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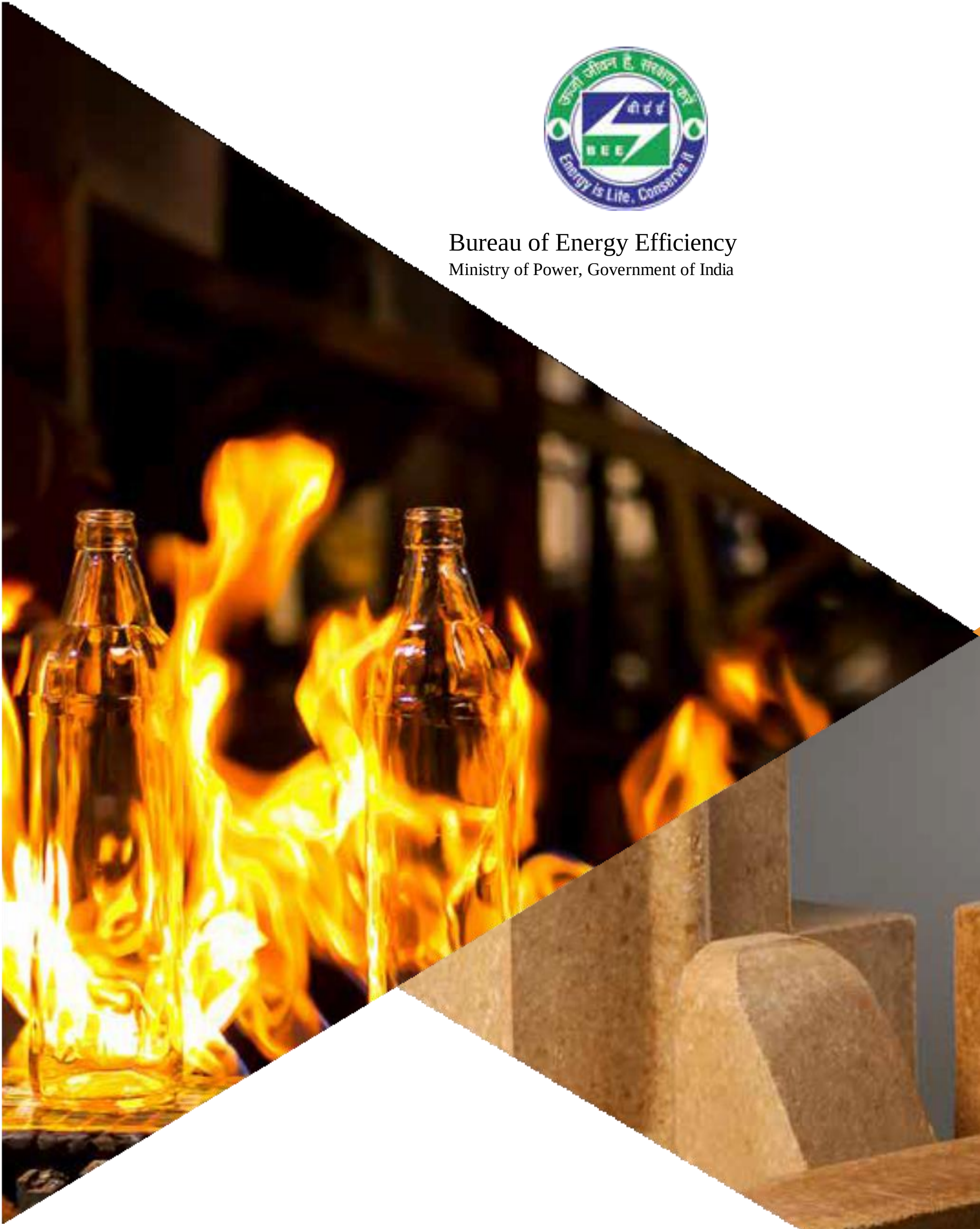

ACHIEVING ENERGY AND RESOURCE EFFICIENCY IN **GLASS AND REFRACTORY INDUSTRIES**

A Sectoral Roadmap for Micro Small and Medium Enterprises

Prepared by

THE ENERGY AND RESOURCES INSTITUTE
Creating Innovative Solutions for a Sustainable Future

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We also take this opportunity to express our deep appreciation for the excellent support and baseline information provided by the individual entrepreneurs of glass and refractory manufacturing units of various clusters.

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Abbreviations

AIGMF	All India Glass Manufacturers Federation
BEE	Bureau of Energy Efficiency
BOP	Best Operating Practices
BP	Bottom Pouring
CAGR	Compounded Annual Growth Rate
CBM	Coal Bed Methane
CDGI	Centre for the Development of Glass Industry
CFC	Common Facility Centre
CGCRI	Central Glass and Ceramic Research Institute
DD	Downdraft
DIC	District Industries Centre
DPR	Detailed Project Report
EC	Energy Conservation
EE	Energy Efficiency
EESL	Energy Efficiency Services Limited
EMC	Energy Management Centre
ESCO	Energy Service Company
FI	Financial Institution
GHG	Greenhouse Gases
GJ	Giga Joule
HSD	High Speed Diesel
IRMA	Indian Refractory Makers Association
kWh	Kilowatt-hour
LPG	Liquefied Petroleum Gas
LSP	Local Service Provider
MSME	Micro Small and Medium Enterprises
MSME-DI	MSME-Development Institutes
mt	million tonne
NCR	National Capital Region
NG	Natural gas
NSIC	National Small Industries Corporation
O&M	Operation and maintenance
PNG	Piped Natural Gas
R&D	Research and Development
SDAs	State Designated Agencies

SEC	Specific Energy Consumption
SIDBI	Small Industries Development Bank of India
SPV	solar photovoltaic
SPV-CDP	Special purpose vehicle for cluster development programmes
toe	tonne of oil equivalent
tpd	tonne per day
WHR	Waste Heat Recovery

Achieving Energy & Resource Efficiency: A Roadmap for Glass and Refractory Industries

The roadmap provides the rationale for energy and resource efficiency improvements and further outlines the potential for improvements through deployment of efficient technologies and practices in the glass and refractory sector.

