data collection using the prepared questionnaire. After the physical surveys, further mapping was conducted using Google Earth to identify more kilns within and around the visited clusters based on visual cues identifiable from satellite imagery. However, with meetings with Member Secretary PCBA and other regional offices of PCBA at Nagaon, Dibrugarh, Bongaigaon etc. it was understood that the number of brick kilns are much more than officially reported. Thus, PCBA was contacted for giving the actual number of bricks kilns as per their record. Upon verbal discussion with PCBA it was learnt that the actual number of operating brick kilns are more than 1400 of which around 20% are unreported which are not in the books of PCBA.

Some units manufacturing other types of bricks such as fly ash blocks, AAC blocks (Aerated Autoclaved Concrete), etc. were also surveyed.

2.2.1 Sample collection and testing:

Samples of bricks being produced and coal used for firing were collected from the surveyed kilns. Red fired brick samples were collected from 6 kilns in Guwahati, 7 kilns in Silchar, and 3 kilns in Dibrugarh. Apart from red bricks, few samples of Fly Ash bricks and Autoclaved Aerated Concrete (AAC) Blocks were also collected. Testing was carried out in local labs for these samples including Dimension Test, Water Absorption Test, and Compressive Strength Test.

Coal samples were also collected from 12 different sources including brick kilns in target geographies and coal depots in Guwahati. These samples were tested for their calorific value to understand the energy consumption and associated environmental impacts from coal sourced from different regions. The results from these tests have been presented in Table 8 in Section 5.

2.2.2 Action Research

Based on the desk and field research, **techno-economic models** were developed for alternative brick technologies. This helped in identifying appropriate technologies for application as replacement for the fired red bricks currently in use. This assessment has been presented in Section 5.

2.3 Phase III: Consultation and Documentation

In the final phase, the findings from the desk and field research were compiled and analysed into a draft pre-feasibility assessment report. The results were shared with relevant stakeholders including ACCMS, etc. and the final report was prepared based on the comments and recommendations put forth in the consultations.

2.4 Challenges and Limitations

The overall implementation of the project and data collection was impacted by certain challenges that have been listed below:

- Field visits to study sites were hindered at the scheduled times due to lockdown and restrictions owing to the COVID 19 pandemic as well as slowing down of economic activities and unavailability of kiln workers during the festival times (such as *Durga Pujo* and *Chhat Puja*).
- Exhaustive mapping and survey of all existing kilns in the identified demand centres could not be conducted due to remoteness and unsafe locations of some kilns.
- Hostile attitudes of workers at some kilns led to unwillingness to share information or sharing inaccurate data.
- The actual data of brick kilns were not received from PCBA on time to make a realistic assessment as requested by TARA and Government of Assam.

3

Research findings

This chapter describes the findings based on the primary and secondary research conducted as per the methodology described above. Detailed findings have been presented for the three identified demand centres, that is Guwahati, Silchar and Dibrugarh.

The first section - 'Socio-Ecological Profile' - includes the various social, economic and ecological parameters at the state level that influence the brick production and processes used including climate and topography, demographic and economic aspects, as well as the availability of resources and geology of the state.

The second section - 'Overview of Brick Production' - describes the current status of the brick industry in Assam along with the actual brick production levels, technologies and processes practised, consumption of resources, and various social, environmental and economic impacts and other considerations around the same.

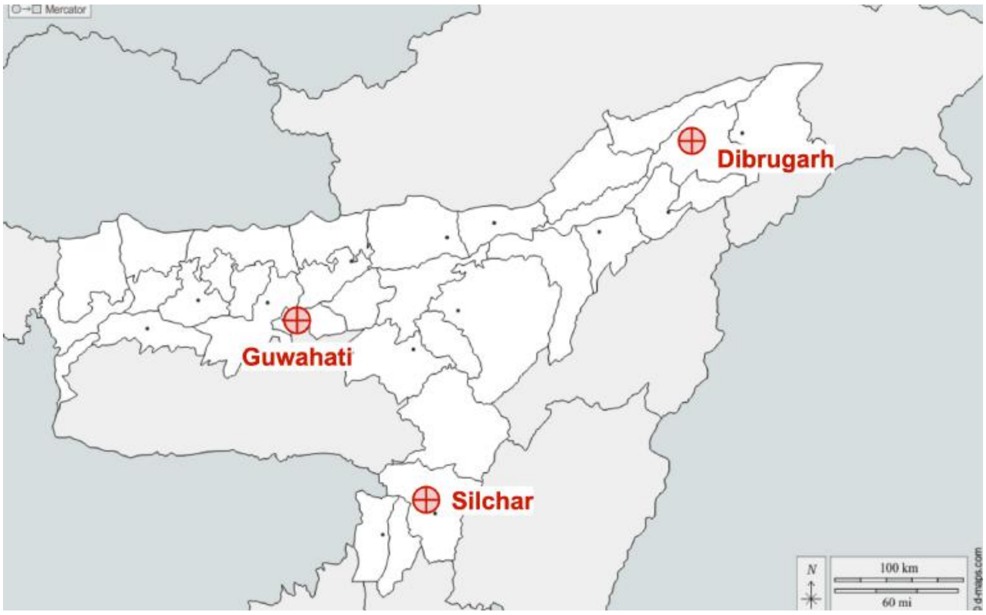


Figure 1: District Map and location of the three demand centres - Guwahati, Silchar, and Dibrugarh.

(Source: Author)

3.1 Socio-ecological profile

3.1.1 Topography and climate of the state

Physiographically, Assam has three broad geographical domains. The first domain is the Brahmaputra valley referring to the vast alluvial plains of Brahmaputra valley covering North Assam, including both Guwahati & Dibrugarh. Next is the Central Assam Hills which is the hilly terrain in Central Assam comprising Mikir Hill in Karbi Anglong and North Cachar Hill districts. Finally, the Barak valley area covers hilly and alluvial terrain in the south covering the Cachar and Karimganj districts in the Barak (Surma) valley, including Silchar.

The climate of Assam is typically a 'Tropical Monsoon Rainforest Climate', with high levels of humidity and heavy rainfall. Winters begin in November and last until February. The overall climate through the year is moderate with warm summers and mild winters. Spring (March–April) and autumn (September–October) are usually pleasant with moderate rainfall and temperature. The levels of precipitation and number of rainy days are highest during May to August due to the south-west monsoons gaining momentum in June which is the primary rainy season. This period of high humidity extends to November. The continuous high humidity persists almost throughout the year causing unpleasant weather conditions. The combination of rainfall and high humidity creates sub-optimal conditions for brick production activities for a large part of the year, since excavation of availability of suitable soil as well as the brick making process gets hampered.

Table 2: Annual temperature variations across demand centres (in °C)

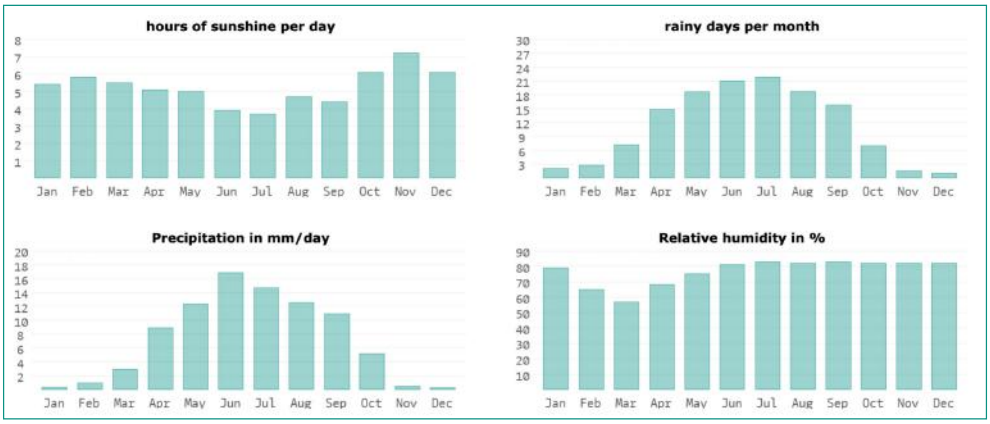
Average Temperatures	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Guwahati	17.6	20.2	23.9	25.1	26.1	27.3	27.5	27.7	27	25.3	22	18.9
SiLehar	17.5	20	23.3	25.3	26.3	27	27.1	27.2	26.8	25.3	21.8	18.6
Dibrugarh	17	18.9	21.4	23.3	25.8	27.4	27.6	28	27.4	25.4	21.7	18.3

(Source: Climate Data, 2019)

There are some regional characteristics of the demand centres with respect to climatic conditions. Guwahati belongs to the Kamrup district in west-central Assam which has high rainfall and foggy winters. Winters last from December to February while there are chances of thunderstorms and sandstorms between March and May. Late June to late September comprises the monsoon time and pre-monsoon conditions last till November. Silchar, lying in Cachar District in south-central Assam, experiences heavy rainfall, high humidity and moderate temperatures. Finally, Dibrugarh, belonging to the Dibrugarh district in east Assam, reaches its highest temperatures during the south-west monsoon season and does not have a dry hot summer as other regions in the state. The region experiences marginally lower temperatures than surrounding areas. Humidity in the region persists throughout the year and rainfall is abundant[3].

The climatic conditions of the state play an important role in the brick production across the entire state of Assam. 6 months of the year there are more than an average of 15 days of rainfall. Thus only around 6 months brick production is possible unlike the plains where this extends upto 8 months. With an average of 5 lakh bricks per month, this amounts to a maximum of around 30 lakhs bricks per year compared to around double the amount in the Northern and Central part of India.

Figure 2: Climatic data for Assam state (WorldData, 2020)[4]



In addition to the rainfall, it is seen that the average humidity of the state of Assam is on an average around 80%. This has quite an effect on drying of the unfired bricks. Drying of bricks is the process of removal of moisture within an unfired brick. Open air drying is an economic choice to most of the brickmakers where climatic and atmospheric conditions are suitable. Drying of unfired bricks is a process in which the water is eliminated from the bricks which shrinks in the process. Accordingly, based on the type of soil used for making bricks the water content might vary upto even 40% of the total weight of the bricks. This has to be reduced

3 Status of Environment and Related Issues, Assam Science, Technology and Environment Council, Ministry of Environment, Forests & Climate Change, Government of India, Available at: http://asmenvis.nic.in/Database/Climate_1042.aspx

4 WorldData. (2020, January 1). Climate in Assam (India). Retrieved from WorldData.info: https://www.worlddata.info/asia/india/climate-assam.php

to below 0.5% for optimum firing. This is also directly proportional to time taken. However, in most of the cases the bricks are externally dry but contain an overall moisture of between 5-7% by weight. Under the conditions of humidity and temperature that exists in Assam it cannot be dried further. There will always be a moisture content of around 5-10% within the unfired bricks.

It is generally calculated that around 3% of energy is required to remove 1% of moisture. This moisture is in the form of free moisture within an incompletely dried unfired brick. Therefore, if the moisture content of a unfired brick is around 10%, then you would require around 30% of the total input energy to drive out this moisture. Removal of moisture is important during the firing process since chemical reactions will not start until and unless the free moisture is removed. To remove free moisture, energy in the form of external fuel is needed. For any type of clay brick firing process, it is directly related to the consumption of coal. Thus, if there is a moisture of around 10% in the unfired bricks in Assam, then around 30% of extra coal is wasted to drive off this moisture. Given the climatic conditions of Assam and the moisture content, total removal of moisture is not possible and thus wastage of coal is a given truth.

In the state of Assam, no scientific study has been undertaken to define the optimum moisture content in unfired brick considering the geographical and soil quality conditions. A study needs to be taken up to define the optimum drying time based on the soils of the three topographical regions. This will immensely help the brick makers to decide on the drying time and reduce their energy losses.

3.1.2 Demography

The total population of Assam is expected to grow from 31.17 million in 2011 to 34.18 million by 2021 and 35.60 million by 2026. Within this rapidly rising population, the urban population in the state stands at about 14.08% which is significantly lower than the national figure of 31.16%, however, decadal population growth in urban areas (27.89%) is higher than for rural areas (15.47%) indicating a growing trend towards urbanisation.[5]

Women in rural areas make up more than 40% of the state's population and the overall female literacy rate in the state at 67.27% fares marginally higher than the national average of 65.46%. Further demographic statistics are provided in the table below.

Table 3: Demographic Profile of Assam (Census 2011)

Demographic Indicators (2011)	
Total population	31,169,272
% contribution to national population	2.58
Population density (per sq. km)	397
Rural-Urban Composition	
Rural	85.92
Urban	14.08
Decadal growth rate - Rural (in %)	15.47
Decadal growth - Urban (in %)	27.89
Female population - Urban	21,38,088
Female population - Rural	131,28,045
Male population - Urban	22,60,454
Male population - Rural	136,78,989
Population Facts	
Scheduled castes population	7.15%
Scheduled tribes population	12.45%

5 Census (2011), Primary Census Abstracts, Registrar General of India, Ministry of Home Affairs, Government of India, Available at: http://www.censusindia.gov

Literacy Status	
Literacy rate (%)	73.18
Male literacy rate (%)	78.81
Female literacy rate (%)	67.27

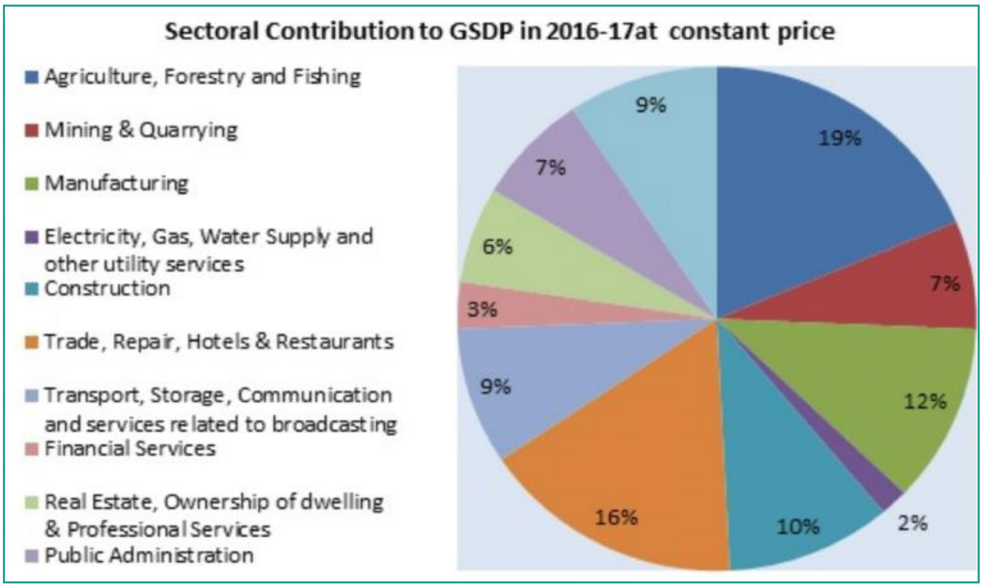
This decadal growth in urban population is quite important considering the fact that it will lead to rapid urbanisation. This will directly have a consequence on the demand of bricks since housing and infrastructure demand will go up. However, it is predicted that this growth will be more in the capital city and Tier II and Tier III cities and towns. To cater to this demand, more clay brick making units will come up until and unless alternative walling materials are developed and practised.

3.1.3 Economic Profile

Between 2017-18 and 2019-2020, the Gross State Domestic Product (GSDP) grew at an average annual growth rate of 7.18% to reach a total of INR 2,59,997 crores at current prices in 2019-20. The estimated annual per capita income in Assam in 2019-20 stood at INR 72,289 which is lower compared to the national figure of INR 1,11,782 (DESA, 2021).

Sectorally, the highest average annual growth was seen in the industry sector at 10.58% followed by the service sector (6.87%) and agriculture & allied sector (2.35%). However, the contribution of industry, comprising manufacturing, construction, electricity and water supply, is only 13.68% of the GSDP, which is less than the national figure. About 52% of the workforce of Assam is currently engaged in the agriculture sector, which contributed 24.44 percent of GDP, more than India's average. The sectoral distribution within the GSDP of the state has been shown in Figure 3 below.

Figure 3: Economic profile of Assam



Source : Directorate of Economics and Statistics, Government of Assam

The contribution of the construction sector to the GSDP is around 10%. Thus it is quite an important industry in Assam. However, in the construction most of the contribution is from the cement, sand and the steel industry. If the brick industry is regulated, then it is expected that this contribution will grow even further. The related sectors of manufacturing, utility services, repairs, tourism, and real estate contribute a cumulative of 36% to the GSDP. Growth in all these sectors will also indirectly boost the construction sector accelerating the demand of bricks and therefore the brick sector.

3.1.4 Geology of North East India

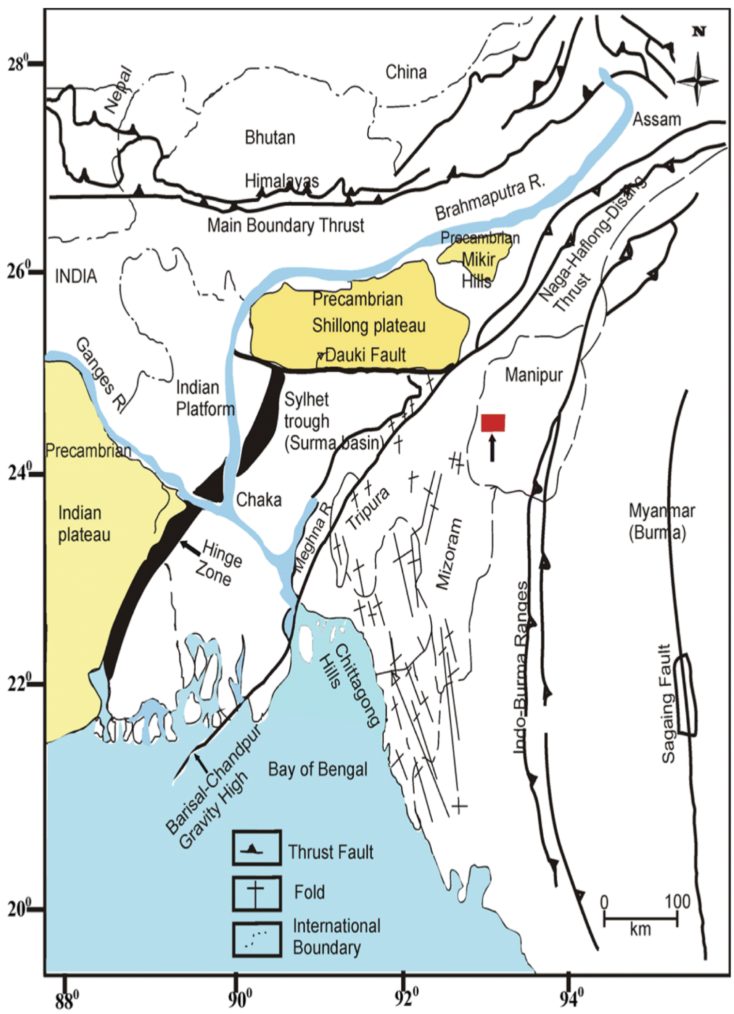
The Himalaya is the largest orogenic belt of the world, where a continental crust thrusts another continental crust. The entire Himalayan arc evolved as a consequence of the collision of the Asian and Indian continents about 50 million years ago.

In Northeast India and its adjacent regions, convergence occurs between three major plates - India, Eurasia and Sunda. The domain between 20°N—31°N in latitude and 86°E—98°E in longitude (Fig. 4) thus includes two major mountain ranges, the Eastern Himalayas to the north and the Indo-Burma Ranges to the southeast, in addition to a large intraplate domain of India.

Northeast India is a region of tectonic complexity and diversity that mainly stems from its evolutionary history and subsequent modifications to its structure imposed by an on-going collision in the North and the Indo-Burmese convergence to the East. This is indeed testified by the surface geology and sustained seismicity.

The region comprises distinct geological units, i.e., the Himalayan frontal arc, the highly folded Indo-Burman mountain ranges, the Brahmaputra alluvium in the Assam valley, the Shillong plateau and the Mikir hills (Figure 4). The Shillong plateau, believed to be uplifting even at present, is the site of the 1897 Great Assam earthquake of M > 8.0. The Assam valley is a narrow E-W trending feature, filled up by sediments brought by the Brahmaputra river system. The prominent geological units of the northeast India region remain geophysically less studied owing to the inaccessibility of this terrain.

Figure 4: Tectonic mapping of North East



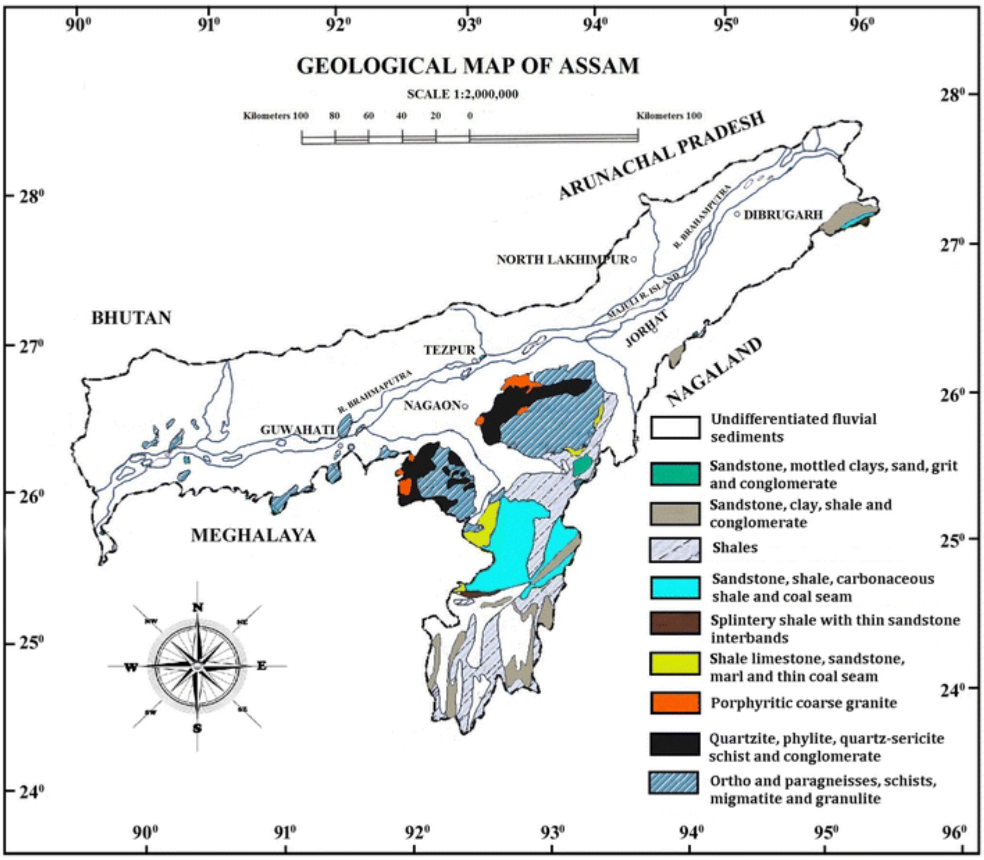
Understanding the geo-tectonics activity is essential to have an idea on the rock formation and therefore the derivatives of it e.g., brick and kaolinitic clays.

3.1.5 Geology of Assam and availability of resources

The State of Assam, a fertile land known for the famous Brahmaputra Valley hosts most of the natural drainage and transport network of north-east India. Three major physiographic divisions are the Brahmaputra plain extending eastward for 720 km from Dhubri, the Karbi Anglong-North Cachar Hills block of metamorphic and sedimentary rocks and the Cachar plain in the south, comprising Hailakandi, Karimganj and Cachar districts.

Precambrian gneisses, schists and quartzites surrounded by the vast recent alluvium are exposed as isolated hillocks in the Brahmaputra Valley (Figure 5). The hills of Karbi Anglong are composed of gneisses and schists with granite intrusions. Folded Tertiary sedimentaries of the Naga-Arakan sequence comprise the North Cachar Hills, while the Cachar plains form part of the Barak-Surma river system, are composed of alluvium covered young Tertiary sediments. Frequent floods along the Brahmaputra river is a major recurring natural hazard affecting the State, while the Cachar plains and North Cachar Hills areas are prone to frequent earthquakes of moderate intensity.

Figure 5: Geological and Mineral map of Assam



Source : Modified from Geological Survey of India and Environmental Earth Science

Crude oil is found in the upper part of the Tertiary Barail sequence, where the largest amount of oil has been discovered in this region so far, while Tipam sandstone is another important oil-producing horizon. In the shelf zone, oil was discovered just above the basement at Borholla and gas in Eocene sand near Tengakhat coalfields.

The Tertiary coal deposits of Ledo, Makum, Dilli –Jeypore and Mikir Hills area are the major coal resources of the State. The coal deposits in Mikir Hills occur within Sylhet Formation. The coal occurrences in Assam are reported from two geological horizons viz., Gondwana and Tertiary, of which Tertiary coal deposits from Makum, Mikir Hills and Dilli-Jeypore are the most important of Jaintia Group and are located in the southern part of Mikir Hills and to the north of the railway line between Lumding and Dimapur. However, most of the coal has high sulphur content.

Three prominent limestone bands Shella Formation occur between Jadukata River in the west and Lubha River in the east, where inferred reserves of limestone are about 900 million tonnes are estimated in Upper Sylhet Limestone (6.5 km length X 2.5 km width) near Lobang, Longkingdong, Larphing and Baralarphing, while at Timbung area 4.6 million tonne reserve of cement grade limestone is established, while 105.6 million tonnes of limestone is known around Langkri nala on Garampani-Lauka road in North Cachar Hills. Preliminary investigation revealed inferred reserve of 12.35 million tonnes of cement grade limestone at Boralokhinder in North Cachar Hills, while a band of ferruginous limestone (15-60 m thick) occur near Selvetta-Meyongdisa area over an area of 5 sq. km along the Jamuna valley. 31 million tonnes of cement grade limestone occur near Koilajon-Dilai area in Mikir Hills over an area of 12 sq km. The total inferred reserve of limestone from Mikir Hills is about 154 million tonnes.

Minor base metal sulphide minerals are reported from Gneissic Complex of Mahamaya Pancharatna and Agia areas and Deolina and Khardong Hills in Goalpara district. In Karbi Hills, occurrences of sulphide minerals (pyrite and chalcopyrite) have been noticed in basic rocks (epidiorite and amphibolite) and also in quartz veins traversing basic rocks around Borjuri. Occasional sulphide minerals have been reported from suspected ultrabasic diatreme in Luhajuri–Bajajuri–Tarapung areas.

Minor placer gold is reported from a few places in rivers of Upper Assam, of which Subansiri riverbed yielded placer gold in the past. Minor occurrences of beryl are reported from pegmatite veins in Goalpara district and gneissic rocks in Naga-Largo-Mukjap area of the northeastern parts of Karbi Hills. Carbonatite samples of the Samchampi Alkaline Ultramafic Carbonatite Complex yielded 1000 ppm – 1500 ppm Nb and high concentration of Zr and Sr. Indications of radioactivity to the extent of 3 to 4 times background value on G.M. counter have been noted on a quartz vein body located SW of Pancharatna and laterites of Dillai area in Karbi Anglong district in Kailajan River.

Iron ore associated with ferruginous quartzite magnetite, hematite and goethite are found near Chandradinga Hill, Chakrasila range and Malai Hills in Goalpara district. The estimated reserves are 12 million tonnes in Chadradinga Hill, 2.2 million tonnes in Malai Hill, and 0.64 million tonnes in Chakrasila range. A reserve of 7 million tonnes and 1 million tonnes in Lengupara and Kumri Hills respectively. A few bands of banded hematite–quartzite are located near Ranighat for an extent of about 1500 m. Iron ore occurrences have been reported from Malegarh and adjacent Lengupara and Kummi hills in the Goalpara district.

Granite and granite gneisses occurring in Goalpara, Kamrup and Nagaon districts are quarried for use as building and road metals, while pink and grey granite found in parts of Karbi Hills and Goalpara and Dhubri districts and Agiyathuri and Digheswari hill ranges (near Guwahati) are suitable as dimensional stones.

In Upper Assam, hard and massive sandstone underlying the coal measures are found abundantly in headwaters of the Namdang, Ledo and the Likha streams, the Tipang and Tirap Rivers. Laterite, ferruginous conglomerate, compact hard calcareous sandstone and ferruginous of the Surma Group in Cachar district are also used locally for building purpose and road metals. Fire clay commonly occurs in association with coal seams of Upper Assam.

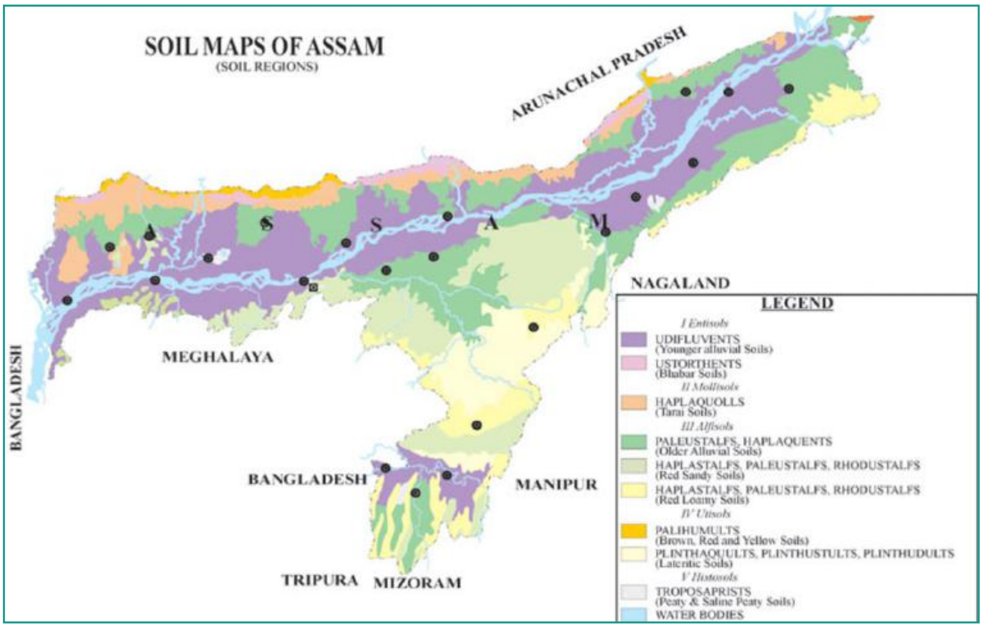
Several thin fire clay bands containing small amounts of impurities are found with seams in Makum and Jaipur coalfields. A three to five metre band of fire clay occurs below coal outcrops at Koilajan in Mikir Hills. Inferred reserve of this deposit is about 2 million tonnes. Another 1.5 m thick band of white clay is found associated with coal seams at Selvetta area containing an inferred reserve of about 55,000 tonnes. In Namdang-Ledo area, fireclay bands are found below the coal seams that belong to the Barail Group. The inferred reserve of fireclay around Namdang is estimated to be 47,115 tonnes. Kaolin is reported from Dora River in Lakhimpur district.

Recently, kaolin has been found as an altered product of feldspar in granites of Selvetta area. An occurrence of inferior quality fuller's earth has been reported from north of Bhutan Khuti, north of Suban Khata on the left bank of Pagladiya River in northern part of Kamrup district. The inferred reserve is 13 million tons. Large deposits of black alluvial clay (Oil well drilling clay) are located near Mathurapur along Sibsagar–Nahorkatiya road in Sibsagar district. Black clay is also found within Dihing Group and Older Alluvium in several parts of Dibrugarh district.

3.1.6 Availability of clays for bricks

From the brick making and construction perspective, soils of Assam can be broadly divided into three divisions' i.e. alluvial soils, lateritic soils and fluvial soils. The alluvial soils are formed by weathering of rocks by flowing rivers. Thus, in and around the floodplains of the Brahmaputra and its various tributaries and distributaries, alluvial soils are found. These are generally finer grained in the downstream areas of rivers but are suitable for brick making. These are silty clay in nature but low in plasticity. These are good for clay brick making and abundantly available in Assam.

Figure 6: Soil map of Assam showing the available soils suitable for brick making



Source : National Atlas and Thematic Mapping Organisation Eastern India

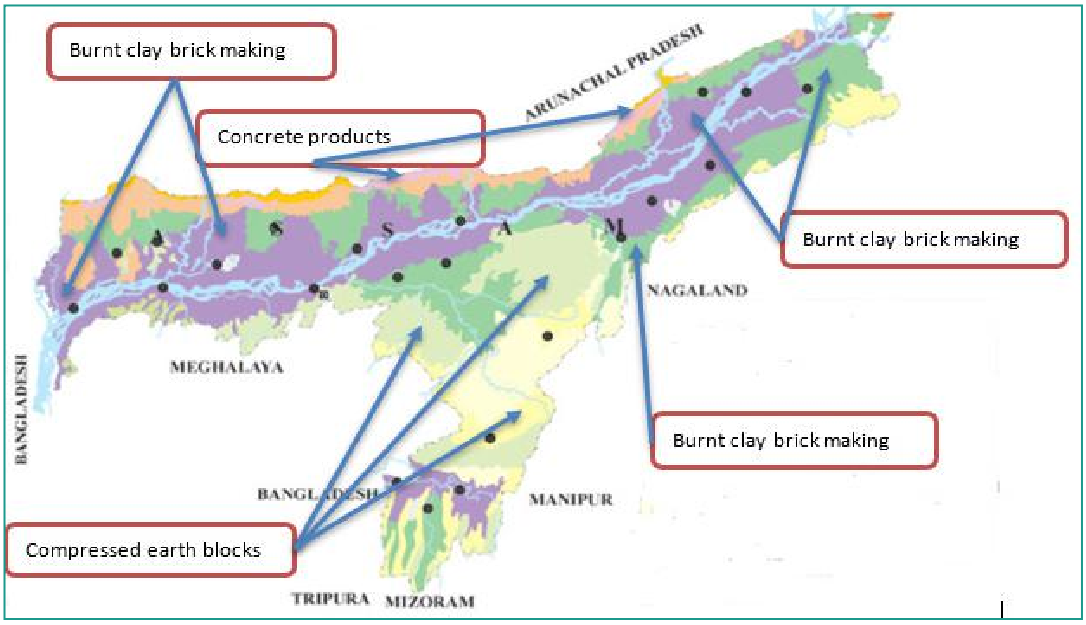
The most preferred soils are the older Terai soils found in the Sivalik ranges along the foothills of the Himalayas. These soils are generally rich in organic matter and are extremely suitable for good quality clay brick making. In fact the organic matter content in the soils provides energy from within the bricks thus reducing the need for external energy.

In some parts of Assam there are occurrences of Bhabar soils. These are coarse grained soils generally found parallel to the mountains and are formed by deposition of coarse grained soils by rivers. Although these soils are not suitable for clay brick making but due to its clean nature, they can be very suitable for making concrete products. Generally, Bhabar soils are coarse-grained, roundish in shape and need to be crushed for use in concrete products.

The Karbi Anglong, Diphu and Cachar hills are typically characterised by sandy to loamy iron-rich soils. These soils are formed under conditions of high temperature and heavy rainfall with alternate wet and dry periods, which leads to leaching of soil, leaving behind oxides of iron and aluminium. Since these soils are sandy in nature and lack plasticity, they are not suitable for making good quality clay bricks. In isolated areas, lateritic soils are being used for brick making in clamps. However they are not of very good quality and often result in high breakage. Contrary to their use in clay brick making, these lateritic, sandy and loamy soils can be very useful raw materials for producing compressed earth blocks.

The figure given below shows the approximate zoning of building material production in Assam. This is a suggestive map and can be used for zoning of building material production.

Figure 7: Zoning of Building Material Production



Source : Modified from National Atlas and Thematic Mapping Organisation Eastern India

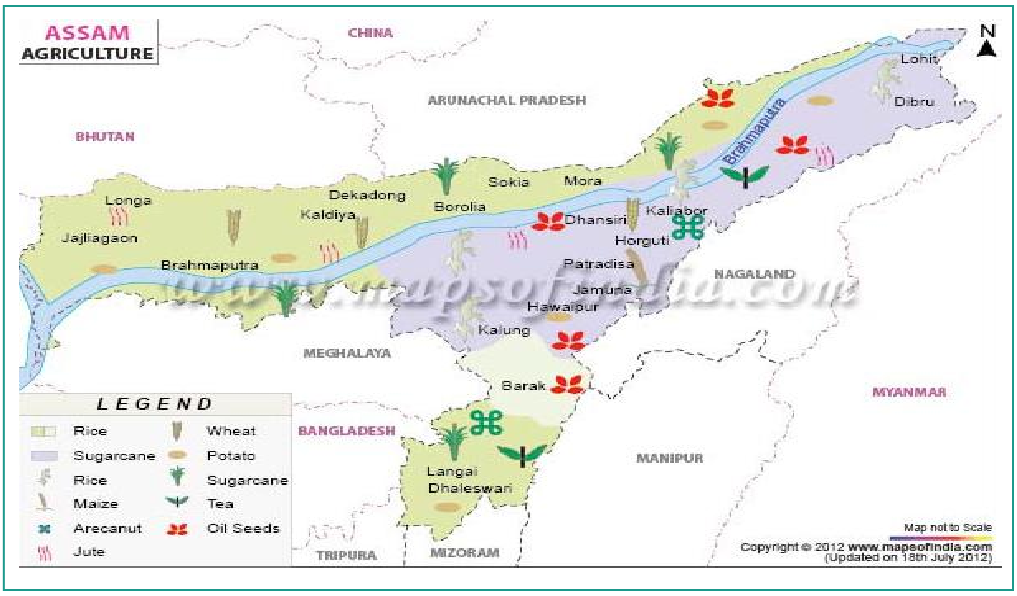
The above zoning of the prevalent soil types of Assam informs us on the location and availability of raw materials (soil, sand) for production of any proposed brick or masonry material. It can be observed that the soil for making compressed earth blocks is the lateritic and loamy soil, prevalent in southern parts consisting of Karbi Anglong Diphu and Cachar hills. Bhabar soil, which is suitable for making concrete products, is naturally available in the Northern areas of Lakhimpur and Udalguri districts. Alluvial soils, predominant in the Terai region are found abundantly along the floodplains of the river Brahmaputra. These are suited for the soil mix of burnt clay bricks. By locating these regions through GIS mapping data, a correlation can be made with the ground situation of brick production units in Assam.

3.1.7 Availability of alternate resources

Apart from clay, one of the major raw materials used in burnt clay brick making is coal. With the emphasis of Government of India and International agencies on reducing use of fossil fuels to reduce CO_2 emissions, the study also explored local sources of renewable fuels.

The map below (Figure 11) shows the approximate distribution of agriculture in Assam. Some of the major crops being cultivated are rice, wheat, sugarcane, maize, tea etc. These crops produce substantial amounts of agricultural wastes in the form of stalks, stems, husks etc. These, if compressed in the form of green briquettes, can be an excellent renewable fuel for use in clay brick making. Incidentally these are also aligned to the brick production areas making it profitable and manageable to use.

Figure 8: Availability of agriculture produce and biomass in Assam



Source : mapsofindia.com

3.2 Overview of brick production in Assam

As per the detailed documentation and analysis conducted by the project team through field visits to the identified demand centres, this section presents the research findings regarding brick production capacities and associated processes and impacts in the state.

3.2.1 Quantification of brick kilns in Assam

There have been quite a number of issues in identifying the number of brick kilns in the state of Assam. As per published figures from PCBA till December 2012, there were 731 brick kilns across the State. 193 out of these 731 brick kilns were operating illegally and flouting environmental regulations under the Air (Pollution Control and Prevention) Act, 1981. However, no reliable secondary data could be found to validate these numbers. Recently it was also reported by the State Environment and Forest minister Parimal Suklabaidya on 5th March 2020 that there are 669 brick manufacturing kilns operating in Assam as per reports collected from the Divisional Forest Offices. This was in reply to questions during the Budget Session of Assam Legislative Assembly on 5th of March 2020. It was also stated that the Assam government's revenue collection from brick kilns as per Assam Mineral Concession Rule, 2013 has drastically dropped from Rs 3.07 crore in 2018-19 to Rs 1.32 crore in 2019-20 (up to January), excluding Sixth Schedule areas. It was also mentioned that the quantum of earth used by brick kilns in 2019-20 (till January) is 362,928 m^3, which is also half of the previous year figures which were 655,906 m^3.

As per the reports received from the PCBA, the status of brick kilns in Assam based on districts is as follows:

Table 4 : List of brick kilns as received from PCBA

Division	Divisional Head Quarters	Districts	No. of brick kilns
Barak Valley	Silchar	Cachar	36
		Hailakandi	20
		Karimganj	24
Central Assam	Nagaon	Dima Hasao	NA
		Hojai	11
		East Karbi Anglong	NA
		West Karbi Anglong	8
		Morigaon	76
		Nagaon	77
Lower Assam	Guwahati	Baksa	23
		Barpeta	42
		Bongaigaon	47
		Chirang	NA
		Dhubri	147
		Goalpara	15
		Nalbari	14
		Kamrup Metropolitan	53
		Kamrup Rural	76
		Kokrajhar	10
		South Salmara-Mankachar	NA
North Assam	Tezpur	Biswanath	57
		Darrang	66
		Sonitpur	107
		Udalguri	11
Upper Assam	Jorhat	Charaideo	19
		Dhemaji	NA
		Dibrugarh	90
		Golaghat	33
		Jorhat	55
		Lakhimpur	6
		Majuli	7
		Sivasagar	45
		Tinsukia	67
		Total	**1242**

Since the focus areas of interventions were Silchar, Dibrugarh and Guwahati, a more detailed survey was conducted through GIS mapping for these geographies. The results of the same are presented in the Table 5 below.

Table 5: Details of kilns surveyed

Demand Centre	No. of kilns Interviews conducted	No. of kilns GIS mapping	No. of kilns As per PCBA data
Guwahati	23	112	129 (metro and rural)
Silchar	32	83	80 (all 3 districts)
Dibrugarh	14	51	90

Maps showing all surveyed kilns in the three regions are presented below. Although the data from the GIS mapping exercise does not accurately overlap with data from PCBA, it allows for a fair estimation of the present conditions.

To arrive at an accurate record of all the brick kilns in Assam, the following is recommended:

- Partnering with UNDP for mapping existing brick kilns using the Geo AI tool and verifying the same through ground truthing surveys
- Henceforth, all NOC (No objection certificate) applications of brick kilns shall be mandated to provide GPS data of the respective brick kiln. This shall provide a database of the number of brick kilns and their precise location, for efficient monitoring and regulation by PCBA and other authorities

Figure 9: Map of brick kilns in Guwahati (Source: Author)

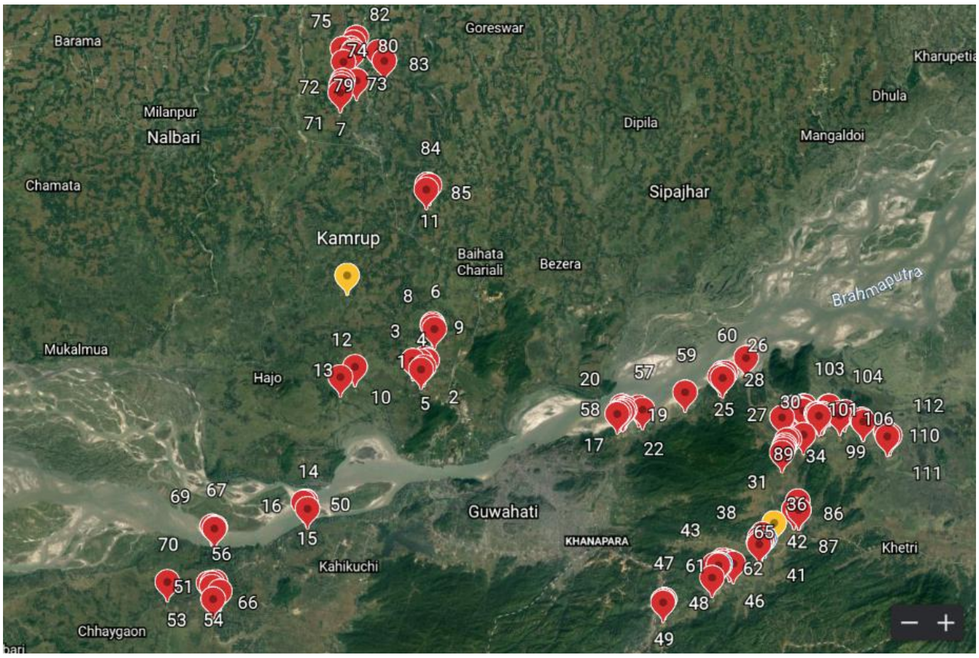


Figure 10: Map of brick kilns in Silchar

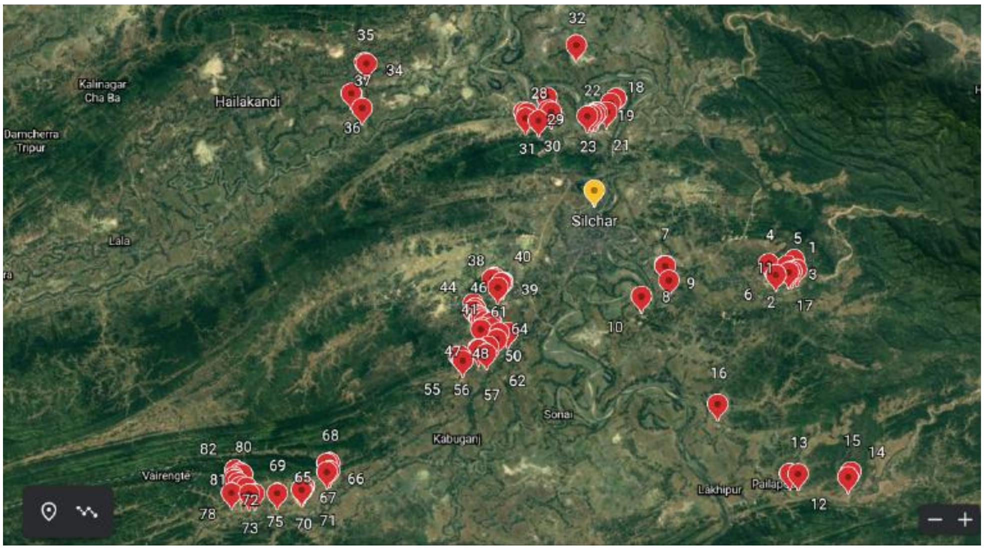
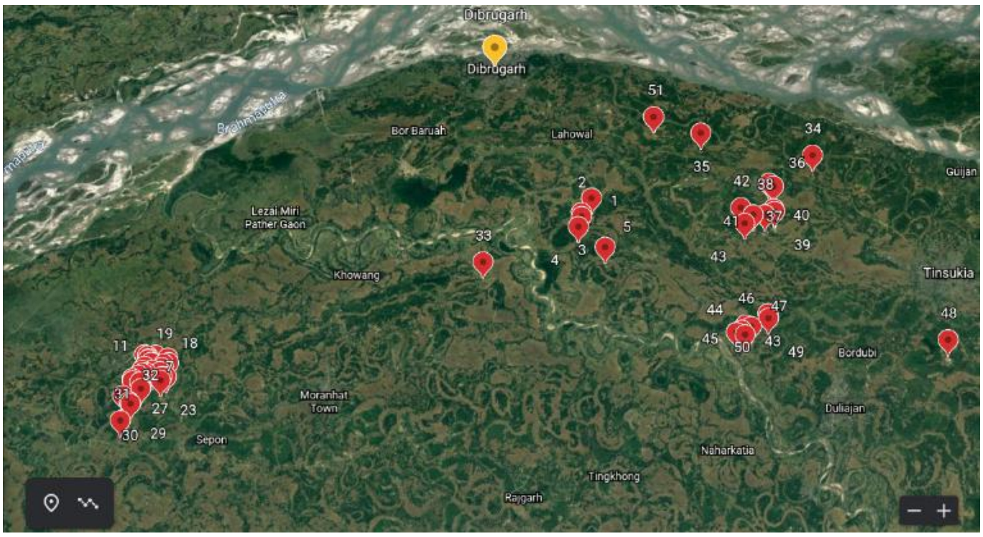


Figure 11: Map of brick kilns in Dibrugarh



Source: Google earth

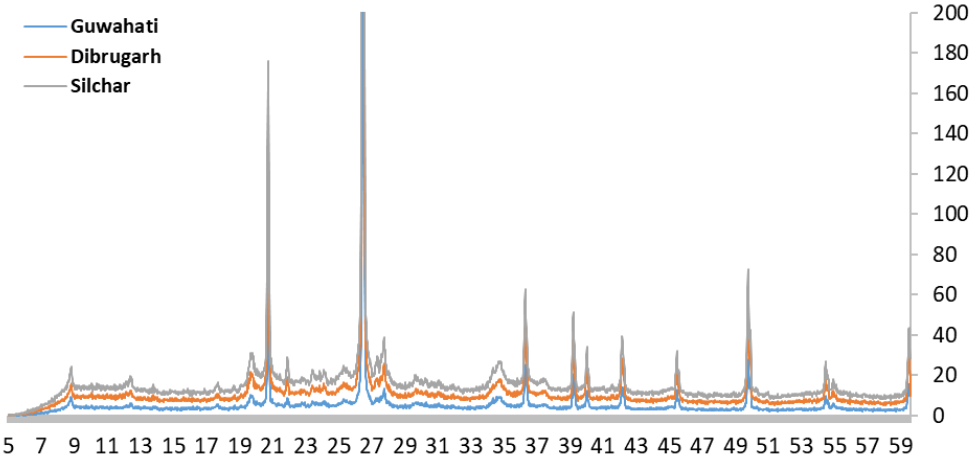
3.2.2 Soil quality

To understand the soil quality in the three priority areas of Guwahati, Silchar and Dibrugarh and its relation to brick making, the soils of the three regions were tested. A total of 7 soil samples were collected and tested for sieve analysis and XRD for phase analysis. The sieve analysis is given in Table 5. The X-ray diffraction analysis of the soils are also given in Figure 12.

Table 6 : Sieve analysis of brick making soils in priority areas

Sieve analysis	Guwahati	Dibrugarh	Silchar
>1.18	2.38%	2.91%	1.54%
1.18 - 600	1.16%	3.11%	1.28%
600 - 150	7.53%	30.29%	19.14%
150 - 75	29.06%	20.01%	33.10%
<75μm	59.28%	43.00%	44.51%

Figure 12: X-ray diffraction analysis of soils from Guwahati, Silchar and Dibrugarh



In the priority areas of the study no other soil types were found. This is mainly due to the flood plains topography of the areas. Dibrugarh and Guwahati are dominated by the Brahmaputra flood plains and Silchar by the meandering flood plains of Barak river. Thus there is scant scope of alternate building materials for brick making in these priority areas.

The results of sieve analysis are in agreement with the flow pattern and sedimentation of the rivers. The soils of Dibrugarh are coarser compared to Guwahati. This is due to the reason that the Brahmaputra flows for a distance of around 400 km from Dibrugarh and enters Guwahati. The soils get finer due to the flow of water and required fineness from attrition of particles. This is proven by the fact that Guwahati soils are finer than Dibrugarh. For Silchar the soils are even finer in nature. This is mainly due to the fact that the Barak river originates in Manipur and flows a distance of more than 200 km before it flows through Silchar. The characteristic meandering of the river makes the soil much finer as compared to other soils of the region.

The XRD analysis (Figure 12) of the soils show a predominant phase of quartz. The clay content is much less with minor presence of muscovite and other micaceous minerals. Not much difference is seen in the composition of all the 7 soil samples collected.

Looking at the possibility of use of soils from the river banks and floodplains it is suggested that an extensive study be taken up to characterise such type of soils across various river basins and tributaries of major rivers e.g. Brahmaputra, Barak, Dhanasiri, Manas etc. If soils can be sustainably and scientifically excavated from the river beds then it will prevent use of agricultural land for brick making. Moreover, it will also help in dredging the rivers, thereby improving water flow and reducing flooding during monsoon seasons.

3.2.3 Brick production trends

The variations in brick kilns in Assam with respect to scale and size were evident from the data collected on brick production capacity of individual kilns. Annual production in kilns ranged from anywhere between 7 lakhs to 40 lakhs in FCBTKs and going up to 63 lakhs in zigzag kilns. The average chimney size as observed during field visits for FCBTK was 90-100 feet and 110-120 feet for Zigzag kilns. Brick production capacities and methods did not vary much across the three regions.

The team visited and collected information from several kiln clusters in Guwahati, Silchar and Dibrugarh. All kilns could not be covered exhaustively due to field challenges such as inaccessibility of kilns, hostile environments along with security concerns. Based on the visited clusters, the geographical coordinates of kilns were mapped for several kilns. In addition to the kilns surveyed physically, further kilns were identified through visual mapping using Google Earth. This mapping was based on recognition of the brick kilns based on distinctive characteristics visible in the satellite data including shape of the kilns, height and size of the chimney, area of the soil that is being excavated from surroundings, visible through colour variations.

Figure 13: Different kilns from the demand centres. Semi-covered kiln design such as the one observed in Silchar (centre) allows for brick production during adverse weather conditions

(Source: Author)

For Guwahati region, the average brick production rate of Fixed Chimney Bull's Trench Kiln (FCBTK) was about 22 lakh/year, whereas in Zigzag kilns the rate of production was almost double that of FCBTK at 40 lakh/year. In Silchar, 32 brick kilns were observed. Out of these, the average brick production rate of FCBTK was 21 lakh/year and that of Zigzag kilns was 45 lakh/year. In the Dibrugarh region, 14 brick kilns were observed. Out of these, the average rate of brick production from FCBTK was 19 lakh/year and that from Zigzag kilns was 36 lakh/year.

Table 7: Average annual brick production in demand centres

S.no	Region	Type of kiln	Average annual brick production (in lakh)
1	Guwahati	FCBTK	22.04
2		Zig-Zag	40.33
3	Silchar	FCBTK	21.70
4		Zig-Zag	45.00
5	Dibrugarh	FCBTK	19.5
6		Zig-Zag	36.00

Firing rounds

Firing rounds are typically described as the number of bricks fired for one complete round of the kiln. As per the data analysis, the number of firing rounds per year mostly ranged from 3 to 5 per year across the different regions of Assam i.e. Guwahati, Silchar and Dibrugarh. The number of rounds conducted each year depends on factors such as availability of labour, availability of coal, rainfall pattern, mining regulations with respect to coal and soil.

Brick Parameters

Samples of bricks were collected from various kilns and tested for basic parameters including dimensions, water absorption, and compressive strength. Apart from red bricks, few samples of Aerated Autoclaved Concrete (AAC) blocks and fly ash bricks were also collected for testing purposes and to compare red bricks, fly ash bricks and AAC blocks with respect to strength and other parameters since they are also being used in construction.

The Autoclaved Aerated Concrete (AAC) block is a product of fly ash, sand and other raw materials. These are mixed with lime, cement, water and an aerating agent. They are solidified into required shapes through autoclaving. The AAC is mainly produced as cuboid blocks. The AAC blocks are energy efficient, durable, less dense, and lightweight.

There were quite a number of issues with the moulding process and the resultant brick dimensions. Within the same kiln, dried unfired brick sizes ranged between 250-230mm x 115-110mm x 62-65mm. This will result in non-uniform and non-standard bricks This usually happens if the mould sizes are not proper, too much water has been used during moulding, unevenness of the stacking area.

Thus proper training is required to entrepreneurs and moulders for making uniform and good quality unfired bricks. This is most important and urgent since FCBTK is a firing process only. Poor quality and non-uniform unfired bricks will result in similar quality of burnt bricks only. Table 8 gives a summary of the quality of various types of bricks collected from the priority areas. No AAC or fly ash blocks were available in Dibrugarh.

Table 8: Brick parameters as per lab test results

Size (length x breadth x height) in mm	Type of brick(s)/ block	Water absorption (%)	Compressive strength (N/mm²)
Guwahati			
235 x 110 x 70	Red	14.39	12.42
230 x 110 x 72	Fly ash	6.76	12.00
Silchar			
231 x 114 x 68	Red	16.61	12.21
600 x 190 x 73	AAC	30.81	2.79
Dibrugarh			
230 x 106 x 68	Red	14.21	12.00

All the bricks from various areas were collected and tested in NABL certified labs in respective cities. Details of the test reports are given in the Annexures. As per IS 1077:1992 the minimum strength of any brick should be greater than 3.5 N/mm^2. The water absorption should not be greater than 15%. Thus as per BIS both the burnt clay and the fly ash bricks are well above the required standards. In addition, PWD and CPWD specify a requirement of 7.5N/mm^2 for any construction using burnt clay or fly ash bricks. Even by PWD or CPWD standards the bricks of Assam are well above the permissible limit. However, the AAC blocks are poor in quality and well below any standard. They should not be allowed in any construction except external boundary walls. This should be checked immediately to avoid any catastrophic failure of buildings.

Uses of fired bricks in the construction sector

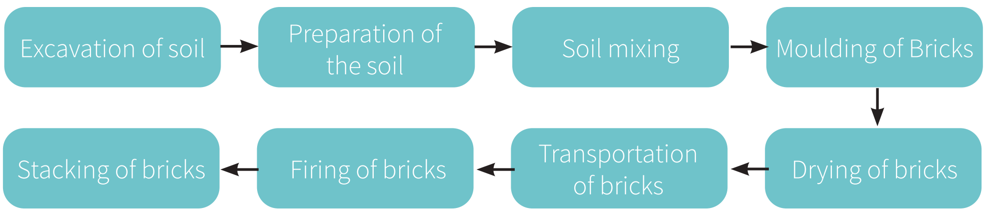
After firing, bricks are majorly classified into three categories i.e. 1st class, 2nd class, and 3rd class based on the size, colour, strength, and metallic ringing sound achieved as markers of quality. The application of bricks in the construction sector varies as per the typology and durability of the bricks. For example, 1st class bricks are majorly used for masonry and structural purposes in the construction of buildings, whereas 2nd class bricks are used for construction of semi-pucca houses and 3rd class bricks are used for flooring and under filling purposes.

Other bricks like AAC blocks are mainly being used as filler walls in multi-storeyed buildings in the major cities of Assam. Fly ash blocks have not yet gained popularity for use in residential buildings. However, in certain cases it is used in high rise buildings and as boundary walls.

3.2.4 Existing Technologies and Processes

The usual raw materials for brick making are soil, anti-shrinkage material, internal fuel, and water. The common procedure used in brick manufacturing kilns in Assam has been explained in detail as per the following steps:

Figure 14: Steps of brick-making process.



Source: Author

Excavation of soil

Any brick production unit needs to have good quality soil to produce a high strength unfired brick. Better the unfired bricks quality, better the fired bricks. Certain types of soil are not suitable for brick making. For example, soil with a high sand content has no plasticity and is difficult to form into quality unfired bricks. After moulding such bricks have a tendency to deform and are prone to cracking during handling. Similarly, the soil used in pottery is not suitable for manufacturing bricks due to its high shrinkage rate which causes the brick to crack during drying. The availability of suitable soils has been discussed in previous sections.

Currently, brick owners are excavating soil from various sources in surrounding areas such as barren land, river banks and mainly from agricultural land. The soil is excavated to a depth of around 3 feet to 9 feet, depending upon the quality and availability of soil, using mechanical excavators or earth movers. The land which is dug at a depth of 8-9 feet is sometimes used as a pond by the people for fishing purposes. But if found unsuitable for pond usage, it is left barren. On the other hand, the land from where the soil is excavated to a depth of 3 feet continues to lie barren or is sometimes used for agriculture if found suitable. All brick kilns based in Guwahati, Silchar and Dibrugarh, were employing the same process of excavating the soil mechanically using excavators or earth moving machinery.

Figure 15: Excavation of soil using earth movers

Figure 16: Deep excavation of soil leaves behind barren land (bottom).

Source: Author

Preparation of the soil

Once the process of soil excavation has been completed, it is then spread evenly on the ground at a height of around 1 feet. The soil is further cleaned by removing stone particles and then the water is sprinkled over the soil which is left for 24 hours for proper ageing. This process is done manually by hand.

In and around the three brick making locations visited e.g. Guwahati, Silchar and Dibrugarh, the soil is usually delivered by small and big trucks. At a few places it was observed that soil is mined directly in the brick making locations at present. Whereas in a few kilns it was observed that brick entrepreneurs have stored the soil in large heaps. Stacking of soil helps in proper ageing of the soil and it also helps in the quicker production right after the monsoon season is over rather than procuring it from outside. It was observed that most of the kilns in Assam have stacked the soil in the form of small mounds up to a height of about 3-5 feet for later usage. Generally, the soil which is stored in a season generally lasts for about 4-5 months. After stocks are depleted, they are again replenished for present consumption as well as the next season.

Moreover, stacking of soils in a predetermined manner helps in managing the processing of the soils. As per need, and informed by practical experience, both plastic and non-plastic soils are stacked in layers. This is to ensure that suitable soils are available for moulding. During the season and before the start of moulding the two types of soils are mixed together by mechanised and semi-mechanised means.

Soil mixing

An essential part of any brick making activity is the process of mixing the raw materials into a smooth uniform mass. This is necessary because a good and uniform unfired brick is the key requirement for a high quality product. Two types of soil mixture processing were observed in different regions of Assam. However, the most commonly and widely followed mixing is through pug mills.

(i) Mixing through semi-mechanized process (The pug mill)

Figure 17: Semi-mechanised equipment such as pug mills can be seen being used at kilns for mixing soil.

(Source: Author)

In this process of wet mixing, the mixed soil is cut manually from stored heaps. In the process preliminary mixing is ensured. They are then opened out in layers and watered. The measure of water is by experience. The watered soil is left to age for at least 8-12 hours. Next day the aged soil is cut in layers from top to bottom and loaded in small hand carts known as wheelbarrows for transportation to pug mills (mechanised mixing machines). The pug mills are generally placed near the soil heaps to minimise transportation. These pug mills are installed within the ground with 2-3 workers engaged in taking out the pugged soils which are then carried to respective moulding sites by moulders. This type of mixing is followed in almost all the open firing techniques e.g., Fixed Chimney Bull's Trench Kiln (FCBTK) and Zigzag kilns.

(ii) Mixing through mechanised process (tractor operated pugmill)

Figure 18: Mixing of soil using tractor operated pugmill.

(Source: Author)

Tractor operated pug mill was also being used in a few places for soil mixing. In this method, the pug mill is attached to a tractor, in the centre of the conical shaped pug mill, there is an iron shaft. To this shaft are fixed a number of arms with several vertical cutting blades attached to each arm. The central iron shaft is then rotated mechanically by the tractor which is operated by using tractor, diesel or electric power.

Blended soil along with the required quantity of water is fed in the mill from top. When the shaft rotates the cutting blades, fitted to arms, cut through the clay and break up all clods or lumps of clay. After the clay has been thoroughly ***pugged*** then it is taken out through an opening provided in the side near the bottom.

Moulding of unfired bricks

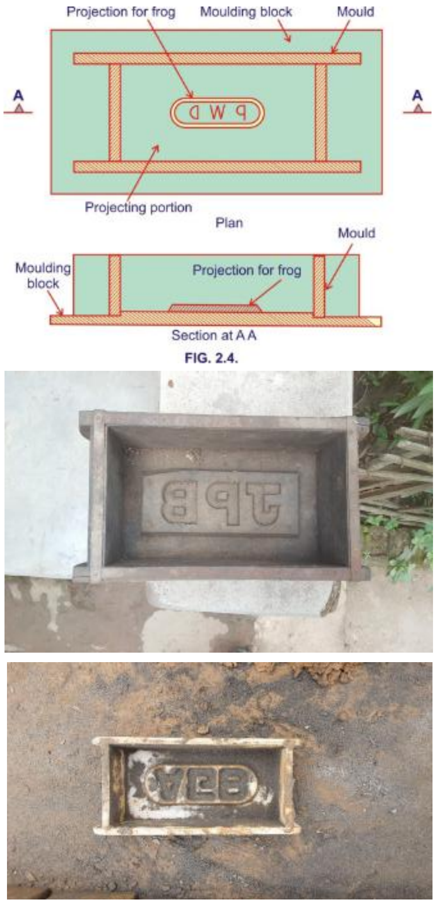
Two types of unfired brick moulding processes were observed - manual moulding and mechanised moulding using extruder machines

(i) Manual process, hand moulding

Figure 19: Brick moulding by hand in process.

(Source: Author)

Figure 20: Design of mould for brick making.



Source: Author

The most common unfired brick making process that was observed in Guwahati, Silchar and Dibrugarh is through manual hand moulding. This method is adopted when a large and level area of land is available for the purpose. The area of land on which moulding is to be done is levelled, plastered smooth and sprinkled over with sand.

Moulding is done at ground level though sitting and not in a standing posture. To prevent the moulded bricks from sticking to the moulds either sand is sprinkled on the inner sides of the mould or the mould is dipped in water each time before moulding is done. Sand moulded bricks have better finish and sharper edges.In some kilns, moulding was being done by female members while in some cases the female member assists in preparing the dough while the male member does the moulding and vice-versa. In one day, 1 person makes around 1000 bricks at a cost of 60 paise to INR 1 per brick depending upon the area. To cast the bricks, two types of moulds are being used i.e. wooden and plastic by the moulders. Moulding is done through a single, open mould system and is of (a) 250mm x 120mm x 70mm, (b) 250mm x 130mm x 75mm size. The mould size varies from place to place depending on the shrinkage of the soil. For instance, at a few brick kilns, size of 235mm x 120mm x 65mm, 220mm x 105mm x 64mm and 224mm x 121mm x 73mm after firing were observed.

Another important observation was that in a few kilns, moulds were defective in nature which impacts the quality of the bricks during the firing process resulting in broken edges and corners instead of being sharp. At some brick kilns, it was also observed that the process of brick moulding is being done by using automatic unfired brick production machines. As per the observation, once the bricks are dried, they are stacked in multiple rows having not more than 5 to 6 bricks in a single row to avoid breakage of unfired bricks due to heavy load.

The entire process of soil homogenization, ageing, pug milling, moulding and stacking is done through a single contractor or site supervisor. There are separate teams for soil preparation, transportation to field to kiln, kiln to field, moulding activity etc.

The entire process of moulding is done in the open atmosphere under the sun. Moulding is generally done as per the convenience in two shifts. In winter months, it's done in the morning and afternoon. In summer months, moulding is usually done in the early morning and late afternoon.

Bricks moulded directly on the ground have their lower faces objectionably rough and can have ***no frog.*** Frog is an indentation provided in the face of the brick. It may carry the trade mark of the manufacturer such as Lucky, Nokia, LG bricks etc. as observed in the Assam region. Bricks are laid in masonry with frog up. Frog provides a key for the mortar and holds the bricks on top firmly in place. To avoid breakage, bricks are moulded on a block of wood known as the moulding block, having a projection 0.5 cm thick and of same length and breadth as the inside of the mould (Fig. 2.4).In this case the mould should be made 0.5 cm deeper than the thickness of brick. The mould is so placed on the moulding block that it closely fits round the projection. The projected portion is protected by means of metallic strips. To provide frog or any other impression on the finished brick a corresponding raised projection is provided on the projection itself as is clear from the figure. The clay is then filled in the mould as explained before and the brick is moulded. Then a thin fiat board a little larger than the mould, known as the *pallet*, is placed on the mould containing the brick.

The moulder then lifts the mould containing the brick and sandwiched between the pallet and the moulding board, inverts it bringing the pallet below. He/she then removes the moulding board and the mould, leaving the brick on the pallet. Another pallet is then placed on the brick which is then carried between the two pallets to the drying site and laid on the side. The next moulded brick is placed by its side and the process repeated. As the bricks in this method are not laid flat for drying, as in moulding directly on the ground, but on the sides so lesser space is required for drying in this method. The bricks dry better and quicker, and also the faces are all smooth.

(ii) Extrusion process

Figure 21: Automatic movable brick extrusion machine

Source: Author

In Guwahati it was observed that at one or two kilns, unfired bricks were also being made using a fully mechanised machine which is known as automatic movable clay brick production machine. The truck, which is also the brick-machine, holds a generator, a mixer, and a mould to produce bricks. Once raw materials are added into the truck, the bricks are ready to be laid. A driver has to operate the machine and move it over the field, where the bricks are to be baked.

The mixture is supplied through a system and finally reaches the mould, which is placed behind the wheels. From one foot off the ground, the mould gently drops the bricks and continues to do this with every inch the vehicle moves. Once the unfired bricks are fully dried, the bricks are then ready to be transported from field to the kiln for firing.

However, the quality of unfired bricks that are being produced by using an extruder machine is not of very high standards compared to that of hand moulded bricks. While the edges are sharp, with smooth corners and glossy finish, the overall quality is impacted by the plasticity of the soil which is quite high in most of the areas of Assam. Due to these characteristics of the local soil, mechanised extruder machines have not seen much success in the region for wider adoption.

Figure 22: Mechanized extrusion process.

Source: Author

Drying of bricks

Drying of bricks is normally done in the open atmosphere for conventional FCBTK and Zigzag kiln technologies. After initial moulding on the flat side, they are overturned on the longer side after 24 hours of drying. In winter months, the drying duration is increased by about 25%. After leather hard conditions, they are stacked in rows.

Generally, the stacks are openly packed and in most cases are about 5-10 bricks high. Some additional bricks are kept at the top layer also in case of emergencies. To protect the stacked layers from damage due to water logging, each row of unfired bricks is generally kept on a layer of fired bricks. This is to ensure that the bottom most layers of unfired bricks are not dissolved leading to toppling of the whole stack. It was observed that in Assam mostly kilns were following this practise of drying the bricks. In some kilns, it was also observed that the dried unfired brick stacks were covered in long plastic sheets to protect from the sudden rains. In a few kilns, they were also being stored in a shaded area which is made up of GI sheets in order to protect it from the direct rain.

Figure 23: Different stacking patterns during brick drying phase (left and right).

Source: Author

One of the most important observations was the presence of drying shrinkage cracks in the unfired bricks at a few places. Majorly it's because the plasticity of the soil is high and when it's mixed using a pug mill, both the plasticity and density of the bricks further increases. Therefore, when the bricks are dried, the outer surface appearance apparently gives a dry look with the interior still containing high moisture and when the moisture forces itself out through the capillary action, it results in hair crack or thick crack. This phenomenon is termed as unfired brick shrinkage.

Absence of air flows and very high humidity within the stacking and drying area hinders uniform and reasonable fast drying of the unfired bricks during the winter season. Although not much of a difference is seen in between the humidity and temperature of the winter and summer months. It has also been observed that the unfired bricks are never optimally dry as claimed by the entrepreneurs.

Unfired brick transportation

The topography of the brick making areas in Guwahati, Silchar and Dibrugarh makes use of simple means of unfired brick transportation system. Since the area is flat, hand pulled carts and wheelbarrows are generally used. In some areas it was observed that the transportation of the bricks is also being done by using a cycle and manually by loading the bricks (around 10) on the head. Generally male workers were transporting the unfired bricks using cycle or wheelbarrows and female workers were carrying it on the head. Of the three systems, wheelbarrow one is the most preferred system for unfired brick transportation from the drying area to the kiln loading since they have direct access to the kiln loading area. Also it reduces the time and manual effort as well as labour cost.

Figure 24: Unfired brick transportation methods - on cycles, wheelbarrows and manual carriage.

Source: Author

Firing of bricks

In Assam, in and around the areas visited, two types of brick kilns were observed i.e. Fixed Chimney Bull's Trench Kiln (FCBTK) and Zigzag kiln. As per the observations, the brick industry in Assam predominantly consists of FCBTK. The designs of the kilns are remarkably uniform and all the kilns are more or less identical. There are three size variations in terms of capacity being termed as half section, one section and one and a half section. Generally, the height of the chimneys observed was in the range of 110-120 feet and around 200-250 feet long having a trench width of 28-31 feet and a height of 8 feet.

Figure 25: Brick stacking patterns during firing – FCBTK (left) and zigzag kiln (right).

Source: Author

Initiation of the brick industry has been through the transfer of design and fire technology within the Indian counterparts itself. Afterwards growth has been through replication of one kiln to another. Thus most of the kiln designs that were observed are identical with no or little variation in design and operation.

The firing observed in FCBTK kilns follows the conventional pattern as in most of India. Most of the kilns are constructed on the ground with ordinary red brick walls followed by mud plastering. There is a considerable amount of heat loss in the kilns from the below mentioned areas:

- Side walls of the kiln
- Bottom of the kiln
- Non-insulated fire holes

Coal feeding is done through bigger sized spoons and in a continuous pattern. An appreciable amount of unburnt coal was also observed at the bottom of the kiln. These unburnt coal tend to accumulate between the bottom most layers thereby over firing the bricks. In a way this is desired since the over burnt bricks are manually broken to be sold as aggregates for construction work. Thus in spite of using a high chimney for appreciable draught, the required coal savings are not seen due to the firing systems being practised.

In the Zigzag kilns observed in Guwahati, Silchar and Dibrugarh, the kiln size was comparatively small and denser as compared to that of FCBTK. In a Zigzag kiln, the air is forced through ducts whereas in FCBTK, it's induced naturally. However due to forced draught through an induced fan the firing process is much faster than a fixed chimney. Normally FCBTK takes about 20-26 days for a cycle due to a natural induced air system whereas in Zigzag kiln, one cycle takes around 18-21 days. Also, the Zigzag kilns are much denser in terms of pattern whereas, FCBTK are more of an open pattern.

The process of firing is carried out throughout the period of 24 x 7hrs and is done in several shifts by the labourers. It also depends on the availability of the unfired bricks, coal and the weather conditions. It was observed that in a few kilns, after firing, the upper surface of the bricks was white in colour which is due to the exposure to sunlight and wind that results in the capillary action and water is being drawn to the surface. When the water evaporates, it causes the salts to be left behind. These salts are known as scum salts which are a sign of good bricks and come into the category of 1st class.

Figure 26: Brick firing in process.

Source: Author

Stacking of bricks

From the unloading area, bricks are manually sorted and unloaded. Fired bricks are normally stacked following the local tradition. Depending upon the quality of the fired bricks, stacking is done in three categories. Bricks in the upper part of the trench are typically under fired and are classified into 2nd class. The bricks at the middle part of the trench are the best quality and are classified into Class 1. Bricks at the bottom of the trench are over fired and are categorised as 3rd class bricks. The stacks are well maintained and each of them contains an equal number of fired bricks. This is an advantage from the loading and dispatching point of view. All the bricks are stacked in different places and as sold as per the gradation. Normally as per the feedback received in FCBTK the class 1 percentage ranges between 70-75% and the rest are 2nd and 3rd class. In both the firing technologies, the stacking pattern is similar and is segregated as per quality, especially the metallic sound and colour.

Figure 27: Stacking of fired bricks.

Source: Author

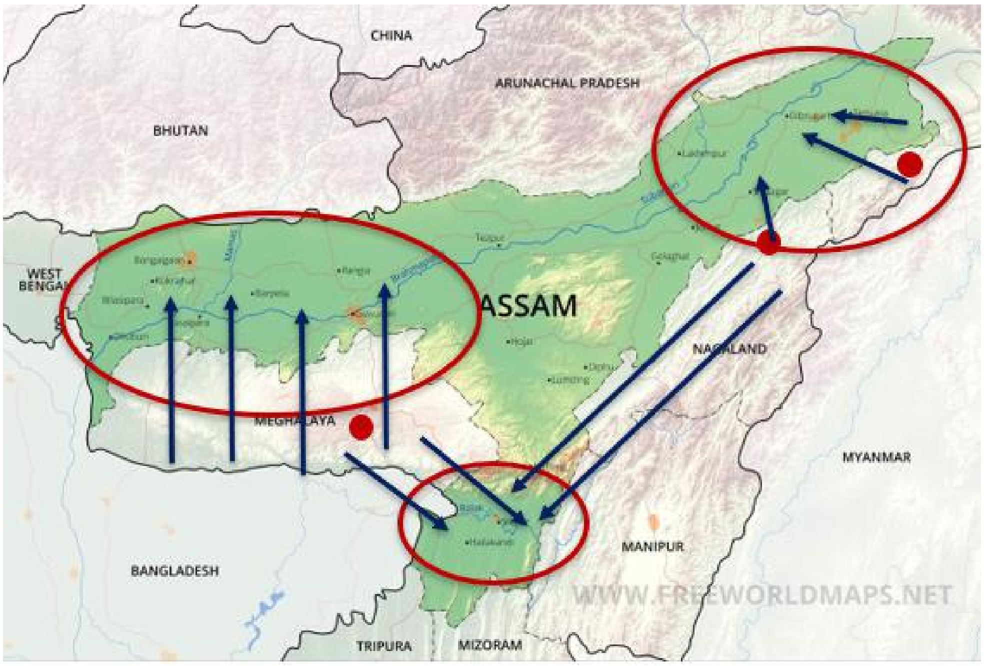
3.2.5 Consumption of fuel and raw material

The most common fuel used in brick firing in Assam is coal. No other alternate materials e.g. biomass, oil or gas is being used. This is probably due to the easy availability and low cost of coal available in and around Assam and neighbouring states. In addition to coal, wood and even rubber tyres have been seen used in firing. These are used only during the initial firing cycle. Due to quite a long period of hiatus and the rainy season, all types of kilns have high moisture in the ground and also in the outer and inner walls. To effect a faster drying of the moisture and reduction on coal quantity, additional heat is supplied in the form of wood and other flammable materials only at the periphery of the firing zones. These do not have any effect on energy required for brick firing. It was understood from the survey that on an average 18-20 tons of wood is used for brick firing in FCBTK's. Wood and rubber tyres are mostly used to initiate the firing process while coal consumption continues on a round by round basis.

Types of fuel used for firing and its mapping

Coal suitable for brick firing is generally found in the states of Assam, Meghalaya and Nagaland. The coal of Meghalaya is immature sub-bituminous coal with high sulphur content. However customers and brick entrepreneurs prefer Meghalaya coal due to its high calorific value. Compared to Meghalaya, the state of Assam also has high reserves of coal mainly in the Upper Assam area in and around Tinsukia. This is also a bituminous coal with high sulphur content. In Nagaland the coal quality is sub-bituminous to bituminous-D in rank, characterised by low to medium moisture (4%–7%), moderately high volatile matter content (22% and 42%) and high sulphur (5%–11%) content. There are specific places where coal is supplied to brick kilns. In and around Lower Assam of Guwahati-Bongaigaon-Bilasipara-Dhubri region coal is sourced from Meghalaya mainly from Salang. For Silchar since both Meghalaya and Nagaland are of similar distance, thus the coal procurement is mainly governed by economics. Various brick kilns procure coal from both these states. In Dibrugarh which is located at a distance of 150 km from Nagaland, coal is usually procured from various locations of Nagaland such as Naganimora and Margherita in Assam(Tinsukhia).

Figure 28: Types of fuel used for the firing of the bricks and it's mapping



Source : Modified from www.freeworldmaps.net

However, in all cases, the area to procure the coal is not fixed and depends mainly on the coal availability in the market, its price and quality. Figure 28 shows the occurrences and procurement map of coal for brick kilns in Assam.

However it was seen that coal is not procured directly from mines. In India coal is mainly procured through e-auction. However the brick kiln owners are low consumers of coal and thus cannot procure directly from mines. In almost all the cases coal is procured from dealers. Thus there is a flexibility of procurement based on price and quality. It was also noted that coal from Nagaland and Meghalaya is also procured in an illegal manner. There are no bills or invoices based on which payments are made. This is quite a thriving business and quite a large number of such suppliers exist in the two states. Since there are no regulations of coal usage and mining, thus during certain seasons shortage of coal is rampant resulting in black marketing of coal and rise in prices.

Coal consumption

The consumption of coal has been calculated based on the two prevalent technologies i.e. FCBTK and Zig Zag kiln. Table 9 shows the average amount of coal consumed in the three study areas.

Figure 29: Coal crusher machine in Silchar

Source: Author

The average coal consumption matches with the figures from other similar brick kilns in the Indo Gangetic plains. However, the variation of coal consumption among the three regions is also within assumption limits. The most important observation is the similar coal consumption in Zigzag kilns. As per industry standards, there should be at least 20-30% of energy reduction in Zigzag kilns compared to FCBTK. Since this was not seen, thus it is inferred that the Zig Zag technology and process is not properly being followed. This might be due to lack of knowledge and improper technology deployment or adoption. Thus training programmes and manuals are proposed to be made available for all alternate technologies so that they can be followed.

Table 9 : Region-wise distribution of average annual consumption

Region	Type of Kiln	Average coal consumption (in tonnes) per lakh of fired bricks
Guwahati	FCBTK	17.17
	Zig-Zag	16.00
Silchar	FCBTK	20.41
	Zig-Zag	18.00
Dibrugarh	FCBTK	18.67
	Zig-Zag	15.27

It can be seen that the average coal consumption for making one lakh of bricks through FCBTK was slightly higher in the Silchar region as compared to that of Guwahati and Dibrugarh, whereas the coal consumption in Zigzag kilns was fairly in the same range for Guwahati and Silchar but it was significantly lower in Dibrugarh. The variation in coal consumption can be attributed to various reasons such as the quality of the raw material available, plasticity and moisture content of the soil, etc. Climatic conditions of the region such as rate of precipitation, humidity etc. also contribute to this factor.

Consumption of wood

Figure 30: Timber stored for firing initiation.

Source: Author

In Guwahati, on an average, 38.30 T of wood is being used in the initial firing process along with the rubber tyres that are procured from local scrap markets. In Silchar it was observed that 53.27 T of wood was being used whereas in Dibrugarh, the average consumption was around 50.72 T. It can be observed that brick kilns in Guwahati are consuming less wood as compared to that of Silchar and Dibrugarh while the average brick production is almost in the same range. This may be due to variations in the quality of locally available timber in terms of calorific value as well as moisture content.

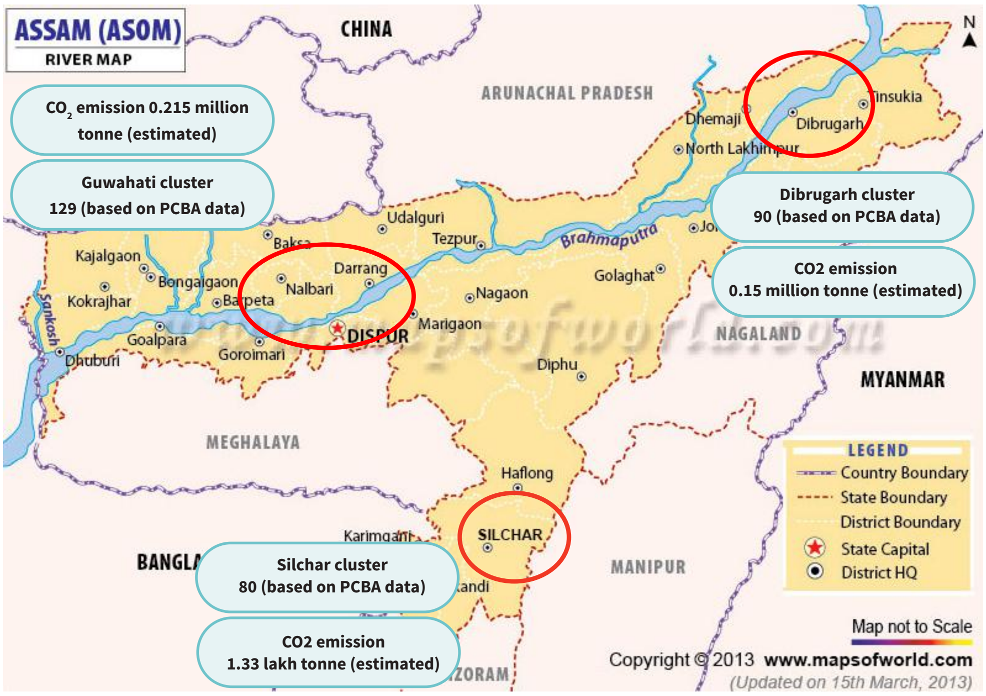
3.2.6 Environmental Impact

(a) Environmental scenario

The brick industry in Assam is based on widespread production activity which is energy-intensive, resource-depleting and highly polluting. One of the major pollutants emitted from a FCBTK and other brick kilns are Suspended Particulate Matter (SPM). These are generated due to the firing practices being adopted. In FCBTK firing practises the coal is fed from the top. To reduce the drudgery of labour working in high heat conditions, it is a practice to put in high amounts of coal. This results in incomplete combustion and therefore release of black carbon and high particulate matter. Due to the high amount of sulphur in the coals of North East India it is also expected that the release of SO_2 in the atmosphere will also be very high. Considerably high levels of pollution are evident at each and every stage of the production process in the kilns. The high levels of brick dust during the loading and unloading process creates potential health hazards, thereby reducing the life expectancy of brick workers to a large extent.

Judging by the amount of smoke released to the atmosphere, pollution is a big concern in the brick kilns. Apart from workplace pollution, one of the major issues from burning fuel is the creation of numerous by-products, some of which may be useful and others that are undesirable, irritating or dangerous. Wood burning creates particulate air pollution that can contribute to human health problems and increased hospital admissions for asthma and heart diseases. Wood burning smoke pollutants include nitrogen oxide, sulphur dioxide, volatile organics, radioactive compounds, carbon monoxide, formaldehyde and suspect carcinogens (polycyclic aromatics and dioxins).

Figure 31: Estimated CO2 emissions for study areas



Source : Modified from mapsofindia.com

It is suggested that in the future a comprehensive emission monitoring exercise is undertaken along with airflow modelling to understand the effect of high pollution from brick kilns. This has to be monitored in various seasons also to gather comprehensive data.

In addition to the above based on the data on the number of brick kilns an estimation of CO_2 being emitted from brick kilns has been presented in Chapter 4. A preliminary estimate (Figure 31) in the priority brick kiln clusters surveyed is also presented above.

(b) Energy scenario

According to feedback received from various FCBTK and Zig Zag kiln entrepreneurs during the feasibility study, energy consumption differs significantly in almost all the FCBTK. This is evident from the variation in coal consumption across both the technologies in various areas.

Although the variation is not much, it depends majorly on the type of coal, soil used and the atmospheric conditions like humidity etc. Table 10 below gives the calorific value of the coals being used in various regions and the specific energy consumption across the various regions. It is pertinent to mention that coal in Guwahati is accessed through dealers which stock coal of various varieties. The coals vary in quality as shown in Table 6. In Silchar and Dibrugarh no such coal depot exists and all are sourced illegally as mentioned earlier. It is evident that there are low value coals available in various places in Assam. If they are of no use in high value applications, then can be easily used as internal fuels.

The coals being used by private entrepreneurs are quite consistent. Although no testing has been done, we presume that the choice of coal and the quality is based on energy consumption in the brick kilns. Thus an average of 29.21 MJ/kg energy value has been assumed in all calculations. The Table 11 below shows the Specific Energy Consumption of the two practised technologies based on the coal consumption.

Table 10: Coal quality in Assam

Sl	Cluster	Calorific value (MJ/kg)	Ash content (%)
1	Guwahati depot		
	Sourced from Meghalaya (not disclosed)	34.52	6
	Sourced from Assam (Garampani)	14.19	55
	Sourced from Nagaland (Margharita)	24.38	28
2	FCBTK in Guwahati		
	HBI (sourced from Meghalaya)	28.30	7
	SMB (sourced from Nagaland)	30.13	21

Table 11: Specific Energy Consumption for fired bricks

Sl.	Cluster	Coal consumption Ton/lakh of fired bricks	Specific Energy Consumption (MJ/kg of fired bricks)
1	Guwahati		
	FCBTK	17.17	1.52
	Zig Zag	16.00	1.42
2	Silchar		
	FCBTK	20.41	2.21
	Zig Zag	18.00	1.95
3	Dibrugarh		
	FCBTK	18.67	1.56
	Zig Zag	15.27	1.27

The SEC of Silchar overall seems to be quite high compared to the other regions. These might be due to excess moisture in coal or bricks and also high consumption of coal to dry off excess moisture in the kiln surfaces. Overall the SEC in FCBTK seems to be quite high compared to existing sources. Generally under Indian conditions, the SEC in a well-managed and properly fired FCBTK ranges between 1.10-1.20 MJ/kg of fired bricks. Thus the energy consumption across all the clusters seems to be very high. The following measures if undertaken will reduce the SEC resulting in greater energy efficiencies, reduced pollution load and increased profitability. Some of the measures are:

- Use of dry coal as much as possible. Stock the coal in a raised platform and cover it with a black plastic to avoid moisture gain.

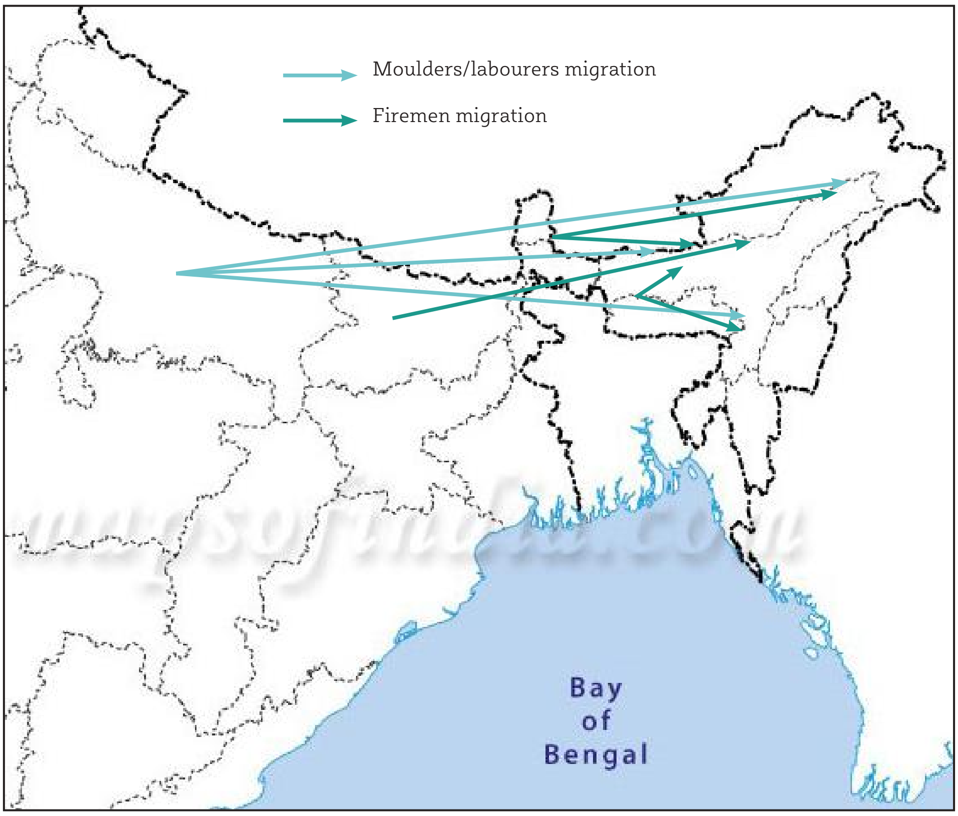
- Use of dry unfired bricks as far as possible. Although bricks seem to be dry from outside, more than often they are wet from inside containing moisture in the excess of 5%. Generally, as a thumb rule, to dry off 1% moisture we spend 3% of energy.
- Use of proper firing and feeding practice
- Construction of kilns in higher areas i.e. where the water table is low. This will result in quick drying of the kiln firing area resulting in savings of energy.
- Proper insulation covers to be followed in the kiln firing area to avoid heat loss and conservation of energy.