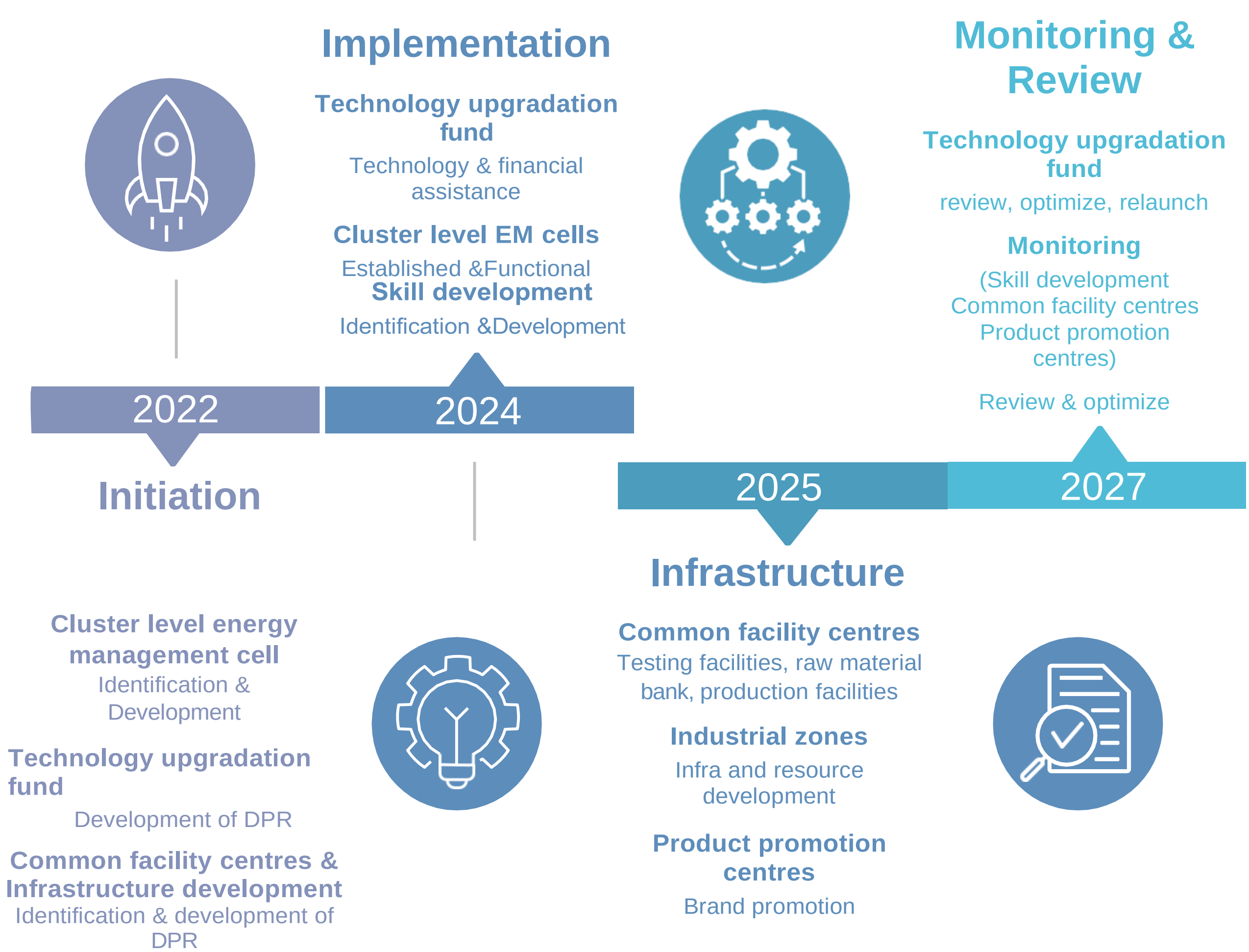
The roadmap provides energy and resource efficiency goals, sectoral scenario and energy and resource saving potential in glass and refractory industries in MSME sector. It identifies key barriers at sector level, which must be addressed to achieve optimum efficiency levels in glass and refractory sector. Based on the type of interventions proposed, the roadmap proposes two distinct strategies i.e. policy level and cluster level for move towards energy efficiency for the sector. It is envisaged that achievement of milestones through implementation of the roadmap will contribute towards sustainability of the glass and refractory sector as well as energy security of the country.