3.2.7 Social conditions

Migration factor

Migration of labour and moulders was one of the dominating factors in the brick production of Assam. It was seen that the fire-masters in most kilns come from Uttar Pradesh and moulders involved in unfired brick moulding, transportation from field to kiln, handling of fired bricks are generally from local areas of Guwahati, Silchar and Dibrugarh depending upon where the kiln is located along with labourers coming from various clusters of Assam, West Bengal and Bihar such as Patna, Dhubri, Gwalpara, Cooch Behar and Barpeta.

Figure 32: map showing migration of moulders and firemen



Source : Modified from mapsofindia.com

Due to the migration factor and low literacy rate in the state, in some of the brick kilns it was identified that contractors or the managers are mostly not equipped with proper technical knowledge in terms of processes and quantities of the raw materials such as coal during the firing process. As a result, the quality of brick produced is not suitably good, degrading the environment and also adding to the GHG emission.

Working Conditions

The working conditions in the kilns are quite extreme especially during the firing of bricks. The kilns are often operational 24x7 for this process as the heat needs to be provided to the bricks in a continuous manner leading to long working hours for labourers extending beyond the ideal range of 7-8 hours. It was also observed that in the production and manufacturing of red bricks, there are three categories of workforce that were being involved. These were green brick making moulders, transportation of green bricks from field to kiln and kiln to field followed by stacking and firing. Majority of male population is involved in the process of transporting green bricks and firing, while the women are mostly involved in the mixing and moulding process.

In the overall process of brick making, the ratio of men to women is approximately 70: 30 which is the same for almost all the kilns that were observed in Guwahati, Silchar and Dibrugarh. In a few brick kilns it was observed that the masons who were involved in the process of manufacturing bricks resided in the temporary or permanent shelters along with their family members including children. In some instances, children could be seen helping out in the brick-making process, assisting their parents for small tasks.

Living Conditions

While documenting brick kilns, it was observed that basic amenities such as toilets, temporary housing, and drinking water system were being provided by the brick kiln owners in almost all the kilns. In one of the FCBTK based in Silchar, permanent housing had been built for the workers along with toilets. In most kilns, temporary shelters were made with thatched roofs, bricks for walling, bamboo for roofing support, etc. and were built by the workers themselves. The waste from the toilets was being stored in the soak pit and no direct discharge of the waste into the river was observed. For drinking water purposes, bore well systems were available in most of the kilns for the labourers which were also being used for other domestic chores. Health and safety equipment such as gloves, helmet, eye glasses, boots etc. were not provided for workers in most kilns.

3.2.8 Economics of brick production

Based on the production rate of the bricks, the wage type has been categorised into two systems i.e. monthly salaries and contractual per thousand bricks. The daily and monthly wages of the labourers varies from place to place. It can be observed that in Silchar, the monthly salary of the manager is starting comparatively from a lower range to that of Guwahati and Dibrugarh. Whereas for the process of green brick making and moulding, the daily wages in Guwahati region is lower compared to the other two regions. No critical variations could be seen for the process of transportation, with costs being more or less the same in all three regions.

Table 12: Wages for different processes in brick making

Occupation	Wage type	Guwahati (INR)	Silchar (INR)	Dibrugarh (INR)
Manager	Monthly salary	12,000 -15,000	8,000 -1,6000	1,000 -13,000
Fire master		11,000 -15,000	10,000 -15,000	13,000 -15,000
Site supervisor		10,000 -11,000	10,000 -11,000	10,000 -11,000

Occupation	Wage type	Guwahati (INR)	Silchar (INR)	Dibrugarh (INR)
Unfired brick making (mixing + moulding)	Contractual per thousand bricks	150 - 900	1,000 - 1,500	800 – 1,200
Transportation charge for unfired brick from field to kiln:		250 - 380	350 - 700	280 - 450
Transportation charge for unfired brick from kiln to stacking yard		280 - 360	350 - 400	300 - 450

Based on the data collected on wages and costs for raw materials, an estimate of the actual production cost has been presented in the table below. It can be seen that the average cost of production of one thousand bricks is approximately INR 5,735 or INR 5.73 per brick. Depending on the quality and local demand for bricks, the selling price for fired bricks in most regions was around INR 9-10.

Table 13: Estimated production cost for bricks

Parameters (per 1000 bricks)	Cost (in INR)
Soil	1200
Brick moulding releasing sand	150
Unfired brick production	800
Transportation and Loading of unfired bricks	250
Unloading and transportation fired bricks	350
Fuel	2650
Fire master	280
Electricity	30
Diesel	5
Maintenance	20
Total production cost (per thousand bricks)	**5735**

3.2.9 Regulatory frameworks

There are several regulatory frameworks that apply to the brick sector in Assam including those by the Pollution Control Board, Ministry of Environment, Forest, and Climate Change, as well as the Energy Conservation Building Code. These have been detailed out in the following sub-sections:

(i) Pollution Control Board

In order to decrease pollution from brick kilns to the bare minimum, the PCBA has notified guidelines for brick manufacturing in the state. The guidelines provide guidance on competent authority, land location, plant and machinery location, standards to be achieved, pollution control measures required, operation and maintenance, and general conditions. Apart from this the guidelines also provide guidance on procedure to apply for establishment consent, operation consent, consent renewal, reporting mechanism, penalties for non-compliance, and conditions for consent revocation.

Location of Land

The guidelines have provided distance requirements of the plant from several entities. A brick kiln must be at least 300 metres and 500 metres away from a residential area with a population of 100-150 people and more than 150 people respectively. The distance from the notified municipal area/town committee shall not be less than 1.0 km. The brick kiln should be beyond an aerial distance of 500 metres from hospitals, schools, public places, religious places, and from places where flammable items are stored. It is restricted to establish brick kilns within a 1km radius of notified sensitive areas like zoos, sanctuary and so on. Further the brick kilns should be at least 200 metres away from the nearest railway tracks and 500 metres away from the natural path of water flows. According to the guidelines, the brick kiln's collection/excavation area should not be within the restriction limits set out in Rule 7 of the Assam Minor Mineral Concession Rules, 2013. The guidelines have specified the minimum permissible distance between two kilns to be 500 metres. The guidelines have restricted the establishment of brick kilns in the 'No-Development Zone'. According to the guideline, after reviewing the proponent's application, the Board's Regional Office will convene a public hearing in the relevant Gram Panchayat to determine whether the industry is acceptable to the local community or not.

Location of plant and machinery

As per the guidelines, the land should be vast enough that after establishing the plant and reserving space for material stock and vehicle movement, there should be enough space to plant at least two rows of trees, shrubs or bamboo along the periphery.

Standards to be achieved

The rule has mandated compliance of brick kiln units to the standards notified by Ministry of Environment & Forests (MoEF), Govt. of India under Schedule I at Sl. No. 74 of Environment (Protection) Rules and Notified National Ambient Air Quality Standards for activities involved like mining, quarrying of clay, handling & transportation of raw material or bricks and so on.

Pollution Control Measures Required

Further the guidelines provide instructions to support the abatement of pollution such as specification for approach roads and haul roads within the premises of brick kiln, specification for chimney or stack usage of crushed coal for better burning efficiency, and staggered brick laying for baking to entrap maximum particulate matter at the source. It also recommends the usage of a properly designed gravity chamber, installation of water sprayers, and upward alignment of the exhausts of trucks for transportation of materials within the site. The guidelines mandates establishing wheel cleaning facilities for delivery trucks for the removal of mud.

Operation and maintenance

For efficient operation of the unit, the guidelines recommend establishing a water storage facility of capacity of at least 3000 litres at the brick kiln site. It mandates a high standard of housekeeping. Any equipment / machinery that is malfunctioning or breakdown leading to abnormal emissions should be dealt with promptly.

General Conditions

Apart from these specific conditions the rule also provides general conditions on reporting mechanism, usage of local agri-waste as fuel, waste that cannot be used as fuel, standard design to be installed, and other general conditions the brick kiln should comply with. Brick kiln owners should arrange facilities to avoid noise pollution. The brick kiln industry should have a reliable source of raw materials, either in its own possession or through lawful arrangements. The guidelines mandates use of fly ash in brick moulding in compliance with the notification issued under the provision of Environment (Protection) Act, 1986 to manufacture soil – fly ash brick.

Green Belt Development

To protect the environment from negative impacts of pollution, the guidelines mandate that a minimum of 33% of the land on which industry is built or proposed to be established should be covered with plantation. Along the periphery of the brick kiln, a multi-layer and multi-storey green belt of 10 m width or two rows of bamboo shall be built, allowing two 10 m wide openings in the boundary for material and vehicle entry and exit. To limit dust emission, a 3 m high wall should be built on the sides where land is not available for green belt development. The minimum area required for the installation of a brick kiln with green belt development is 5 bighas.

Reports to be submitted for monitoring

The following reports shall be submitted by the brick kiln to prove their compliance to the regulations;

a) Annual compliance report of Consent conditions to the Competent Authority

b) Annual stack emission and Ambient Air Quality Monitoring Report to the Competent Authority

c) Annual Environment Statement in the prescribed format as under Environment (Protection) Act 1986 to the Competent Authority

d) Annual production and dispatch details of bricks

Reclamation of brick fields

The top layer of the soil of minimum 1.5ft in depth removed during mining and establishing the kiln should be stored safely within the brick field. This can be used for reclamation of abandoned or depleted kiln areas at a later stage. This will help in retaining the fertility of the land used for brick manufacturing after being abandoned.

Competent Authority & Licensing Process

According to the guidelines any brick kiln proponent must attain appropriate permissions before commissioning the plant. The kiln can be established on the owner's land or a leased land for not less than 10 years. Project proponents intending to establish brick kilns must submit an application to regional Office of the Pollution Control Board to request:

- Consent to Establish (CTE) under Air (Prevention & Control of Pollution) Act, 1981 before taking any step for establishing the brick Kiln
- Consent to Operate (CTO) before commissioning the plant

(ii) Guidelines by Ministry of Environment, Forest, and Climate Change

As per the Ministry of Environment, Forest and Climate Change notification of April, 2021, "All building construction projects (Central, State & Local authorities, Govt. undertakings, other Govt. agencies and all private agencies) located within a radius of three hundred kilometres from a coal or lignite based thermal power plant shall use ash bricks, tiles, sintered ash aggregate or other ash based products, provided these are made available at prices not higher than the price of alternative products."

In the case of Assam which has only one coal-based thermal power plant in Bongaigaon and thus limited availability of fly ash, there are currently no other regulations concerning brick manufacturing units in the region or those mandating the use of alternative building materials instead of burnt bricks.

With regard to brick kilns, the MoEF also came out with revised guidelines based on notification No. G.S.R. 143(E) dated 22 February 2022. The detailed notification has been attached as Annexure 9. The notification broadly states that:

- All new brick kilns shall be allowed only with zig-zag technology or vertical shaft or use of Piped Natural Gas as fuel in brick making and shall comply with these standards as stipulated in the notification.
- The existing brick kilns which are not following zig-zag technology or vertical shaft or use Piped Natural Gas as fuel in brick making shall be converted to zig-zag technology or vertical shaft or use Piped Natural Gas as fuel in brick making within a period of
  a. one year in case of kilns located within ten kilometre radius of non-attainment cities as defined by Central Pollution Control Board
  b. two years for other areas. Further, in cases where Central Pollution Control Board/ State Pollution Control Boards/Pollution Control Committees have separately laid down timelines for conversion, such orders shall prevail
- All brick kilns shall use only approved fuel such as Piped Natural Gas, coal, fire wood and/or agricultural residues. Use of pet coke, tyres, plastic, hazardous waste shall not be allowed in brick kilns.
- Brick kilns shall construct permanent facilities (port hole and platform) as per the norms or design laid down by the Central Pollution Control Board for monitoring of emissions.
- Particulate Matter (PM) results shall be normalised at 4% CO_2 as below:

  PM (normalised) = (PM (measured)x 4%)/ (% of CO_2 measured in stack), no normalisation in case CO_2 measured ≥ 4%. Stack height (in metre) shall also be calculated by formula H=14Q0.3 (where Q is SO2 emission rate in kg/hr), and the maximum of two shall apply.
- Brick kilns should be established at a minimum distance of 0.8 kilometre from habitation and fruit orchards. State Pollution Control Boards/Pollution Control Committees may make siting criteria stringent considering proximity to habitation, population density, water bodies, sensitive receptors, etc.
- Brick kilns should be established at a minimum distance of one kilometre from an existing brick kiln to avoid clustering of kilns in an area.
- Brick kilns shall follow process emission/fugitive dust emission control guidelines as prescribed by concerned State Pollution Control Boards/Pollution Control Committees.
- The ash generated in the brick kilns shall be fully utilised in-house in brick making.
- All necessary approvals from the concerned authorities including mining department of the concerned State or Union Territory shall be obtained for extracting the soil to be used for brick making in the brick kiln.
- The brick kiln owners shall ensure that the road utilised for transporting raw materials or bricks are paved roads.
- Vehicles shall be covered during transportation of raw material/bricks.

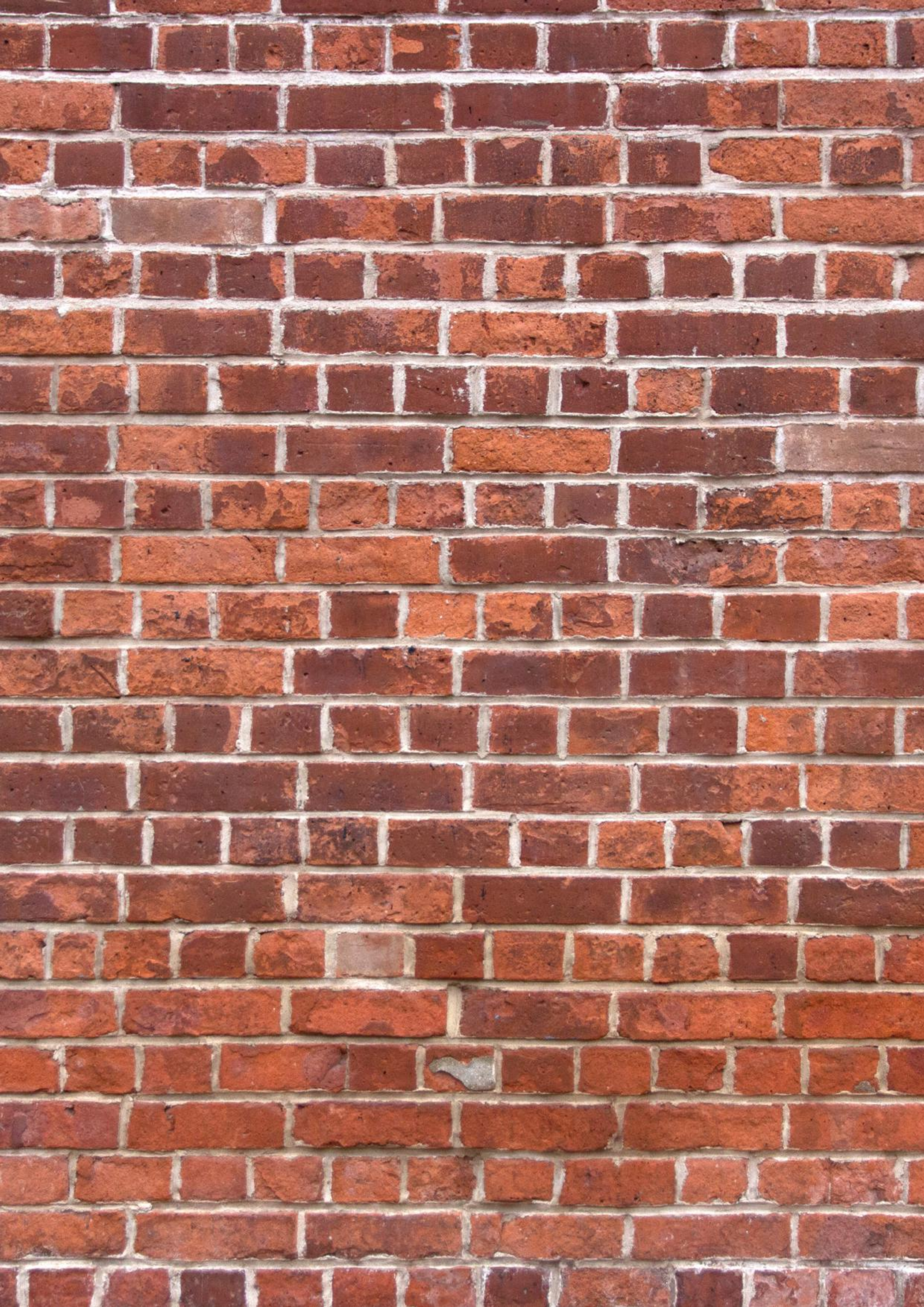
(iii) Energy Conservation Building Code (ECBC)

Assam is moving towards adoption of the ECBC 2017 with code amendments and plans for its notification. The Assam draft code is currently under public review and comment. The state is yet to incorporate the code into the state bylaws or develop a compliance system.

The state plans to form technical and policy committees with urban local bodies for integration of the code into the building bylaws. The Assam State Designated Authority is the Assam Energy Development Agency. Adoption of the code in the future may also have implications for the brick industry with respect to permissible emissions, availability of raw materials and the overall demand for bricks in both public and private sector developments.

Unlike other states, there are in-significant fly ash producing thermal power plants in Assam. Thus most of the rules for banning clay bricks and adopting fly ash bricks are not possible in Assam. It is clear that burnt clay bricks will continue to be the mainstay in providing walling materials in the absence of viable alternatives. To regulate the burnt clay brick industry and transform it into an energy efficient and environment friendly process, it is suggested that PCBA issues notification and guidelines to restrict the particulate matter in stack emissions of brick kilns to 250 mg/Nm^3 as stated in the MoEF guidelines. The three technologies to be suggested are:

- Natural draught zig zag kiln
- Vertical shaft brick kiln
- Internal fuel use in the green unfired making process.



4

Resource and emissions

4.1 Soil usage

At present, most of the brick production in Assam is based on FCBTK technology. FCBTK produces only burnt clay bricks and the only raw material being used in making the bricks is agricultural topsoil which is being dug out from nearby agricultural land. This creates an enormous pressure on the land use pattern since it takes millions of years to regenerate the soil. The map given below (Figure 33(a)) gives a perspective on the proliferation of brick kilns and soil usage over more than a decade of time span. The soil usage figures are from Dumardaha, Dhubri district and have been taken from google earth map.

Figure 33(a): Figure showing proliferation of brick kilns and resultant land use pattern in Dumardaha, Dhubri district of Assam from 2003 to 2018

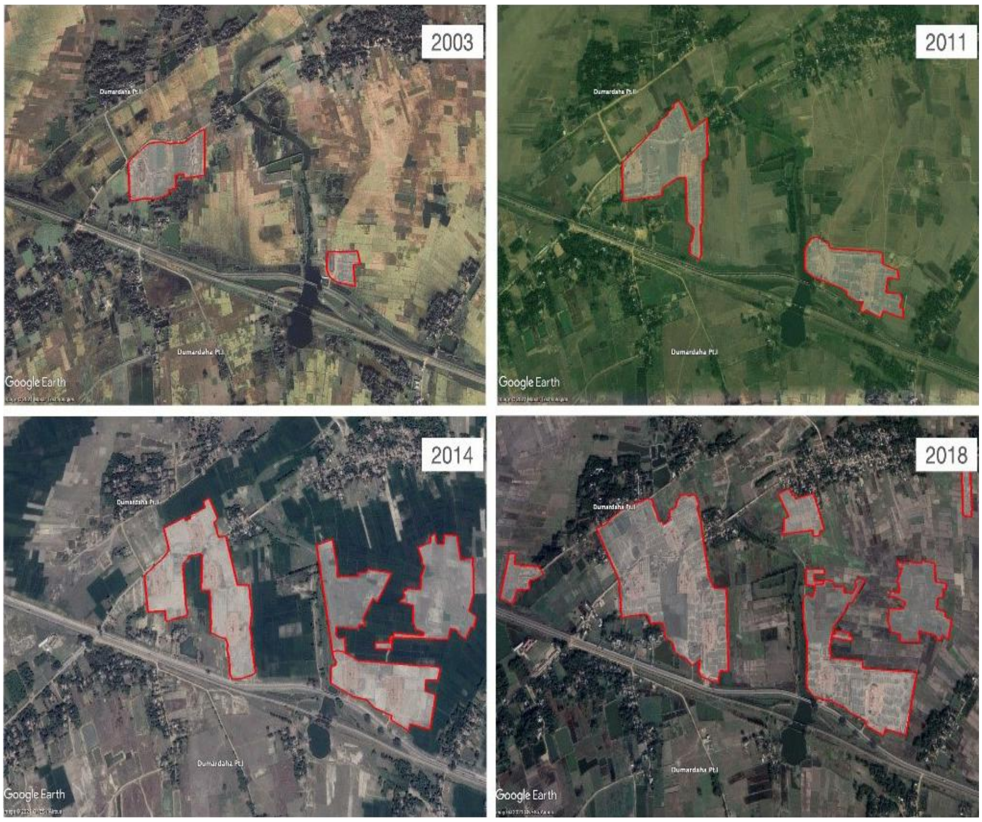


Image source :Modified from Google earth

4.1.1 Brick production and land use trends

The proliferation of brick kilns in Assam is accompanied by substantial land diversion for kiln use and increasing soil mining for the same purpose, which has been increasing substantially over the years. The graphs below track this growing trend, in order to establish the correlation between the two. These trends have been estimated based on calculations since on-ground plotting of soil excavation was not carried out.

Fig 33 (b) Graph showing the trend of soil mining by brick kiln manufacturers

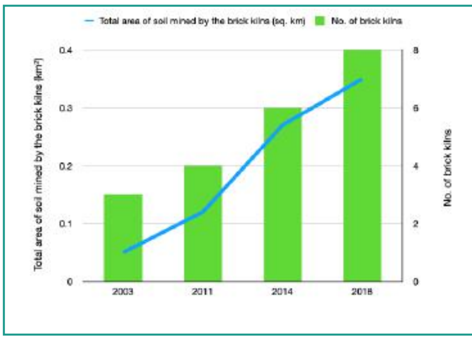
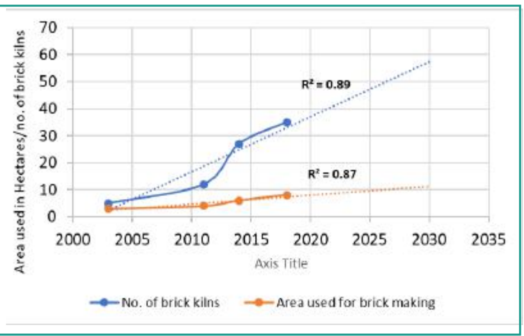


Fig 33(c) Graph showing trend of land area used for brick production.



From the above two graphs (Fig. 33(b) and 33(c)), it is clear that the trend of projections has an R-Square value greater than 0.8, confirming a strong effect size and good correlation. Thus if trends are projected beyond 2018, then the same unit area, having 8 to 9 brick kilns at present, will have around 12 brick kilns by 2030 consuming around 58 hectares of land on a year-to-year basis.

Although the above analysis is representative of the brick making activity in Assam, it is apparent that the growth of brick kilns has been high over the past decades. The soil consumption pattern is proportional to the growth of brick kilns. It can be assumed in the last couple of years that the rate of soil consumption for brick making may have decreased on account of the COVID-19 pandemic since the actual areas used for brick making activity could not be plotted.

At present there are 1242[6] bricks kilns (considering 31 districts only). Considering an average production of 30 lakh[7] bricks per year the total soil usage is around 96.88 lakh tonne of soil mined from an area of 6210[8] acres of land equivalent to around 25 km^2. Thus each and every year an equivalent area of agricultural land is being used up for brick making. Till date with the unabated brick making activity in the state, around 215 km^2 of agricultural topsoil has been lost to brick making, which is equivalent to the area of Guwahati alone. This calculation has been done during the period 2012-2022 only, since figures before 2012 were not available at the time of this study. Thus the actual area lost may be much more.

With growing trends in brick consumption and production and no alternative building materials in sight, the brick making activity is slated to cumulatively consume about 593 km^2 of agricultural land by 2030 and 3101 km^2 of agricultural land by 2050. Such a huge amount of land use for brick making is bound to affect the food grain production in the state of Assam. Apart from food grain, this land use pattern is bound to have an effect on the flood situation in the state of Assam and water logging issues.

It would therefore be desirable to study soil usage patterns in relation to top soil excavation for brick making in order to scientifically analyse the land use patterns and the corresponding effect on agricultural activity and food grain production.

4.2 Emissions in the brick sector of Assam

Although energy and environmental monitoring was not part of the scope of this study, a fair estimate and analysis of the emissions trend has been initiated based on secondary data and relevant literature[9]. This was undertaken to establish links with climate change and GHG

6 As per data received from PCBA
7 Based on average brick production as per field data
8 1 acre of land dug upto 1 ft produces 6,00,000 bricks. Assumption based on field experience
9 Brick kiln performance assessment, Shakti Sustainable Energy Foundation

emissions, since they bear a direct causal relation. The results of this extrapolation have been presented in the following section using the parameters described below.

4.2.1 Parameters used for emissions study

i. Suspended Particulate Matter (PM2.5)

Suspended Particulate Matter (SPM) is a term used for airborne particles of diameter less than 100 µm. The emission factor assumed in terms of g/kg of fired brick for SPM in this study is 0.86 g/kg of fired brick. This is based on a published report from Shakti Sustainable Energy Foundation (2012) and is based on field measurements.

ii. Particulate Matter (PM2.5)

Emission norms in India do not address PM2.5 specifically, but it is frequently monitored because of its environmental and health effects. Fine particulate matter (diameters less than 2.5 µm) can penetrate more deeply into lungs than larger particles. It also has a longer atmospheric lifetime and a disproportionately greater effect on visibility and climate, relative to larger particles. The values assumed for calculations are given in Table 8.

iii. Gaseous pollutants

Estimations were also made for sulphur dioxide (SO_2). Table 8 provides the emission factors for SO2 normalised to grams of pollutant/kg of fired brick. SO2 emissions stem from the sulphur content of fuel; therefore, significant variations in the SO2 concentration are possible. Especially the coal in the North East has high sulphur content and the results might increase.

iv. Black carbon

Black carbon (BC) is a combustion product predominantly composed of strongly bonded graphitic-like carbon rings. This composition causes black carbon to be thermally stable at high temperatures and to strongly absorb visible light, causing warming. Organic carbon (OC) comprises all carbon species that are neither black nor carbonate carbon.

In November 2011, the United Nations Environmental Program in its assessment, Near-term Climate Protection and Clean Air Benefits: Actions for Controlling Short-Lived Climate Forcers, proposed replacing traditional brick kilns with more efficient ones, particularly VSBKs, as a measure to reduce BC.

4.2.2 GHG emission results

As per data received from Pollution Control Board of Assam (PCBA), the total number of brick kilns across the 35 districts in Assam are 1242 (excluding the districts of Dima Hasao, East Karbi Anglong, Chirang, South Salmara-Mankachar & Dhemaji). These 1242 kilns, on an average produce 30 lakh bricks per year and, emit over 2 million tonnes (20,69,357 tonnes) CO_2 of GHG emissions (assuming the weight of each fired brick to be 2.60 kg). The results are given in the following table (Table 14) while the emissions of gaseous pollutants from FCBTK brick kilns are shown in Table 15.

Table 14: GHG emissions in the brick sector of Assam

Parameters	Total emission (tCO_2/year)
Total emission from combustion of fuel used in brick firing	19,63,220
Total emission from transportation of coal	44,291
Total emission from transport of fired bricks	61,846
Total annual GHG emissions	**20,69,357**

Table 15: Gaseous emissions in the brick sector of Assam

Parameters	SPM	$PM_{2.5}$	SO_2	Elemental Carbon
FCBTK emission factor	0.86 (g/kg)	0.18 (g/kg)	0.66 (g/kg)	0.13 (g/kg)
Total emission from 1 FCBTK	6.71 tons	1.40 tons	5.15 tons	1.01 tons
Total emission for 1242 FCBTK in Assam	8,333.82 tons	1,738.80 tons	6,396.30 tons	1,254.42 tons

From the above two tables, it is clear that the emissions from the brick sector are tremendous, especially when viewed from the life cycle and embodied carbon perspective. It is therefore recommended that a more detailed GHG inventorisation study of the brick sector in Assam is carried out to understand in detail the scenario and understand the measures to mitigate the same.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5

Alternative technology options

Based on the field surveys and the data analysed, two possible pathways of alternative options have emerged. These are:

Improvement of existing firing practices

It has been seen that in the three large brick making clusters of Guwahati, Dibrugarh and Silchar majority of the brick kilns are FCBTK. Sporadic occurrences of Zig Zag kilns were seen which are not very effective in terms of energy reduction or environmental efficiencies. There is still scope for reducing energy consumption by improvement of existing firing practices or introducing internal fuel in unfired brick making.

Introduction of transformative new technologies

Based on the resources available e.g. various types of soil, wastes and alternate biomass based fuels, there are quite a number of technology choices and alternatives. The alternative technology options mentioned in the report are not only for the three brick making clusters but should be looked at from the perspective of the State of Assam.

5.1 Identified alternative materials and technologies

5.1.1 Improvement in existing firing practices

Better feeding, firing and operating practices:

Pollution control and energy conservation are inter-related in brick kilns. The combination of energy saving and reduction in pollution is a win-win situation, in which the brick kilns benefit because of saving in energy costs and better working conditions and the society gains due to reduction in pollution and conservation of precious energy resources. But this can happen only if the pollution control packages and energy efficient operations are sincerely followed. New approach to operational practices requires a paradigm shift, integrating the whole process innovations with new patterns of technology designs. The technology innovations and trained human resources are a valuable asset, but the advantage of all this can only be taken if the workforce is ready to change its mindset. All this requires training of firing men and making them learn and adopt the improved technology options.

Some of the better feeding, firing and operating practices that can be adopted for Assam in existing fixed chimney BTK's are innovations in:

- **Storage of coal**

  Coal must always be stored in covered places and not in the open. This is to prevent high moisture content due to sudden rainfall as prevalent in Assam. High moisture content lowers the ignition quality of the coal and increases fuel consumption. Exposure to high intensity rainfall may also cause the coal, especially the finer particles, to wash out and lead to loss of material.

- **Size of coal**

  The coal should have a size gradation. It should be bigger than 2 inch. The size of coal shall depend on the type of the kiln with possible requirement of finer sizes and powdered form in certain cases, which must be based on proper analysis as per quality of coal and type of kiln.

- **Size of spoon**

  The spoon should have a capacity of 250 gms. This is to enable continuous feeding of coal. A standard size of the spoon must be selected and used to ensure uniform feeding throughout operations and reduce overfeeding or under-feeding during the firing process.

- **Feeding pattern and interval**

  Feeding should start from the first firing hole from the periphery and then return back. It should ideally be done in a Z-pattern.

- **Role of chimney**

  The chimney should be a minimum of 100ft in height with good construction. The size may vary based on the type of kiln. For instance, higher chimneys may be required for zigzag kilns. This must be based on proper technical inputs. Any leakages must be avoided to ensure optimum firing operations and proper maintenance should be carried out for the structure after every brick firing cycle.

- **Air supply**

  The flue gas ducts should be cleaned regularly to avoid choking of the ducts due to dust and ash. This will ensure regular flow of air and a better firing process. Active measures such as exhaust fans may be used in certain types of kilns for assisting the process.

- **Damper and its operation**

  The closing and the opening of the dampers should be by an experienced firemaster. It should not be kept open at all times.

- **Arresting heat losses**

  Proper care should be taken in spreading burnt coal ash on the top surface, use of *tirpals* and regular plastering of the outer layers by insulating materials should be done to arrest heat loss.

- **Flue damper**

  Flue dampers must be maintained regularly.

All the above individually will not result in any significant changes in energy consumption and environmental emissions. However, when worked in unison will achieve the desired results.

5.1.2 Use of internal fuels in green brick making

Internal fuels are generally waste materials with medium calorific values (1000 – 2000 KCal/kg) mixed with the soil during the unfired brick formation process. The various types of internal fuels recommended for use in brick making are generally waste materials e.g. boiler ash, sponge iron waste, bottom ash from thermal power plants, rice husk ash and other carbon bearing wastes. In the absence of waste materials in Assam, the coal used for firing can be used as an internal fuel also.

Before using the same it has to be processed in a predetermined way so as to retain the characteristics and quality of the fired product similar to non-internal fuel bricks. Various theoretical energy calculations need to be done to determine the quantity of internal fuel to be mixed. Existing processes of soil selection, processing, and moulding need to be studied for determining the most cost effective and beneficial way for mixing of internal fuel. Care should also be taken during the above to consider social and cultural conditions. An added advantage for Assam for adopting the technology is the use of mechanised soil mixing which is most important during the adoption of the technology. Thus it only needs demonstration and technical support.

The various advantages of using waste materials as internal fuel are:

- Reduction in external coal consumption, thereby saving natural resources.
- Uniform quality of fired material, in terms of ring, colour and strength.
- Lower levels of pollution thereby reducing emissions and savings in greenhouse gases.
- Utilisation of waste materials in a profitable manner thereby reducing soil consumption and preventing solid waste pollution.

5.1.3 Transformative new technologies

The various brick firing options described in this section have all been taken from existing and practising technologies in various Asian countries. Practising technologies from other continents have not been described here since they do not match the socio-economic or socio-cultural or geo-cultural characteristics of Assam. All the technologies described have relevance to Assam and the North East and have been carefully selected after judging the possibility of technical adaptability to Assamese conditions. No attempts have been made to suggest the suitability of a particular technology. Choice of technology depends on many factors and is best left to the practitioner to decide.

5.1.4 Essential features of brick kilns

The importance of chemical reactions occurring during clay firing makes it clear that kilns are not simply heat-generating systems but are chemical reaction vessels. To complete various chemical and physical changes in clay and to get a good quality fired product, it is essential that the heating and cooling rates are controlled. In ancient times, clay products were fired in the open, with very little control over the firing process. The requirement to control the firing process and conserving the energy resulted in development of kilns. The word kiln is derived from the Latin 'culina', meaning kitchen. As brick kiln technology developed, more and more control on the firing process and lower energy consumption levels were achieved. The main processes that occur during firing in a brick kiln are:

- Heat generation through combustion of fuel
- Transfer of heat generated to bricks
- Controlled heating and cooling of bricks

Combustion is generation of heat by chemical reactions that take place when a fuel is burnt. The fuels generally contain carbon, hydrogen, oxygen, nitrogen, sulphur and ash. When fuel is burnt, carbon and hydrogen combine with the oxygen in combustion air, to form carbon dioxide (CO_2) and water (H_2O) respectively. Both these chemical reactions produce heat. A chimney (to produce natural draught) or a fan (to produce artificial draught) is employed in brick kilns for supplying air for combustion in certain types of brick firing technologies.

In brick kilns, convection (heat transfer by virtue of fluid motion) is the main mode of heat transfer. Air initially picks up heat from hot fired bricks. It is then heated with combustion of fuel. The hot air then travels to the unfired bricks and transfers part of heat to them. Like combustion, heat transfer is also greatly affected by airflow. It also depends on the setting of bricks in the kiln. For a brick kiln with a given raw material (clay), controls on heating and cooling are achieved by:

- Control of air supply and flow
- Fuel supply
- Stacking of bricks
- Controlling heat loss to the surroundings

5.1.5 Classification of brick kilns

A literature survey shows use of several types of kilns for firing bricks. During the several thousand years long history of the brick industry, whenever a new kiln was designed or modified it was given a new name. However, there are several similarities between different kilns, which are used for classification of brick kilns:

- Intermittent and continuous categories based on the process. Continuous kilns can further be classified as moving fire (in which fire moves and goods are stationary) or moving ware (bricks move, firing zone is stationary)
- Up-draught, cross-draught or down-draught, based on the direction of flow of air
- Natural (chimney) or artificial (fan) draught based on the production of draught

Classification of brick kilns

Intermittent kilns

- Clamp
- Scove
- Scotch
- Down draught

Continuous kilns

- Moving fire annular kilns
  - Hoffman
  - Bull's Trench
    - Movable chimney
    - Fixed chimney
  - Simple / Straight line
    - Zig-Zag (forced draught)
    - Zig-Zag (natural draught)
- Moving ware kilns

5.2 Alternate clay brick firing technologies

The section below gives a brief overview of technologies that can be adopted for Assam.

i. High draught Zig Zag kiln:

Figure 34: High draught Zigzag Kiln

High draught kilns are normally termed in Asia countries e.g. India, Nepal, Bangladesh as Zig-Zag kilns. It should be mentioned here that Zig-Zag is only a firing pattern followed in High Draught kilns.

In these types of kilns, the length of the kiln gallery is increased by zig-zagging the chambers and the fire follows a zigzag path instead of a straight path followed in BTK. At any point of time these types of kilns were widely used in developed countries particularly in Germany and Australia. In Europe,

Figure 35: Firing of bricks in high draught Zigzag kiln

Figure 36: Stacking of unfired bricks before firing

the interior cross- section of the kiln used to be small in original zigzag kilns (7.5 ft. wide x 7.5 ft. high) and the kiln used to have 16-20 chambers each 20-25 ft. long. Fan draught was provided and the kiln operated on high draught at a very fast rate of fire travel (50-100 ft. per day). The Habla kiln developed in Australia is a form of zigzag without a crown and in which the division walls between chambers are made of unfired bricks. The top of the setting is covered by a layer of two or three courses of bricks followed by a layer of ash.

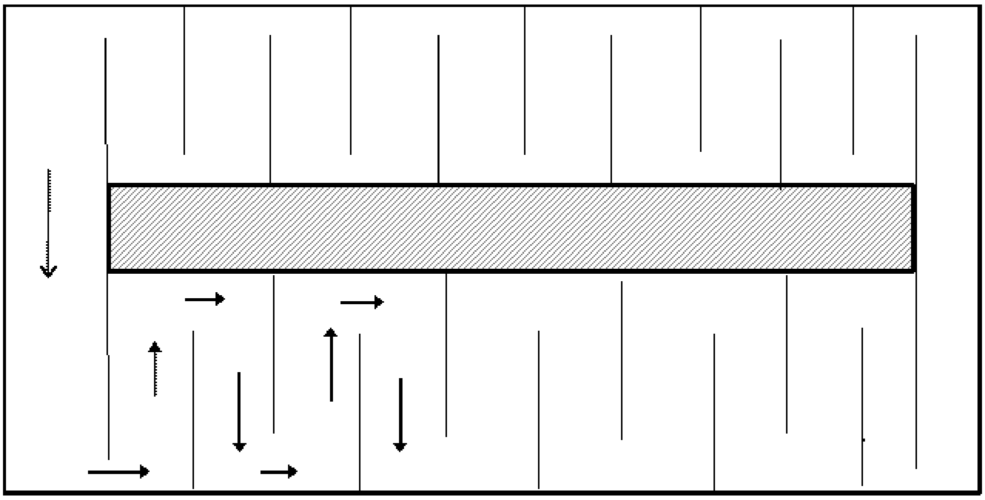
The Zig-Zag firing concept in Bangladesh is generally introduced and if followed in the form of a High Draught (HD) kiln. The HD kiln has several similarities with the Habla kiln. The kiln consists of a rectangular gallery which is divided into 24 chambers by providing temporary partition walls with unfired bricks. The wall of each chamber runs along the width of the gallery except one end, wherein a space of 60 to 65 cm is left for communication to the next chamber. Draught is created by an induced draught fan with a 20-35 HP motor for proper combustion of fuel. Depending on the design capacity of a kiln, a chamber can hold 7,500 to 15,000 bricks.

Normally two chambers are fired per day and an output of 15,000 to 30,000 bricks per day can be obtained. When brought to full firing, the kiln operates on a draught of 50 mm Hg. However, several problems are being encountered in the HD kiln in different countries:

- Bricks remain too hot for handling at unloading point.
- Dampers in the flues provided in the inner wall communicating with the main central flue being too close to the firing floor, were exposed to high heat resulting in rapid deterioration.
- As the draught and hence the negative pressure in the kiln is several times more than that observed in fixed chimney BTK's, the HD kiln is also more susceptible to air leakage. Most of the leakage takes place through wicket walls and through leaking valves and dampers.

Specific energy consumption of around 1.35 MJ/kg of fired bricks has been achieved in HD kilns being operated under full capacity. However, it is generally observed that due to shortage of trained manpower and lack of exposure to proper operating practices the performance of HD kilns are much below the expected level of performance. Moreover, in most of the rural areas either electricity supply is not available at brick kiln sites or the supply is not reliable. Therefore, installation of a DG set for electricity generation becomes essential with a High Draught kiln which further adds to the complexity of the problem.

Figure 37: Air flow through high draught kilns



ii. Natural draught Zig Zag kiln

Natural Draught Zigzag Firing kiln is a continuous, cross draught, moving fire kiln in which the air flows in a zigzag path due to the draught provided by a chimney. It has many similarities with FCBTK technology; the main difference being the zigzag air flow path. Zigzag firing concept was first used in the Buhrer kiln (Patented in 1868). The concept was later used in Habla kilns. In India, Central Building Research Institute (CBRI) first introduced the zigzag firing technology based on induced draught (with the help of a fan) during the early 1970's.

As per available information, natural draught Zigzag firing technology was first used in India in 1997 by Priya Bricks in Kolkata by modifying an existing FCBTK. The technology was adopted by Prayag Clay Products at Varanasi and, through them, has been propagated to more than 50 kilns by the end of 2013. It is now gaining popularity as an alternative to FCBTK technology.

Figure 38: Natural draught Zigzag Kiln

Natural Draught Zigzag firing kiln is a moving fire kiln in which the fire moves in a closed rectangular circuit (central perimeter 140-180 m) through the bricks stacked in the annular space between the outer and the inner wall of the kiln. It operates under the natural draught provided by the chimney (30 – 40 m high) located at the centre of the kiln.

The bricks are stacked in such a manner to form distinct chambers (~2 m long) and guide the air flow in a zigzag path. Zigzag flow increases the air flow path length and turbulence in the air, thereby resulting in improved combustion & heat transfer rate and uniform temperature across the kiln cross section. The kiln does not have a permanent roof and bricks stacked in the kiln are covered with a layer of ash & brick dust, which acts as a temporary roof and inhibits the heat loss as well as seals the kiln from leakages. There are 3 distinct zones in an operating zigzag kiln:

- Brick firing zone where the fuel is fed and combustion is happening,
- Brick preheating zone (in front of the firing zone) where unfired bricks are stacked and being preheated by the flue gases and
- Brick cooling zone (behind the firing zone) where fired bricks are cooled by the cold air flowing into the kiln.

Some of the critical features of the technology are-

- Air Inlet: Air enters into the kiln from the back end of the cooling zone which is kept open to allow air entrance.
- Seal to guide flue gas: Front end of the preheating zone is sealed by a plastic sheet to guide the flue gas to the chimney through the flue gas duct system.

Firing zone extends to 6 chambers (~12 m) and solid fuels like coal, firewood, agriculture residue etc. are fed through the feed holes provided at the top of the kiln continuously by a single fireman standing on the top of the kiln. The fire travels a distance of 6-7 m in 24 hours and fires 20,000 to 50,000 bricks. Daily, fired bricks are unloaded from the front of the brick cooling zone and an equivalent batch of unfired bricks is loaded ahead of the brick preheating zone.

Some of the basic advantages of the natural draught zig zag kilns as stated by various agencies are:

- Natural draught zigzag kilns emit ~80% lower PM and ~90% lower Black Carbon as compared to FCBTKs. This is mainly because of better combustion of fuel and settling of particulates in the kiln itself due to zigzag flow. Emission of CO_2 and CO from zigzag kilns is lower because of less consumption of fuel and improved combustion.
- Natural draught zigzag kilns consume ~20% less fuel as compared to FCBTK because of better combustion and heat recovery.
- Capital cost of setting up a natural draught zigzag kiln and its production capacity range is the same as that of a FCBTK. However, due to less fuel consumption and better product quality, the return on investment of natural draught zigzag kiln is higher than FCBTK.
- The range of products of natural draught zigzag kiln is the same as that of FCBTK. But due to improved combustion and uniform temperature attained throughout the kiln cross-section in natural draught zigzag kiln, product quality is improved.
- On OHS, natural draught zigzag kiln offers no improvement over FCBTK. Both kilns have poor OHS conditions, which is a major shortcoming of these technologies.

iii. Hoffmann kiln

(a) The original Hoffmann Kiln

The first Hoffmann kilns were in the form of a great circular ring chamber, with massive walls and a large chimney at the centre, to which underground radial flues converged from the inside walls of each of the twelve chambers. The chambers were barrel arched (like a railway tunnel), and in the roof arches there were several small feed holes through which fine coal could be fed into spaces made among the bricks to be fired. Around the outer wall

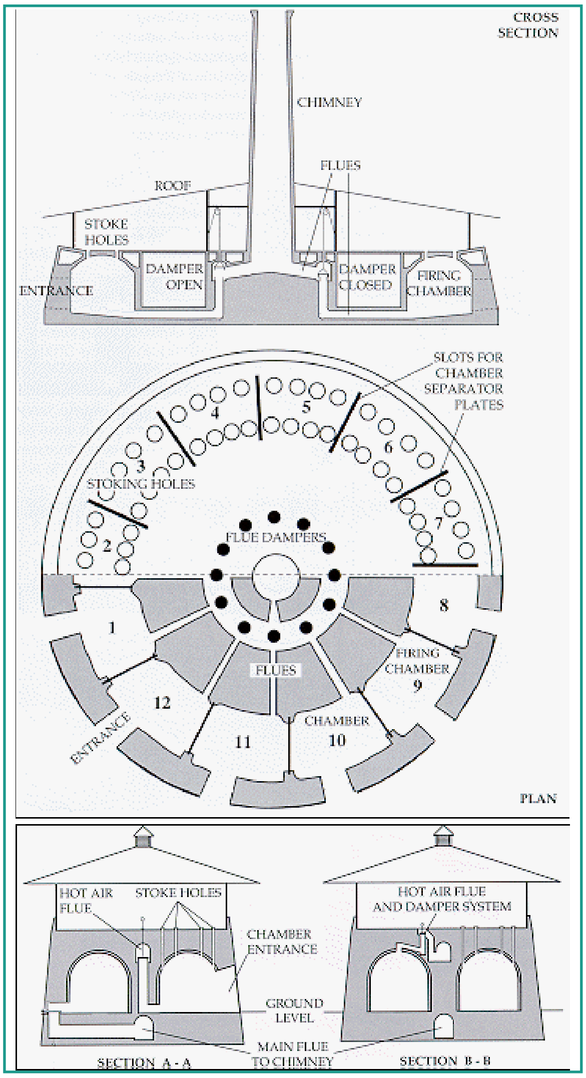


Figure 39: Hoffman Kiln

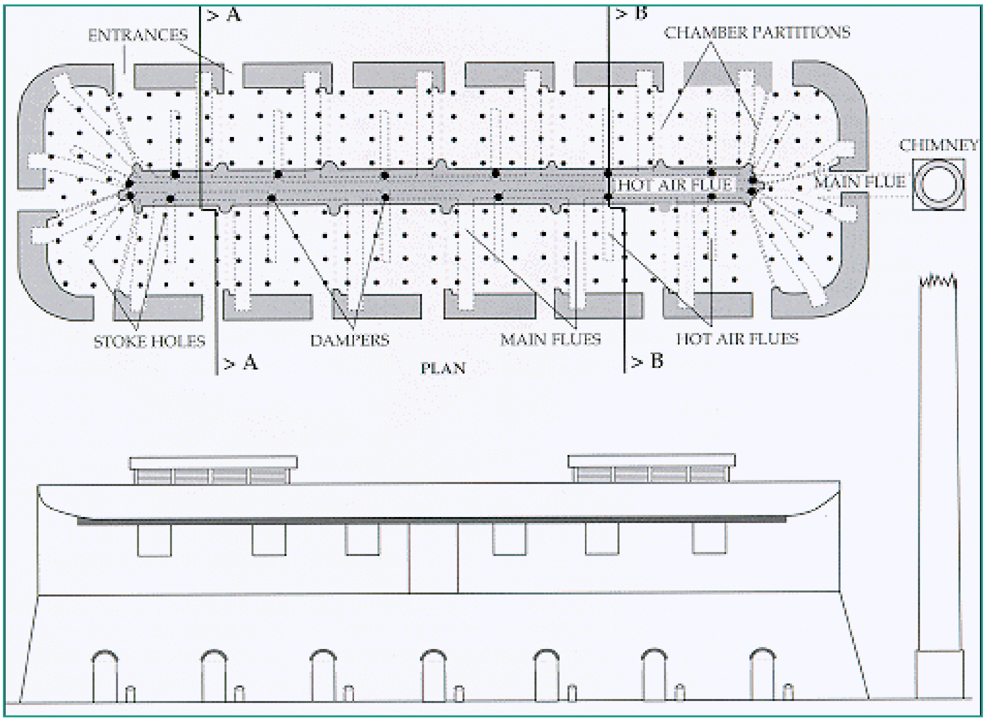
or the kiln were the twelve openings for loading and unloading the individual firing chambers. These chambers were separated from each other by very large metal dampers that could be raised and lowered as the fire moved around the kiln from chamber to chamber. Once the kiln is lit it is allowed to go out, and the sequence of operation is continuous. With the kiln in full operation two chambers will be open, and the other ten sealed up at the door and by the interconnecting steel dampers. If the chambers are numbered from 1 to 12, then bricks are being unloaded from 2 and loaded in 1. The damper is closed between 1 and 12, but opens between all other chambers. Air is drawn through the open door of 2 and through the bricks in 3, 4, 5, and 6, cooling them down and at the same time being heated itself. The temperatures of the chambers increase from 3 to 6, with the temperature at 6 being close to the firing temperature.

Chamber 7 is being fired, with fuel being fed at intervals through the roof, which is immediately ignited by the hot air from 6. The products of combustion pass on to 8, 9, 10, and 11 drying and pre-firing the bricks in these chambers. In 8, the bricks are at the pre-firing stage, and in 11 they are going through the water smoking stage. From 11 the combustion gases pass through the flue and up the central chimney. All the other 11 flues from the other chambers are closed off with dampers. At regular intervals, the firing zone is moved forward and the corresponding changes made to the dampers between the chambers and into the chimney. The chambers being loaded and unloaded move forward in sequence, and this way heat is extracted from the cooling bricks and also from the hot combustion gases.

(b) The modern Hoffmann kiln

The original round Hoffman kiln is no longer in use, having been replaced by the more modern version, which takes the form of two parallel tunnels built side by side, connected by curved tunnels at either end. With such an arrangement, the chimney is built outside the kiln structure and may be connected to more than one kiln. Sixteen chambers are about the minimum for effective working; twenty-two chambers are preferable. The original Hoffmann was superseded, because it had such a large heat absorbing mass, and the tapering firing chambers were small and unnecessarily complicated to load, while the very large damper between chambers was cumbersome and awkward to operate. This damper was replaced by the pasting of a paper or fabric screen between the sections of the firing tunnel as it is loaded. The screen seals the tunnel at this point and prevents cold air being drawn the wrong way round the kiln to the firing zone. The screen is destroyed by the approaching firing zone, at just the right time, as it moves around the kiln. There are now many different designs of continuous kiln, based on the moving firing zone perfected in the Hoffmann kiln, but the basic principle of the moving firing zone, coupled with continuous loading and unloading, remains the same.

Figure 40: Detailed plan of Hoffman kiln



The path of fire travel in the original Hoffmann was circular, later distorted into an ellipse, the arch of the tunnel being supported on the side walls. In order to increase output, continuous kilns with longer circuits through which the firing zone travels more rapidly are built. Two firing zones running simultaneously are possible on the larger kilns. To save space, the firing circuit is bent into a Zig Zag form. Other designs, in which the circuits are built in the form of a T, Y or X, with the chimney in the centre, are also used. In principle, they do not differ from the Hoffmann Kiln, but with a high rate of fire travel, assisted by a strong fan draught system, they are still popular in some countries.

Figure 41: Firing process in Hoffman Kiln

Although Hoffmann kilns use coal as the primary fuel, in Bangladesh they have been modified to use natural gas. This type of fuel creates very low levels of pollution. However, the energy consumption is high compared to other efficient kilns. One of the major deterrents of this technology is the availability of gas and the extremely high capital cost of the kiln. These kilns are suitable for high capacity consumption and high price e.g. in and around Guwahati. They are not feasible in other smaller towns where the demands of bricks are less.

Figure 42: Process of controlling excess air

(c) Achieving firing efficiency

It is important to determine where and how the heat is lost during firing, and to see what measures can be taken to keep them as low as possible. A high proportion of the heat lost is carried away in the combustion waste gases, and, more importantly, a lot of the waste gas heat is carried out by the excess air passing through the kiln. The heat lost through excess air can be as high as 50% of the total heat input. This loss can be measured by monitoring the temperature of the waste gases going up the chimney and comparing it to the fuel: fired brick figures.

The fuel consumed in kilograms per 1000 bricks in a continuous kiln increases from 35 at a waste gas temperature of 100°C to 75 at 300°C with 500% excess air. This figure shows the importance of controlling the excess air: for example, at 200°C, if the excess air is increased from 100% to 800%, for the same rise in temperature, the fuel consumption has to be more than doubled, as most of the available heat from the fuel is going straight up the chimney. If the waste gas temperature falls too low, it is an indication that the draught through the system is impaired. This introduces another set of problems, like inefficient combustion, poor heat distribution and the condensation of flue gases on the unfired bricks, causing discoloration. A flue gas temperature of 100°C is a reasonable temperature to work to, but if the kiln is small, with less than 16 chambers, a temperature this low may not be obtainable. The minimum of excess air is, of course, desirable for maximum efficiency, but some leakage of air is inevitable with such an extensive structure as a continuous kiln.

Figure 43: Features of Hoffman Kilns

The other main source of heat loss is by radiation and convection through the kiln structure. One way this can be reduced is to increase the kiln output, because the radiation and convection of heat remain almost constant, whether the output is high or low. Packing more bricks into the kiln by placing the bricks tightly together does not work, as it tends to decrease the rate of fire travel and leads to a higher percentage of bricks being unevenly fired. There is a best rate of fire travel corresponding to the proportion of solid bricks to gas spaces in the kiln chamber. By reducing the brick stacking density and using a higher draught, the rate of fire travel may be increased, which will result in an increased output. To establish the best and most productive conditions require a lot of experimentation. With barrel arch and chamber kilns, radiation and convection losses from the kiln structure are usually kept down by building the wall a metre or so thick, through which the heat penetrates slowly. It is true that the thicker the walls the more heat is required to raise the kiln to top temperature, but in continuous kilns this heat is largely recovered. A large heat capacity in a kiln structure, however, reduces the rate of natural cooling, so a chamber of fired bricks will be too hot to unload for a long time. Extra insulation on the top of a kiln will reduce the heat and make the working conditions for the kiln stokers more pleasant. It will also reduce the rate of cooling. If lower density insulation material is used to replace high density firebrick, then heat losses will be reduced at the same time as through draught cooling time. This is because of the lower heat absorption and retention of the insulation material.

There is also a case for insulating the base of continuous kilns; less heat will pass into the foundations during high temperatures, so the reservoir of heat that returns into the kiln during cooling would be reduced. On all types of kilns, careful maintenance is the first requisite for efficient working. The brickwork of all kilns must be kept in good repair. Cracks let unwanted cold air in and greatly facilitate heat loss during firing. When the doors of the kilns are sealed up, this should be done with double thickness brick, preferable with an insulation space between them and a good layer of clay slurry plastered across the outside for sealant. Level top firing floors indicate structural soundness and lower heat losses. With intermittent kilns, it is important to see that flues are kept clean, that dampers fit and seal well and that the chamber floors are level and clean. The positioning of the unfired bricks during loading needs to be done accurately, or increased brick wastage will result.

(d) Advantages of Hoffmann kilns:

- They are fuel efficient, because of the direct stoking into the bricks and their use of waste heat to dry and preheat the unfired bricks before firing. Efficiency figures for Hoffmann kilns using coal as a fuel, in England and China, range from 1,800 at best to 2,350 kJ per kg fired brick at worst.
- They have the capacity to fire very large quantities of bricks evenly and with minimal wastage.
- The use of the down or cross draught system, with the fuel being burnt at regular intervals amongst the bricks, provides an even firing throughout the kiln.
- The firing is controllable by the use of the dampers and careful stoking.
- A variety of biomass fuels can be used successfully, for example, sawdust and wood processing waste, rice and coffee husk. These fuels can be added through the roof of the kiln with the use of mechanised fuel charging hoppers that run on compressed air or electricity. This is necessary when burning the biomass fuels that have a higher mass and lower calorific value than other fuels, like coal or coke.

(e) Disadvantages of Hoffmann kilns:

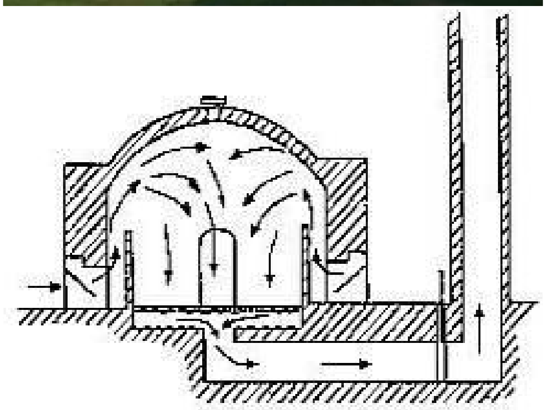
- They have a large mass that absorbs a lot of heat as the firing zone moves forward through the cold kiln. This is compensated by the fact that some of the residual heat in the kiln and fired bricks is used to preheat the air for combustion.
- They are expensive to build and require regular maintenance. Some models are large and complicated structures with very intricate systems of flues and dampers.

- They occupy a lot of space; because of this they are often built in the clay pit after all the usable clay has been extracted, so as not to occupy large areas of clay reserves.
- Direct stoking affects the quality of the bricks directly beneath the stoke holes. These bricks can be over fired and are usually discoloured. This can be avoided by incorporating firing trenches beneath the stoking holes, along the sides and in the centre of the firing chamber. These trenches contain the burning fuel and prevent localised brick spoilage in the kiln. The fitting of firing trenches, however, means that the capacity of the kiln is reduced to produce a higher quantity of evenly fired bricks.

iv. Down draft kiln:

A downdraft kiln consists of three basic structural elements. The firebox, where fuel combustion takes place; the stacking area, where bricks are placed; and the kiln chimney, which includes the flue damper system. Since the basic principle of a downdraft kiln entails directing flame downward inside the kiln, and not upward, the firebox is usually a separate section, located apart from the brick stacking area.

Figure 44: Operating mechanism of down draft kiln



The firebox is usually located on one side of the kiln. The function of the chimney is to create a draft for the flame in the firebox so that the flame is drawn through the bricks in the stack area. The height of the chimney, plus its diameter, is directly related to the size of the kiln if the proper draft is to be created. For the purpose of reduction, fuel back pressure within the kiln is controlled with the damper, which is located at the bottom of the kiln chimney. The damper is handled in much the same way as for updraft kilns, but it is important to understand other characteristics of a downdraft kiln in order to control reduction during the firing cycle.

During firing, time is needed during the early portion of the firing cycle for the firebox area to be heated. This is done before the brick stacking area reaches any substantial temperature. At the onset of a firing it is difficult to acquire even a little draft within the kiln to draw the flame up from the burners because the kiln chimney is at some distance from the firebox. One actual advantage of such a firebox arrangement, however, is that the bricks are protected from being licked by flame in the early part of the firing cycle. Once heat has begun to build up within the kiln, a substantial draft usually occurs if the damper is wide open. As heat continues to build up, the damper is regulated to achieve maximum efficiency.

Since the kiln itself is a retaining box for heat, a system that will generate heat must be provided. One must understand burners and the basic types of fuels that burners use in order to reach a given temperature within the kiln. Kilns constructed with ceramic fibre materials provide such excellent insulation that the heat input needed is considerably less than for conventional brick kilns and there is a resulting saving of fuel. Generally it takes 7-8 days for completing a firing cycle. One day to load the kiln, 2 days to heat to optimum temperature, 1 day for soaking and another 3-4 days for cooling before they can be taken out. The capacity depends on the kiln size and ranges between 12,000 – 25,000 bricks per charge.

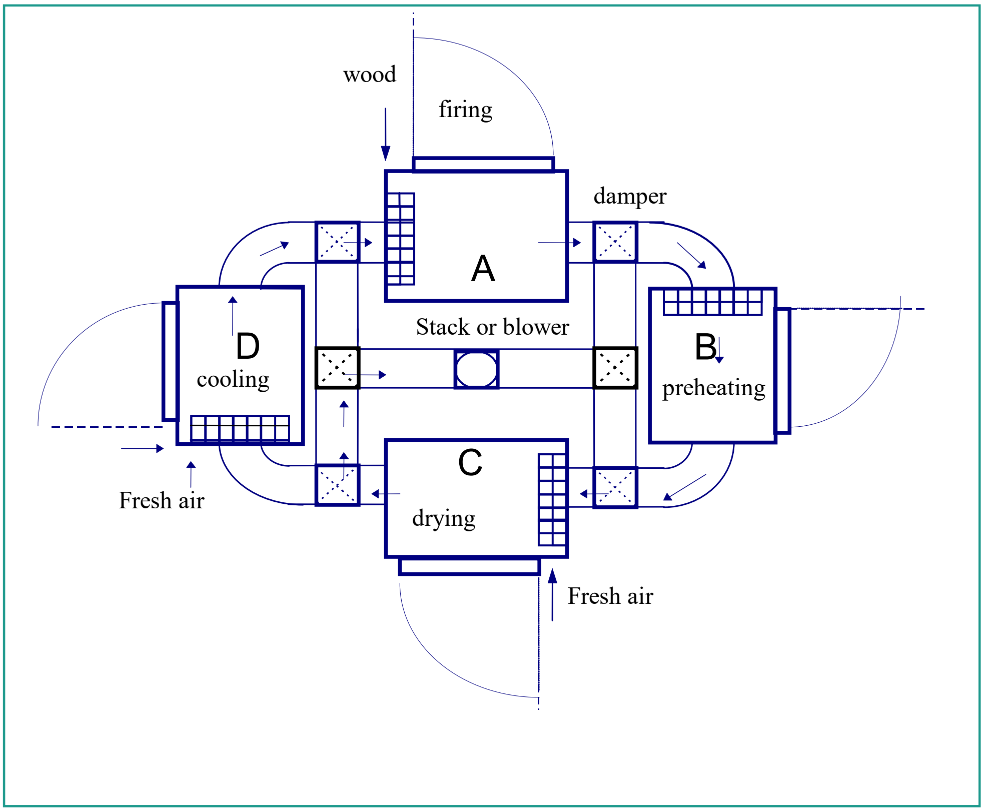
v. Chamber kiln

For not so well educated labourers, there are many technical constraints to be considered in the working of a brick firing kiln. The construction and operation of the kiln must be technically applicable and acceptable by both entrepreneurs and workers. The kiln must be economically feasible and competitive compared to the existing kilns.

Figure 45: Chamber kiln

Energy efficiency is the key word for development and operation of any kiln. Similarly, batch operation is preferable because of the limited production scale to supply local markets only. The fluctuation of brick demand, with the peak always in dry season, makes the batch production more suitable than the continuous process.

Figure 46: Design of chamber kiln



Based on the above-mentioned requirements and constraints, a new kiln has been under operation in India and other countries and is appropriately termed as "Chamber Kiln". The kiln consists of four down-draft chambers which take turns to serve the four processes namely; cooling, firing, preheating and drying. The combustion air of the firing chamber is preheated by the cooling process in the preceding chamber. The exhaust gas from the firing chamber is channelled to preheat and dry the bricks in the next two chambers. Both the bricks and the combustion air are preheated, thus resulting in less firewood consumption in the firing process. Heat lost to the atmosphere is relatively low in comparison to the traditional batch firing. The four chambers are interconnected by a duct network. A blower is installed at the end of the duct to induce draft for the system. After chamber A finishes the firing process, it will become the cooling chamber and later on drying and preheating, and so on for other chambers.

One can imagine that different processes (in the four chambers) required different processing times. The brick temperature in the cooling chamber is reduced from 900 o C to less than 100 o C, while the temperature lift in the firing chamber is from 400 o C to 900 o C. The corresponding figures for the preheating and drying chambers are 100 o C to 400 o C and 30 o C to 100 o C, respectively. There is no doubt that cooling is the longest process. Unless a strategic time matching operation is worked out, the proposed kiln is not functional. The capacity of each chamber is around 2,200 bricks, the production rate is about 50,000-70,000 bricks per month depending on the firing temperature and combustion air flow rate. Moreover, this kiln can be operated by about 3-4 workers all the time. The fuel used is coal. However, waste biomass e.g. rice husk, wheat straw and other biomass can also be used for firing. Thus essentially it is a multifuel kiln.

vi. Tunnel kiln:

Figure 47: Tunnel Kiln

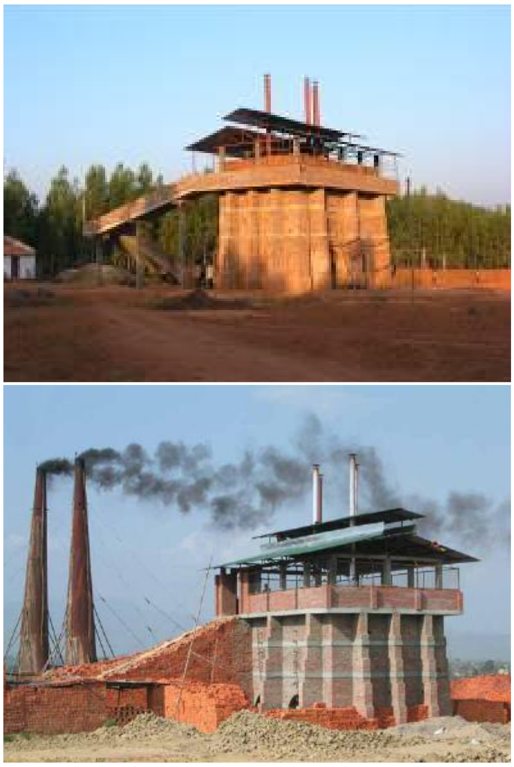
The first version of the Tunnel Kiln was developed in Germany in 1947 taking over from the annular and zigzag type kilns. It is essentially a 50-100 ft. long rectangular chamber lined with high quality refractory bricks. The bricks are loaded from one end in a car at a predetermined pattern. After a fixed interval of time, depending on the firing cycle, a car is pushed from one end, simultaneously taking one car out from the other end of the tunnel. Maximum fire zone is maintained at the middle portion of the tunnel with a heating and a cooling zone. The fuel used is high speed diesel or natural gas. The improvements in the working conditions at a tunnel kiln proved to be a big advantage. There were no more hot and dusty chambers to deal with and workers were no longer exposed to the extreme changes of temperature when loading and unloading the kiln. In winter this could mean working between temperature differences of – 20° C in the storage area to + 50°C inside the chambers. Also of great importance for the future of the brick manufacturing industry is that the tunnel kiln could be ideally used for continuous production operations.

Today's tunnel kiln is a very complex and complicated high-tech type of system, so much so that it has been partly forgotten that a relatively simple tunnel kiln can be built that still produces very good bricks. Tunnel kilns are most widely used in Vietnam in state sponsored units due to their extremely high investment cost. However, tunnel kilns are economical for firing low mass bricks i.e. at least 40% hollow bricks. Firing of solid bricks is not economical in a tunnel kiln.

vii. The Vertical Shaft Brick Kiln

Vertical Shaft Brick Kiln (VSBK) technology is an energy efficient technology for firing clay bricks. It is particularly suited to the needs of brick production in developing countries – which is small scale and decentralised type. The evolution and initial development of VSBK technology took place in rural China. The first version of VSBK in China originated from traditional updraft intermittent kiln during 1960's. During the 70's, the kiln became popular in several provinces of China. In 1985, the Chinese government commissioned the Energy Research Institute of the Henan Academy of Sciences at Zhengzhou (Henan province), to study the kiln to improve the energy efficiency. The institute came up with an improved design of VSBK in 1988 which had a higher shaft height and provisions for a pair of chimneys. About 50,000 VSBKs were estimated to be operating in China during 1996. Various attempts to disseminate VSBK technology outside China started in the early 1990's. It was demonstrated in several Asian countries such as Nepal, Afghanistan, Pakistan and Bangladesh. However, no appreciable success was reported in the external domain to document factors of success.

Figure 48: Vertical shaft brick kiln



VSBK in India was launched in 1995 by the Swiss Agency for Development & Cooperation (SDC) as a project on introducing sustainable production systems for building materials. The factors that have contributed towards its successful adoption in India was its suitability for decentralised production systems and positioning as a means of improving the product quality thus ensuring higher returns of investment. Simple mechanisation was implemented for unfired brick making, material handling, transportation and extrusion of unfired bricks. Internal fuel in the form of coal, biomass and sawdust is added during the moulding of unfired bricks – this creates highly favourable conditions for short cycle firing.

Thus within a span of 5 years (2000 – 2005) more than 100 VSBK's were established in a commercial mode. The qualities of bricks were accepted in the market at a premium. Most of the entrepreneurs were satisfied with the flexibility and performance of the kiln. This was reiterated by the increasing investment in selective mechanisation and capacity augmentation.

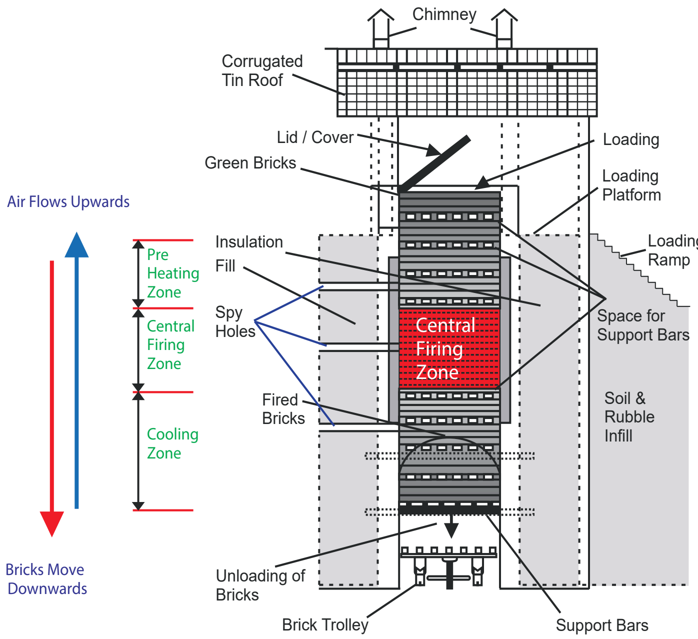
After the commercial success of VSBK in India as a viable alternative to traditional brick making with huge potential to energy and environment savings, VSBK technology was reopened in Nepal. The programme is being implemented by Skat Consulting in association with Development Alternatives and HMG, Nepal. Under this technical support programme, two pilot kilns were constructed and successfully implemented by 2004. Initial operation achieved a 30% reduction in energy consumption and around 80% reduction in emission parameters.

Encouraged by positive results, HMG, Nepal banned the operation of movable chimney BTK's and has also initiated legal and administrative action to convert the existing polluting brick kilns into energy efficient and less polluting technologies. A high level of awareness on economics of VSBK business has also been created amongst brick producers.

Kiln description and working principle

VSBK has a vertical shaft of rectangular or square cross-section. The gap between the shaft wall and outer kiln wall is filled with insulating materials – broken bricks and burnt coal ash. The kiln works as a counter-current heat exchanger, with heat transfer taking place between the air moving up (continuous flow) and bricks moving down (intermittent movement). Unfired bricks are loaded in batches from the kiln top. Bricks move down the shaft through brick pre-heating, firing and cooling zones and unloaded from bottom. The combustion of coal (added along with bricks at the top) takes place in the middle of the shaft. Combustion air enters the shaft from bottom, gets preheated by hot fired bricks in the lower portion of the shaft before reaching the combustion zone. Hot combustion gases preheat unfired bricks in the upper portion of the shaft before exiting from the kiln through the shaft or chimney.

Figure 49: Working principle of VSBK



The brick setting in the kiln is kept on support bars at the bottom of the shaft. Unloading of bricks is done from the bottom of the shaft using a trolley. The trolley is lifted (using a single screw mechanism) till the iron beams placed on the trolley touches the bottom of the brick setting and the weight of bricks is transferred onto the trolley. The freed support bars are taken out. The trolley is then lowered by one batch (equivalent to 4 layers of bricks) – support bars are again put in place through the holes provided in the brick setting for the purpose. With slight downward movement, the weight of the brick setting is transferred to support bars. The trolley (with one batch of fired bricks on it) is further lowered till it touches ground level and then pulled out of the kiln on a pair of rails provided for the purpose. Every 2 - 3 hours, one batch of fired bricks is unloaded at bottom and a batch of fresh unfired bricks is loaded at the top simultaneously. At any given time, there are typically 11 to 12 batches in the kiln depending on the unfired brick quality.

Two chimneys located diagonally opposite to each other in the shaft remove flue gases from the kiln. A lid is also provided on the shaft top which is kept closed during normal operation. Flue gases are directed to pass through chimneys thus not polluting the working area on the kiln top. The provision of shaft lid, better ventilation of the working area on kiln top and higher and bigger chimneys are some of the highlights of VSBK kiln and its related process.

The heating cycle for the unfired bricks is raw material specific (pre-heating, vitrification and cooling down) and is normally completed within 24-30 hours. A batch of bricks is loaded and unloaded every 2-3 hours, requiring round the clock operations and supervision. This requires special skills and the firing operator needs to maintain a correct balance between:

Energy
Controlled by amount of coal feeding

Airflow
Controlled by stacking density and damper position

Unloading speed
Controlled by the operator

CASE STUDY

Brick sector in Bihar

Bihar has been demonstrated as a successful example in adoption of alternate technologies in the brick sector. Besides the uptake of fly ash bricks in the state, the transition of existing FCBTK kilns to zig zag kilns has also been making much headway. Infact, almost half (43%) of the existing kilns have been converted to zig zag. This offers a very promising picture for the emissions reduction targets for the state.

A mapping exercise of the brick kilns in Bihar was conducted based on which the following data has emerged. Note that the map below merely identifies the location of the kilns . Further investigation and zooming in will reveal the detailed numbers of the kilns around these clusters. These have been mapped through ground verification, the details of which have been enlisted in the subsequent Table

Figure 50: Location of brick kilns operating in Bihar as of year 2022

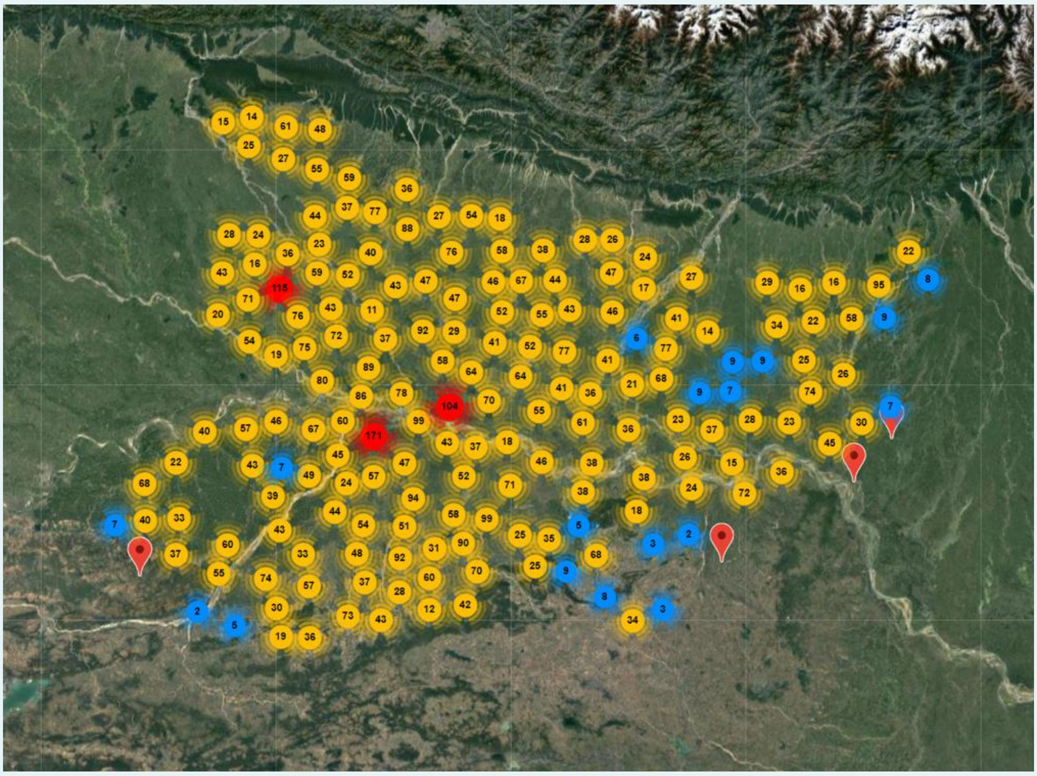


Table 16: District wise classification of kilns operational in Bihar as of 2022

District wise - Technology classification				
District wise - Technology classification	**FCBTK**	**uncertain**	**ZigZag**	**Grand Total**
Araria	23	2	83	108
Arwal	53	3	7	63
Aurangabad	174	16	62	252
Banka	3	4	3	10
Begusarai	28	8	119	155
Bhagalpur	56	6	95	157
Bhojpur	89	10	112	211
Buxar	72	10	67	149
Darbhanga	71	21	200	292
Gaya	314	47	132	493
Gopalganj	177	22	46	245
Jamui	79	17	66	162
Jehanabad	84	21	18	123
Kaimur (Bhabua)	103	8	61	172
Katihar	19	1	118	138
Khagaria	17	13	46	76
Kishanganj	14	8	168	190
Lakhisarai	23	5	29	57
Madhepura	37	16	69	122
Madhubani	120	11	178	309
Munger	16	1	30	47
Muzaffarpur	144	21	175	340
Nalanda	175	13	64	252
Nawada	214	8	54	276
Pashchim Champaran	160	4	83	247
Patna	151	109	240	500
Purba Champaran	321	14	91	426
Purnia	31	4	116	151
Rohtas	97	13	57	167
Saharsa	53	3	66	122
Samastipur	177	6	78	261
Saran	185	7	198	390
Sheikhpura	25	4	14	43
Sheohar	14	2	14	30
Sitamarhi	75	28	153	256
Siwan	193	15	96	304
Supaul	42	3	43	88
Vaishali	200	5	90	295
Grand Total	3829	509	3341	7679

5.3 Comparative analysis of alternative technologies

It is apparent that most technologies being practised in India and neighbouring countries with conditions similar to Assam will not be suitable for adoption. Based on the technology briefed above, to decide the best suitable kiln type for Assam some basic criteria were decided. These criteria were based on technical suitability and performance economics. Thus the following criteria were assumed during the technology selection:

i. Production capacity

Considering the market and the socio-economic fabric of Assam it is well defined that all and any type of brick production has to be of medium scale and not of very high capacity unlike the brick production usually followed in the Indo Gangetic plains of Uttar Pradesh, West Bengal, Punjab, Haryana and Bihar.

ii. Fuel type

Any fuel can be used for brick firing except "non-renewable". However, gas or high-speed diesel availability is not feasible in Assam. Thus, the only fuels used for brick firing technologies have to be only coal or waste biomass in pelletized form.

iii. Product quality

The product quality is of very high concern in Assam and should necessarily fulfil the existing market standards. Therefore, the bricks should be of uniform shape and size with acceptable strength suitable for construction as per the local codes. In this respect, the feasibility of using compressed earth blocks may be explored depending upon the rainfall and humidity conditions. While CEB is not recommended in areas of high rainfall due to the adverse effect of humidity on the comprehensive strength of bricks , it may however be used in areas with low to medium humidity.

iv. Investment capacity

With the Covid-19 conditions the investment capacity of entrepreneurs has reduced. In Assam the brick consumption is restricted to a couple of areas and is not very high. Brick activity cannot be taken up for extended seasons due to climatic conditions. Although entrepreneurship initiatives are also picking up however under present conditions any technologies should be of low to medium investment and not the high end one.

v. Carbon market

Any technology to be adopted in Assam should be energy saving and less polluting. With the savings in greenhouse gases, the technology should be able to mitigate climate change thereby creating a possibility of earning carbon credits.

vi. Feasibility of utilization of Industrial Hazardous and Other Waste including Drilling mud, drill cuttings

Various types of industrial wastes are available in Assam. They range from boiler ash from foundry, steel re-rolling, agri-processing industry to even bentonite clays from the oil well drilling industry. The boiler ash is an important additive that can be used for various types of brick making depending on the calorific value. If of low calorific value i.e. < 1000 KCal/kg then it can be used for lime gypsum based bricks. If higher then it will be a good raw material for addition as internal fuel replacing the coal.

Generally the oil well drilling mud has a composition of bentonite and other smectite rich plastic clays. They also contain an appreciable amount of crude oils and other drilling fluids.

These can be a good source of brick making clays. It is expected to consume much less energy and produce a high quality bricks due to the inherent plastic properties of the clayey soil being used. However the amount of waste availability needs to be assessed through a study along with the economics of production.

Table 17: Decision making matrix

Decision making matrix					
Criteria		**Brick firing technologies**			
		FCBTK	**Zig Zag kiln Forced draught**	**Zig Zag kiln Natural draught**	**Bench mark for Assam context**
Capacity of kiln		High	High	High	Medium-low
Type of fuel		Variable	Fixed	Fixed	Coal/biomass
Fuel switch facility		Yes	No	No	No
Homogeneity of temperature		High	High	High	High
Energy requirement /kg brick		High	Moderate	Moderate	Low - Very Low
Heat recovery for drying		Yes	Yes	Yes	High - Moderate
Capable to produce	Roofing tiles	Yes		Yes	NA
	Hollow bricks	Yes		Yes	Yes
	Solid bricks	Yes		Yes	Yes
	Floor tiles	Yes		Yes	NA
Emissions to atmosphere		Moderate	Moderate	Moderate	Low
Workplace emissions		Moderate	Moderate	Moderate	Low
Possibility of fulfilling emission norms		Moderate	High	High	High
Requirement of quality unfired brick		Low	Low	Low	High
Product quality		Good	Good	Good	High
Monthly production		High	High	High	Moderate
Land requirement		High	High	High	Low
Ability to operate throughout the year		No	No	No	Yes
Production losses		Low	Low	Low	Low
Investment		Medium	Medium	Medium	Low - medium
Return on investment		Medium	Medium	Medium	Fast
Organisational requirements		High	High	High	High
Local capacities for construction		No	No	No	Yes
Availability of materials for construction		Yes	Yes	Yes	Yes
Experience of implementation		No	No	No	Yes
Valid PDD		No	No	No	Yes
Total positive points		**7**	**10**	**10**	

Criteria		Brick firing technologies			
		Hoffmann	Down draught	VSBK	Benchmark for Assam context
Capacity of kiln		High	High	Variable	Medium-low
Type of fuel		Variable	Variable	Fixed	Coal/biomass
Fuel switch facility		Yes	Yes	No	No
Homogeneity of temperature		High	High	High	High
Energy requirement /kg brick		Moderate	Moderate	Very low	Low - Very Low
Heat recovery for drying		Yes	Yes	Yes	High - Moderate
Capable to produce	Roofing tiles	Yes	No	Yes	NA
	Hollow bricks	Yes	Yes	Yes	Yes
	Solid bricks	Yes	Yes	Yes	Yes
	Floor tiles	Yes	No	Yes	NA
Emissions to atmosphere		Moderate	Moderate	Low	Low
Workplace emissions		Moderate	Moderate	Low	Low
Possibility of fulfilling emission norms		High	Moderate	Very high	High
Requirement of quality unfired brick		Low	Low	High	High
Product quality		Good	Good	Good	High
Monthly production		High	High	Variable	Moderate
Land requirement		High	High	Low	Low
Ability to operate throughout the year		Yes	Yes	Yes	Yes
Production losses		Low	Low	Low	Low
Investment		Very high	Medium	Medium	Low - medium
Return on investment		Medium	Medium	Medium	Fast
Organisational requirements		High	High	High	High
Local capacities for construction		No	No	No	Yes
Availability of materials for construction		Yes	Yes	Yes	Yes
Experience of implementation		No	No	No	Yes
Valid PDD		No	No	Yes	Yes
Total positive points		**8**	**8**	**17**	

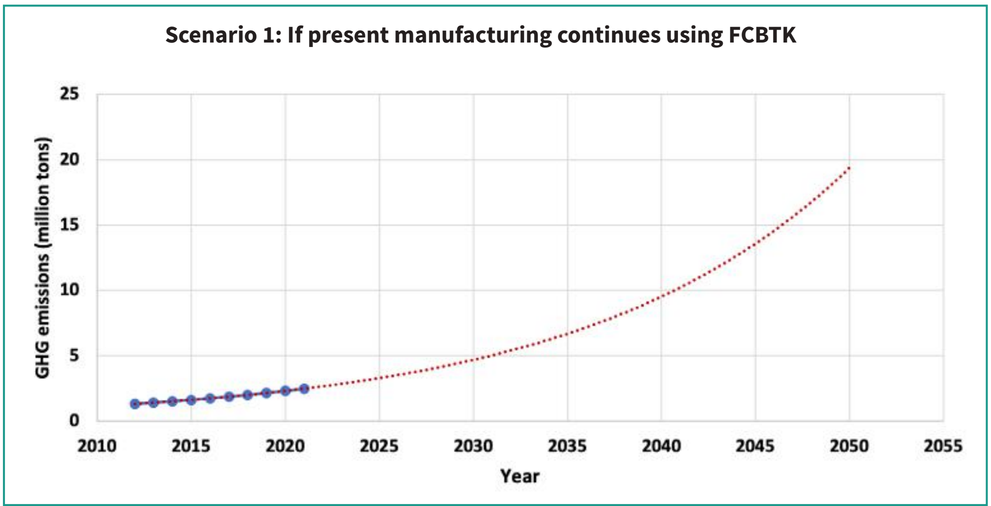
Criteria's		Brick firing technologies			
		Internal fuel	CEB	Fly ash block	Bench mark for Assam context
Capacity of kiln		High	Low	Low	Medium-low
Type of fuel		Variable	Nil	Nil	Coal/biomass
Fuel switch facility		Yes	NA	NA	No
Homogeneity of temperature		High	NA	NA	High
Energy requirement /kg brick		Low	Very low	Very low	Low - Very Low
Heat recovery for drying		Yes	NA	NA	High - Moderate
Capable to produce	Roofing tiles	Yes	Yes	Yes	NA
	Hollow bricks	Yes	Yes	Yes	Yes
	Solid bricks	Yes	Yes	Yes	Yes
	Floor tiles	Yes	Yes	Yes	NA
Emissions to atmosphere		Moderate	Nil	Nil	Low
Workplace emissions		Moderate	Nil	Nil	Low
Possibility of fulfilling emission norms		High	Very high	Very high	High
Requirement of quality unfired brick		Low	NA	NA	High
Product quality		Good	Good	Good	High
Monthly production		High	Low	Low	Moderate
Land requirement		High	Very low	Very low	Low
Ability to operate throughout the year		Yes	Yes	Yes	Yes
Production losses		Low	Low	Low	Low
Investment		Very low	Very low	Low	Low - medium
Return on investment		Very high	Medium	Very high	Fast
Organisational requirements		High	Low	Low	Low
Availability of replicas		Difficult	Difficult	Easy	Easy
Availability of materials for construction		Yes	Yes	Yes	Yes
Experience of implementation		No	No	Yes	Yes
Valid PDD		No	No	Yes	Yes
Total positive points		**12**	**13**	**13**	

5.4 Scenario Building for GHG Emissions

Furthering our findings from the above study on brick kiln GHG emissions, computational analysis was undertaken to arrive at a realistic projection of emissions under different scenarios. The same has been enumerated and mapped in Figure 33. An analysis of findings from the scenario cases is presented in the summary section below.

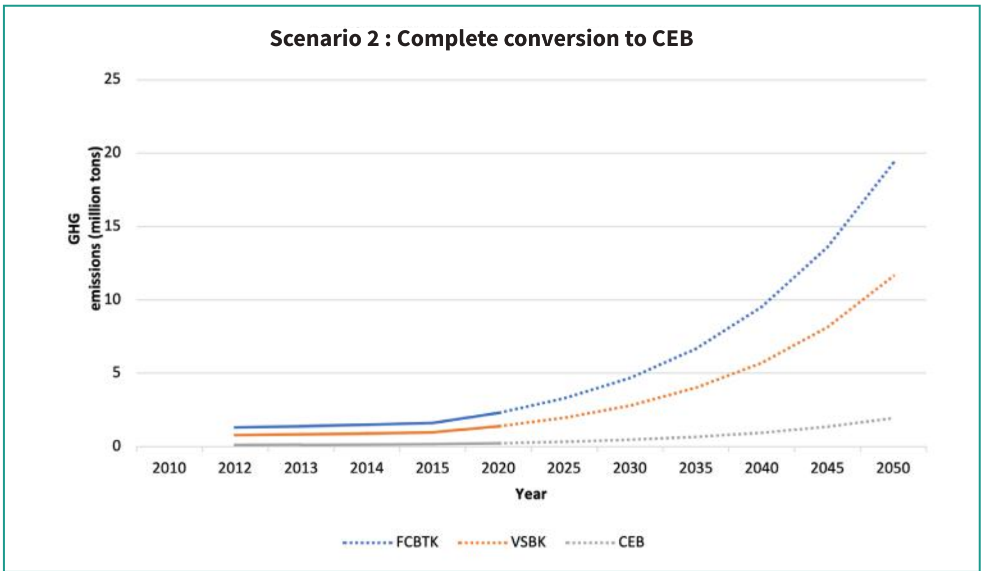
Scenario 01: The following projection is computed using a cumulative compound annual growth rate (CAGR) of 7.3% which is the annual average of the Indian construction industry and business as usual i.e. no replacement of FCBTK by alternate technology, the total GHG emission from brick kilns only will reach around 46.87 tons per year by 2030 and 193.60 tons per year by 2050.