CLUSTER LEVEL STRATEGIES

- Energy efficiency institutional framework
- Capacity building
- Market &financing

POLICY LEVEL STRATEGIES

- Regulation for technology & infrastructure development
- Human resources
- Research, development & innovation



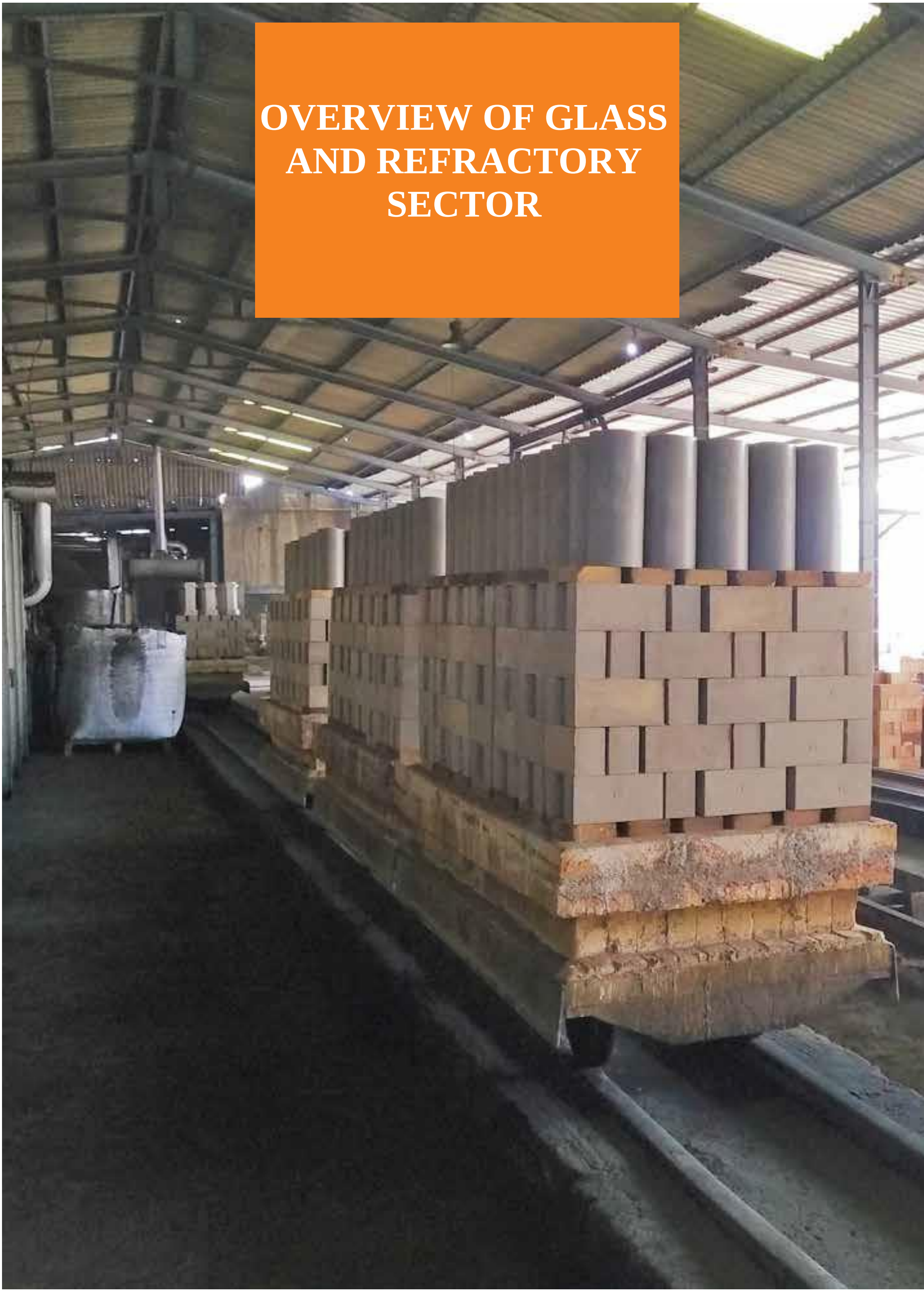
INTRODUCTION

The micro, small and medium enterprises (MSMEs) sector is the backbone of India's non-agricultural economy, making up 90% of manufacturing sector and contributed to 45% of total industrial value addition and almost half of exports (2019-20). Most of the manufacturing industries in the MSME sector are traditional and deploy technologies that are predominantly inefficient and resource intensive.

The MSME sector has a significant impact not only on the economy but also on the environment. The energy efficiency path of the MSME sector is quite challenging due to its fragmented nature. Further, the absence of data and information on energy consumption and technologies at national level limits the design of appropriate policy instruments for the sustainable growth of energy intensive MSME sectors.

To improve sustainability and competitiveness, the Bureau of Energy Efficiency had undertaken mapping of energy consumption of select energy intensive MSME sub-sectors. The glass and refractory sector is one of the sectors covered under this study. A sector-specific roadmap was prepared for promoting adoption of energy and resource efficiency measures in glass and refractory sector.

OVERVIEW OF GLASS AND REFRACTORY SECTOR



This section discusses about key growth drivers of the market and major challenges of glass and refractory sectors. It also provides the geographical coverage and sectoral level stakeholders of glass and refractory industries in MSME sector.

Overview of glass industries

Glass is an important material in the day-to-day requirements, from laboratory to infrastructure, glass has secured its position in the world of construction and interior designing. The MSME sector produces mainly container glass, decorative glass, bangles, and other value-added glass products. While hollow glass and flat glass are produced from the melting process, products such as toughened glass and other value-added hollow products use annealed glass and /or raw glass (float glass, borosilicate glass tubes, etc.) as input feed material.