Figure 51 : Graph depicting projected estimate of GHG emission under scenario 1 i.e. if present brick manufacturing continues using FCBTK.



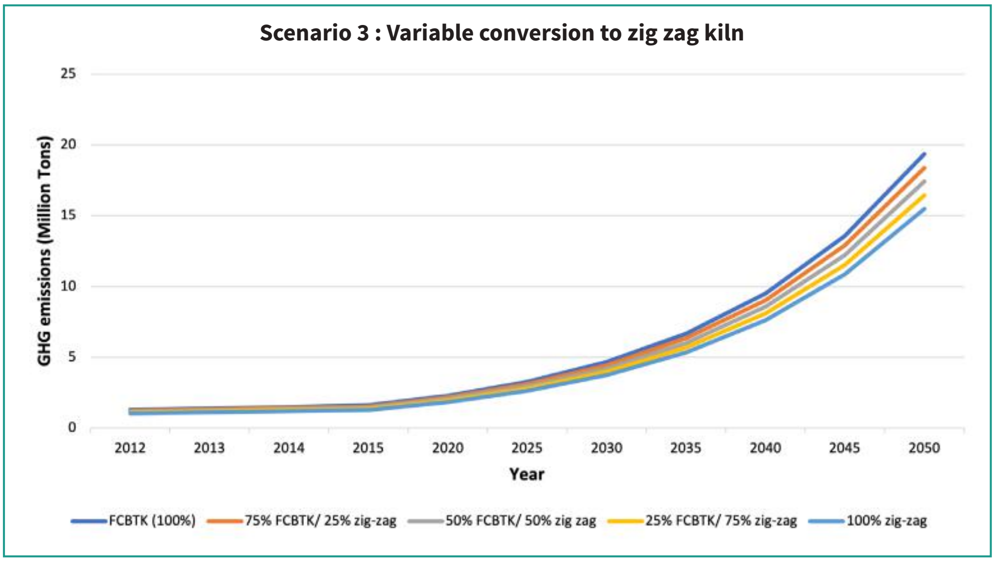
Scenario 02: The following projection shows the comparative GHG emissions in lakh tons of the different technologies in comparison to the existing brick technology of FCBTK kiln. It can be seen from the graph below that a 100 percent conversion to compressed earth block making would lead to the maximum reduction of GHG emissions and is the most ideal technology.

Figure 52: Graph depicting projected estimate of GHG emission under scenario 2 i.e. if present brick manufacturing is completely replaced by CEB



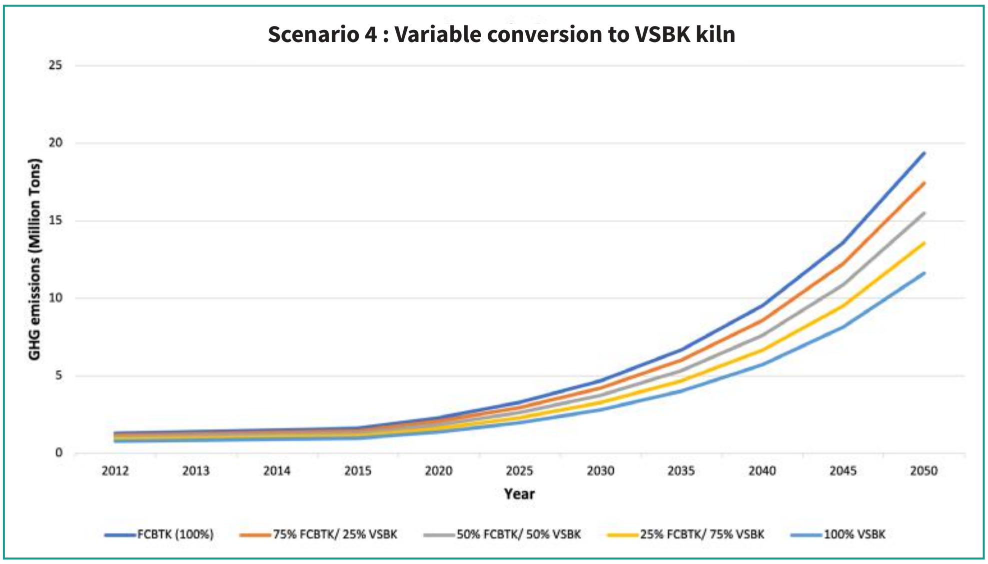
Scenario 03 : The following projection shows the comparative GHG emissions of partial conversion of FCBTK kiln technologies with zig zag kilns.It can be seen from the graph below that a 100 percent conversion to zig zag kiln would be the most ideal for reducing GHG emissions as compared to FCBTK which is currently used.

Figure 53 : Graph depicting projected estimate of GHG emission under scenario 3 i.e. if present brick manufacturing through FCBTK undergoes gradual and partial conversion with zig zag kiln.



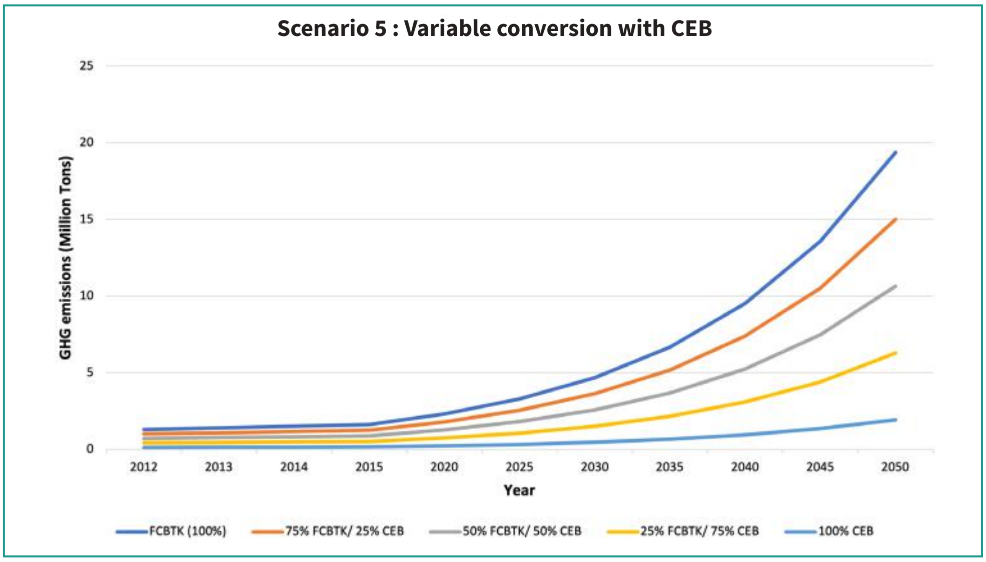
Scenario 04: The following projection shows the comparative GHG emissions of partial conversion of FCBTK kiln technologies with VSBK .It can be seen from the graph below that a 100 percent conversion to VSBK would be the most ideal for reducing GHG emissions as compared to FCBTK which is currently used.

Figure 54 : Graph depicting projected estimate of GHG emission under scenario 4 i.e. if present brick manufacturing through FCBTK undergoes gradual and partial conversion with VSBK.



Scenario 05: The following projection shows the comparative GHG emissions of partial conversion of FCBTK kiln technologies Compressed earth blocks as a brick technology.It can be seen from the graph below that a 100 percent conversion to CEB would be the most ideal for reducing substantially the GHG emissions as compared to FCBTK which is currently used.

Figure 54: Graph depicting projected estimate of GHG emission under scenario 5 i.e. if present brick manufacturing through FCBTK undergoes gradual and partial conversion with CEB.



5.5 SUMMARY

It is evident from the comparative analysis of alternative technologies against conventional practices that the environmental impact and economic feasibility of certain technologies is more suited for Assam. The criteria setting and decision making matrix provides a clear path for transforming the brick sector in favour of VSBK and zigzag as the kiln type, and compressed earth block as brick type, while internal fuel or coal and waste biomass in pelletised form may be used to for optimisation of the firing process.

This is substantiated through the following learnings of the research: VSBK scores the highest positive points in brick firing technologies (17) while Zig Zag kiln comes in second in both, natural and forced draught with a score of 10. In terms of brick type, both CEB and flyash score similar positive points (10).

It can also be seen from the scenarios presented for GHG emissions reduction that completely replacing FCBTKs with a zig zag kilns can lead to a reduction of almost 20% in GHG emissions annually, compared to almost 40% reduction with complete conversion to VSBK. However, the maximum reduction in GHG emissions can be seen in conversion from FCBTK to CEB making with potential 90% savings. Hence, it can be seen that out of all the options, CEB offers the maximum decarbonising and emission reduction potential.

With respect to their applicability to the size and scale of enterprises, all these proposed alternatives are most suited for medium to small scale brick producing enterprises. While the adoption of these new technologies requires consistent training and capacity building, they score well above conventional technologies with respect to energy consumption, environmental emissions and return on investment. In comparison to FCBTK on the initial investment required, VSBK has the ability to produce consistent quality bricks getting higher returns which is a more sustainable trade off in the long term, both from the prospect of financial recovery and for achieving higher productivity.

The complete transformation of the brick making sector needs to consider strategies for long-term, medium-term and short-term action considering the findings from the comparative analysis based on the decision-making matrix as well as the scenario building graphs for GHG emission reduction potential. The policy pathways for this transition must critically consider all social, environmental and economic parameters to ensure the balancing of both demand and supply side factors and the readiness of the enterprises as well as the markets.

In order to ensure easy adaptability of these technologies, business plans for the selected technologies have been given in Annex 4, 5 and 6. These have been formulated after thorough ground research into financial and technical research to arrive at replicable business models for small and medium enterprises and entrepreneurs.

5.6 Enabling Access to Finance for Transitioning to Green Brick Production

Transitioning to greener brick production from the current FCBTK technologies being currently practiced in Assam requires a major shift in the technologies, infrastructure and skills of the brick manufacturers, which necessitates availability of finance to enable the transition since most brick production in the state is presently carried out by micro and small enterprises.

Considering the substantial size of the MSME sector in India and the numerous challenges faced by such entrepreneurs, many government schemes and programmes have been initiated to support them. Such initiatives seek to address the various needs of MSMEs including improving access to finance and credit, providing infrastructure support, supporting technology upgradation and green certification, marketing and web services, as well as skill development and training.

To promote entrepreneurship in the brick production sector, several government schemes promoting local manufacturing activities can be leveraged to facilitate finance for both capital and operational expenses. Specific schemes are also targeted towards women entrepreneurs and vulnerable groups. Some possible opportunities for enabling access to finance as per their specific needs for transitioning to greener brick production in Assam have been listed below:

5.6.1 PRADHAN MANTRI EMPLOYMENT GENERATION PROGRAMME (PMEGP)

This initiative aims to generate employment opportunities in rural as well as urban areas of the country through enhancing access to finance for new self-employment ventures/ projects/micro enterprises with collateral free loans up to INR 10 lakhs while requirement for collateral guarantee for loans above INR 10 lakhs may be supported by Credit Guarantee Trust for Micro and Small Enterprises (CGTMSE). The scheme is implemented by Khadi and Village Industries Commission (KVIC) as the nodal agency at the national level and through state bodies, District Industries Centres (DICs) and banks at the state level.

5.6.2 PRADHAN MANTRI MUDRA YOJANA (PMMY) | MICRO UNITS DEVELOPMENT & REFINANCE AGENCY LTD. (MUDRA)

MUDRA loans are extended to eligible applicants under the Pradhan Mantri Mudra Yojana (PMMY). Micro Units Development and Refinance Agency Ltd. (MUDRA) is a refinance agency which extends loans to Commercial Banks, Regional Rural Banks (RRBs), Small Finance Banks, Micro Finance institutions (MFIs) and Non-banking finance corporations (NBFCs) which then further provide loans to individuals. Within MUDRA there are three kinds of loans – Shishu, Kishore and Tarun to signify the stage of growth and funding needs of the beneficiary micro unit or entrepreneur.

- Shishu: loans up to INR 50,000
- Kishor: loans above Rs.50,000 and up to Rs.5 lakh
- Tarun: loans above Rs.5 lakh and up to Rs.10 lakh

5.6.3 STAND-UP INDIA

The Stand-Up India scheme was launched to support SC/ST entrepreneurs and women entrepreneurs in setting up enterprises, & obtaining loans and other support needed from time to time for succeeding in business. Composite loans (inclusive of term loan and working capital) are provided between Rs.10 lakh and up to Rs.100 lakh representing up to 75% of the project cost.

5.6.4 MAHILA UDYAM NIDHI YOJNA

Under Mahila Udyam Nidhi Yojana (MUNY), women entrepreneurs may obtain loans from public and private sector banks to undertake small/micro business for upto 25% of project cost, with maximum project cost limited to INR 10 lakhs.

5.6.5 UDYAM NIDHI YOJNA

Under the Udyam Nidhi Yojana (UDY), National Scheduled Castes Finance And Development Corporation (NSFDC) offers loans to eligible Scheduled Caste persons to undertake small/ micro business. Loans are offered under this scheme through Cooperative Societies and Cooperative Banks (Channelling Agencies) to pursue small/micro operations that meet the needs of the recipients with loans limited to 90% of the project cost.

5.6.6 CGTMSE | Credit Guarantee Fund Trust for Micro and Small Enterprises

The Ministry of Micro, Small and Medium Enterprises (MoMSME), Government of India (GOI) and Small Industries Development Bank of India (SIDBI) set up the Credit Guarantee Fund Trust for Micro and Small Enterprises (CGTMSE) to strengthen collateral-free credit. Additionally, to enable the possibility of lending composite credit to the borrowers so that they can get both a term loan and working capital from a single source. Under this initiative, new and existing Micro and Small Enterprises engaged in manufacturing and services can avail loans up to INR 2 crores and retail trade up to INR 1 crore.

5.6.7 Micro and Small Enterprises- Cluster Development Programme (MSE-CDP)

This scheme was launched to support the sustainability and growth of MSMEs by addressing common issues such as improvement of technology, skills & quality, market access, to create/ upgrade infrastructural facilities in the new/existing industrial areas/clusters of MSEs, to set up common facility centres (for testing, training, raw material depot, effluent treatment, complementing production processes, etc.), and promotion of green & sustainable manufacturing technology for the clusters.

5.6.8 Credit Linked Capital Subsidy for Technology Upgradation (CLCS-TU)

The Credit Linked Capital Subsidy Scheme is a scheme run by the Ministry of Small Scale Industries (SSI) to help Small Scale Industries upgrade their production equipment (plant and machinery) by giving an upfront capital incentive. The Small Industries Development Bank of India (SIDBI) and the National Bank for Agriculture and Rural Development (NABARD), and nine Public Sector Banks/ Government Agencies act as the Nodal Agencies for the implementation of this scheme.

5.6.9 Sustainable Finance Scheme

The Small Industries Development Bank of India (SIDBI) launched the Sustainable Finance Scheme, to fund sustainable development projects that contribute to energy efficiency and cleaner manufacturing but are not covered by international or bilateral lines of credit. Suitable assistance is provided using term loans or working capital loans to cover all sustainable development projects, including renewable energy projects, Bureau of Energy Efficiency (BEE) star ratings, green micro-finance, green buildings, and eco-friendly labelling, among others.

5.6.10 10. Lean Manufacturing Competitiveness Scheme (LMCS)

Under this scheme, MSMEs are assisted in reducing their manufacturing costs, through personnel management, better space utilization, scientific inventory management, improved process flows, reduced engineering time and so on with the application of LM (lean manufacturing) techniques. The Scheme is basically a business initiative to reduce “waste” in manufacturing. Existing MSMEs are required to form a Mini Cluster (6-10 units) (These units would work with the assigned LMC to implement the specific LM techniques). Mini clusters (MCs) are required to formalize their association by forming a SPV.

5.6.11 ZED Certification Scheme - Zero Defect Zero Effect

This scheme was launched to raise MSMEs’ knowledge of ZED (zero defect, zero effect) manufacturing, push them to assess their businesses for ZED, and provide them with support. Following a ZED assessment, MSMEs can significantly cut waste, enhance productivity, expand their market etc. All the Udyog Aadhar Memorandum (UAM) registered manufacturing MSMEs are eligible to apply for ZED registration. A self-declaration / undertaking is to be given by the MSME willing to obtain the ZED certification.

The certification helps in providing a competitive edge in public procurement because of certificate of excellence and national recognition. Incentives under the scheme include reimbursement of 80% for Micro, 60 % for Small and 50% for Medium for ZED Certification of level 2 and 3 (silver, gold), 80% of the cost of consultancy reimbursed by Ministry of MSME, subject to an upper ceiling fixed for level 4 and 5 (Diamond and Platinum)


26/08/2021

6

Conclusion, recommendations and way forward

This chapter suggests recommendations and the way forward for greening the brick sector in Assam based on the key findings of the pre-feasibility study. These recommendations are grounded on secondary research and field studies conducted by the team in the main centres of brick production in Assam. Based on the discussions and studies conducted at ground level with the brick producers, local entrepreneurs and government bodies in Assam, limitations were identified. The recommendations and way forward being proposed are in keeping with the local context and practical challenges faced by the producers and some key areas of intervention have been identified for sustainably developing the brick sector in Assam. These are enumerated in the subsequent sections.

6.1 Approach for sectoral transformation

It has emerged from this study that in order to operate a successful brick business in Assam, the three most essential criteria to be fulfilled are adequate capital, efficient entrepreneurship/management approach and a sustained market demand for the product. The same criteria extends to introduction of any new production methodology, system or technique in the state.

However, none of this can take place without an enabling environment, promoted by the key stakeholders i.e the brick producers on one hand and policy makers on the other. While the former is driven by profitability, the latter looks at all-round sustainability. Both their intentions need to be met in order to sustain growth and greening of the brick sector.

Hence four criterias emerge, which, once fulfilled, can ensure profitability for the brick producing enterprise. The same holds true for introducing any new techniques, methodologies or processes. For successful acceptance and adaptation of technologies and methodologies, a crucial role needs to be played by key players of brick producers and policy makers. While the brick producers' sole intent is profitability, policy makers look at long term sustainability.

In this respect, it must be noted that while introducing any new methodology, some resistance is to be expected and even prepared for. A more appropriate approach in such a scenario would be to target local needs, aspirations, socio-economic and behavioural change in all stakeholders. This involves a paradigm shift in mindsets which can be achieved through extensive awareness campaigns, widespread demonstration of technologies, training, capacity building and sustained technology support to the entrepreneurs, workforce and government agencies. Such an approach ensures a conducive environment for conducting pilot or demonstration studies since the stakeholders would be better equipped to receive new technology and inputs.

With respect to the technology and process, brickmaking is still largely a manual and labour intensive activity in Assam, associated with long working hours and occupational hazards. It is however envisaged that mechanised brick production will be introduced in Assam in a big way to cater to the challenges faced by entrepreneurs from skilled moulders. In fact the local soil is also most appropriate for mechanised brick making. Thus, attempts must be made to usher in various green and mechanised brick production at an appropriate time.

Other than these, systemic change in the technology and brick production process as a whole is an equally crucial determinant for any new initiative to sustain. Experiences in other states of the country indicate that in the brick sector any technology transfers should not only include improved firing methods and technologies but incremental changes in the entire production system. It should not only be seen as a short time investment of commercial approach but a long term development strategy demonstrating success, thereby creating sustainable demand. Simultaneously supply services should be matured enough to meet the demand in commercial terms. Thus the project should and will possess the skills of timely intervention and appropriate withdrawal from the developmental approach to a more commercial environment.

With the above in mind it is imperative that the initiatives and interest created be sustained through a demonstration initiative. Given that demand has already been created in the minds of entrepreneurs at Bongaigaon and Nagaon, it must be acted upon by demonstration of the pilot kiln and strengthened through favourable policy directives. This initiative needs to be carefully nurtured and developed over the next couple of years.

Coming to the management of brick producing enterprises and businesses, efficiency and competency is key. Unfortunately this aspect is not given due importance in the existing units since it is presently associated with relatively simple technology ,lacking a robust business strategy to withstand any external shocks. It must be emphasised that unlike a standard commercial business practice with its contingency plans in place, a brick production unit in remote areas of Assam is ill-equipped to withstand comparable setbacks by virtue of its location, access to technology, knowledge or entrepreneurship environment.

Management, in this regard, entails planning, organising, staffing and controlling the production such that the bricks can be produced within budget and sold profitably. This is achieved by ensuring good financial , logistics , human resource management, production process management etc. as elaborated below :

- Production process management
    - Adequate and timely supplies of raw material
    - Maintenance of equipment
    - Quality control of raw material, process and finished product
    - Smooth flow of production
- Financial management
    - Adequate financial arrangements for wages and general purchases
    - Good bookkeeping system
- Human resource management
    - Suitable recruitment and training of skilled personnel
    - Specific tasks and roles for each staff
    - Periodic skill upgradation
    - Good human behaviour
- Conducive work environment equipped with sanitary facilities for workers, ensuring their safety and comfort and in accordance with building codes.

In addition to the above, good management also extends to efficiently managing the workforce, its morale and participation in the process, especially since the current practices are dependent on labour productivity. To achieve this, an equitable business strategy which links and redistributes the enterprise’s surplus profits with the productivity and performance of the workforce would motivate the workforce, especially in the case of Assam.

6.2 Recommendations and way forward

Based on the findings, conclusions and inferences drawn from this study, major areas of intervention have been identified, both for the short term and subsequently for the long term. Once addressed, it shall help resolve the bottlenecks and challenges faced in greening the brick sector in Assam. The recommendations proposed in this respect are essentially hinged upon technical improvement and data collection to further research in the short term while institutional, social, structural and systemic transformation is proposed for the long term approach. These are explained in detail below:

6.2.1 Recommendations for mapping and data collection:

In order to address the existing data gaps in the brick making sectors in the state, it is essential to establish robust data collection and management mechanisms to ensure ready availability of information on the production and consumption trends as well as the socio-environmental impacts of the same. As a first step, the following activities are proposed to get a holistic overview of the current status of the industry with accurate and verified numbers of the kilns and the quantification of its impacts.

i) GIS based mapping of brick kilns

Till date, no reliable information exists either with the brick kiln association or Government of Assam or even with the State Pollution Control Board of Assam. According to Pollution Control Board (PCB), Assam there were 731 brick kilns across the State till December 2012. In addition, the Honourable Minister of Environment and Forest has informed the State assembly that as of 2019-2020 there are 669 brick manufacturing kilns in the state as per reports collected from divisional forest offices. It is hard to believe that while the demand for housing and infrastructure is increasing over the years, in a 7-year period the number of brick kilns has been reduced by 62.

Thus, it is of utmost importance to identify and map the exact number of brick kilns functioning in the state. This can be done easily through the GeoAI tool which gives fairly accurate data and can be further verified by ground truthing exercises to a limited variance.

ii) Resource mapping of raw materials for brick kilns

The major building material in Assam is clay bricks. Presently only agricultural topsoil is being used for brick making. It has been estimated in Assam Tribune that in 2021 more than 1,000 hectares of prime agricultural land are being lost annually to accommodate the brick-making industry only in and around Dhubri district.

Therefore, it is recommended to carry out a primary and secondary resource mapping study in Assam to identify the different raw materials available for making alternate building materials which are low carbon and eco friendly. Based on the mapping, a zoning of brick kilns can be planned.

iii) GHG Inventorization of brick kilns in Assam

No data exists till date on the carbon emission load in Assam from brick kilns. An immediate study needs to be undertaken to define the GHG inventorisation of brick kilns in Assam and the industrial sector. This will help in estimating the intensity of emissions and take appropriate measures for reducing the same.

6.2.2 Recommendations for technological improvement :

The mainstreaming and popular uptake of the alternative technologies recommended in this report requires visibility and demonstration of such technologies to build trust and confidence of the brick manufacturers. For this, pilot demonstration and capacity building towards the same are suggested as described below.

Annexure 7 gives further details on the implementation of such measures in the form of a Detailed Proposal on *'Greening of the Brick Industry in Assam - Proposal for introducing energy efficient, low carbon burnt brick production technologies'.*

i) Pilot demonstration of alternate technologies

To undertake any pilot demonstration activity, involvement and ownership of entrepreneurs and beneficiaries are an absolute must. Based on discussion and agreement on the type and choice of technologies, there should be a pilot demonstration kiln constructed in each and every feasible district. The choice of technologies should depend upon the criteria and decision making matrix developed in previous sections (Table 15) . These will act as a confidence building measure amongst brick kiln owners, enabling them to shift towards cleaner brick production systems and processes.

With respect to the feasibility of using piped natural gas as fuel in accordance with Government notification vide. G.D.R 143(E) dated 22 February 2022 , the State Pollution Control Board of Assam must enforce and implement these notifications urgently

ii) Technology transfer, Training and capacity building of stakeholders and awareness generation

To assist local brick manufacturers to achieve self-sustainability, interventions in technology upgradation through training and capacity building during any technology transfer are of utmost importance. The TARA team had accompanied ACCMS in two awareness workshops at Bongaigaon and Nagaon. It is to be noted that the majority of the entrepreneurs were unaware of alternative technologies and materials like VSBK kilns, Zig Zag kilns, compressed earth block, fly ash. Even the possibility of using internal fuel was an eye-opener. Thus, awareness workshops are suggested to be carried out in each district at regular intervals to enable informed decision making.

6.2.3 Recommendations for structural transformation

In addition to the immediate and short term measures listed above, a long term approach also needs to be developed and implemented, in order to effect a systemic transformation of the Assam brick sector . This may be achieved through a sustained programme focussing on Greening the Brick Sector in Assam. Major strategies to be adopted throughout this long term programme are listed below:

i) Policy and institutional support

It is suggested to institutionalise a “Clean Brick Sector Programme”. This can be made possible through a close collaboration with the concerned governmental institutions at all the stages of project implementation. They must be consulted as and when required and must be supported in fulfilling their roles and responsibilities in relation to sustainable development and livelihoods. Support and technical assistance must be provided to government agencies to develop and enforce policies and standards such as performance monitoring mechanisms,, technical support to co-develop a sound brick sector policy, setting suitable emission standards and evaluation or decision making criteria and formulating associated rules, regulations and guidelines for facilitating effective technology dissemination.

ii) Business and financial support

A demand-driven commercial and business development approach must be developed for technology transfer in any project/programme/pilot. It shall not advocate for any specific technologies but rather work on creating a demand for the same in the market through successful demonstrations.

iii) Implementation support through ancillary service providers

Local suppliers, manufacturers, ancillary enterprises and service providers must be supported and the successful implementation of the programme must be facilitated through a robust economic model and network which benefits all stakeholders equitably. Such a support network of suppliers and support service providers will help in anchoring the technologies at a local level, thereby enabling them to "sell" professional services at competitive market rates.

iv) Contextualisation of technology

The introduction of new technologies such as VSBK, internal fuel, fly ash bricks, compressed earth blocks or even AAC blocks must be well anchored within the local socio-political-economic and geographical context of Assam. This is needed to create ownership and also to address the dissemination potentials. Relevant public/private sector agencies need to be included in the project process in order to guarantee their support and facilitation to the programme.

v) Incubation centres/Pilot projects in every district

To sustain the efficacy and adoption of pilot demonstrations, a startup/incubation approach may be adopted to prepare the foundation/basework for the first phase of the long term development process. This will test the suitability and feasibility of selected retrofitting initiatives or clean brick technologies with local entrepreneurs in each district of Assam. This is envisaged with an aim to initiate and encourage technology adoption across the district through successful pilot demonstration.

vi) Periodic training and capacity building

A long term capacity building sub-programme must be developed for different levels of stakeholders. This must be sustained through periodic revisions and upgraded based on field response. Assistance in building a favourable environment may be provided by external experts , however the main responsibility or anchors/pivots must be with local partners. The aim is to engage local organisations or capable individuals to deliver support services as much as possible.

vii) Human capital development and knowledge management

The products, processes, technologies and economic models created through the programme should be documented and made accessible in a user-friendly way. Different media of dissemination may then be explored based on the target audiences and their access and limitations. Some of these may be in the form of videos, brochures, leaflets, manuals, books, technical notes and documents, project websites. These shall be customised in both, national and international vernacular languages for easy understanding.

viii) Social development and occupational safety

Any green initiative must also be 'responsible' and conscious of its impact on human health and wellbeing . In this respect, occupational safety and health issues of workers in the brick making sector should be continuously monitored for safe working processes and use of personal protective measures. Awareness and training sessions on safety and health should be conducted in greater detail and dovetailed with existing initiatives of the government or external agencies. This will inform workers to take necessary precautions while undertaking tasks like coal breaking, coal crushing, pug mill operation, brick moulding process, head load and transportation of bricks, particularly in the firing zone.

ix) Social responsibility

Last but not the least, any change in technology ,process, or means of production warrants an equivalent shift in social structures and entrepreneurs being the risk takers and change makers directly and indirectly influence these social changes. They must therefore be sensitised about their role in influencing education and learning and their social responsibility towards their society. In this respect, they themselves must be coached on the benefits of non-formal learning programmes and child education for the children of workers, who, due to lack of knowledge, end up working in kilns at a risk to their lives. A sensitisation programme/ initiative may be taken up throughout the state. This will further motivate the brick makers/workers once they realise the long term benefits of education for their family members and future generations.

Hence, a holistic programme for greening the brick sector is suggested , which addresses the economics, policy, and social challenges of the brick producers and workers through a systems approach. This multi level, multi stakeholder approach when implemented at a sustained pace over a period of time is bound to change the business as usual approach and help develop sustainable materials and sustainable livelihood.

7

ANNEXURES

ANNEXURE 1 - Baseline Assessment Framework

1. **Socio-Ecological Profile of State**

    1.1 Climate and topography of the state
    a. General weather condition
    b. Climatic condition
    c. Duration of rainy seasons
    d. Season related average humidity
    e. General topography of kiln cluster (if any)

    1.2 Socio economic features of the state
    a. Total population of state
    b. Per capita income of the people
    c. Major economic activities of the people
    d. Literacy rate of people

2. **Resource Availability**

    2.1 Soil mapping suitable for clay brick production

    2.2 Alternate Material Availability

3. **Overview of Brick Industry**

    3.1 Structure of Brick Industry in Assam
    a. Current and projected brick production and consumption trends in the state
    b. Who produces the brick, the private sector or the government sector?
    c. Scale of brick industry (small, medium, large), business environment of the brick producers/industry in
    d. Uses of fired brick in construction sector
    e. Most common brick size (in mm) - length, width, height
    f. During what time of the year are bricks produced?
    g. Other types of bricks currently used for walling construction and acceptance amongst masons and house owners (eg. hollow bricks, concrete blocks, etc.)

    3.2 Technologies available and being practiced
    a. Soil testing methods
    b. Soil mining and ageing methods
    c. Brick forming (moulding) methods
    d. Brick drying methods
    e. Brick firing technologies (which are available, which are most used)
    f. Minimum annual brick production rate from most commonly used firing technology mentioned above
    g. What kind of mechanization (e.g. excavators, extruders, pug mills, convey belts etc. are used to produce fired bricks?
    h. Overall brick firing history of the state in general, detailed information about brick making history of the hotspot study areas.
    i. Brick making contracting methods, if any (e.g. mining, moulding and transporting to the kiln) (kiln loading and unloading)
    j. Unfired brick transporting system (e.g. wheelbarrows, convey belts, manual transportation etc.)

    3.3 Understanding the fuel and material value chain
    a. Types of fuel used for firing
    b. Availability of coal and it’s uninterrupted supply

c. Origin of coal
d. Sources of soil used in brick production
e. Sources of any other raw materials used in brick production

4. **Operational Aspects of Brick Production**

4.1 Energy and environment
a. Major pollutants that are emitted by brick kilns
b. GHG emission impact
c. Impact of brick kilns upon surrounding vegetation and the soil fertility

4.2 Social and labour
a. Major labour issues related to brick industries
b. Child labour
c. Average number of workers working per brick kiln
d. Wage rate of workers
e. Average working hours per day
f. Employment ratio of men and women
g. Workplace facilities such as school, canteen, toilet, drinking water, housing etc.
h. Originality of workers (migration)
i. Literacy status of workers
j. Labour law applicable to brick industries
k. Existing working condition standards
l. General skill requirements for industries
m. How workers are trained
n. Assessment of occupational safety and health measures

5. **Financial Summary of Brick Production**

5.1 Economics of brick production
a. Average construction cost of kiln
b. Running cost of kiln
c. Average cost of unfired bricks (per thousand)
d. Cost of fuel commonly used in brick industries (per ton)
e. Wages of firemen / fire master (per month, or thousand bricks)
f. Cost of fired bricks (per thousand bricks)
g. Selling price of fired bricks (per thousand)
h. Taxes to be paid by brick industries (annually or per thousand bricks)
i. Availability of financial supports from government and banks (if any)

5.2 Profit and loss situation of brick producers
a. Return on investment (ROI)
b. Payback period
c. Fixed investment

6. **Regulatory Landscape of Brick Production**

6.1 Environmental concerns of people, government and other stakeholders
a. Environmental standards set by government for brick kilns
b. Standards set by government for the quality of coal
c. Environmental monitoring of the kiln
d. Public pressure upon brick kiln owners related with environmental concerns
e. Environment related and active NGOs

6.2 Licensing Process
a. Current licensing process for establishing brick industry

b. Existing rules and regulations
c. Authorities involved in licensing and their responsibilities & duties
d. Challenges in current process

6.3 Other factors
a. Political issues and significant actors related to brick industries, if any
b. Non-governmental organizations involved in brick sector and their tasks (in environmental monitoring, Institution involved in brick, coal and soil testing)
c. Corruption level, specially related to government administration and brick industry

ANNEXURE 2 - Impact Assessment Matrix

For Assessment of Suitability of Proposed Technologies for Brick Production

1. **Technical suitability**
   - Possibility for reduction in energy/liquid fuel/electricity
   - Possibility to reuse waste heat
   - Weather resistance of bricks
   - Compressive strength, tolerance, water absorption, efflorescence test of bricks
   - Homogeneity in brick quality for different kiln technologies
   - Brick materials suitability for kiln technologies
   - Capacity v/s market comparison for different kiln technologies
   - Capacity utilisation
   - Design life comparison of different kiln technologies
   - Flexibility in production capacity and operability throughout the year
   - Space requirement for different types of kilns
   - Product quality comparison for different firing process
   - Requirement of additional infrastructure for alternative kilns e.g., conveyor/lift (and electricity) for lifting of bricks to the top in VSBK
   - Suitability of kiln for any type of brick/tile/block production – diverse product portfolio

2. **Financial Sustainability**
   - Reduction in cost of fuel
   - Profits due to fuel savings and quality improvements.
   - Capital investment required for alternative measures
   - Contribution to local economy
   - Time frame for ROI
   - Cost-Benefit analysis
   - Financial instruments tailored for the sector
   - Financial knowledge of entrepreneurs in the brick sector
   - Tax compliance of the sector as majority of the transactions takes place in cash

3. **Environmental indicators**
   - CO_2 and other gaseous pollutants
   - Black carbon emission

- Suspended particulate matter formation
- Annual coal savings
- Alternative material source sustainability
- Waste generation comparison by the use of alternative material
- Extent of deforestation, top soil extraction, water consumption, fossil fuel extraction, and gas exhaustion avoided by the use of alternative materials and technologies
- Impact on agricultural soil
- Impact of de-silting and clay mining

4. Social indicators

- Employment generation
- Women employment generation
- Working condition of site workers
- Comparison of labour requirements for different kiln technologies
- Additional skill and training requirement for effective implementation of alternative technologies and methods of brick production.
- Impact on health of residents in close proximity to brick production
- Health impact – pulmonary/vision disorders in site workers
- Impact on food security
- Casualties related to brick sector pollution

ANNEXURE 3 – Characteristics of coal usage

CALORIFIC VALUE OF ASSAM MATERIALS					
SL.NO	SAMPLE NAME	MATERIAL	Calorific Value(kcal/kg)	Ash Content (%)	Loss of Ignition (%)
1	BAPUNG(MEGHALAYA)	Coal	8251.75	6	94
2	LATUNG BAI MEGHALAYA	Coal	7283.12	10	90
3	BAPUN-MEGHALAYA(BRICKS)	Coal	3300.61	57	43
4	MGNHUAYA-BAPUN	Coal	2782.03	66	34
5	MBI-CHEPTI	Coal	7468.46	11	89
6	ASSAM- GARAMPANI	Coal	3391.00	55	45
7	SMB-NAGALAND	Coal	7203.69	21	79
8	ASSAM- MNU	Coal	5826.88	28	72
9	HBI-CHEPTI	Coal	6764.53	7	93
10	JPB-CHANDRAPUR	Coal	7097.78	18	82
11	SRB-GUWAHATI	Coal	7680.27	7	93
12	BBS-SINGHMARI	Coal	7907.61	11	89

ANNEXURE 4 – Compressed Earth Block Technology Business Plan Details

Detailed Project Report

Compressed Earth Block Technology

JUNE 16, 2022

Technology and Action for Rural Advancement

B-32 TARA Crescent, Qutab Institutional Area

New Delhi - 110016

1. Introduction

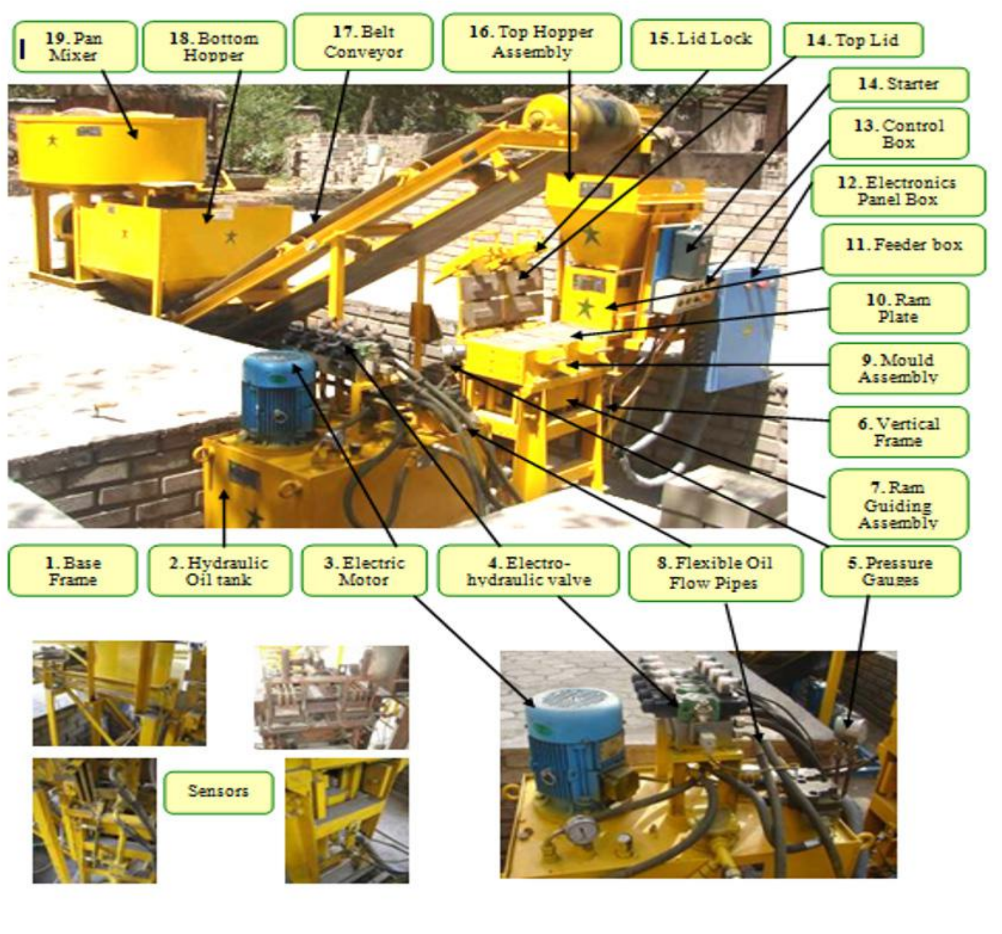
Earth as a construction material has been used for thousands of years by civilizations all over the world. It is the most abundant building material known and available in majority of the locations across the world. The traditional soil construction methods followed in many countries are cob (mixture of straw, gravel and clay), wattle and daub (coarse basket work of twigs woven between upright poles and plastered with earth) and adobe (roughly moulded, sundried clay bricks). The main drawback of these types of earth construction is their lack of durability and therefore the research and development of stabilized soil blocks or SSB's.

Stabilized soil blocks are known in various parts of the world differently i.e. Stabilized soil blocks, stabilized earth blocks, compressed earth blocks or compressed stabilized earth blocks. Compressed Stabilized Earth Block (CSEB) is a technology, in which blocks are made by compressing soil mixed with suitable stabilizer in the form of cement or lime at optimum moisture content by simple mechanical means. Densification of soil at optimum moisture content and use of stabilizer make CSEB durable. If made in the right manner with proper stabilization, it does not disintegrate due to action of the water. Production of CSEB generates employment to the local unskilled labour. Firing is not required and thus it is environmentally friendly. These blocks can be used in construction of houses, government buildings, toilets, etc.

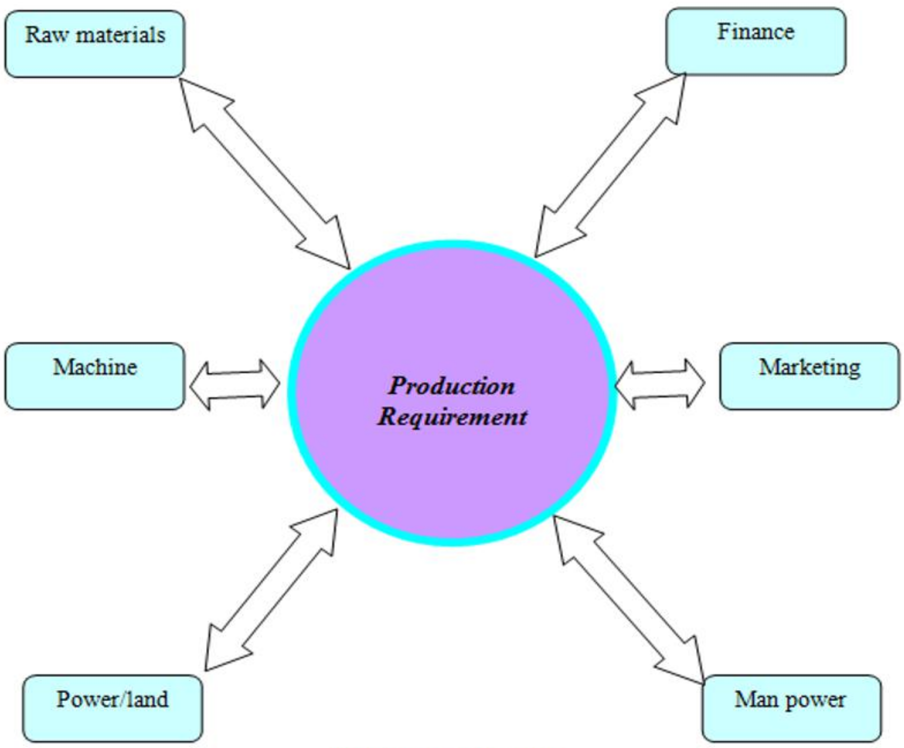
2. Raw materials

Sl. No.	Item	Physical characteristics	Chemical characteristics	Quality standardization
1.	Soil	Whitish is color, free of stones and foreign particles & organic matter	Calorific value: 1000Kcal/kg Specific gravity: 1.80gm/cm^3	Grade 1 or Grade 2 of IS 3812
2.	Lime	Hydrated form, free from impurities	CaO content higher than 60%	Class C hydrated lime of IS 712
3.	Gypsum	Powder form, white in color		As per IS Code 12894: 2002
4.	Cement	Free from lumps , good quality cement like ACC, Ultratech, Birla etc.	Setting of cement through a cube test by forming 1:2:4 mortar	53 grade OPC
4.	Sand	Free from clay, soil or any other organic impurities, size should be 2mm	Clay and silt content measured by a wet sedimentation process should not be more than 4%	As per IS Code 12894: 2002

3. Equipment and machine layout

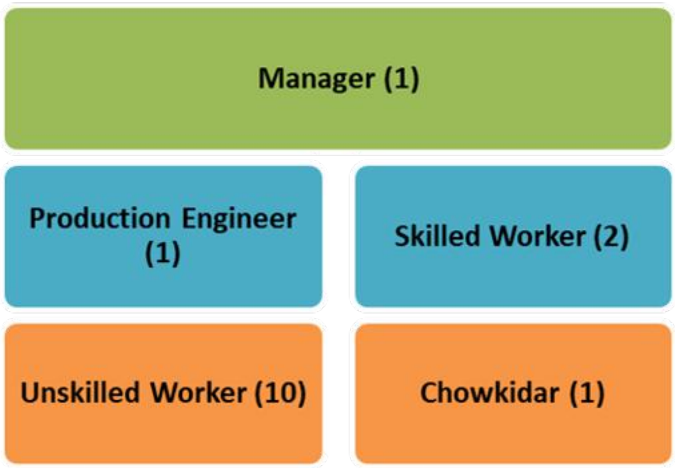


4. Production process

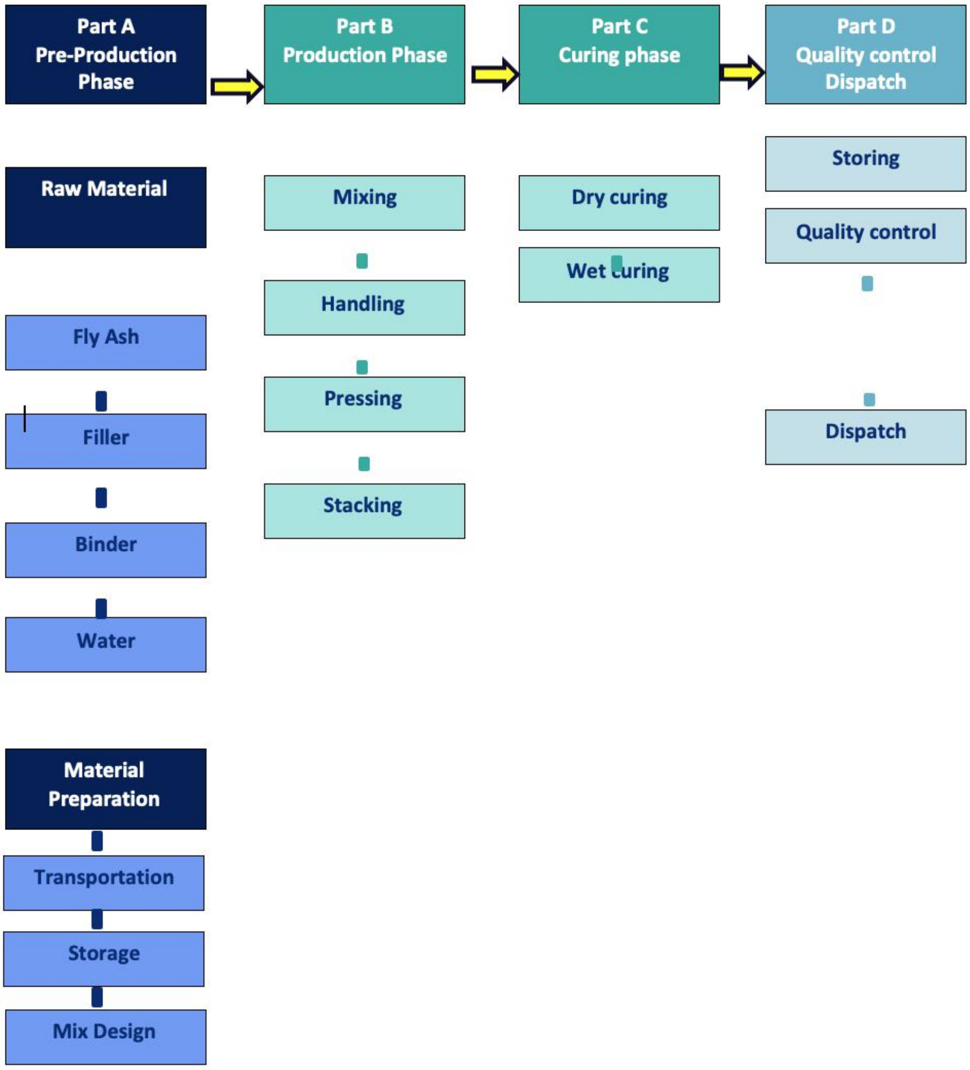


Production Planning

5. Staffing



6. Operations



7. Financial projections

7.1. Key assumptions

- The process of manufacture is on the basis of single shift of 8 hours per day with three hundred working days in a year.
- To achieve full plant capacity, it requires one year after trial production
- Labor and wages mentioned in profile are as per prevailing local rates.
- Interest rate at 12% considered in the project
- However the rate of interest may be varying while implementing the project.
- The Promoter contribution will be 10% of the total project cost which is applicable in the PMEGP scheme.
- The capacity of the unit is assumed as 24,000 bricks per day on the single shift basis

7.2. Key financial parameters

Capital Investment	
Rent per month	5,000
Total project cost	10,00,000
Margin	20%
Total loan	8,00,000
Rate of Interest %	14%
No of installments	60
EMI	18,615

Cost of Raw Material	
	INR Per Kg
Soil (including transportation)	0.30
Cement	6.00
Coarse sand	0.25
Lime	0.40
Gypsum	0.40

Ideal mix design	
Soil	55%
Cement	8%
Coarse Sand	10%
Lime	3%
Gypsum	32%
	108%

Production	
Utilised capacity	90%
Monthly Production	1,80,000

Selling Price	
Selling Price per brick	4.00
Turn key Production	No
Avg Selling Price per brick	4.00

FIXED CAPITAL			
Particulars	**Area (Sq.ft)**	**Rate (Sq.ft)**	**Amount (Rs.)**
LAND AND BUILDING			
Land Development Cost (fencing, gate, etc.)	-	10	-
Working Shed (workshop)	-	100	-
Curing Tank (Water Tank) 4.60* 3.0 * 0.75 meter	150	100	15,000
Sub Total			**15,000**
MACHINERY AND EQUIPMENTS	**Quantity**	**Rate**	**Amount (Rs.)**
TARA MechRam -MX & Conveyor belt with Pan mixer 2 nos. 300 kg capacity, Hydraulic pallet truck & 4 wheel barrow	1	13,50,000	13,50,000
Wooden plates @400/piece	50	400	20,000
Tax @5% on Machines & Information Technology Software			69,500
Installation and training charges		40,000	40,000
Transportation		60,000	60,000
Sub Total			**15,39,500**
PRE OPERATIVE EXPENSES	**Qty.(nos.)**	**Rate**	**Amount (Rs.)**
Office Furniture	LS		20,000
Pre-operative expenses	LS		25,000
Sub Total			**45,000**

WORKING CAPITAL (per month@25 days)				
		No of bricks per month	**1,80,000**	
1	**Raw Materials**	Per brick weight	3kg	
		Total Material weight	**540000 kg**	
	Descriptions	**Qty.**	**Rate/Kg**	**Amount (Rs.)**
a	Soil	2,97,000	0.30	89,100
b	Cement	-	6.00	-
c	Coarse Sand	54,000	0.30	16,200
d	Lime	16,200	1.50	24,300
e	Gypsum	1,72,800	2.00	3,45,600
	Sub Total			**4,75,200**

2	Staff and Labor			
	Descriptions	**Quantity (no.)**	**Rate**	**Salary (Rs.)**
a	Production Supervisor	1	7,500	7,500
b	Skilled Workers	2	6,000	12,000
c	Unskilled Workers	8	4,000	32,000
	Sub Total			**51,500**
	Add Perquisites @10%			5,150
	Sub Total			**56,650**
3	**Utilities (Per month)**			
	Descriptions	**Qty.**	**Rate / unit**	**Amount (Rs.)**
a	Electric Power 24.0 hp (6 hp MX+2x7.5 hp pan mixer+ 2 hp conveyor +0.50 hp water pump+ 0.5 Misc) for 25 days	3,581	6	21,485
b	Water charges approx.	LS		3,000
	Sub Total			24,485
4	**Other Contingent Expenses (Per month)**			
	Descriptions	**Qty.**	**Unit**	**Amount (Rs.)**
a	Rent	LS		10,000
b	Stationery	LS		1,000
c	Telephone / mobile / internet etc.	LS		1,000
d	Transportation	LS		1,000
e	Insurance	LS		1,000
f	Repair and maintenance	LS		1,000
	Sub Total			**15,000**
5	**Total Recurring Expenditure (per month)**			**5,71,335**
6	**Total Working Capital for 2 months**			**11,42,670**

Total Capital Investment	
Fixed capital	15,99,500
Working capital	11,42,670
Total	27,42,170

Project summary	
Particulars	**INR**
Buildings	15,000
Indigenous Plant and Machinery	15,39,500
Miscellaneous fixed assets	20,000
Pre-operative expenses	25,000

Capital cost of the project	15,99,500
Working capital per month	5,71,335
Working capital investment	11,42,670
Total capital investment	27,42,170
Loan value	21,93,736
Entrepreneur contribution	5,48,434
Production per month	1,80,000
Selling price per brick	4.00
Monthly revenue	7,20,000
Annual revenue	86,40,000
Rate of Interest %	14%
No of installments	60
EMI	51,044
Monthly income	97,621
No of months to recover capital	**28**

Production	
Utilised capacity	90%
Monthly Production	1,80,000

ANNEXURE 5 – Conversion of FCBTK to Zig zag Kiln Technology Business Plan Details

Detailed Project Report

Conversion of FCBTK to Zig-Zag Kiln technology

JUNE 16, 2022

Technology and Action for Rural Advancement

B-32 TARA Crescent, Qutab Institutional Area

New Delhi - 110016

Adapted based on the DPR published by Bureau of Energy Efficiency, Govt. of India.

1. INTRODUCTION

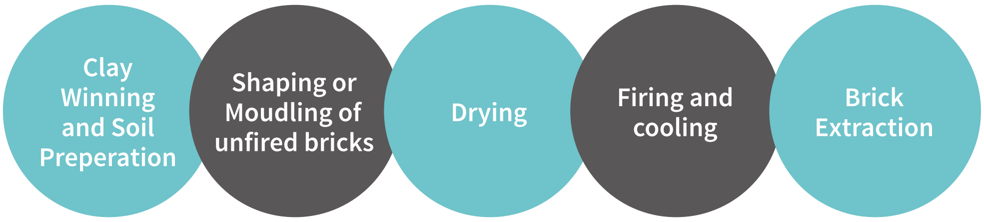
Existing burnt brick production process and technology

Although there are many brick production technologies existing in the country, but almost all the brick kilns throughout the state of Assam are the traditional coal fired fixed chimney Bull's Trench Kilns (BTK) type, with fixed natural draft chimneys except a few kilns which have converted to zig zag firing technology. Amongst more than 2000 FCBTK, Zig Zag kiln will be around 10 only.

Brick production process

While the principles of brick manufacture in BTK's is fairly consistent, individual units may and sometimes do depart from these basics to fit their particular requirements, raw materials and mode of operations. The essential steps in brick making are shown in the diagram below.

Figure 1: Process flow chart of typical brick kiln process



The first three steps of the brick making process usually start around about 20-40 days before the actual firing of the kiln. This is done to build up a decent stockpile of dried unfired bricks for continuous operation of the brick kiln. The firing up process of the brick kiln takes 10-20 days to make the kiln reach its appropriate temperature for the bricks to solidify and acquire its pre requisite fired brick attributes. The entire process is continual and once the firing is initiated, very rarely is the kiln operation course halted.

Clay Winning and Soil preparation

Clay is usually dug from the local vicinity of the brick kiln. The clay is then processed as to be free from gravel, lime and other bio wastes/ matter. This soil once excavated is then watered and left over a period of 8 – 12 hours for weathering and processing. After aging the moistened soil is kneaded/ pugged as required.

Moulding / Brick formation

The plastic clay after been through the previous process is then moulded into the required brick shape and size with its makers mark using a metal/ wooden / PVC mould.

Brick Drying

Once the clay has been formed into the pre required unfired brick shape, it is then left out in the sun to dry and reduce its moisture content. Fast drying on extremely hot days may lead to creation of cracks in the unfired brick which is undesirable. Therefore to minimize crack creation and quick moisture loss, the drying process takes place over a period of 8 -12 days with the bricks left out in the Sun. The bricks are usually laid out in stacks with a horizontal vertical alignment as to maximize usage of space and sunlight

Firing and cooling

The firing and cooling is done in the Bull's Trench Kiln (BTK). Relative to combustion zone within the kiln, the trench can be divided into cooling, firing and pre heating zones. The cooling zone is the upstream region in which the fired brick extraction takes place. This area is also vital in the mechanics of the brick kiln functionality as it allows cool air to flow into the combustion zone. The cool air while flowing through the fired brick arrangement cools the brick arrangement while at the same time gaining heat from the previous lines of fired bricks.

The combustion zone is the area where the firing of bricks takes place. To achieve the desired/ required properties of fired bricks the unfired bricks in this zone are subjected to temperatures of 800 – 1080 degree Celsius. Holes are made in lines on the top layer of the brick arrangement through which coal is fed in regular intervals into the combustion zone. To minimize heat losses during feeding, these holes are covered with metallic lids. Coal feeding of a line within the combustion zone may take anywhere from 3 to 6 hours depending on the draft and temperature of the Pre heating line.

The pre-heating zone is located downstream to the combustion zone. Sufficiently dried unfired bricks are brought over from the ***Pathai*** (brick moulding area) and systematically stacked within this zone. This stacking arrangement is then covered with a top layer of fly ash (3 – 6 inches) to offer insulation and minimize heat losses. The hot air/gases coming from the combustion zone flow through these lines of bricks further reducing their moisture and heating these bricks. A hole connected to the chimney is opened at a suitable location downstream to allow for maximum heating of bricks in the pre heat zone before it is discharged through the chimney. The difference in temperature between the hot air in the chimney and the cold ambient air creates a draft which sucks in air from the cooling zone.

Brick Extraction

The extraction of bricks takes place in the beyond the cooling zone of the brick kiln. As the brick firing and cooling is a continuous process the brick discharge takes place daily in tandem with the position of the firing/cooling of the lines.

1.1 Proposed Technology

The existing technology being used in Assam is mainly the traditional coal fired fixed chimney Bull's Trench Kilns (BTK), with fixed natural draft chimneys. This main reason for the need of technology up gradation is that the existing technology a high coal consuming process. As per studies done in Assam, a typical BTK consumes between 20-28 Tonne of coal for producing one lakh of bricks.

1.1.1 Description of Technology

A BTK is an oval or circular shaped brick kiln with its chimney usually in the centre. The trench is connected to the chimney by means of evenly spaced chambers along the trench. The outer wall has exit points for loading & Unloading of bricks. The firing & cooling process in a BTK comprises of three zones: i) Pre-heating zone, ii) firing/ combustion zone, iii) cooling zone.

Pre-heating zone is the area which is stacked with unfired bricks and utilizes the hot air coming from the firing zone for drying the unfired bricks by absorbing the moisture present in it.

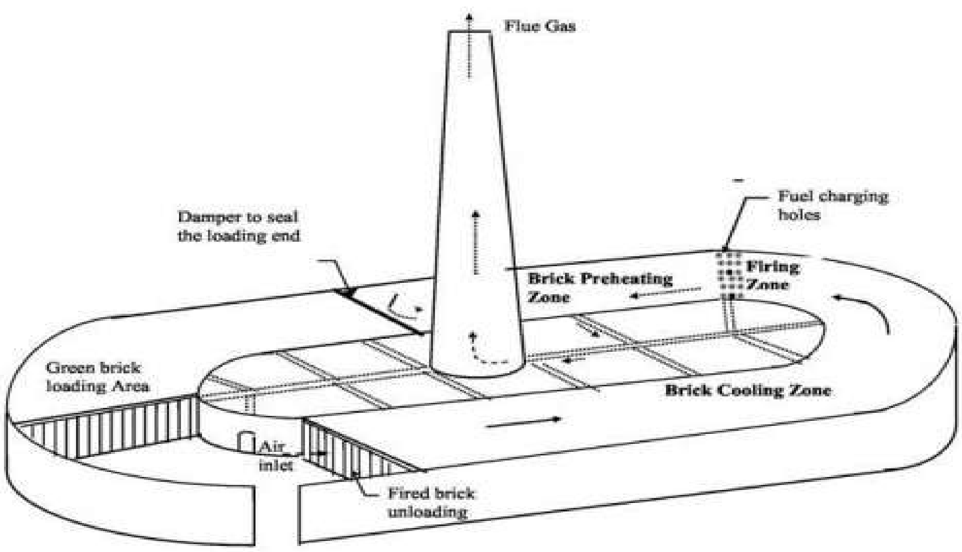
Firing zone is the actual area where the firing takes place. In a straight line firing process, bricks are fired one line at a time at a temperature of around 900^0C - 1000^0C. The temperature is maintained by continuous feeding of coal at regular intervals until the bricks get ready. Once one line of brick is ready, its holes are closed and the firing is moved forward to the next line towards the pre-heating zone.

Cooling zone is the area where the firing has already taken place and the bricks are kept for cooling before they are unloaded from the kiln. Since bricks are fired at a very high temperature, they take few days to cool down. Cooling time is lesser in the winter season compared to the summers due to the difference in the ambient temperature.

1.1.2 Design and Operating Parameters

BTK has a circular or oval kiln circuit. The bricks to be fired are arranged in column setting. The fire is progressively moved round the kiln through the brick setting. Before entering the brick-firing zone, the air is preheated by exchanging heat with hot-fired bricks in the brick-cooling zone. Brick firing takes place in a narrow brick-firing zone; in which, coal is added manually from the holes provided in the roof of the kiln. The combustion products (hot flue gases) pass over the unfired bricks resulting in drying and preheating of bricks in the brick-preheating zone. The fire travel takes place in the direction of the airflow. Cooled fired bricks are removed from the brick cooling zone, while fresh unfired bricks are added in front of the brick preheating zone. A chimney stack provides the necessary draft. The below figure depicts the structure of a BTK.

Figure 2: Typical structure of BTK



2. PROPOSED TECHNOLOGY

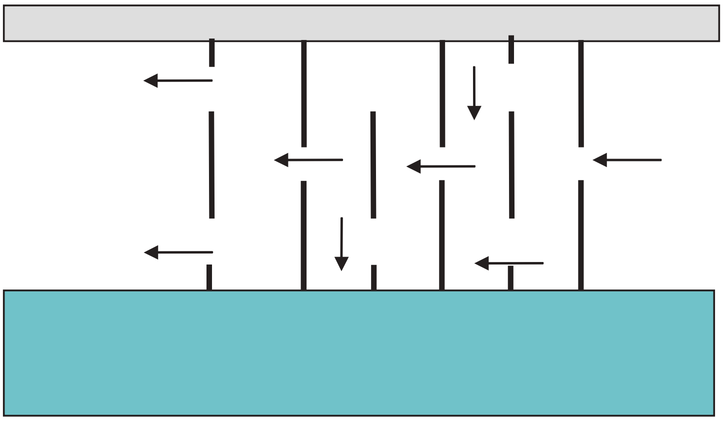
2.1 Detailed Description of Technology

2.1.1 Description of Technology

A BTK with zigzag firing is one of the most fuel efficient kilns. It is different from a straight line BTK in terms of its fire zone & the coal feeding practices. A BTK with zigzag firing has a long firing zone (almost two times to six times as compared to a BTK with straight firing) and the coal feeding process is continuous without any break. The Zigzag kiln consumes less fuel, uses less mechanical energy and requires far less capital outlay with very low maintenance. It also has a roof resulting in improved working conditions and longer operational time during raining conditions. The Zigzag kiln is ideally suited to both large scale brick making settings and to very small village applications in developing countries.

In Zigzag mode of operation, the combustion zone is divided into 2-6 chamber (4 -12 lines) using partitioning unfired brick arrangement and the kiln is operated at a high draught for a fast rate of fire travel. The wall chamber runs along the width of the gallery except one end, where a space of 1.0ft is left for communication to the next chamber. The number of bricks per chamber depends upon the design capacity of the kiln and can vary anywhere from 5,400 – 10,000 bricks.

Figure 4: Zig-zag technology



2.1.2 Suitability over Existing Technology

Zigzag firing pattern is easily suitable in the existing system as there is no technology change as such. It is only process change with requirement of some structural changes. Zigzag is already being successfully in use in Varanasi cluster in 3 kilns. It is one of the most energy efficient technologies available.

2.1.3 Superiority over Existing Technology

Among existing kiln designs being used in India, kilns based on Zigzag firing is one of the brick kiln designs having lowest specific energy consumption. A specific energy consumption table in brick kilns is provided in Table 2 below:

Table 2: Specific Energy Consumption

S.No	Kiln	Specific Energy Consumption (MJ/kg) fired product
1	Clamp (Biomass)	1.9
2	Clamp (Cole)	1.2 - 1.75
3	Moving chimney (BTK)	1.2-1.75
4	Fixed chimney	1.1-1.4
5	Zigzag	0.8-1.1
6	VSBK	0.7-1.0

Zigzag firing technique has been derived from Habla kiln which was invented in Germany in 1927. This technology was widely used developed countries like Germany and Australia. It was first introduced in India in the year 1970. Though it is not a very popular technique in brick industry in Assam, but it is one of the most fuel efficient technologies available.

2.2 Suitable Unit for Implementation of Proposed Technology

BTK having capacity of 7 to 10 lakh bricks per round and production of more than 45 lakh brick per season are ideal for implementing the Zigzag firing process.

3. ECONOMIC BENEFITS FROM PROPOSED TECHNOLOGY

3.1 Technical Benefits

3.1.1 Fuel Saving

On basis of field studies conducted in the Varanasi cluster and technology gap assessment of available technology/ process up-gradations, the entrepreneurs can be convinced to adopt Zigzag technologies based on the information provided. Applying a generic ruling for adoption of technologies, the probability of low and medium investment technologies will be high as compared to high investment technologies. So for that zigzag is one of the most suitable technology. Savings in a typical unit by adopting zigzag firing are tabulated in Table 3 below:

Table 3: Coal savings per year

Energy Efficient Technology/ Measure	Annual Coal Savings (tonne)	Annual Energy Savings (Tera joules)
Process Change from straight line to Zigzag Firing	139.50	2.915

The zigzag technology suggested does not have any electricity consumption during any process, so there is no electricity savings as such while adopting this technology.

1.1.3 Improvement in Product Quality

The zigzag firing process utilizes the fuel to its max and the fire travels in such a manner that it heats up the unfired bricks at equal temperature. A resultant of which is high quality of bricks being produced as compared to the other process.

1.1.4 Increase in Production

In Zigzag mode of operation, the combustion zone is divided into 2-6 chamber (4 -12 lines) using partitioning unfired brick arrangement and the kiln is operated at a high draught for a fast rate of fire travel. As a result of the long firing & cooling zone, the zigzag process increases the production capacity of the kiln.

3.2 Monetary Benefits

3.2.1 Monetary Savings due to Reduction in Energy Consumption

Monetary savings in a typical unit after adoption of zigzag firing process has been estimated around ₹ 7 lakhs This figure has been arrived based on the annual coal savings in a typical unit multiplied by average rate of coal/ Ton.

3.3 Environmental Benefits

3.3.1 Reduction in GHG Emission

There are significant reductions to be achieved in Green House Gas emission by adoption of zigzag firing technology. Reduction in coal consumption translates into GHG reductions roughly to the order of 2 tonnes of GHG per ton of coal which is 279 tonne CO_2 reductions per year. The other benefits include, decrease in particulate pollution levels in kiln and surrounding area.

3.3.2 Reduction in other Emissions like SOx

Due to Zigzag flue exhaust gas path it capture maximum emission product in comparison to other brick kilns.

4. IMPLEMENTATION OF PROPOSED TECHNOLOGY

4.1 Cost of Technology Implementation

4.1.1 Cost of Technology

The costs of equipments that will be required after adoption of zigzag technology is approx. INR 1.22 lakh. The details are provided in Table 4 & Table 5 below:

Table 4: Detail of Cost of Technology

S.No	Cost of Equipment	Cost
a)	Feed hole covers – 100 nos. @ INR 550/-	INR 55,000/-
b)	Insulated Shunt – 2 nos. @ INR 25000/-	INR 50,000/-
c)	Temperature gauge for Shunt – 2 nos. @ INR 1500/-	INR 3,000/-
d)	Thermocouple – 1 set (includes 1 small and 1 big)	INR 10,500/-
e)	Temperature Indicator- 1 no. @ INR 3000/-	INR 3,000/-
Total	Rupees One lakh twenty one thousand only/-	**INR** 1,21,500/-

Note: *The prices will vary substantially based on the current procurement and other costs based on Assam and its districts.*

4.1.2 Other Costs

Table 5: Cost of civil work and consultancy

S.No.	Particulars	Cost
1.	Cost of modification in Civil structure	INR 4,50,000/-
2.	Cost of Consultancy and training to workers and supervisors	INR 1,50,000/-
3	EPC Cost	INR 36,000/-
4	Total cost of implementation	INR 7,58,000/-

4.1.3 Arrangements of funds

Proposed financing for the Zig Zag firing-31 lakh per year is made considering a debt equity ratio of 3:1, which is normally allowed by financial institutions for financing energy efficiency projects. On the basis of debt equity ratio of 3:1 the promoter's contribution works out to 25% of the project cost and the balance would be term loan from the Bank / FIs.

4.2 Financial Indicators

4.2.1 Cash Flow Analysis

Cash flow analysis is given in Annexure – 5.

4.2.2 Simple Payback Period

Payback period will be 1.09 Years.

4.2.3 Net Present Value (NPV)

Net Present Value at 10% works out to be ₹18.86 lakh.

4.2.4 Internal Rate of Return (IRR)

After tax IRR of the project works out to be 72.42%. Thus the project is financially viable.

4.2.5 Return on Investment (ROI)

The average ROI of the project activity works out at 28.74%. Details of financial indicator are furnished in Table 7 below:

Table 7: Financial Indicator of Proposed Technology

S.No	Particulars	Unit	Value
1	Simple Pay Back period	Month	13
2	IRR	% age	72.42
3	NPV	lakh	18.86
4	ROI	% age	28.74
5	DSCR	Ratio	3.96

Proposed Technology from Straight line firing to Zigzag Firing Description:

Zigzag firing kilns were at one time widely popular in developed countries like Australia and in Europe. These kilns are typically shorter in size (trench size, and overall kiln length) and have a longer combustion zone than straight line firing kilns.

In Zigzag mode of operation, the combustion zone is divided into 2-6 chamber (4 -12 lines) using partitioning unfired brick arrangement and the kiln is operated at a high draught for a fast rate of fire travel. The wall chamber runs along the width of the gallery except one end, where a space of 1.0ft is left for communication to the next chamber. The number of bricks per chamber depends upon the design capacity of the kiln and can vary anywhere from 5,400 – 10,000 bricks.

S.No	Particular	Unit	Value
1	Coal consumption per lakh bricks in base case scenario	tonne	18
2	Coal consumption per lakh bricks after adoption of Zigzag Firing technology	tonne	13.5
3	Total brick production	Lakh/year	31
4	Coal consumption in base case scenario	tonne/year	558
5	Coal consumption in proposed case	tonne/year	418.5
6	Coal saving	tonne/year	139.5
7	Energy Savings	Tera Joule/year	2.92
8	Monetary saving	INR in lakh/year	6.98
9	Investment required	INR in lakh	7.58
10	Simple payback period	Years	1.09

Detailed Financial Calculations & Analysis

Assumptions

Name of the Technology	BTK With Zigzag Firing		
Rated Capacity	31 lakh		
Details	Unit	Value	Basis
Installed Capacity	Bricks/Year	31 lakh	
No of working days	Days	250	
Proposed Investment			
Plant & Machinery	INR (in lakh)	1.22	Feasibility Study
Cost of modification in civil construction	INR (in lakh)	4.50	Feasibility Study
Cost of consultancy	INR (in lakh)	1.50	Feasibility Study
EPC Cost	INR (in lakh)	0.36	Feasibility Study
Total Investment	INR (in lakh)	7.58	
Financing pattern			
Own Funds (Equity)	` (in lakh)	1.89	Feasibility Study
Loan Funds (Term Loan)	` (in lakh)	5.68	Assumed
Loan Tenure	Years	5	Assumed
Moratorium Period	Months	6	Assumed
Repayment Period	Months	66	Assumed
Interest rate	% age	10	SIDBI EE Lending rate
Estimation of Costs			
O & M Costs	on Plant & Equip	2.00%	Feasibility Study
Annual Escalation	%	2.00%	Feasibility Study
Estimation of Revenue			
Coal savings	tons	139.50	
Cost	INR / tonne	5000	
St. line Depn.	%	5.28	Indian Companies Act
IT Depreciation	%	100.00	Income Tax Rules
Income Tax	%	33.99	Income Tax

Estimation of Interest on term loan INR (in lakh)

Years	Opening Balance	Repayment	Closing Balance	Interest
1	5.68	0.48	5.20	0.51
2	5.20	0.96	4.24	0.48
3	4.24	1.02	3.22	0.38
4	3.22	1.08	2.14	0.27
5	2.14	1.20	0.94	0.16
6	0.94	0.94	0.00	0.03
		5.68		

WDV Depreciation INR (in lakh)

Particulars / years	1
Plant and Machinery	
Cost	7.22
Depreciation	7.22
WDV	-

Projected Profitability` (in lakh)

Particulars / Years	1	2	3	4	5	6	7	8	Total
Fuel savings	6.98	6.98	6.98	6.98	6.98	6.98	6.98	6.98	55.80
Total Revenue (A)	6.98	6.98	6.98	6.98	6.98	6.98	6.98	6.98	55.80
Expenses									
O & M Expenses	0.15	0.15	0.16	0.16	0.16	0.17	0.17	0.17	1.30
Total Expenses (B)	0.15	0.15	0.16	0.16	0.16	0.17	0.17	0.17	1.30
PBDIT (A)-(B)	6.82	6.82	6.82	6.81	6.81	6.81	6.80	6.80	54.50
Interest	0.51	0.48	0.38	0.27	0.16	0.03	-	-	1.83
PBDT	6.31	6.34	6.44	6.54	6.65	6.78	6.80	6.80	52.67
Depreciation	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	3.20
PBT	5.91	5.94	6.04	6.14	6.25	6.38	6.40	6.40	49.47
Income tax	-	2.16	2.19	2.22	2.26	2.30	2.31	2.31	15.76
Profit after tax (PAT)	5.91	3.79	3.85	3.92	3.99	4.08	4.09	4.09	33.71

Computation of Tax` (in lakh)

Particulars / Years	1	2	3	4	5	6	7	8
Profit before tax	5.91	5.94	6.04	6.14	6.25	6.38	6.40	6.40
Add: Book depreciation	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Less: WDV depreciation	7.22	-	-	-	-	-	-	-
Taxable profit	(0.90)	6.34	6.44	6.54	6.65	6.78	6.80	6.80
Income Tax	-	2.16	2.19	2.22	2.26	2.30	2.31	2.31

Projected Balance Sheet

Particulars / Years	1	2	3	4	5	6	7	8
Liabilities								
Share Capital (D)	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89
Reserves & Surplus (E)	5.91	9.70	13.55	17.47	21.46	25.53	29.63	33.71
Term Loans (F)	5.20	4.24	3.22	2.14	0.94	0.00	0.00	0.00
Total Liabilities (D)+(E)+(F)	13.01	15.84	18.67	21.50	24.29	27.43	31.52	35.61
Assets								
Gross Fixed Assets	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58
Less Accm. depreciation	0.40	0.80	1.20	1.60	2.00	2.40	2.80	3.20
Net Fixed Assets	7.18	6.78	6.38	5.98	5.58	5.18	4.78	4.38
Cash & Bank Balance	5.83	9.06	12.29	15.53	18.72	22.25	26.75	31.23
Total Assets	13.01	15.84	18.67	21.50	24.29	27.43	31.52	35.61
Net Worth	7.81	11.59	15.44	19.36	23.35	27.43	31.52	35.61
Debt Equity Ratio	0.67	0.37	0.21	0.11	0.04	0.00	0.00	0.00

Projected Cash Flow: ` (in lakh)

Particulars / Years	0	1	2	3	4	5	6	7	8
Sources									
Share Capital	1.89	-	-	-	-	-	-	-	-
Term Loan	5.68								
Profit After tax		5.91	3.79	3.85	3.92	3.99	4.08	4.09	4.09
Depreciation		0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Total Sources	7.58	6.31	4.19	4.25	4.32	4.39	4.48	4.49	4.49
Application									
Capital Expenditure	7.58								
Repayment Of Loan	-	0.48	0.96	1.02	1.08	1.20	0.94	-	-
Total Application	7.58	0.48	0.96	1.02	1.08	1.20	0.94	-	-
Net Surplus	-	5.83	3.23	3.23	3.24	3.19	3.54	4.49	4.49
Add: Opening Balance	-	-	5.83	9.06	12.29	15.53	18.72	22.25	26.75
Closing Balance	-	5.83	9.06	12.29	15.53	18.72	22.25	26.75	31.23

IRR ` (in lakh)

Particulars / months	0	1	2	3	4	5	6	7	8
Profit after Tax		5.91	3.79	3.85	3.92	3.99	4.08	4.09	4.09
Depreciation		0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Interest on Term Loan		0.51	0.48	0.38	0.27	0.16	0.03	-	-
Salvage / Realisable value						-	-	-	-
Cash outflow	(7.58)	-	-	-	-	-	-	-	-
Net Cash flow	(7.58)	6.82	4.66	4.63	4.59	4.55	4.50	4.49	4.49
IRR	72.42%								
NPV	18.86								

Break Even Point

Particulars / Years	1	2	3	4	5	6	7	8
Variable Expenses								
Oper. & Maintenance Exp (75%)	0.11	0.12	0.12	0.12	0.12	0.13	0.13	0.13
Sub Total(G)	0.11	0.12	0.12	0.12	0.12	0.13	0.13	0.13
Fixed Expenses								
Oper. & Maintenance Exp (25%)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Interest on Term Loan	0.51	0.48	0.38	0.27	0.16	0.03	0.00	0.00
Depreciation (H)	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Sub Total (I)	0.95	0.92	0.82	0.71	0.60	0.47	0.44	0.44
Sales (J)	6.98	6.98	6.98	6.98	6.98	6.98	6.98	6.98
Contribution (K)	6.86	6.86	6.86	6.85	6.85	6.85	6.85	6.84
Break Even Point (L= G/I)	13.84%	13.34%	11.94%	10.40%	8.77%	6.84%	6.46%	6.48%
Cash Break Even {(I)-(H)}	8.01%	7.51%	6.11%	4.57%	2.93%	1.00%	0.62%	0.64%
Break Even Sales (J)*(L)	0.97	0.93	0.83	0.73	0.61	0.48	0.45	0.45

Return on Investment` (in lakh)

Particulars / Years	1	2	3	4	5	6	7	8	Total
Net Profit Before Taxes	5.91	5.94	6.04	6.14	6.25	6.38	6.40	6.40	49.47
Net Worth	7.81	11.59	15.44	19.36	23.35	27.43	31.52	35.61	172.11
28.74%									

Debt Service Coverage Ratio ` (in lakh)

Particulars / Years	1	2	3	4	5	6	7	8	Total
Cash Inflow									
Profit after Tax	5.91	3.79	3.85	3.92	3.99	4.08	4.09	4.09	25.53
Depreciation	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	2.40
Interest on Term Loan	0.51	0.48	0.38	0.27	0.16	0.03	0.00	0.00	1.83
Total (M)	6.82	4.66	4.63	4.59	4.55	4.50	4.49	4.49	29.76

Debt

Interest on Term Loan	0.51	0.48	0.38	0.27	0.16	0.03	0.00	0.00	1.83
Repayment of Term Loan	0.48	0.96	1.02	1.08	1.20	0.94	0.00	0.00	5.68
Total (N)	0.99	1.44	1.40	1.35	1.36	0.97	0.00	0.00	7.51
Average DSCR (M/N)	3.96								

ANNEXURE 6

VSBK Business Plan Details

JUNE 16, 2022

Technology and Action for Rural Advancement

B-32 TARA Crescent, Qutab Institutional Area

New Delhi - 110016

Adapted based on the DPR published by Bureau of Energy Efficiency, Govt. of India.

ANNEXURE 6 – VSBK Business Plan Details

The process of owning and adopting a VSBK technology should be three fold. The process is as follows:

Step 1: Testing of soil and making a decision that quality bricks are possible to be produced with required soil quality.

Step 2: Designing the VSBK and preparing the detailed project report for understanding the economics

Step 3: Providing technical, operational and troubleshooting support

Soil testing and recommendations

In general, soils containing high proportions of sand lead to poor brick strength, while on the other hand, high levels of clay content cause excessive shrinkage and result in cracking of the brick even during the unfired brick preparation stage. Thus, to assess the future quality of brick production, soil testing is an important step which should be mandatory before adoption of VSBK technology.

VSBK production system design

Design principles

The design of VSBK is the result of efforts and processes developed in the past and the practical experiences of VSBK's performances in India and different countries. The design of the shaft size is the most important part of VSBK because it determines the dimensions of the entire VSBK structure. The shaft design also plays an important role in the performance of VSBK. Any fault in the design of the shaft can lead to failure of the kiln. Also, once designed and constructed, the shaft size cannot be changed.

The following criteria are derived from design aims and errors applicable to the present issue of developing the same for an VSBK system and limited not only to the final civil superstructure.

Identification and review of critical decisions

Every decision which carries a high penalty must be identified as early as possible. Such decisions should be taken only tentatively at first and should be reversible if they are later found to be conflicting with reliable evidence or with informed opinions.

Relating the cost of research to the penalties for taking wrong decisions

The penalty for not knowing must exceed the cost for finding out if it is worth using expensive design efforts to answer any questions. The first requirement in evaluating a proposed action is to identify the questions to which the action will provide answers.

Matching design activities to the implementation team

The design team members must be confident of their actions. They should have the capabilities and the motivation to carry out these actions. This must also match the capability of the implementation team and therefore be within their reach and understanding.

Identifying usable sources of information

Information should be sought from all the major sources of stability or instability to ensure their compatibility with the designs. The reliability of alternative sources of information should be assessed independently before undertaking the design exercise.

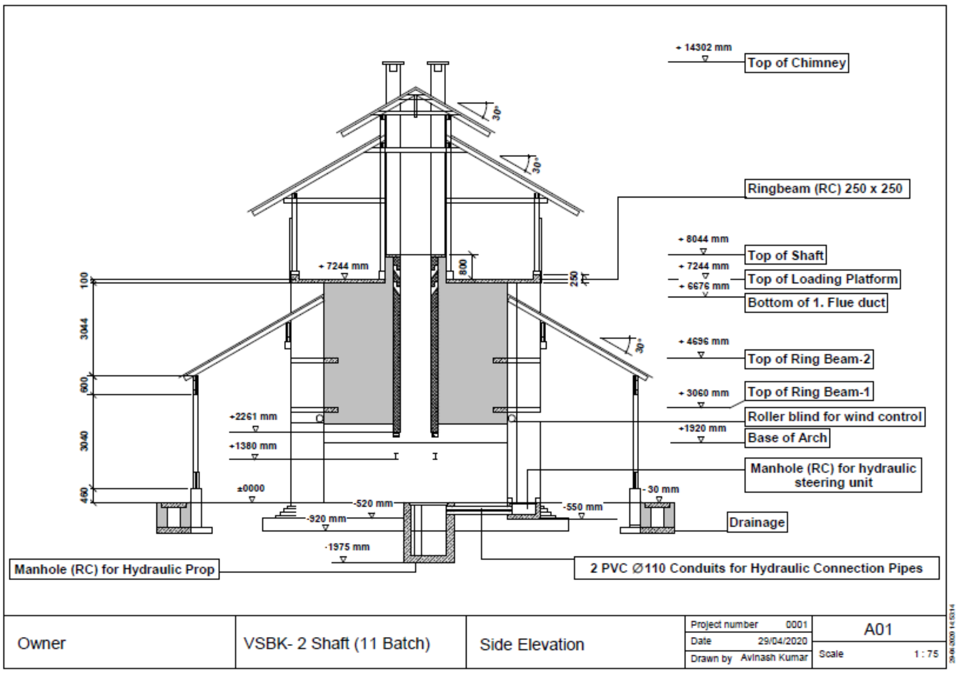
Specific design criteria

The VSBK design parameter majorly depends on following things

- Brick dimension
- Shaft cross section
- Batch height
- Kiln height from ground level
- Flue duct level
- Loading platform level

Kiln design

Figure 51: Cross section of side view of VSBK



The above gives an idea of the perspective of a VSBK. This is a general drawing and needs to be customised for each and every individual VSBK based on brick type, soil type, shrinkage, strength and production requirement.

Operational parameters

VSBK is a firing technology and provides strength to the burnt clay brick through an application of a thermal process. However, it cannot modify or improve upon whatever is fed into in the form of a unfired brick. Some of the basic operation parameters of the VSBK therefore are as follows:

- Regular field testing of soil
- Proper processing of soil and use of internal fuel in unfired bricks
- Use of dried and good quality unfired bricks
- Ensuring required coal quality and its size
- Following proper loading and unloading of unfired and fired bricks
- Ensuring operation of kilns as per standards throughout the day and night also.
- Regular preventive maintenance and proper repair of equipment and machineries

Bill of materials

Principles of selection of materials

The Bill of materials represents the necessary and sufficient items that would be required to suitably construct an VSBK in Assam. During making the bill of materials for Assam the following principles were followed:

- All materials, including bricks, cement, steel, wood etc. should be available in the local market in India as far as possible
- Reduce purchase of goods as deemed appropriate without compromising the quality
- Selection of equipment and machineries which should be easily maintained and repaired in local markets in Assam
- Imports of equipment and machineries were considered where it is available at cheaper rates meeting required quality standards
- The construction will use materials of the highest quality available in the market.
- All the materials will be used to arrive at the end of the product system

Bill of materials calculation criteria

A bill of materials is the record of the raw materials, sub-assemblies and supplies used to construct a product i.e. the VSBK. The bill of materials is and will be used to calculate the cost of the brick to be produced and understanding the business economics. It is also an essential requirement when an enterprise is planning to develop a plan for material requirements.

During the calculation of bill of materials for VSBK the following criteria were followed:

- Bill of materials may include not only the unit quantity required to construct the VSBK but an estimate of the scrap that will be produced and where it can be used.
- The Bill of materials should be extremely accurate with reasonable flexibility. This is to ensure that wrong or excess items are not procured which might cause a major delay in the construction process.
- A bill of materials is a centralised source of information used to manufacture the VSBK. Thus, correct parts must be available during the construction process. Improper Bill of

materials might cause the construction to be delayed which will increase the operating costs of the enterprise and therefore profitability.

- The Bill of materials will define all the products including their codes, specifications and features.

Bill of materials for VSBK in Assam (2 shaft VSBK)

All rates have been calculated based on Indian Currency (In Rs.)