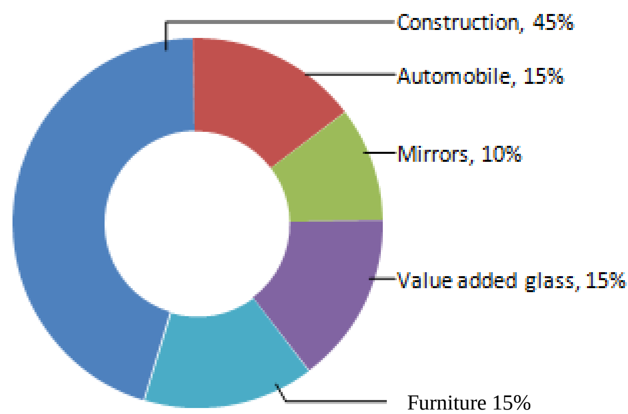


Figure 1: End-use applications of glass

The glass industries in MSME sector can be categorised into (i) glass melting industries producing container glass, decorative glass, glass bangles, etc., and (ii) glass processing industries producing toughened glass, laboratory & industrial glassware, etc. The glass products have widespread applications[1] in different end-use sectors such as the construction, automotive, and furniture industries (Figure 1). About 60% of total glass consumption is accounted by construction sector (45%) and automobile sector (15%).

Growth drivers

The major growth drivers of Indian glass industries include construction and automobile sector. The main applications of glass in construction sector are windows, facades, doors, interior partitions, etc. The rise in middle class come and population will drive the growth of automobile segment such as public transportation and privately owned vehicle including the evolving electric vehicle will lead to increase use of glass in automobile sector. Increasing use of glass in packaging and consumer segment will further increase the demand for assorted glass products. Also there is a growing demand for electronic devices such as solar PV panels, televisions, smartphones, laptops, wearables, etc., which will lead to wider applications of glass products resulting in an additional market growth for glass.

Figure 2: Major glass industry clusters in India

[1] Glass & Glass Products Industry (https://www.ngeninvest.com/glass--glass-products); 2015-16

Geographical coverage

The glass industries are located mostly as clusters across different regions of country. Some of the important glass clusters in the MSME category include Firozabad (Uttar Pradesh), Jaipur (Rajasthan), Ambala (Haryana), Vadodara (Gujarat), Hyderabad (Telangana), Pune (Maharashtra), Purdinagar (Uttar Pradesh), etc. (Figure 2). Among these, the Firozabad glass cluster is the largest hub for glass melting industries producing container glass, bangles, and other decorative items through melting process. The toughened glass industries are located across the country and processing the annealed glass sheets to cater to the end-use requirements. The blown glass products such as laboratory and industrial glassware are mainly processed using borosilicate tubes in Ambala and Vadodara clusters.

Sector level stakeholders

The institutional framework in glass industries comprises industry associations, research and development (R&D) institutes and governmental bodies. The major institutions providing services to glass industries in MSME sector are provided below.

Industry associations

The industry associations and apex bodies in the glass sector are available at the national level and/or cluster level. The 'All India Glass Manufacturers' Federation' (AIGMF) is the apex body at national level to deal with policy issues pertaining to glass industries. The federation is also actively involved in awareness generation on energy efficiency through newsletter and dissemination programmes. The industry associations are generally involved in redressal of grievances, infrastructural development, and operational issues. The prominent industry associations in glass sector are provided in Table 1.

Table 1: Details of industry associations in glass sector

Cluster	Industry segment	Industry association	Contact details
Ambala	Glass blowing	The Ambala Scientific Instruments Manufacturers' Association	# 3575, Timber Market, Ambala Cantt 133001 Tel: 00 91 171-4003837 Website : www.asimaindia.org
	Laboratory glassware	Scientific Apparatus Manufacturer Association	3703/1, NEAR S.D. MANDIR, Ambala Cantt, Haryana-133001 Tel: 0171-2631837
Firozabad	Tank furnace	Uttar Pradesh Glass Manufacturers Syndicate	c/o General traders Firozabad Firozabad, Uttar Pradesh
	Pot furnace	The Glass Industrial Syndicate	Chadamilal Jain Building, Chotti Chapeti, Firozabad – 283203 (Uttar Pradesh) Contact person: Mr. Ajay Bihari Sharma (Secretary) Contact No: +91 92596 44700

Cluster	Industry segment	Industry association	Contact details
	Muffle furnace	Pakai Bhatti Vikas Sahakari Samiti Ltd.	Near Mathur Glass, Ashafabad Road, NH-2,Firozabad – 283203 (Uttar Pradesh) Contact person: Mr. Narayan Das Gupta (President) Contact No: +91 92587 03199
		Kanch Udyog Pakai Bhatti Sahakari Samiti	Firozabad – 283203 (Uttar Pradesh) Contact person: Mr. Mukesh Bansal (President) Contact No: +91 98370 95756
		Pakai Bhatti Hitkari Odhoyogik Sahkari Samiti	Firozabad – 283203 Uttar Pradesh Contact person: Mr. Ashish Bansal (President) Mob : 98370 95756
Jaipur	• Toughened glass • Decorative mirrors	Federation of Safety Glass	Mr. Suresh Shah Federation of Safety Glass (FOSG) RIICO Industrial Area, Jhotwara Extension,Sarna Dunger,Jaipur,Rajasthan -302012 admin@ridhisidhiglasses.com
Vadodara	• Toughened glass • Glass blowing • Industries glassware	Vadodara Chamber of Commerce & Industry	VCCI Commercial Complex 73, GIDC Makarpura Vadodara – 390010, Gujarat Tel: 0265 - 2642291, 2636969
		Federation of Gujarat Industries	FGI Business Centre, Gotri - Sevasi Rd, Khanpur, nr. Sevasi, Vadodara, Gujarat 391101 Tel : 0265 237 2901

Research and development institutions

The important R&D institutions in glass sector include Central Glass and Ceramic Research Institute (CGCRI) and Centre for the Development of Glass Industry (CDGI). The glass division of CGCRI is involved in providing services related to product development and quality assurance. The CDGI provides technical backup support for energy efficiency related services and undertakes product and skill development in Firozabad glass industry cluster.

Government bodies

The government bodies associated with glass industries include MSME-Development Institutes, state designated agencies (SDAs) on behalf of Bureau of Energy Efficiency (SDA-BEE), district industries centre (DIC), National Small Industries Corporation (NSIC) and GAIL.

Overview of refractory industries

The Indian refractory industry comprises both large industries as well as MSMEs which cater to the needs of various industry sub-sectors. Refractories are used as a primary material for internal linings in large industrial equipment for their safe, low-maintenance, and cost-effective operations. A few important and generic products manufactured in the refractory industry include refractory bricks, bottom pouring sections, high temperature alumina bricks, etc. A wide range of products is manufactured in the MSME sector to cater to the requirements of industries such as steel, cement, glass industries, etc. Refractories can withstand high temperatures without major transformation in their physical properties. Refractory products are primarily used in iron & steel, non-metallic, non-ferrous metals and others. The iron and steel industry is the major end user of refractories, which accounts for around 75% of the market. This is followed by the cement sector (15%) for the production clinker. The end-use consumption profile of Indian refractory sector is shown in Figure 3.

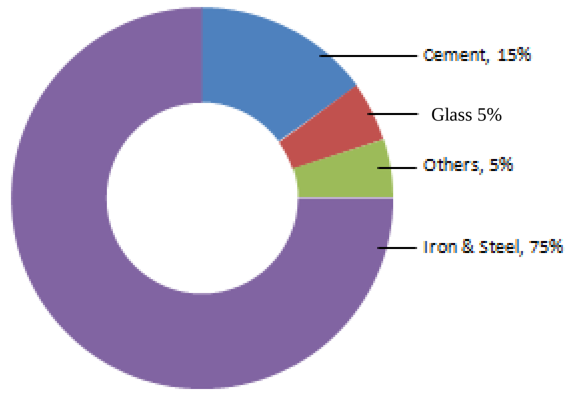


Figure 3: End use applications of refractory

Growth drivers

The growth of the refractory sector is dependent on the demand from its diverse end-use sectors. The largest user of the refractories i.e. iron & steel sector (including secondary steel sectors) is poised for growth of around 9 % CAGR. The production of the refractory sector is directly linked to demands of the iron and steel sector; the annual crude steel capacity is projected to reach about 300 million tonne by the year 2030 (National steel policy 2017). Similarly, the cement industry is also another important sector, which can influence the growth of refractory industries. The production of the cement sector is projected increase at 6% CAGR to reach about 660 million tonne by the year 2030. The substantial increase in capacity in both primary end user sector like iron and steel as well as cement sector will boost the demand for the refractory products in the country.

Geographical coverage

The major refractory clusters in the MSME sector are Asansol (West Bengal), Chirkunda (Jharkhand), East & West Godavari (Andhra Pradesh), Katni (Madhya Pradesh), Ramgarh (Jharkhand), Ranchi (Jharkhand), Virudhachalam (Tamil Nadu), and Wankaner (Gujarat) (Figure 4).

Figure 4: Major refractory industry clusters

Sector level stakeholders

The major institutions providing services to refractory industries in MSME sector are provided below.

Industry associations

The industry associations and apex bodies in the refractory sector are available at the national level and/or cluster level. The 'Indian Refractory Makers Association' (IRMA) is the national level body for refractory industries. It is actively involved in awareness generation on energy efficiency through international conference and regular publications. The industry associations in refractory sector are generally involved in local level issues such as redressal of grievances, infrastructural development, procurement of raw material and fuel, etc. The prominent industry associations in refractory sector are shown in Table 2.

Table 2: Details of industry associations in refractory sector

Cluster	Industry association	
National level	Indian Refractory Makers Association	41, Shakespeare Sarani Rd, Mullick Bazar, Park Street area, Kolkata, West Bengal - 700017
Asansol	Refractory Manufacturers Association	Refractory Bhawan, Bdo Para, Asansol – 713343 Contact: Mr B P Biyani, President Tel : 94340 25307
Chirkunda	Jharkhand Refractory Manufacturers Association	Chirkunda Dhanbad-826001, Jharkhand Email: jrma_india@yahoo.in Contact person: Mr. B.L Jalan (General Secretary)
East & West Godavari	Ceramic Manufacturers welfare Association, Rajahmundry	A George Babu Dwaraka Tirumala Industrial Association, West Godavari Mob: 98488 57577
	Dwaraka Tirumala Industrial Association, West Godavari	
Ramgarh	Federation of Jharkhand Chamber and Industries	Chamber Bhawan, Chamber Path, Main Road, Ranchi – 834001 Tel : 0651 – 2331250
Ranchi	Jharkhand Small Industries Association	Udyog Bhavan, Industrial Area, Kokar, Ranchi – 834001 Email: jsiaranchi2009@gmail.com Contact person: Mr. Philip Mathew (President)
Wankaner	Morbi Wankaner Industrial Development Association	Vajepar sr no 919 P, plot no. 3,4&5 4^{th} floor office no 4044 sq mtr-24-86 Morbi – 363641 Rajkot district, Gujarat
	Wankaner GIDC Industries Association	C/O Kohinoor Refectories Pvt. Ltd Plot No, 82/83 GIDC Estate, Wankaner, Morbi – 363621, Gujarat