VSBK Assam

Standard cost estimate of a 2 shaft VSBK

Kiln size: 12.302 m x 8.098 m **Shaft size: 1986 mm x 998 mm** **Batch height: 11 m**

Sl.	Item	Specification	Quantity	Unit	Rate (Rs.)	Total Cost (Rs)
A	**Kiln Construction:**					
1	Material:					
	Cement	42.5 Grade OPC @50 kg bags	1,169	bags	350	4,09,009
	Sand	Medium, coarse sand for masonry work	295	tons	1,500	4,42,870
	Stone for foundation	Coarse	60	tons	900	53,796
	Bricks	230mm x 110mm x 70mm	1,45,878	no's	7	10,21,144
	Shurkhi	Brick dust	2,439	kgs	2	4,878
	Coarse Aggregate	(10-20) mm size	52.4	tons	1,200	62,867
	Refractory bricks	230mm x 110mm x 70mm; Al_2O_3 >32%,	8,224	no's	35	2,87,836
	Refractory mortar	High alumina cement, 50 kg bag	24	bags	400	9,600
	Lime	Slaked @ 640 Kg/Cum	368	kg	7	2,576
	Bricks bats	Crushed bricks	13	tons	100	1,300
2	MS steel bars:					
	Steel @6mm	MS Fe 450,@ 0.22 kg/m	175	kg	60	10,470
	Steel @8mm	MS Fe 450,@ 0.40 kg/m	20	kg	62	1,240
	Steel @10mm	MS Fe 450,@ 0.62 kg/m	1,807	kg	62	1,12,034
	Steel @12mm	MS Fe 450,@ 0.88 kg/m	63	kg	62	3,918
	Binding wire		32	kg	45	1,440
	Angle Iron 60X60 Plate	96.00	269	kg	60	16,128
	Nails	2"	14	kg	40	560
	Nails	3"	37	kg	40	1,463
3	I - Joist:					
	I beam	ISMB 200x100x6mm @ 2436mm long	4	Nos.	850	3,400
4	Channel section:					
	C- beam	ISMC 125x65x6mm @ 2436mm	8	Nos.	850	6,800
5	G.I.roof with 600 mm monitor gape					
	MS bolt for struss base plate	16 mm dia, L= 300 mm, 3" threads	48.00	no's	70	3360.00
	Base plates for strusses	200 x 200 x 6 mm, 12 no's	0.96	Sqm	2967	2848.61
	Tubuler steel strusses:	As per VSBK specification				
	# Tie member	50 mm dia MS pipe	33.75	Rm	120	4050.00
	# Other then tie member	40 mm dia MS pipe	95.00	Rm	90	8550.00
	MS pipe for cooling chamber roof	50 mm dia	20.86	Rm	120	2503.20
	Purlins	40 x 25 mm ractangular MS pipe	114.00	Rm	95	10830.00
	G.I. Sheet for kiln roof	3600 x 800 mm, 22 gauge	45.00	no's	1800	81000.00
	G.I. Sheet for cooling chamber roof	3600 x 800 mm, 24 gauge	20.00	no's	1800	36000.00
	U bolts with bitumen washer for Kiln	5 mm dia, L= 75 mm long, for kiln	120.00	no's	24	2880.00
	U bolts & bitumen washer for cooling	5 mm dia, L= 75 mm long, cooling chambe	20.00	no's	24	480.00
6	Manpower:					
	Mason	Skilled	300	no's	650	1,95,000
	Helper	Unskilled	900	no's	450	4,05,000
		Kiln Construction Cost (In Rs.)				32,05,830
B	**Staircase**					
	Brick and mortar including ramp		1	No.	1,50,000	1,50,000
		Staircase Cost (In Rs.)				1,50,000
C	**Equipment cost**					
1	Brick support bars	As per VSBK specifications	16	no's	5,000	80,000
2	Transfer trolleys for fired brick stacking	As per VSBK specifications	4	no's	7,000	28,000
3	Crow bars	32mm dia, L= 1500mm	2	no's	1,200	2,400
4	Hot brick lifting tong	As per VSBK specification	4	no's	200	800
5	Weighing balance, 25 kg	Weights (50gm - 10kg)	1	no's	500	500
6	Plastic rope	C	20	Rm	200	4,000
7	Wooden square bars:					
	a. Hard core wood	1090 (3'-7") x 100mm x 100mm, size	28	no's	800	22,400
	b. Hard core wood	1090 (3'-7") x 100mm x 50mm, size	8	no's	800	6,400
	c. Plain strips (26 gauge G.I. sheet)	1100 (3'-10") x 200mm, 20 no's	4.40	Sqm	1,000	4,400
	d. Nails	1.5mm, L = 25mm	3.00	kg	70	210
8	Steel Pipes for thermo couple	2" dia@2m long	6.00	no's	250	1,500
9	Thermo couples		6.00	no's	6,000	36,000
		Equipment Cost (In Rs.)				1,86,610
D	**Fabrication charges**	As per requirement	1.00	Job	40,000	40,000
E	**Transportation charges**	As per requirement	1.00	Job	10,000	10,000
F	**Electrical work**	As per requirement	1.00	Job	15,000	15,000
		TOTAL COST Rs.				**36,07,440**

Principles for determining business plan

A successful business cannot be built and run spontaneously. Planning is essential, and not just an initial business plan but regular, ongoing evaluations and updated strategies. For building a prosperous business, use of good principles of business planning is essential. The principles for determining business plan are as following

- The plan needs to be checked and modified on a regular basis
- The cost considered while making a business plan should be as accurate as possible
- The plan must contain short term and long term goals
- The plan should reflect payback period for the investment

Key assumptions:

- Installed capacity: 9000 bricks per day (27,00,000 bricks per annum)
- No. of working days per annum: 300
- Average utilisation capacity: 85%
- Average production cost per brick: INR 4.16
- Average selling price per brick: Rs.9
- Project finance: 100% from entrepreneur
- Land acquisition cost not taken into account.

The 2 shaft VSBK business plan

Summary

The business plan has been calculated for 11 batch height double shaft VSBK. The rates

STANDARD VSBK BUSINESS PLAN
for ASSAM
(2 shaft)

PROJECT SNAPSHOT

Business Economics of VSBK Enterprise	
Item of Cost	**Amount (in Rs.)**
Capital Cost of the project	**60,63,927**
Land & Site development	30,000
Building & other civil works cost	36,07,440
Machinery & equipment	14,38,800
Miscellaneous Fixed Assets	1,30,000
Preliminary & Pre-operative Expenses	38,70,000
Contingencies	5,67,500
Working Capital	**19,18,934**
Total Project Cost	**79,82,861**
Production Cost (per Annum)	**1,12,44,192**
Revenue (per Annum)	**2,00,89,933**
Profit (per Annum)	**75,91,233**
Payback Period (in Years)	**2**
NPV of the Project	**31,70,90,404**
IRR of the Project	**82.78%**

Key considerations and assumptions:

- EcoKiln type: Double Shaft (11 batches)
- Installed capacity: 9,000 bricks per day (2,700,000 bricks per annum)
- No. of working days per annum: 300
- Average plant utlisation capacity: 83%
- Average production cost per brick: Rs. 4.16
- Average selling price per brick: Rs. 9
- Project finance: 100% from entrepreneur

considered here are as per inputs provided in discussion with entrepreneurs in Assam and also the rates available and applicable for Assam. The detailed calculations and the list of schedules have been attached in the annexes.

The total project has been calculated to be around INR 79.82 lakhs with a brick selling price of INR 9 as per the market assessment, the payback period will be around 2 years. A simulation of the payback period with brick selling price has also been done where it is observed that the payback period is inversely proportional to that of the brick selling price. But to keep the business more realistic and competitive, one should not increase the brick selling price.

ANNEXURE - VSBK Business Plan Detail

LIST OF SCHEDULES			
SCHEDULE - A COST OF PROJECT			
			USD 75.00
Item of Cost	Annexure	Total	
	Nos.	Rs.	USD
Land & Site development	1	105,000	1,400
Building & other civil works cost	2	4,523,603	60,315
Machinery & equipment	3	2,551,000	34,013
Miscellaneous Fixed Assets	4	190,000	2,533
Preliminary & Pre-operative Expenses	5	282,000	3,760
Contingencies	6	382,580	5,101
Capital Cost of the project		8,034,183	107,122
Working Capital	16	1,887,924	25,172
Total Project Cost		9,922,107	132,295

SCHEDULE - B MEANS OF FINANCE				
Sources of funds		Already Raised	To be Raised	Total
		Rs.	Rs.	Rs.
Capital				
Promoter's Capital	100.00%	-	9,922,107	9,922,107
Subsidy/donor grant/government scheme	0.00%	-	-	-
Secured Loans				
Bank	0.00%	-	-	-
Other financial institutions	0.00%		-	
Total source of funds		-	9,922,107	9,922,107

SCHEDULE -C PROFIT AND LOSS PROJECTION											
Particulars	Annexure	Operating Years									
	Numbers	1	2	3	4	5	6	7	8	9	10
A. Estimated sales revenue/ income		14,369,898	17,195,940	18,317,970	18,360,000	18,360,000	18,360,000	18,360,000	18,360,000	18,360,000	18,360,000
Production cost:											
Raw materials		3,836,700	4,384,800	4,658,850	4,658,850	4,658,850	4,658,850	4,658,850	4,658,850	4,658,850	4,658,850
Consumables		115,101	131,544	139,766	139,766	139,766	139,766	139,766	139,766	139,766	139,766
Utilities		638,400	729,600	775,200	775,200	775,200	775,200	775,200	775,200	775,200	775,200
Salaries and wages		4,899,000	5,304,000	5,506,500	5,506,500	5,506,500	5,506,500	5,506,500	5,506,500	5,506,500	5,506,500
Repairs & Maintenance		86,566	98,933	105,116	105,116	105,116	105,116	105,116	105,116	105,116	105,116
Other manufacturing expenses		84,362	86,060	86,909	86,909	86,909	86,909	86,909	86,909	86,909	86,909
Administrative Overheads		35,000	40,000	42,500	42,500	42,500	42,500	42,500	42,500	42,500	42,500
Sub-total		9,695,130	0,774,937	1,314,841	1,314,841	11,314,841	11,314,841	11,314,841	1,314,841	11,314,841	11,314,841
Add: Provision for Production Losses	10.00%	969,513	1,077,494	1,131,484	1,131,484	1,131,484	1,131,484	1,131,484	1,131,484	1,131,484	1,131,484
Add: Opening stocks of Work In Progress (W.I.P)		-	319,192	354,963	372,848	372,848	372,848	372,848	372,848	372,848	372,848
Add: Opening stocks of Finished Goods (F.G)		-	430,910	479,199	503,344	503,344	503,344	503,344	503,344	503,344	503,344
Less: Closing stocks of F.G.		319,192	354,963	372,848	372,848	372,848	372,848	372,848	372,848	372,848	372,848
Less: Closing stocks of W.I.P.		430,910	479,199	503,344	503,344	503,344	503,344	503,344	503,344	503,344	503,344
B. Total cost of production		9,914,541	11,768,371	12,404,295	12,446,325	12,446,325	12,446,325	12,446,325	12,446,325	12,446,325	12,446,325
C. EBIDT (A-B)		4,455,358	5,427,569	5,913,675	5,913,675	5,913,675	5,913,675	5,913,675	5,913,675	5,913,675	5,913,675
D. Total interest expenses		-	-	-	-	-	-	-	-	-	-
E. Income before depreciation and tax (C-D)		4,455,358	5,427,569	5,913,675	5,913,675	5,913,675	5,913,675	5,913,675	5,913,675	5,913,675	5,913,675
Depreciation		1,200,521	1,200,521	1,200,521	1,200,521	1,200,521	1,200,521	1,200,521	1,200,521	1,200,521	1,200,521
Preliminary expenses (written off over the given years)	5	26,400	26,400	26,400	26,400	26,400	-	-	-	-	-
F. Profit Before Tax (PBT)		3,228,436	4,200,648	4,686,754	4,686,754	4,686,754	4,713,154	4,713,154	4,713,154	4,713,154	4,713,154
G. Provision for taxation	30.00%	968,531	1,260,194	1,406,026	1,406,026	1,406,026	1,413,946	1,413,946	1,413,946	1,413,946	1,413,946
H. Profit After Tax (PAT)		2,259,905	2,940,453	3,280,728	3,280,728	3,280,728	3,299,208	3,299,208	3,299,208	3,299,208	3,299,208

SCHEDULE - D CASH FLOW STATEMENT											
Particulars	**Annexure Numbers**	**Operating Years**									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Cash at the beginning of the year		-	(3,578,826)	1,848,744	7,762,418	13,676,093	19,589,768	25,503,443	31,417,118	37,330,793	43,244,468
Cash at the end of the year		(3,578,826)	1,848,744	7,762,418	13,676,093	19,589,768	25,503,443	31,417,118	37,330,793	43,244,468	49,158,143
OPERATING ACTIVITIES											
Cash receipt:											
Sales		14,369,898	17,195,940	18,317,970	18,360,000	18,360,000	18,360,000	18,360,000	18,360,000	18,360,000	18,360,000
Cash paid for:											
Production		(9,914,541)	(11,768,371)	(12,404,295)	(12,446,325)	(12,446,325)	(12,446,325)	(12,446,325)	(12,446,325)	(12,446,325)	(12,446,325)
Interest expenses		-	-	-	-	-	-	-	-	-	-
Net Cash Flow from Operating Activities		4,455,358	5,427,569	5,913,675	5,913,675	5,913,675	5,913,675	5,913,675	5,913,675	5,913,675	5,913,675
INVESTING ACTIVITIES											
Cash receipt:											
		-	-	-	-	-	-	-	-	-	-
Cash paid for:											
Capital cost of the project		(8,034,183)	-	-	-	-	-	-	-	-	-
Net Cash Flow from Investing Activities		(8,034,183)	-	-	-	-	-	-	-	-	-
FINANCING ACTIVITIES											
Cash receipt											
Term Loan		-	-	-	-	-	-	-	-	-	-
Cash paid for											
Term Loan principal		-	-	-	-	-	-	-	-	-	-
Net Cash Flow from Financing Activities		-	-	-	-	-	-	-	-	-	-
NET CASH FLOW		(3,578,826)	5,427,569	5,913,675	5,913,675	5,913,675	5,913,675	5,913,675	5,913,675	5,913,675	5,913,675

SCHEDULE - E BREAK EVEN POINT											
Particulars	Annexure Number	Operating Years									
		1	2	3	4	5	6	7	8	9	10
Installed Capacity/Day		9000	9000	9000	9000	9000	9000	9000	9000	9000	9000
Working days		300	300	300	300	300	300	300	300	300	300
Annual Installed Capacity		2700000	2700000	2700000	2700000	2700000	2700000	2700000	2700000	2700000	2700000
Capacity utilization as a %		70.00%	80.00%	85.00%	85.00%	85.00%	85.00%	85.00%	85.00%	85.00%	85.00%
Total production/ Annum		1890000	2160000	2295000	2295000	2295000	2295000	2295000	2295000	2295000	2295000
Estimated sales revenue		14,369,898	17,195,940	18,317,970	18,360,000	18,360,000	18,360,000	18,360,000	18,360,000	18,360,000	18,360,000
Variable costs:											
Raw materials		3,836,700	4,384,800	4,658,850	4,658,850	4,658,850	4,658,850	4,658,850	4,658,850	4,658,850	4,658,850
Consumables		115,101	131,544	139,766	139,766	139,766	139,766	139,766	139,766	139,766	139,766
Utilities	90%	574,560	656,640	697,680	697,680	697,680	697,680	697,680	697,680	697,680	697,680
Salaries and wages	70%	3,429,300	3,712,800	3,854,550	3,854,550	3,854,550	3,854,550	3,854,550	3,854,550	3,854,550	3,854,550
Repairs and maintenance		86,566	98,933	105,116	105,116	105,116	105,116	105,116	105,116	105,116	105,116
Other manufacturing expenses	20%	16,872	17,212	17,382	17,382	17,382	17,382	17,382	17,382	17,382	17,382
Provision for production loss		969,513	1,077,494	1,131,484	1,131,484	1,131,484	1,131,484	1,131,484	1,131,484	1,131,484	1,131,484
Interest on cash credit facility for working capital		-	-	-	-	-	-	-	-	-	-
Administration overheads	20%	7,000	8,000	8,500	8,500	8,500	8,500	8,500	8,500	8,500	8,500
Less: Variation in stocks		(750,102)	(84,060)	(42,030)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total variable costs		9,785,714	10,171,483	10,655,358	10,613,328	10,613,328	10,613,328	10,613,328	10,613,328	10,613,328	10,613,328
Variable cost per unit	Rs.	5	5	5	5	5	5	5	5	5	5
Gross income	Rs.	4,584,184	7,024,457	7,662,612	7,746,672	7,746,672	7,746,672	7,746,672	7,746,672	7,746,672	7,746,672
Gross income per unit	Rs.	2	3	3	3	3	3	3	3	3	3
Fixed costs:											
Utilities	10%	63,840	72,960	77,520	77,520	77,520	77,520	77,520	77,520	77,520	77,520
Salaries and wages	30%	1,469,700	1,591,200	1,651,950	1,651,950	1,651,950	1,651,950	1,651,950	1,651,950	1,651,950	1,651,950
Other manufacturing expenses	80%	67,490	68,848	69,527	69,527	69,527	69,527	69,527	69,527	69,527	69,527
Administration overheads	80%	28,000	32,000	34,000	34,000	34,000	34,000	34,000	34,000	34,000	34,000
Interest on term loan		-	-	-	-	-	-	0.00	0.00	0.00	0.00
Depreciation and preliminary expenses		1,226,921	1,226,921	1,226,921	1,226,921	1,226,921	1,200,521	1,200,521	1,200,521	1,200,521	1,200,521
Total fixed and semi variable cost		2,855,951	2,991,930	3,059,919	3,059,919	3,059,919	3,033,519	3,033,519	3,033,519	3,033,519	3,033,519
Break even point in sales revenue per year	Rs.	8,952,461	7,324,273	7,314,934	7,252,160	7,252,160	7,189,591	7,189,591	7,189,591	7,189,591	7,189,591
Break even point in number of bricks per year	number	1,177,472	920,010	916,465	906,520	906,520	898,699	898,699	898,699	898,699	898,699

SCHEDULE - F PAYBACK PERIOD, NPV AND IRR					
	Operating Year	**Profit After Tax (PAT)**	**Total Project Cost (in Rs.)**	**Cumulative Cash Inflow (in Rs.)**	**Projected Cost Recovery (in Rs.)**
Construction Period			9,922,107		(9,922,107)
	1	2,259,905		2,259,905	(7,662,202)
	2	2,940,453		5,200,359	(4,721,748)
	3	3,280,728		8,481,086	(1,441,021)
	4	3,280,728		11,761,814	1,839,707
	5	3,280,728		15,042,541	5,120,435
	6	3,299,208		18,341,749	8,419,642
	7	3,299,208		21,640,956	11,718,850
	8	3,299,208		24,940,164	15,018,057
	9	3,299,208		28,239,371	18,317,265
	10	3,299,208		31,538,579	21,616,472
Payback period is between operating years		1	to	2	
NPV of the Project (in Rs.)					58,303,350
IRR of the Project					19.26%

LIST OF ANNEXURES

ANNEXURE - 1

PARTICULARS OF LAND AND SITE DEVELOPMENT COST

Particulars	Unit	Quantity	Rate Rs.	Total Rs.
Land:				
Acquisition cost	square meter	9000.00	-	-
Other cost (land title deed and registration)	lump sum	1.00	-	-
Sub-total				-
Site development:				
Fencing (Complete Plot)	lump sum	1.00	40,000	40,000
Gates, internal roads	lump sum	1.00	65,000	65,000
Drainage	lump sum	1.00	-	-
Sub-total				105,000
Total: Land and Site Development cost				105,000

ANNEXURE - 2
PARTICULARS OF BUILDINGS & OTHER CIVIL WORKS COST

Particulars	No. of Floor	Built Up Area Length (m)	Width (m)	Quantity	Total Floor Area (square meter)	Lump Sum Cost Rs.
Vertical Shaft Brick Kiln (2-Shaft with 11 Batch)	-	12.30	8.10	1.00	99.61	4,523,603
Total: Buildings and other civil works cost						4,523,603

ANNEXURE - 3
PARTICULARS OF MACHINERY & EQUIPMENT COST

Particulars	Supplier's Name	Quantity	Unit	Invoice Price INR / Unit	Total Rs.
Brick Making Machine		1.00	set	800,000	800,000
Conveyor Belt System		1.00	set	350,000	350,000
Transfer Trolleys		4.00	number	60,000	240,000
Hydraulic Jack		2.00	set	380,000	760,000
Total					2,150,000
Add: Handling & Forwarding Charges @10%					215,000
Add: Warehouse charges					100,000
Add: Transportation & Insurance @ 4%					86,000
Grand Total: Machinery & Equipment Cost					2,551,000

ANNEXURE - 4
PARTICULARS OF MISCELLANEOUS FIXED ASSETS

Description	Unit	Quantity	Rate Rs.	Total Rs.
Office furniture and fixtures	lump sum	1.00	20,000	20,000
Borehole, water storage, distribution pipes, pump	lump sum	1.00	50,000	50,000
Cost of drawing power, cabling, and electric installations for wiring, lighting, and deposits	lump sum	1.00	120,000	120,000
Total				190,000

ANNEXURE - 5
PRELIMINARY AND PREOPERATIVE EXPENSES

Description	Unit	Quantity	Rate	To be incurred
			Rs.	Rs.
Preliminary expenses:				
Soil Feasibility test*	lump sum	0.50	10,000	5,000
Environment Impact Analysis	lump sum	1.00	100,000	100,000
Business Plan and BoQ for EcoKiln*	lump sum	0.50	30,000	15,000
Legal Expenses	lump sum	1.00	10,000	10,000
Other Charges including bank	lump sum	1.00	2,000	2,000
Total				132,000
Preoperative expenses:				

ANNEXURE - 5 PRELIMINARY AND PREOPERATIVE EXPENSES				
Description	**Unit**	**Quantity**	**Rate**	**To be incurred**
Technical know-how fees*	lump sum	0.50	300,000	150,000
Total				150,000
Grand Total: Prelim. & Preop. Expenses				282,000
* Calculation at 50% discount as part of the project support				

ANNEXURE -6 ESTIMATES OF CONTINGENCY ESCALATION PROVISION		
Item of Cost	**Annexure Nos.**	**Total Rs.**
Land & site development	1	105,000
Buildings and other civil works	2	4,523,603
Machinery & equipment	3	2,551,000
Miscellaneous Fixed Assets	4	190,000
Preliminary & Pre-operative Expenses	5	282,000
Total		7,651,603
Contingency	5%	382,580

ANNEXURE - 7 CALCULATION OF DEPRECIATION					
Description		**Site Development & Buildings**	**Machinery & Equipment**	**Misc. Fixed Assets**	**Total**
Straight Line Method:					
Rate of depreciation	%	10	25	10	
Acquired cost		4,628,603	2,551,000	190,000	7,369,603
Preoperative Expenses	150,000	94,210	51,923	3,867	150,000
Contingencies	382,580	240,286	132,431	9,864	382,580
Total apportioned cost		4,963,099	2,735,353	203,731	7,902,183
Depreciation amount		496,310	683,838	20,373	1,200,521

ANNEXURE - 8
ESTIMATED ANNUAL PRODUCTION AND SALES VALUE

Description	Unit	Operating Years 1	2	3	4	5	6	7	8	9	10
Installed Capacity/Day	number	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000
Number of Working Days	number	300	300	300	300	300	300	300	300	300	300
Annual Installed Capacity	number	2700000	2700000	2700000	2700000	2700000	2700000	2700000	2700000	2700000	2700000
Capacity utilisation	percentage	70%	80%	85%	85%	85%	85%	85%	85%	85%	85%
Target Production	number	1890000	2160000	2295000	2295000	2295000	2295000	2295000	2295000	2295000	2295000
Sales Value:											
Average selling price per year	8.00	8	8	8	8	8	8	8	8	8	8
Target brick sales per year		15,120,000	17,280,000	18,360,000	18,360,000	18,360,000	18,360,000	18,360,000	18,360,000	18,360,000	18,360,000
Add: Opening stock of Work In Progress & Finished Goods		-	750,102	834,162	876,192	876,192	876,192	876,192	876,192	876,192	876,192
Less: Closing stock of Work In Progress & Finished Goods		750,102	834,162	876,192	876,192	876,192	876,192	876,192	876,192	876,192	876,192
Total estimated sales revenue		14,369,898	17,195,940	18,317,970	18,360,000	18,360,000	18,360,000	18,360,000	18,360,000	18,360,000	18,360,000
Ratio of Pavers & Bricks; 40;60											

ANNEXURE -9
PARTICULARS OF RAW MATERIALS FOR ECO-BRICKS

Raw Material	Consumption per brick (in kg)	Rate/kg Rs.	Operating Years 1	2	3	4	5	6	7	8	9	10
Soil	2.80	0.50	2,646,000	3,024,000	3,213,000	3,213,000	3,213,000	3,213,000	3,213,000	3,213,000	3,213,000	3,213,000
Coal	0.09	7.00	1,190,700	1,360,800	1,445,850	1,445,850	1,445,850	1,445,850	1,445,850	1,445,850	1,445,850	1,445,850
Total			3,836,700	4,384,800	4,658,850	4,658,850	4,658,850	4,658,850	4,658,850	4,658,850	4,658,850	4,658,850

ANNEXURE - 10
PARTICULARS OF CONSUMABLES

Item	Rate	Operating Years 1	2	3	4	5	6	7	8	9	10
Consumables*	3.00%	115,101	131,544	139,766	139,766	139,766	139,766	139,766	139,766	139,766	139,766
Total Consumables		115,101	131,544	139,766	139,766	139,766	139,766	139,766	139,766	139,766	139,766
* Consumables include tools, equipments and other items for production											

ANNEXURE - 11
PARTICULARS OF UTILITIES

Particulars	Unit	Quantity Per Day	Rate Rs.	Operating Years 1	2	3	4	5	6	7	8	9	10
Water	litre	3500.00	0.50	367,500	420,000	446,250	446,250	446,250	446,250	446,250	446,250	446,250	446,250
Power-Diesel: Brick making machine (7.5 HP)	litre	12.00	90.00	226,800	259,200	275,400	275,400	275,400	275,400	275,400	275,400	275,400	275,400
Electricity	kilowatt hour (kWh)	35.00	6.00	44,100	50,400	53,550	53,550	53,550	53,550	53,550	53,550	53,550	53,550
Total				638,400	729,600	775,200	775,200	775,200	775,200	775,200	775,200	775,200	775,200

ANNEXURE - 12
SALARIES AND WAGES

Manpower Requirement	Salary/ wage basis	No. of people	Rate Rs.	Annual Wages Rs.	Operating Years 1	2	3	4	5	6	7	8	9	10
Brick production per year					1,890,000	2,160,000	2,295,000	2,295,000	2,295,000	2,295,000	2,295,000	2,295,000	2,295,000	2,295,000
Supervisor	per month	1	20,000	240,000	240,000	240,000	240,000	240,000	240,000	240,000	240,000	240,000	240,000	240,000
Fire Master	per month	2	12,000	288,000	288,000	288,000	288,000	288,000	288,000	288,000	288,000	288,000	288,000	288,000
Skilled (brick firing)	per month	12	10,000	1,440,000	1,440,000	1,440,000	1,440,000	1,440,000	1,440,000	1,440,000	1,440,000	1,440,000	1,440,000	1,440,000
Maintenance Staff (contractual)	per month	1	8,000	96,000	96,000	96,000	96,000	96,000	96,000	96,000	96,000	96,000	96,000	96,000
Unskilled: Unfired brick making	per brick	10	1	-	1,890,000	2,160,000	2,295,000	2,295,000	2,295,000	2,295,000	2,295,000	2,295,000	2,295,000	2,295,000
Unskilled: Brick handling	per brick	12	1	-	945,000	1,080,000	1,147,500	1,147,500	1,147,500	1,147,500	1,147,500	1,147,500	1,147,500	1,147,500
Total salaries and wages					4,899,000	5,304,000	5,506,500	5,506,500	5,506,500	5,506,500	5,506,500	5,506,500	5,506,500	5,506,500
No. of Workers		38												

ANNEXURE - 13
PARTICULARS OF REPAIRS AND MAINTENANCE

Particulars	Percentage	Operating Years 1	2	3	4	5	6	7	8	9	10
On Buildings	1.00%	31,665	36,189	38,451	38,451	38,451	38,451	38,451	38,451	38,451	38,451
On Machinery and Equipment	3.00%	53,571	61,224	65,051	65,051	65,051	65,051	65,051	65,051	65,051	65,051
On Other Fixed Assets	1.00%	1,330	1,520	1,615	1,615	1,615	1,615	1,615	1,615	1,615	1,615
Total		86,566	98,933	105,116	105,116	105,116	105,116	105,116	105,116	105,116	105,116

ANNEXURE - 14
PARTICULARS OF OTHER MANUFACTURING EXPENSES

Particulars	Percentage	Operating Years 1	2	3	4	5	6	7	8	9	10
Insurance on Fixed Assets	2.50%	68,525	68,525	68,525	68,525	68,525	68,525	68,525	68,525	68,525	68,525
Insurance on Stocks	2.00%	15,002	16,683	17,524	17,524	17,524	17,524	17,524	17,524	17,524	17,524
Contingencies	1.00%	835	852	860	860	860	860	860	860	860	860
Total		84,362	86,060	86,909	86,909	86,909	86,909	86,909	86,909	86,909	86,909

ANNEXURE - 15
ADMINISTRATIVE OVERHEADS

Particulars	Annual overheads INR / unit	Operating Years 1	2	3	4	5	6	7	8	9	10
Printing & Stationery	10,000	7,000	8,000	8,500	8,500	8,500	8,500	8,500	8,500	8,500	8,500
Travelling & Conveyance	20,000	14,000	16,000	17,000	17,000	17,000	17,000	17,000	17,000	17,000	17,000
Miscellaneous Expenses	20,000	14,000	16,000	17,000	17,000	17,000	17,000	17,000	17,000	17,000	17,000
Total Admin. Overheads		35,000	40,000	42,500	42,500	42,500	42,500	42,500	42,500	42,500	42,500

ANNEXURE - 16 WORKING CAPITAL REQUIREMENTS											
Item	Stocking Level (Days)	Operating Years									
		1	2	3	4	5	6	7	8	9	10
No. of Working Days in Year		300	300	300	300	300	300	300	300	300	300
Raw Materials	21	268,569	306,936	326,120	326,120	326,120	326,120	326,120	326,120	326,120	326,120
Consumables	21	8,057	9,208	9,784	9,784	9,784	9,784	9,784	9,784	9,784	9,784
Finished Goods (FGs)	10	319,192	354,963	372,848	372,848	372,848	372,848	372,848	372,848	372,848	372,848
Work-In-Progress (WIP)	15	430,910	479,199	503,344	503,344	503,344	503,344	503,344	503,344	503,344	503,344
Book Debts	21	1,005,893	1,203,716	1,282,258	1,285,200	1,285,200	1,285,200	1,285,200	1,285,200	1,285,200	1,285,200
Expenses (Administrative overheads and Utilities)	21	47,138	53,872	57,239	57,239	57,239	57,239	57,239	57,239	57,239	57,239
Total Current Assets		2,079,759	2,407,894	2,551,592	2,554,534	2,554,534	2,554,534	2,554,534	2,554,534	2,554,534	2,554,534
Less: Creditors	15	191,835	219,240	232,943	232,943	232,943	232,943	232,943	232,943	232,943	232,943
Net Working Capital		1,887,924	2,188,654	2,318,650	2,321,592	2,321,592	2,321,592	2,321,592	2,321,592	2,321,592	2,321,592

Greening of Brick Industry in Assam

Proposal for introducing energy efficient, low carbon
burnt brick production technologies

Submitted to
Swiss Agency for Development
and Cooperation
New Delhi, India

Submitted by
Assam Climate Change Management
Society (ACCMS), Govt. of Assam
Panjabari, Guwahati, Assam

1. Introduction

The construction sector is one of the most widely recognized sectors across the globe. In India, this sector is the second largest employer after agriculture, and is slated to grow at 6.2%[10] over the next decade (2018-2027). This growth places a consequent demand for increased building materials, especially bricks, among others such as sand, aggregates, cement, steel, aluminium, timber, glass and tiles.

India is the second largest producer of bricks, with only China ahead of it. Its estimated annual production of bricks is 240-260 billions[11], manufactured using around 140,000 brick kilns[2]. However, the Indian brick sector relies majorly on technologies that are inefficient in resource and energy, such as Fixed Chimney Bull's Trench Kiln (FCBTK) and clamps, with minimal signs of shifting to efficient technologies. The traditional clay brick sector consumes nearly 35-40 million tonnes[2] (MT) of coal annually, emits around 66 MT[2] of carbon dioxide (CO_2) accounting for 5.5% of total Green House Gas (GHG) emissions from India, and depletes approximately 500 MT[2] of fertile top soil each and every year. While over the last decade there has been a relative growth in the market for alternate building materials such as fly ash bricks, AAC blocks, compressed earth blocks (CEB) and concrete blocks, the share is almost negligible. In India, almost 65% of the total burnt clay brick production is from the Indo-Gangetic plains, with Uttar Pradesh, Bihar, West Bengal, Punjab, Haryana and Assam being the major producers.

Out of the total CO_2 emissions of the country, the state of Assam contributes around 1.6 million tons from the burnt clay brick sector. This is slated to rise considering the increased level of construction and therefore the consumption of building materials.

2. The Brick Industry in Assam

With increasing rural affluence, demand of bricks for construction of houses in villages in India has gone up significantly over the last few years. Rural housing according to industry estimates is expected to account for atleast 50% of the overall demand for bricks during 2010 and beyond, replacing traditional drivers for brick consumption i.e. infrastructure and the urban housing segment. Rural people especially in the rural parts of predominantly under developed states of Bihar, Uttar Pradesh, Assam, Chattisgarh and Jharkhand are increasingly replacing thatched mud hutments and switching over to "brick and mortar" structures.

Assam is dominated by burnt clay bricks similar to the rest of India. Presently Assam has about 669 burnt clay brick kilns[12] which produce approximately 2 billion[13] fired clay bricks annually. In manufacturing these clay bricks, approximately 5.56 million tons[14] of fertile soil is stripped off every year with an emission of 1.6 million tonnes of CO_2. The high use of agricultural soil puts an immense pressure on the agricultural activity also.

However despite a high production of burnt clay bricks, still there is a shortfall between supply and demand. It is estimated that in the next couple of years there will be a demand of around 350 more bricks kilns in the state. To cater to this shortfall, it is obvious that there will be new brick industries coming up in the state of Assam. The brick industry in Assam (typical to any Indian Brick Industry) is besieged with age old Bull's Trench Kiln Technology. Technological advances have brought out fixed chimney variant of BTK technology replacing the movable chimneys. Demand of alternate technologies i.e. VSBK and fly ash are also

10 World Cement, India's construction industry to grow strongly, Jonathan Rowland ,14th March 2018.<https://www.worldcement.com/indian-subcontinent/14032018/indias-construction-industry-to-grow-strongly/ > (accessed on 25th March 2019)

11 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 the Centre for Science and Environment at New Delhi on 8 February 2016

12 Divisional Forest Offices, Assam

13 Average annual brick production of 1 FCBTK is 30 lakhs. Assuming all bricks kilns is functional

14 1 brick consumes 2.8kg of soil

gaining popularity. In spite of the advances made; the brick industry in Assam still remains one of the major polluting and resource inefficiency sectors creating a growing health concern among the local population. Pollution situations are aggravated especially during the winter months with restricted wind movement. In North and Eastern Assam areas, this further worsens during the winter season when thermal inversion, where cold air flowing down from the mountains is trapped under a layer of warmer air, creates a lid, which keeps the pollutants, sealed within the plains.

The fixed chimney brick industry in Assam has a high specific energy consumption of 1.59MJ/kg consuming around 0.4 million tonnes of coal thereby releasing around 1.2 million tonnes of CO_2 each and every year. The amount of suspended particulate matter (SPM) and particulate matter less than 10 microns (PM10) resulting from the same are also beyond tolerable limits higher than WHO guidelines. Use of immature, bituminous, low quality coal from North East India e.g. Assam, Meghalaya etc. (>1% Sulphur content) leads to high CO_2 and SO_2 emissions contributing to anthropogenic climate change. Particulate matters and SO_2 cause serious health problems, predominantly in the respiratory system. Of late interest is the measurement of black carbon or soot also which is also considered to be a major source of global warming.

The brick industry is an important industry in the rural economy of Assam. While there is a geographical space within which brick kiln are located to take advantage of soil, they are not located at very close proximity of one another. Thus brick kilns in Assam can be viewed as a "regional industrial cluster" in the rural sector. It employs millions of workers, mostly migrant in nature who come with their families and works for several months from Bihar, UP and West Bengal. There usually is no work during the rainy season, as a result of which workers are forced to look for other jobs or return to native villages. Many of the workers belong to the poorest sections of society and separated from whatever social and other support structures existed in their area of origin. They are also typically isolated in their new settings. The workers are highly vulnerable to manipulation by contractors bypassing basic labour regulations and rights. The industry also has a high incidence of child labour which is unpaid and exploited.

Similarly, Assam has about 669 burnt clay brick kilns[15] which produce approximately 2 billion[16] fired clay bricks annually. In manufacturing these clay bricks, approximately 5.56 million tons[17] of fertile soil is stripped off every year with an emission of 1.6 million tonnes of CO_2. The high use of agricultural soil puts an immense pressure on the agricultural activity also.

3. Need for improvement

The project aims to demonstrate two types of technologies:

1. Improvement of existing practices i.e. use of internal fuel in unfired brick making
2. Introduction of transformative technologies i.e. the Vertical Shaft Brick Kiln

Demonstration of these technologies will be implemented in a business-like manner with improved profitability as the main target alongwith reducing emissions and improving efficiency in resource use. Additionally coal producers will be demonstrated a solution to use their waste materials in a profitable manner through the use of slurry in internal fuel brick making. The brick manufacturing community will be provided with a solution to lower their energy consumption. Apart from reduced energy consumption, there will be improvement on the environmental emissions from the use of internal fuel and the vertical shaft brick kiln. These solutions will lead to improved profitability for the brick community.

It is a common perception of traditional clay brick manufacturers that new technologies bring in a paradigm shift in approaches to brick production which will be difficult to adopt by the existing workforce. However improved profitability and quality is assumed to be the biggest driver of acceptance amongst new and existing entrepreneurs. A preliminary calculation of specific energy consumption of both the technologies shows that a SEC of 0.75 MJ/kg of fired bricks can be achieved following best practices. This will result in savings of more than 50% of the coal being consumed which will result in enhanced profitability without any degradation in the property of the fired product.

The most important parameter in getting a good quality product is uniform mixing of soil and additives. This can be achieved only through mechanized mixing which is supposed to improve the quality of the fired brick by achieving increased densification. If all the 700 FCK units adopt the best practices, it is expected to result in:

- Saving of 0.2 million tonnes of coal per year
- Profitability of around INR 1.6 billion annually from savings of coal
- Saving of 0.6 million tonnes of CO_2 each and every year

4. Technologies to be implemented

The project aims to demonstrate two types of technologies:

1. Improvement of existing practices i.e. use of internal fuel in unfired brick making
2. Introduction of transformative technologies i.e. the Vertical Shaft Brick Kiln

A brief description of these technologies is given below:

15 Divisional Forest Offices, Assam
16 Average annual brick production of 1 FCBTK is 30 lakhs. Assuming all bricks kilns is functional
17 1 brick consumes 2.8kg of soil

1. Improvement of existing practices i.e. use of internal fuel in unfired brick making

This technology will demonstrate the use of internal fuel in unfired brick making. The internal fuel to be used will be coal dust, boiler ash, rice husk ash or any form of carbonaceous waste materials. These waste materials will be ground in specified sized in a coal crusher or pulveriser and added to the soil during processing. The processing of the soil has to be done through mechanized means i.e. pugmill or any other process to ensure uniformity in mixing.

Once the bricks are dried, then the normal process of loading, firing and unloading will follow. The most important aspect of this technology is that the capital cost requirement is extremely low and no change in existing brick making process needs to be followed.

2. Introduction of transformative technologies i.e. the Vertical Shaft Brick Kiln

Vertical Shaft Brick Kiln (VSBK) technology is an energy efficient technology for firing clay bricks. It is particularly suited to the needs of brick production in developing countries – which is small scale and decentralized type. The evolution and initial development of VSBK technology took place in rural China. The first version of VSBK in China originated from traditional updraft intermittent kiln during 1960's. During 70's, the kiln became popular in several provinces of China. In 1985, Chinese government commissioned the Energy Research Institute of the Henan Academy of Sciences at Zhengzhou (Henan province), to study the kiln to improve the energy efficiency. The institute came up with an improved design of VSBK in 1988 which had a higher shaft height and provisions for a pair of chimneys. About 50,000 VSBKs were estimated to be operating in China during 1996.

Various attempts to disseminate VSBK technology outside China started in early 1990's. It was demonstrated in several Asian countries such as Nepal, Afghanistan, Pakistan and Bangladesh. However no appreciable success was reported in the external domain to document factors of success.

VSBK in India was launched in 1995 by Swiss Agency for Development & Cooperation (SDC) as a project on introducing sustainable production systems for building materials.

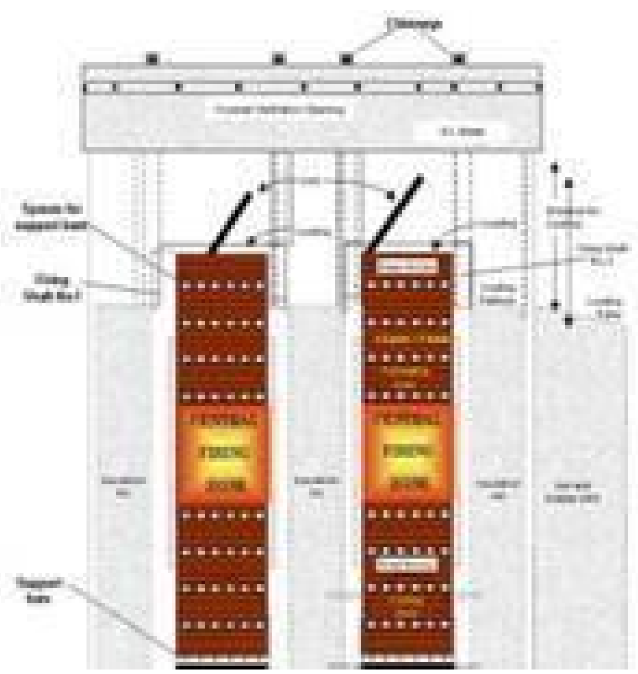
The factors that has contributed towards its successful adoption in India was its suitability for decentralized production systems and positioning as a means of improving the product quality thus ensuring higher returns of investment. Simple mechanization was implemented for unfired brick making, material handling, transportation and extrusion of unfired bricks. Internal fuel in the form of coal, biomass and sawdust is added during the moulding of unfired bricks – this creates highly favourable conditions for short cycle firing.

Thus within a span of 5 years (2000 – 2005) more than 100 VSBK's were established in a commercial mode. The qualities of bricks were accepted in the market at a premium rate. Most of the entrepreneurs were satisfied with the flexibility and performance of the kiln. This was reiterated by the increasing investment in selective mechanization and capacity augmentation. After the commercial success of VSBK in India as a viable alternative to traditional brick making with huge potential to energy and environment savings, VSBK technology was reopened in Nepal.

Kiln description and working principle

VSBK has vertical shaft of rectangular or square cross-section. The gap between shaft wall and outer kiln wall is filled with insulating materials – broken bricks and burnt coal ash. The kiln works as a counter-current heat exchanger, with heat transfer taking place between the air moving up (continuous flow) and bricks moving down (intermittent movement). Unfired bricks are loaded in batches from kiln top. Bricks move down the shaft through brick pre-heating, firing and cooling zones and unloaded from bottom. The combustion of coal (added along with bricks at the top) takes place in the middle of the shaft. Combustion air enters shaft from bottom, gets preheated by hot fired bricks in the lower portion of the shaft before reaching the combustion zone. Hot combustion gases preheat unfired bricks in upper portion of the shaft before exiting from the kiln through shaft or chimney.

The brick setting in kiln is kept on support bars at bottom of the shaft. Unloading of bricks is done from bottom of the shaft using a trolley. The trolley is lifted (using single screw mechanism) till the iron beams placed on the trolley touches the bottom of the brick setting and the weight of bricks is transferred on to the trolley. The freed support bars are taken out.



The trolley is then lowered by one batch (equivalent to 4 layers of bricks) – support bars are again put in place through the holes provided in the brick setting for the purpose. With slight downward movement, the weight of the brick setting is transferred to support bars. The trolley (with one batch of fired bricks on it) is further lowered till it touches ground level and then pulled out of the kiln on a pair of rails provided for the purpose. At every 2 - 3 hours, one batch of

fired bricks is unloaded at bottom and a batch of fresh unfired bricks is loaded at the top simultaneously. At any given time, there are typically 11 to 12 batches in the kiln depending on the unfired brick quality.

Two chimneys located diagonally opposite to each other in the shaft remove flue gases from the kiln. A lid is also provided on the shaft top which is kept closed during normal operation. Flue gases are directed to pass through chimney thus not polluting working area on the kiln top. The provision of shaft lid, better ventilation of working area on kiln top and higher and bigger chimneys are some of the highlights of VSBK kiln and its related process.

The heating cycle for the unfired bricks is raw material specific (pre-heating, vitrification and cooling down) and is normally completed within 24-30 hours. A batch of bricks is loaded and unloaded every 2-3 hours; requiring round the clock operations and supervision. This requires special skills and the firing operator needs to maintain a correct balance between:

- Energy - Controlled by amount of coal feeding
- Airflow - Controlled by stacking density and damper position
- Unloading speed - Controlled by the operator

Comparison of BTK and VSBK operation

Both the types of kilns are continuous updraft kiln with a central chimney for exhaust of flue gases. However the basic differences in both the types of firing are:

- In VSBK to start firing only about 4000 to 5000 bricks are needed (depending upon the shaft cross section). In BTK firing can only start after at least 50 to 60 lines are filled up. The above process requires approximately 2 to 3 lakhs of unfired bricks. Thus VSBK is a low capital investment firing.
- In VSBK for initial firing small fireboxes are made at the bottom. For initial firing from the bottom only about 100 kg of dry firewood is required to start the fire. No firewood is required after initial burning. In BTK the fireboxes are much wider and larger in size. Large quantities of firewood is required alongwith other flammable materials like saw dust, rubber tyres etc.

- In VSBK the fire wood is burnt for an initial period of 3 to 4 hours for firing initialization whereas in BTK a minimum of 16 to 20 hours are required for the same result.
- In VSBK after initial firing stable production is achieved within 3 to 4 days by which saleable bricks are produced. In BTK for production of suitable saleable bricks a gestation period of at least 15 to 20 days are required.

Basic advantages of VSBK over conventional BTK technology

High energy efficiency

The VSBK technology economizes on fuel costs, with savings of between 30 to 50% when compared with other common brick firing technologies such as clamps or Bull's trench kiln with movable chimneys.

Environment friendly operations

The construction of a VSBK requires very little land. The building of multiple shaft production units further enhances the ratio of land use to production output. As a VSBK can only be fired with coal (or with coal dust), deforestation of rural areas can be controlled. Additionally, if a VSBK is operated as per recommended conditions, emissions are reduced by approximately 90% compared to common traditional brick firing technologies.

Economically viable

Brick production using VSBK technology is a profitable business and the overall initial investment is low (considering investment in permanent land). Since in a VSBK the fired bricks are produced in 24 hours so the working capital required is very less.