Research and development institutions

Central Glass and Ceramic Research Institute (CGCRI), Kolkata is the main organization involved in the development of refractory sector in the country. It carries out basic and applied research, testing & evaluation, training & education and dissemination.

Government bodies

The government bodies associated with refractory industries include MSME-Development Institutes, SDA-BEE, DIC and NSIC.

Key challenges in glass and refractory sector

The energy and resources assessment studies, stakeholder consultations and analysis of secondary data of glass and refractory industries show that although the glass and refractory sector has improved its efficiency levels during the past two decades, there is still a significant scope for reducing the overall specific energy consumption (SEC) of the sector through adoption of new and innovative technologies and improved skillsets.

In order to enhance the sustainable development and competitiveness of MSMEs in the domestic and international markets, the Government of India and state governments have rolled out generic and a few sector specific policies and programmes for MSME sector time to time. In addition, a number of bilateral and multilateral organisations have also implemented several projects and programmes in energy efficiency sphere in MSME sector.

These initiatives towards energy efficiency, productivity improvement, skill development, ease of operation, etc., have so far helped the MSMEs to reach midway. However, the small scale industries are still not at par with international standards in terms of energy performance as well as competitive. The glass and refractory sector face stiff competition from international players in domestic market. This is also evident from the fact that the import2 of safety glass has raised to USD 136 million in 2020 from USD 36 million in 2010 registering an annual growth of 14.5%. Similarly, the imports of refractory products also witnessed an increase of 11% in the last decade.

The glass industries have renovated the technologies used in the melting process by adopting energy efficiency measures and cleaner fuel options in process heating (melting and auxiliary furnaces), which accounts for major share of energy consumption. Manual controls and limited automation are the primary causes for sub-standard efficiency levels and higher specific energy costs in glass melting industries. The glass blowing industries use of obsolete technologies e.g. conventional lathe machines, mouth blowing, etc. which are highly dependent on the skillsets of operators. The safety glass industries, however, use imported technologies with PLC based automation.

The technology use and efficiency level in the refractory sector vary from cluster to cluster. The refractory industries in the western region have achieved significant improvements in efficiency levels by adopting tunnel kiln technology. However, the clusters in other regions still employ use conventional downdraft kiln technology. A few refractory industries in eastern region clusters have adopted energy efficient tunnel kiln technology with limited automation.

The high energy intensity levels and low level of competitiveness of the glass and refractory sector are mainly attributed to various barriers and challenges viz. energy cost & productivity, financing, technology status, etc. The barriers and challenges faced by the glass and refractory industries can be put under the four broad categories: (1) technology (2) financing (3) skillsets (4) policy and (5) infrastructure & others (Table 3).

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[2] Annual International Trade Statistics by Country (HS02); Year 2002-20

Table 3: Key challenges in glass and refractory sector

Key challenge	Specific challenge	Impact
Technical	Lack of R&D by technology providers for customization of technologies relevant for MSME sector Limited/ non-availability of technologies/ technology providers/ local service providers (LSPs) at cluster level Limited knowledge of local service providers/ cluster level consultants Limited knowledge of entrepreneurs and focus on low hanging fruits	• Continued use of old and inefficient technologies • High investment cost for new technologies • Most of the MSME units are unaware about which new energy-efficient technologies/ equipment to adopt and from where to source it. • Lack of information on EE /new technologies • Insufficient number of technology providers leading to poor competitive environment and monopoly • Longer period for adoption of technology • Poor/delayed services/ troubleshooting by technology providers resulting in significant production losses • Information gap on low carbon technologies • Spread of misleading information among entrepreneurs
Financial	Lack of awareness and access to financial schemes for procuring EE technologies/ equipment Limited awareness of banks/ financial Institutions (FIs) on review of EE technologies/ equipment proposals Lack of documentation/ record of credential by MSMEs Mandatory collateral requirements for financing and poor/low credit rating of MSMEs Low level of interest/ reservation for financing low value loans by Banks/ FIs Limited/lack of communication between MSMEs, technology providers and bank officials	• Reluctance in implementation of EE projects by MSMEs thus delayed or no adoption • Poor disbursement of loans on EE projects • Non-ability by MSME units to avail benefits of specific government schemes • Non-ability of MSMEs to upgrade technologies due to limited financial resources • Low prospects for large scale adoption of new and modern technologies at cluster level
Skillsets	Non-availability of sub-sector specific training institutes at cluster level for skillset improvements Lack of in-house technical capabilities	• Variations in production, productivity, energy performance and quality • Apprehension towards development of new processes and products • Investment by individual units on development of skilled manpower • Lack of in-house innovation on EE projects • Less exposure on new and EE equipment leading to inefficient operation

Key challenge	Specific challenge	Impact
Policies	Non-existence/ availability of sector-specific programmes or schemes	• Limited implementation by MSMEs due to high investment required for upgradation of process equipment in targeted sector
Infrastructure & others	Non-availability of cleaner fuels at cluster level e.g. PNG, piped LPG, etc.	• Inefficient use of energy hence high impact on environment • Significant wastage of fuels i.e. LPG use in small size cylinders in glass blowing units • High risk involved in storing gaseous fuel, uncertain landed cost, interruption in operation
	Fragmented and geo graphically dispersed nature of units	• Difficulties in accessing common infrastructure facilities e.g. cleaner fuels (piped natural gas), common facility centres, etc.
	Lack of product branding	• Low profit margin in absence of marketing / advertisement

ENERGY CONSUMPTION AND BENCHMARKS

This section provides energy benchmarking of glass and refractory industries at cluster and sectoral level. An assessment of energy performance i.e. specific energy consumption (SEC) across various clusters in India was undertaken using primary and secondary data collected through questionnaire surveys, energy audits and interactions with stakeholders. The SEC depends on product, technology, raw material, scale of operation, operating practices, etc. A comparison of Indian SEC with International benchmarks is also presented in this section.

Energy benchmarking of glass industries

The cluster level production, energy consumption profile and benchmarking in terms of specific energy consumption of different glass products / processes of glass industries are provided below. This section also provides comparison of SECs with international benchmarks.

Products and production profile

The container glass and bangles account for the largest share of production and diverse product basket. Firozabad glass cluster is estimated to produce about 93% of total glass production in MSME sector. The production profile of different glass clusters are shown in figure 5.

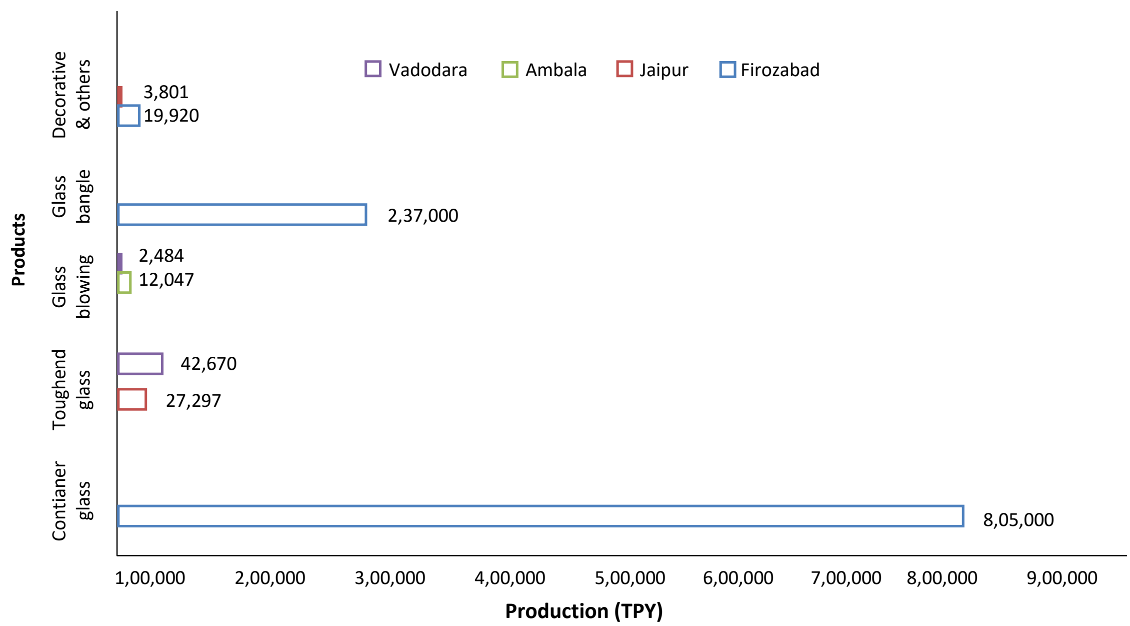


Figure 5: Production profile of major glass clusters

Firozabad is the major MSME cluster involved in both melting and processing. The other glass processing industries are located in Ambala, Jaipur, National Capital Region (NCR), Vadodara, and Ahmedabad. The total production[3] of glass melting industries in MSME sector is estimated to be 1.1 million tonne (mt) during FY 2019-20. The production of toughened glass and blowing glass are estimated to be 70,000 tonne and 14,500 tonne respectively (Figure 6).

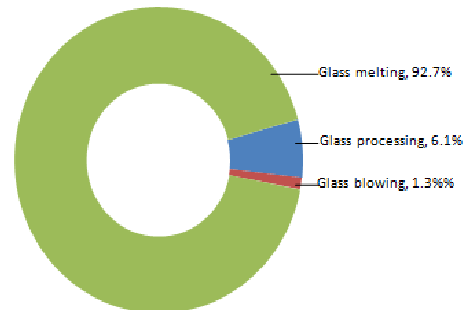
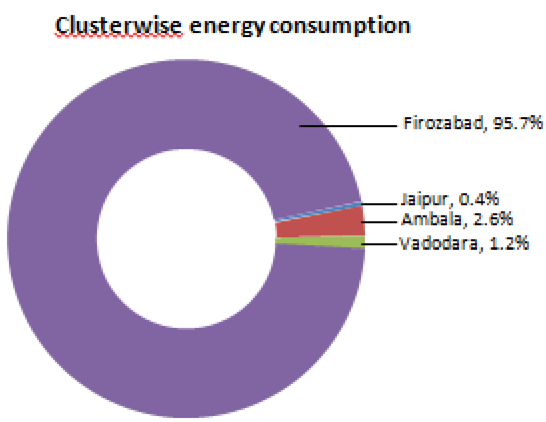


Figure 6: Production profile of glass sector

Energy consumption profile

Natural gas (NG) is the major fuel used in glass industries, mainly in Firozabad cluster, accounting for about 95% of total energy consumption (Figure 7). The glass blowing industries in Ambala and Vadodara use LPG (~3%), electricity and HSD. Toughened glass industries use electricity for processing glass products.