Uniform quality of production

Unlike other brick firing technologies where a uniform quality of fired bricks is not possible due to heat losses, in VSBK the batches of fired bricks produced are 95% uniform in quality segregated into a single class. Compared to the BTK where 2nd and 3rd grade bricks are produced in significant quantities, a VSBK produces mostly 1st grade bricks. Breakage and wastage can be limited to even less than 5% through stable operation of the VSBK and quality unfired brick making.

Round the year production

The VSBK can be operated all the year round and even during monsoon time subject to availability of dried unfired bricks. Weather factors have only a minor influence because a roof protects the kiln.

Consistent quality

VSBK produces high quality bricks if proper firing practices are followed. In fact, the products are even superior to those of existing rural brick production technologies (traditional and BTK firing technologies). VSBK fired bricks show a fine, deep red colour and have a good, metallic ring depending upon the soil quality. A compressive strength of upto 200 kg/cm2 can be achieved using good quality soils.

5. Goal

The goal of this project is to create awareness, sensitize and build capacity of key stakeholders towards large scale dissemination of cleaner technologies and practices in the brick sector in Assam.

6. Objectives

The specific objectives of the proposed project are:

- Sensitization and capacity building of diverse stakeholders to secure interest and future contribution to a large brick sector transformation initiative
- Demonstrate potential benefits of Vertical Shaft Brick Kiln and internal fuel technology and establish a clear baseline in terms of energy efficiency, environmental emissions and profitability
- Make potential benefits visible to key stakeholders through demonstration and knowledge products.

7. Dissemination conducted

Assam Climate Change Management Society (ACCMS), Govt. of Assam and Climate Change Cell, Assam supported by Department of Science and Technology (DST), Govt. of India organized two workshops to create awareness on the current status of brick production in Assam and future scenarios for fired brick production and to build capacity on the unfired brick kiln technologies. The brick manufacturers, brick users, technology providers, financial institutions and knowledge partners participated in the workshops organized at Bongaigaon and Nagaon district on 4th October, 2021 and 5th October, 2021 respectively.

The primary objectives of the workshops were as follows:

- Aware the brick kiln owners on the current status of brick kiln industry and its impact on environment.
- Make the participants familiar with different methods/techniques of upgradation in existing brick production system.
- Knowledge building of the participants on improvement and process optimization in existing brick firing technologies.
- Make the entrepreneurs aware on transformative new technologies like Vertical shaft brick kilns (VSBK), Fly ash bricks, and compressed earth blocks etc.

Despite inclement weather conditions, there were more than 200 entrepreneurs attending the Workshops. Most of them were from the existing burnt clay brick industries. Most workshops meetings and discussions confirmed the interest of more than 50 entrepreneurs in VSBK and use of internal fuel also. They are ready to provide land and also invest into the technology of assurances of technology transfer can be given.

It was recommended that in the areas of Dhubri, Bongaigaon and Nagaon immediate interventions be made to keep up with the interest shown by entrepreneurs.

8. Work plan and methodology

The proposed project will be implemented in two phases:

Phase 1 (June 2021 – August 2021)

Knowledge building initiatives

1. Manuals for technology transfer and dissemination

These manuals are proposed in the draft stage since they will be implemented and verified during the implementation phase. With assessment and required modifications they will be finalized in Phase 2. The documents proposed in this Phase will be key documents in training and capacity building of personnel's in Assam. They will be developed based on the capacities and knowledge developed through more than 2 decades of experience. However there will be a requirement of comprehensive modification and adaptation as per Assam conditions. After adapting and modification as per Assam conditions, required testing will be done in Phase 2 where the final document will be prepared.

Phase 2 (July 2021 – December 2022) Concurrent with Phase 1

Pilot initiatives on introduction of new technology:

1. Introduction of VSBK technology in 2 selected areas of Assam
2. Demonstration of internal fuel technology in existing FC BTK unit in Assam
3. Operation and fine tuning of quality as per local demand and conditions including profitability analysis

Capacity building initiatives:

- Training and capacity building of master masons, machine operators and firemen in Vertical Shaft Brick Kiln and Internal fuel Technology
- Training and capacity building of local resource organization, for enabling adoption of cleaner technologies and practices in the brick sector.
- Build visibility and capacity of the key stakeholders including the brick manufacturers by information dissemination through workshops and knowledge management products

This phase will primary focus on construction and operation of a pilot VSBK in association with TARA. Preliminary groundwork and consultations with TARA have resulted in identification of 3 district as the first intervention area. These are Silchar, Nagaon and Dhubri. This has been based on the potential of maximum impact creation since the traditional practices of brick making are not very resourceful. Thus successful demonstration of an energy and environment efficient technology amongst the brick entrepreneurs and regulatory agencies will increase the basket of choices for technology shift. Capacities will also be created towards enabling large scale dissemination.

9. Outputs

Phase 1

- VSBK Technology package
- Internal fuel technology package

All the packages will be in English and in the draft stage. During the Phase 2 they will be implemented and further refined and adapted to suit Assam conditions. During Phase 2 they will be finalized in both English and local (Assamese) language to suit local needs.

Phase 2

- 2 VSBK constructed and under operation in Assam
- 1 Internal fuel technology demonstrated in Assam
- 80 workers trained in various operations
- Report of energy, and environment monitoring
- Economic analysis and business package

BUDGET HEADS

S.no	Budget Head	Amount (INR)
1	Personnel Costs	7,968,000
2	Travel	3,420,000
3	Capital Costs - Equipment	8,200,000
4	Other Direct Costs	5,900,000
5	Institutional Support Costs (15%)	3,860,700
6	**GRAND TOTAL**	**29,348,700**

ANNEXURE 8 – Brick Lab Testing Reports and Soil Testing Reports

Avante Engineers

(Material and Geotechnical Consultants)

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TEST REPORT

Format No.: Avante/Format/59

Ref. No.: Avante/TR/MT/2021/065a **Date: 11/09/2021**

Name of the Client	Society for Technology and Action for Rural Advancement		
Name of the Project	B-32, TARA, Crescent, Qutub Industrial Area, New Delhi-110016		
Ref. Work Order	**NIL**	Dated: **10/09/21**	
Sample Id	Avante/Sample/2021/065a	Sample Received Date	04/09/2021
Test Start Date	07/09/2021	Test completed date	11/09/2021

Type of Sample	**BRICK (Red)**
Brand	**MBI**

The results are as under:

1. **DIMENSION TEST**

Sample No	Dimension (LxBxH) (mm)
1	235x115x70
2	235x120x65
3	225x110x65

2. **WATER ABSORPTION TEST**

Sample No	% Water Absorption
1	11.80
2	17.69
3	8.14
Average	12.54

3. **COMPRESSIVE STRENGTH TEST**

Sample No	Compressive Strength (N/mm^2)
1	11.68
2	10.48
3	10.57
Average	10.91

Note: The Test report is subjected to the following condition:

1. The report relates to the sample supplied by the client.
2. The report is not to be used for any legal purpose and cannot be produce in the court of law.
3. The report will not be utilized for sales and promotion or advertisement.

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11/9/21

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TEST REPORT

Format No.: Avante/Format/59

Ref. No.: Avante/TR/MT/2021/065b **Date: 11/09/2021**

Name of the Client	Society for Technology and Action for Rural Advancement		
Name of the Project	B-32, TARA, Crescent, Qutub Industrial Area, New Delhi-110016		
Ref. Work Order	**NIL**	Dated: 10/09/21	
Sample Id	Avante/Sample/2021/065b	Sample Received Date	04/09/2021
Test Start Date	07/09/2021	Test completed date	11/09/2021

Type of Sample	**BRICK (RED)**
Brand	**BBS**

The results are as under:

1. **DIMENSION TEST**

Sample No	Dimension (LxBxH) (mm)
1	234x115x70
2	234x115x70
3	234x115x70

2. **WATER ABSORPTION TEST**

Sample No	% Water Absorption
1	15.76
2	17.77
3	12.69
Average	15.41

3. **COMPRESSIVE STRENGTH TEST**

Sample No	Compressive Strength (N/mm^2)
1	8.06
2	8.88
3	8.94
Average	8.63

Note: The Test report is subjected to the following condition:

1. The report relates to the sample supplied by the client.
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TEST REPORT

Format No.: Avante/Format

ɛef. No.: Avante/TR/MT/2021/065c **Date: 11/09/2021**

Name of the Client	Society for Technology and Action for Rural Advancement		
Name of the Project	B-32, TARA, Crescent, Qutub Industrial Area, New Delhi-110016		
Ref. Work Order	**NIL**	Dated: **10/09/21**	
Sample Id	Avante/Sample/2021/065c	Sample Received Date	04/09/2021
Test Start Date	07/09/2021	Test completed date	11/09/2021

Type of Sample	**BRICK (RED)**
Brand	**JPB**

'he results are as under:

. **DIMENSION TEST**

Sample No	Dimension (LxBxH) (mm)
1	223x108x70
2	221x105x64
3	220x105x65

. **WATER ABSORPTION TEST**

Sample No	% Water Absorption
1	10.50
2	8.55
3	10.02
Average	9.69

. **COMPRESSIVE STRENGTH TEST**

Sample No	Compressive Strength (N/mm^2)
1	13.38
2	`13.11
3	13.25
Average	13.25

ɩote: The Test report is subjected to the following condition:

1. The report relates to the sample supplied by the client.
2. The report is not to be used for any legal purpose and cannot be produce in the court of law.
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TEST REPORT

Format No.: Avante/Forma

:ef. No.: Avante/TR/MT/2021/065d **Date: 11/09/2021**

Name of the Client	Society for Technology and Action for Rural Advancement		
Name of the Project	B-32, TARA, Crescent, Qutub Industrial Area, New Delhi-110016		
Ref. Work Order	**NIL**	Dated: 10/09/21	
Sample Id	Avante/Sample/2021/065d	Sample Received Date	04/09/2021
Test Start Date	07/09/2021	Test completed date	11/09/2021

Type of Sample	**BRICK (RED)**
Brand	**HBI**

'he results are as under:

. **DIMENSION TEST**

Sample No	Dimension (LxBxH) (mm)
1	224x121x73
2	235x115x71
3	220x110x65

. **WATER ABSORPTION TEST**

Sample No	% Water Absorption
1	14.80
2	11.38
3	11.85
Average	12.68

. **COMPRESSIVE STRENGTH TEST**

Sample No	Compressive Strength (N/mm^2)
1	8.88
2	8.35
3	9.92
Average	9.05

Note: The Test report is subjected to the following condition:

1. The report relates to the sample supplied by the client.
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TEST REPORT

Format No.: Avante/Forma

.ef. No.: Avante/TR/MT/2021/065e **Date: 11/09/2021**

Name of the Client	Society for Technology and Action for Rural Advancement		
Name of the Project	B-32, TARA, Crescent, Qutub Industrial Area, New Delhi-110016		
Ref. Work Order	**NIL**	Dated: **10/09/21**	
Sample Id	Avante/Sample/2021/065e	Sample Received Date	04/09/2021
Test Start Date	07/09/2021	Test completed date	11/09/2021

Type of Sample	**BRICK (RED)**
Brand	**SMB**

'he results are as under:

DIMENSION TEST

Sample No	Dimension (LxBxH) (mm)
1	230x110x70
2	227x110x65
3	237x115x70

WATER ABSORPTION TEST

Sample No	% Water Absorption
1	11.46
2	14.08
3	20.80
Average	15.45

COMPRESSIVE STRENGTH TEST

Sample No	Compressive Strength (N/mm^2)
1	23.07
2	21.49
3	21.23
Average	21.93

Iote: The Test report is subjected to the following condition:

1. The report relates to the sample supplied by the client.
2. The report is not to be used for any legal purpose and cannot be produce in the court of law.
3. The report will not be utilized for sales and promotion or advertisement.

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TEST REPORT

Format No.: Avante/Forma

:ef. No.: Avante/TR/MT/2021/065f **Date: 11/09/2021**

Name of the Client	Society for Technology and Action for Rural Advancement		
Name of the Project	B-32, TARA, Crescent, Qutub Industrial Area, New Delhi-110016		
Ref. Work Order	NIL	Dated: **10/09/21**	
Sample Id	Avante/Sample/2021/065f	Sample Received Date	04/09/2021
Test Start Date	07/09/2021	Test completed date	11/09/2021

Type of Sample	**BRICK (RED)**
Brand	**ANP**

'he results are as under:

. **DIMENSION TEST**

Sample No	Dimension (LxBxH) (mm)
1	230x115x75
2	230x115x70
3	235x112x63

. **WATER ABSORPTION TEST**

Sample No	% Water Absorption
1	21.78
2	20.56
3	19.38
Average	20.57

. **COMPRESSIVE STRENGTH TEST**

Sample No	Compressive Strength (N/mm^2)
1	11.14
2	10.68
3	10.44
Average	10.75

lote: The Test report is subjected to the following condition:

1. The report relates to the sample supplied by the client.
2. The report is not to be used for any legal purpose and cannot be produce in the court of law.
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TEST REPORT

Format No.: Avante/Format/59

Ref. No.: Avante/TR/MT/2021/065g **Date: 11/09/2021**

Name of the Client	Society for Technology and Action for Rural Advancement		
Name of the Project	B-32, TARA, Crescent, Qutub Industrial Area, New Delhi-110016		
Ref. Work Order	**NIL**	Dated: **10/09/21**	
Sample Id	Avante/Sample/2021/065g	Sample Received Date	04/09/2021
Test Start Date	07/09/2021	Test completed date	11/09/2021

Type of Sample	**BRICK (FLY ASH)**
Brand	**GMI**

The results are as under:

1. **DIMENSION TEST**

Sample No	Dimension (LxBxH) (mm)
1	230x110x72
2	230x110x72

2. **WATER ABSORPTION TEST**

Sample No	% Water Absorption
1	6.20
2	7.32
Average	6.76

3. **COMPRESSIVE STRENGTH TEST**

Sample No	Compressive Strength (N/mm^2)
1	12.54
2	12.24
Average	12.39

Note: The Test report is subjected to the following condition:

1. The report relates to the sample supplied by the client.
2. The report is not to be used for any legal purpose and cannot be produce in the court of law.
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BUILDEAST ENGINEERING

Material Testing Lab | Soil Investigation | Structural Design

Standard ISO/IEC 17025:2017 ISO 9000-2015Certified

GSTIN 18AAVFB4670J1ZU -MSME UAM No: AS05D0000514

Issue No. BEE/BRICK/ Date: 20/11/2020

Client : Society for Technology and Action for Rural Advancement
B-32, TARA Crescent, Qutub Institutional Area
New Delhi, India-110016

Name of Work : Testing of Brick

SAMPLE DETAILS OF BRICK

Item - Brick samples
Brand - **Rahul**
Date of sampling - 18.11.2020
Date of testing - 18.11.2020 to 20.11.2020
Source :Supplied by Client

Notes :

1. This report can neither be used as an evidence in the court of law, nor it can be produced in part or full in any media without prior permission.
2. The result listed refer only to the tested sample and applicable parameters.
3. Perishable samples are destroyed after testing; requested samples are returned back to the customer.
4. Sample(s) not drawn by us, unless otherwise mentioned.

Quality Manager

Build East Engineering

Address- AK Lane Opp. Vivekananda Co-Operative
Meherpur, Silchar–15, Assam
E-mail- buildeastengg@gmail.com
Mob: +91- 6003633880, +91-9402087771

2 Nos. of bricks are selected at random from the lot for determining compressive strength and 2 Nos. of bricks are selected at random from the lot for water absorption test.

Sl. No.	Dry Weight in kg	Soaked Weight in kg	Size in cm	Crushing strength kg/cm2	% of water absorption
Sample No.I	3.298	3.526	22.7 x 11 x 6.5	105.52	6.91
Sample No.II	3.302	3.533	22.8 x 11.1 x 6.5	101.88	6.99

Average of crushing strength : 103.7 kg/cm2
Average of water absorption : 6.95 %
Shape : The brick was averagely rectangular with sharp edges.

Quality Manager

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GSTIN 18AAVFB4670J1ZU -MSME UAM No: AS05D0000514

Issue No. BEE/BRICK/ Date: 20/11/2020

Client : Society for Technology and Action for Rural Advancement
B-32, TARA Crescent, Qutub Institutional Area
New Delhi, India-110016

Name of Work : Testing of Brick

SAMPLE DETAILS OF BRICK

Item - Brick samples
Date of sampling - 18.11.2020
Source :Supplied by Client

Brand - **A. Tara**
Date of testing - 18.11.2020 to 20.11.2020

Notes :

1. This report can neither be used as an evidence in the court of law, nor it can be produced in part or full in any media without prior permission.
2. The result listed refer only to the tested sample and applicable parameters.
3. Perishable samples are destroyed after testing; requested samples are returned back to the customer.
4. Sample(s) not drawn by us, unless otherwise mentioned.

Quality Manager

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2 Nos. of bricks are selected at random from the lot for determining compressive strength and 2 Nos. of bricks are selected at random from the lot for water absorption test.

Sl. No.	Dry Weight in kg	Soaked Weight in kg	Size in cm	Crushing strength kg/cm2	% of water absorption
Sample No.I	3.464	3.712	23.8 x 11.9 x 6.8	89.58	7.15
Sample No.II	3.496	3.781	23.8 x 12 x 6.8	91.63	8.15

Average of crushing strength : 90.6 kg/cm2
Average of water absorption : 7.65 %
Shape : The brick was averagely rectangular with sharp edges.

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GSTIN 18AAVFB4670J1ZU -MSME UAM No: AS05D0000514

Issue No. BEE/BRICK/ Date: 20/11/2020

Client : Society for Technology and Action for Rural Advancement
B-32, TARA Crescent, Qutub Institutional Area
New Delhi, India-110016

Name of Work : Testing of Brick

SAMPLE DETAILS OF BRICK

Item - Brick samples
Date of sampling - 18.11.2020
Source :Supplied by Client

Brand - **Nokia**
Date of testing - 18.11.2020 to 20.11.2020

Notes :

1. This report can neither be used as an evidence in the court of law, nor it can be produced in part or full in any media without prior permission.
2. The result listed refer only to the tested sample and applicable parameters.
3. Perishable samples are destroyed after testing; requested samples are returned back to the customer.
4. Sample(s) not drawn by us, unless otherwise mentioned.

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2 Nos. of bricks are selected at random from the lot for determining compressive strength and 2 Nos. of bricks are selected at random from the lot for water absorption test.

Sl. No.	Dry Weight in kg	Soaked Weight in kg	Size in cm	Crushing strength kg/cm2	% of water absorption
Sample No.I	2.855	3.247	22.9 x 11.1 x 6.4	72.64	13.73
Sample No.II	2.832	3.288	22.9 x 11.2 x 6.3	70.19	16.10

Average of crushing strength : 71.42 kg/cm2
Average of water absorption : 14.92 %
Shape : The brick was averagely rectangular with rough edges.

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GSTIN 18AAVFB4670J1ZU -MSME UAM No: AS05D0000514

Issue No. BEE/BRICK/ Date: 20/11/2020

Client : Society for Technology and Action for Rural Advancement
B-32, TARA Crescent, Qutub Institutional Area
New Delhi, India-110016

Name of Work : Testing of Brick

SAMPLE DETAILS OF BRICK

Item - Brick samples
Brand - **7 Star**
Date of sampling - 18.11.2020
Date of testing - 18.11.2020 to 20.11.2020
Source :Supplied by Client

Notes :

1. This report can neither be used as an evidence in the court of law, nor it can be produced in part or full in any media without prior permission.
2. The result listed refer only to the tested sample and applicable parameters.
3. Perishable samples are destroyed after testing; requested samples are returned back to the customer.
4. Sample(s) not drawn by us, unless otherwise mentioned.

Quality Manager

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GSTIN 18AAVFB4670J1ZU -MSME UAM No: AS05D0000514

2 Nos. of bricks are selected at random from the lot for determining compressive strength and 2 Nos. of bricks are selected at random from the lot for water absorption test.

Sl. No.	Dry Weight in kg	Soaked Weight in kg	Size in cm	Crushing strength kg/cm2	% of water absorption
Sample No.I	2.859	3.206	22.2 x 11.3 x 6.6	130.15	12.13
Sample No.II	2.846	3.221	22.3 x 11.2 x 6.5	132.60	13.17

Average of crushing strength : 131.38 kg/cm2
Average of water absorption : 12.65 %
Shape : The brick was truly rectangular with sharp edges.

Quality Manager

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Standard ISO/IEC 17025:2017 ISO 9000-2015Certified

GSTIN 18AAVFB4670J1ZU -MSME UAM No: AS05D0000514

Issue No. BEE/BRICK/ Date: 20/11/2020

Client : Society for Technology and Action for Rural Advancement
B-32, TARA Crescent, Qutub Institutional Area
New Delhi, India-110016

Name of Work : Testing of Brick

SAMPLE DETAILS OF BRICK

Item - Brick samples
Date of sampling - 18.11.2020
Source :Supplied by Client

Brand - **Lucky**
Date of testing - 18.11.2020 to 20.11.2020

Notes :

1. This report can neither be used as an evidence in the court of law, nor it can be produced in part or full in any media without prior permission.
2. The result listed refer only to the tested sample and applicable parameters.
3. Perishable samples are destroyed after testing; requested samples are returned back to the customer.
4. Sample(s) not drawn by us, unless otherwise mentioned.

Quality Manager

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GSTIN 18AAVFB4670J1ZU -MSME UAM No: AS05D0000514

2 Nos. of bricks are selected at random from the lot for determining compressive strength and 2 Nos. of bricks are selected at random from the lot for water absorption test.

Sl. No.	Dry Weight in kg	Soaked Weight in kg	Size in cm	Crushing strength kg/cm2	% of water absorption
Sample No.I	2.853	3.487	23.6 x 12.1 x 6.4	55.67	22.22
Sample No.II	2.866	3.485	23.5 x 12 x 6.5	58.32	21.59

Average of crushing strength : 56.99 kg/cm2
Average of water absorption : 21.91 %
Shape : The brick was irregular in shape and have broken edges.

Quality Manager

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GSTIN 18AAVFB4670J1ZU -MSME UAM No: AS05D0000514

Issue No. BEE/BRICK/ Date: 23/11/2020

Client : Society for Technology and Action for Rural Advancement
B-32, TARA Crescent, Qutub Institutional Area
New Delhi, India-110016

Name of Work : Testing of Brick

SAMPLE DETAILS OF BRICK

Item - Brick samples
Date of sampling - 19.11.2020
Source :Supplied by Client

Brand - **PRINCE**
Date of testing - 19.11.2020 to 21.11.2020

Notes :

1. This report can neither be used as an evidence in the court of law, nor it can be produced in part or full in any media without prior permission.
2. The result listed refer only to the tested sample and applicable parameters.
3. Perishable samples are destroyed after testing; requested samples are returned back to the customer.
4. Sample(s) not drawn by us, unless otherwise mentioned.

Quality Manager

Build East Engineering

Address- AK Lane Opp. Vivekananda Co-Operative
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3 Nos. of bricks are selected at random from the lot for determining compressive strength and 3 Nos. of bricks are selected at random from the lot for water absorption test.

Sl. No.	Dry Weight in kg	Soaked Weight in kg	Size in cm	Crushing strength kg/cm2	% of water absorption
Sample No.I	2.944	3.433	23.1 x 11.4 x 6.8	67.58	16.61
Sample No.II	2.956	3.426	23.2 x 11.5 x 6.7	71.09	15.89
Sample No.III	2.942	3.444	23.0 x 11.4 x 6.7	68.25	17.06

Average of crushing strength : 68.97 kg/cm2
Average of water absorption : 16.52 %
Shape : The brick was averagely rectangular with rough edges.

Quality Manager

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BUILDEAST ENGINEERING

Material Testing Lab | Soil Investigation | Structural Design

Standard ISO/IEC 17025:2017 ISO 9000-2015Certified

GSTIN 18AAVFB4670J1ZU -MSME UAM No: AS05D0000514

Issue No. BEE/BRICK/ Date: 23/11/2020

Client : Society for Technology and Action for Rural Advancement
B-32, TARA Crescent, Qutub Institutional Area
New Delhi, India-110016

Name of Work : Testing of Brick

SAMPLE DETAILS OF BRICK

Item - Brick samples
Brand - **SINGH**
Date of sampling - 19.11.2020
Date of testing - 19.11.2020 to 21.11.2020
Source :Supplied by Client

Notes :

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2. The result listed refer only to the tested sample and applicable parameters.
3. Perishable samples are destroyed after testing; requested samples are returned back to the customer.
4. Sample(s) not drawn by us, unless otherwise mentioned.

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Material Testing Lab | Soil Investigation | Structural Design
Standard ISO/IEC 17025:2017 ISO 9000-2015Certified
GSTIN 18AAVFB4670J1ZU -MSME UAM No: AS05D0000514

3 Nos. of bricks are selected at random from the lot for determining compressive strength and 3 Nos. of bricks are selected at random from the lot for water absorption test.

Sl. No.	Dry Weight in kg	Soaked Weight in kg	Size in cm	Crushing strength kg/cm2	% of water absorption
Sample No.I	2.627	3.010	22.5 x 10.4 x 6.4	137.62	14.57
Sample No.II	2.646	2.998	22.5 x 10.6 x 6.4	128.78	13.30
Sample No.III	2.638	3.022	22.3 x 10.4 x 6.5	143.83	14.55

Average of crushing strength : 136.74 kg/cm2
Average of water absorption : 14.14 %
Shape : The brick was truly rectangular with sharp edges.

Quality Manager

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BUILDEAST ENGINEERING

Material Testing Lab | Soil Investigation | Structural Design

Standard ISO/IEC 17025:2017 ISO 9000-2015Certified

GSTIN 18AAVFB4670J1ZU -MSME UAM No: AS05D0000514

Issue No. BEE/BRICK/ Date: 23/11/2020

Client : Society for Technology and Action for Rural Advancement
B-32, TARA Crescent, Qutub Institutional Area
New Delhi, India-110016

Name of Work : Testing of Brick

SAMPLE DETAILS OF BRICK

Item - Brick samples
Brand - **ANJANA**
Date of sampling - 19.11.2020
Date of testing - 19.11.2020 to 21.11.2020
Source :Supplied by Client

Notes :

1. This report can neither be used as an evidence in the court of law, nor it can be produced in part or full in any media without prior permission.
2. The result listed refer only to the tested sample and applicable parameters.
3. Perishable samples are destroyed after testing; requested samples are returned back to the customer.
4. Sample(s) not drawn by us, unless otherwise mentioned.

Quality Manager

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3 Nos. of bricks are selected at random from the lot for determining compressive strength and 3 Nos. of bricks are selected at random from the lot for water absorption test.

Sl. No.	Dry Weight in kg	Soaked Weight in kg	Size in cm	Crushing strength kg/cm2	% of water absorption
Sample No.I	2.602	3.025	22.6 x 10.9 x 6.5	132.79	16.25
Sample No.II	2.643	3.001	22.5 x 11.1 x 6.5	128.08	13.54
Sample No.III	2.625	3.011	22.6 x 10.8 x 6.7	137.31	14.70

Average of crushing strength : 132.72 kg/cm2
Average of water absorption : 14.76 %
Shape : The brick was averagely rectangular with rough edges.

Quality Manager

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BUILDEAST ENGINEERING
Material Testing Lab | Soil Investigation | Structural Design
Standard ISO/IEC 17025:2017 ISO 9000-2015Certified
GSTIN 18AAVFB4670J1ZU -MSME UAM No: AS05D0000514

Issue No. BEE/AAC-B/ Date: 23/11/2020

Client : Society for Technology and Action for Rural Advancement
B-32, TARA Crescent, Qutub Institutional Area
New Delhi, India-110016

Name of Work : Testing of Brick

SAMPLE DETAILS OF AAC BLOCK

Item – AAC Block samples
Brand - Unknown
Date of sampling - 18.11.2020
Date of testing - 19.11.2020 to 21.11.2020
Source :Supplied by Client

Notes :

1. This report can neither be used as an evidence in the court of law, nor it can be produced in part or full in any media without prior permission.
2. The result listed refer only to the tested sample and applicable parameters.
3. Perishable samples are destroyed after testing; requested samples are returned back to the customer.
4. Sample(s) not drawn by us, unless otherwise mentioned.

Quality Manager

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3 Nos. of blocks are selected at random from the lot for determining compressive strength and 3 Nos. of blocks are selected at random from the lot for water absorption test.

Sl. No.	Dry Weight in kg	Soaked Weight in kg	Size in cm	Crushing strength kg/cm2	% of water absorption
Sample No.I	5.653	7.377	59.4 x 19.2 x 7.3	31.61	30.49
Sample No.II	5.644	7.390	59.9 x 19.1 x 7.4	24.58	30.93
Sample No.III	5.668	7.426	59.7 x 19.3 x 7.3	29.32	31.01

Average of crushing strength : 28.50 kg/cm2
Average of water absorption : 30.81 %
Shape : The block was truly rectangular with sharp edges.

Quality Manager

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Avante Engineers

(Material and Geotechnical Consultants)

A vision to build better

TEST REPORT

Format No.: Avante/Format/59

Ref. No.: Avante/TR/MT/2021/017 **Date: 29/11/2021**

Name of the Client	Society for Technology and Action for Rural Advancement		
Name of the Project	B-32, TARA, Crescent, Qutub Industrial Area, New Delhi-110016		
Ref. Work Order	**NIL** Dated: 24/11/2021		
Sample Id	Avante/Sample/2021/017	Sample Received Date	25/11/2021
Test Start Date	25/11/2021	Test completed date	29/11/2021

Type of Sample	**BRICK (RED)**
Brand	**RK**

1. DIMENSION TEST

Sample No	Dimension (LxBxH) (mm)
1	230x105x68
2	230x105x66
3	230x105x69

2. WATER ABSORPTION TEST

Sample No	Oven Dry Weight (gm)	Saturated Surface Dry weight (gm)	% Water Absorption
1	3078	3508	13.63
2	3018	3452	14.38
3	3359	3750	11.64
		Average Water Absorption (%)	13.21

3. COMPRESSIVE STRENGTH TEST

Sample No	Compressive Strength (N/mm^2)
1	11.06
2	11.68
3	11.46
Average	11.40

Note: The Test report is subjected to the following condition:

1. The report relates to the sample supplied by the client.
2. The report is not to be used for any legal purpose and cannot be produce in the court of law.
3. The report will not be utilized for sales and promotion or advertisement.

Authorized Signatory

AVANTE ENGINEERS GUWAHATI

29/11/21

Nishant Changkakati
CEO, Avante Engineers

Page: 1 of 1

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Avante Engineers

(Material and Geotechnical Consultants)

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TEST REPORT

Format No.: Avante/Format/59

Ref. No.: Avante/TR/MT/2021/018 **Date: 29/11/2021**

Name of the Client	Society for Technology and Action for Rural Advancement		
Name of the Project	B-32, TARA, Crescent, Qutub Industrial Area, New Delhi-110016		
Ref. Work Order	**NIL** Dated: 24/11/2021		
Sample Id	Avante/Sample/2021/018	Sample Received Date	25/11/2021
Test Start Date	25/11/2021	Test completed date	29/11/2021

Type of Sample	**BRICK (RED)**
Brand	**PBK**

1. DIMENSION TEST

Sample No	Dimension (LxBxH) (mm)
1	239x110x75
2	234x108x75
3	235x110x75

2. WATER ABSORPTION TEST

Sample No	Oven Dry Weight (gm)	Saturated Surface Dry weight (gm)	% Water Absorption
1	3463	3914	13.02
2	3506	3921	11.84
3	3616	4046	11.89
		Average Water Absorption (%)	12.25

3. COMPRESSIVE STRENGTH TEST

Sample No	Compressive Strength (N/mm^2)
1	12.14
2	13.07
3	13.06
Average	12.76

Note: The Test report is subjected to the following condition:

1. The report relates to the sample supplied by the client.
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Authorized Signatory

AVANTE ENGINEERS *GUWAHATI*

29/11/21

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Avante Engineers

(Material and Geotechnical Consultants)

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TEST REPORT

Format No.: Avante/Format/59

Ref. No.: Avante/TR/MT/2021/019 **Date: 29/11/2021**

Name of the Client	Society for Technology and Action for Rural Advancement
Name of the Project	B-32, TARA, Crescent, Qutub Industrial Area, New Delhi-110016
Ref. Work Order	NIL Dated: 24/11/2021

Sample Id	Avante/Sample/2021/019	Sample Received Date	25/11/2021
Test Start Date	25/11/2021	Test completed date	29/11/2021

Type of Sample	**BRICK (RED)**
Brand	**SHAKTI**

1. **DIMENSION TEST**

Sample No	Dimension (LxBxH) (mm)
1	221x105x60
2	229x105x65
3	228x104x65

2. **WATER ABSORPTION TEST**

Sample No	Oven Dry Weight (gm)	Saturated Surface Dry weight (gm)	% Water Absorption
1	2561	2969	15.93
2	2756	3278	18.94
3	3074	3577	16.36
		Average Water Absorption (%)	17.08

3. **COMPRESSIVE STRENGTH TEST**

Sample No	Compressive Strength (N/mm²)
1	12.72
2	12.37
3	12.84
Average	12.64

Note: The Test report is subjected to the following condition:

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Authorized Signatory

AVANTE ENGINEERS "GUWAHATI"

29/11/21

Nishant Changkakati
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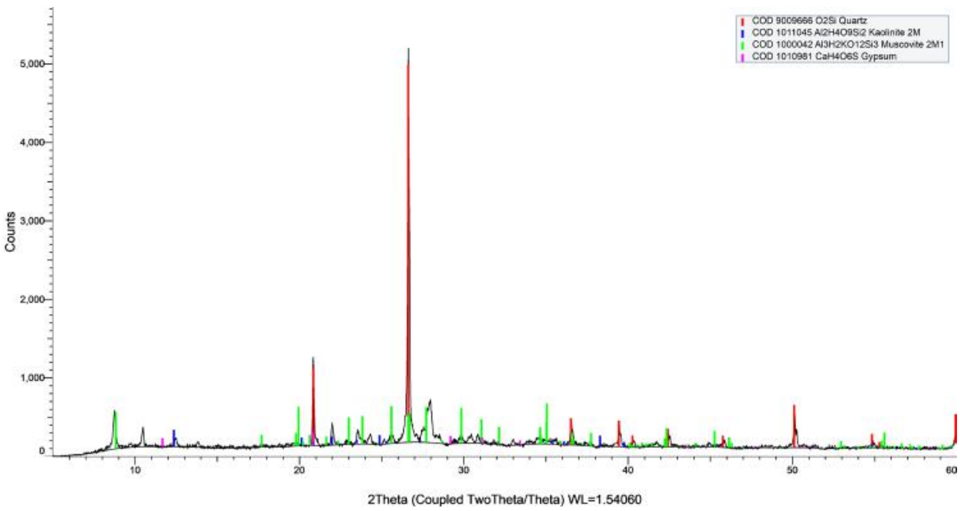
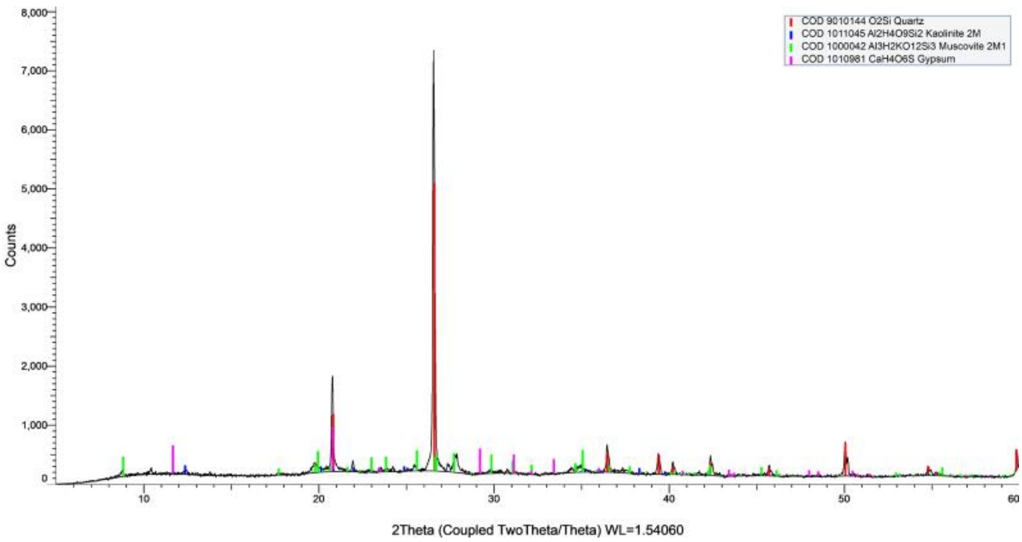
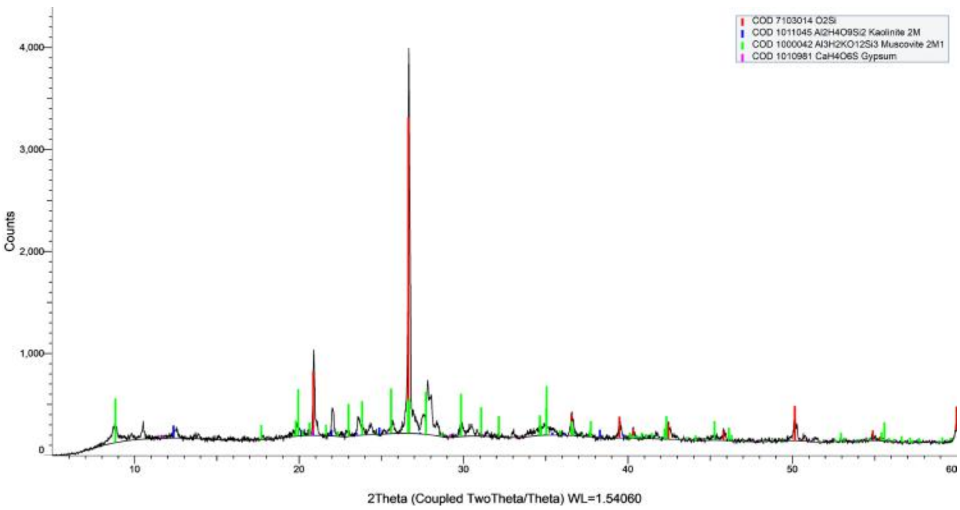
Commander Sample ID (Coupled TwoTheta/Theta)



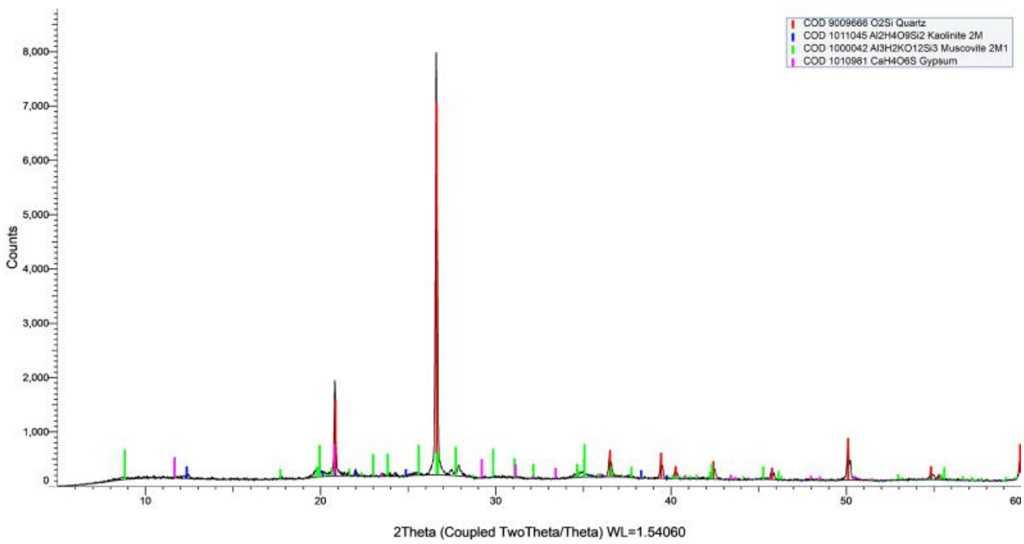
Commander Sample ID (Coupled TwoTheta/Theta)



Commander Sample ID (Coupled TwoTheta/Theta)



Commander Sample ID (Coupled TwoTheta/Theta)



ANNEXURE 9 – Ministry of Environment, Forest and Climate Change Notification, 2022

REGD. No. D. L.-33004/99
xxxGIDExxx
CG-DL-E-22022022-233662
EXTRAORDINARY
PART II—Section 3—Sub-section (i)
PUBLISHED BY AUTHORITY
No. 140] NEW DELHI, TUESDAY, FEBRUARY 22, 2022/PHALGUNA 3, 1943

MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE

NOTIFICATION

New Delhi, the 22nd February, 2022

G.S.R. 143(E).—In exercise of the powers conferred by sections 6 and 25 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government hereby makes the following rules further to amend the Environment (Protection) Rules, 1986, namely:—

1. Short Title and commencement: -

(1) These rules may be called the Environment (Protection) Amendment Rules, 2022. (2) They shall come into force on the date of their publication in the Official Gazette.

2. In the Environment (Protection) Rules, 1986, in the SCHEDULE-I, for entry at Sl. No. 74, the following entry shall be substituted, namely: -

“74	**Brick Kilns**	Particulate matter in stack emission	250 mg/Nm^3
		Minimum stack height (Vertical Shaft Brick Kilns) - Kiln capacity less than 30,000 bricks per day - Kiln capacity equal or more than 30,000 bricks per day	14 m (at least 7.5m from loading platform) 16 m (at least 8.5m from loading platform)
		Minimum stack height (Other than Vertical Shaft Brick Kilns) - Kiln capacity less than 30,000 bricks per day - Kiln capacity equal or more than 30,000 bricks per day	24 m 27 m

Notes :

1. All new brick kilns shall be allowed only with zig-zag technology or vertical shaft or use of Piped Natural Gas as fuel in brick making and shall comply with these standards as stipulated in this notification.

2. The existing brick kilns which are not following zig-zag technology or vertical shaft or use Piped Natural Gas as fuel in brick making shall be converted to zig-zag technology or vertical shaft or use Piped Natural Gas as fuel in brick making within a period of (a) one year in case of kilns located within ten kilometre radius of non-attainment cities as defined by Central Pollution Control Board (b) two years for other areas. Further, in cases where Central Pollution Control Board/State Pollution Control Boards/Pollution Control Committees have separately laid down timelines for conversion, such orders shall prevail.

3. All brick kilns shall use only approved fuel such as Piped Natural Gas, coal, fire wood and/or agricultural residues. Use of pet coke, tyres, plastic, hazardous waste shall not be allowed in brick kilns.

4. Brick kilns shall construct permanent facilities (port hole and platform) as per the norms or design laid down by the Central Pollution Control Board for monitoring of emissions.

5. Particulate Matter (PM) results shall be normalised at 4% CO_2 as below:

   PM (normalised) = (PM (measured)x 4%)/ (% of CO_2 measured in stack), no normalisation in case CO_2 measured ≥ 4%. Stack height (in metre) shall also be calculated by formula $H=14Q^{0.3}$ (where Q is SO_2 emission rate in kg/hr), and the maximum of two shall apply.

4 THE GAZETTE OF INDIA : EXTRAORDINARY [PART II—SEC. 3(i)]

6. Brick kilns should be established at a minimum distance of 0.8 kilometre from habitation and fruit orchards. State Pollution Control Boards/Pollution Control Committees may make siting criteria stringent considering proximity to habitation, population density, water bodies, sensitive receptors, etc.

7. Brick kilns should be established at a minimum distance of one kilometre from an existing brick kiln to avoid clustering of kilns in an area.

8. Brick kilns shall follow process emission/fugitive dust emission control guidelines as prescribed by concerned State Pollution Control Boards/Pollution Control Committees.

9. The ash generated in the brick kilns shall be fully utilised in-house in brick making.

10. All necessary approvals from the concerned authorities including the mining department of the concerned State or Union Territory shall be obtained for extracting the soil to be used for brick making in the brick kiln.

11. The brick kiln owners shall ensure that the road utilised for transporting raw materials or bricks are paved roads.

12. Vehicles shall be covered during transportation of raw material/bricks".

[F. No. Q-15017/35/2007-CPW]

NARESH PAL GANGAWAR, Addl. Secy.

Note : The principle rules were published in the Gazette of India, Extraordinary, Part II, Section 3, Subsection (i) *vide* number S.O. 844(E), dated the 19th November, 1986 and lastly amended *vide* number G.S.R. 724(E), dated the 04th October, 2021.

Uploaded by Dte. of Printing at Government of India Press, Ring Road, Mayapuri, New Delhi-110064 and Published by the Controller of Publications, Delhi-110054.

Assam Climate Change Management Society (ACCMS) - a Special Purpose Vehicle (SPV) was created in 2018 under the chairmanship of the Hon'ble Chief Minister, Government of Assam. Assam Climate Change Management Society was registered under the Societies Registration Act XXI of 1860 on 15th October, 2018. ACCMS coordinates all issues related to climate change and implements the Assam State Action Plan on Climate Change (ASAPCC), aligning state priorities and different national and international goals such as Sustainable Development Goals (SDGs), Nationally Determined Contributions (NDCs), Reducing Emissions from Deforestation and Forest Degradation (REDD+) and others in different sectors.

ACCMS

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