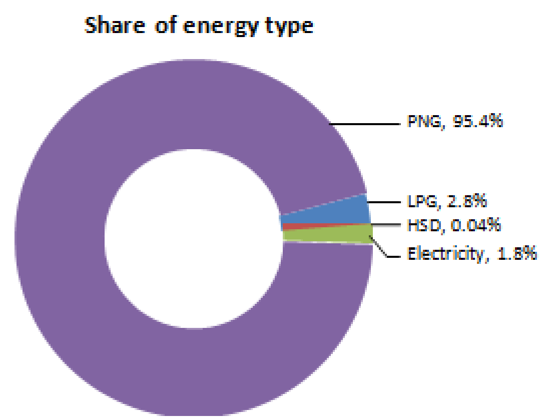


Figure 7: Share of energy consumption in glass sector

The total estimated energy consumption of glass clusters in the MSME sector is estimated to be 2,76,777 toe per year (Table 4). About 95% of energy consumption is accounted by melting industries, whereas glass processing units account for only 5% of total energy consumption. The equivalent GHG emissions are estimated to be 5,87,225 tonne CO_2.

Table 4: Energy consumption and GHG emissions in glass sector

Energy type	Energy consumption	Equivalent toe	GHG emissions (t-CO_2)
PNG (million SCM)	302	2,64,142	5,20,291
LPG (tonne)	6,776	7,655	20,225
HSD (kL)	133	116	338
Electricity (million kWh)	57	4,863	46,371
Total		2,76,777	5,87,225

[3] Estimated data from selected and additional clusters

Specific energy consumption

The specific energy consumption (SEC) of glass melting industries in MSME sector varies from 7.7 GJ per tonne of product for container glass products (Firozabad) to 19.2 GJ per tonne for glass bangles (Firozabad) as shown in figure 8. The average SEC of blown products is 27.5 GJ per tonne (Ambala) and of toughened glass is about 1.7 GJ per tonne (Jaipur), which require only heating to shape the product. A large variation in SEC level was observed which may be attributed to type of end products, feed material to process, technology in use, throughput, operating parameters, etc. The average SECs of technology use in various glass clusters were observed to be higher than their design levels. The present SEC levels can be improved by adopting best operating practices in different glass industries (table 5).

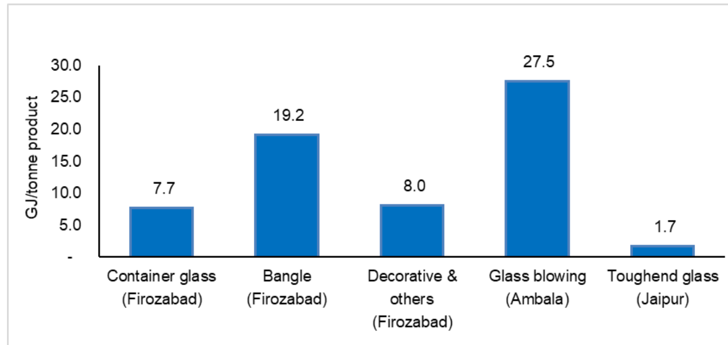


Figure 8: Specific energy consumption of glass products

Table 5: Target values and best operating practices in glass industries

Parameter	Present value	Target value	Best operating practices
Glass melting – Tank furnace (GJ per tonne)	7.7	4.3	• Furnace automation • Air ingression control
Glass melting – Pot furnace (GJ per tonne)	19.2	11.3	• Maintain air fuel ratio • Insulation improvement of furnaces • Minimise flue gas losses through waste heat recovery • Improved life of pots
Toughened glass processing	1.7	1.6	• Maintaining air fuel ratio • Insulation improvements
Glass blowing	29.7	24.7	• Use of LPG bank and central distribution network • Furnace automation
Air compressor - Screw (kW/cfm)	0.130	0.117	• Set air pressure based on end-use requirements • Plug air leakages • Use seamless airline network
Air compressor - Reciprocating (kW/cfm)	0.240	0.185	• Set air pressure based on end-use requirements • Plug air leakages • Use seamless airline network
Motors	85-88%	92%	• Avoid rewinding of motors • Ensure correct size of motors • Use of IE3 motors

SEC comparison with international benchmarks

A comparison of SEC of Indian glass industries in MSME sector vis-a-vis global levels is shown in Table 6.

Table 6: Performance comparison of MSME glass industries with global level

Industry type	Specific energy consumption			
	Unit	Indian MSMEs	Global levels	Remarks
Glass melting - Regenerative tank furnace	GJ/tonne molten glass	4.3	3.8*	50% cullet in the glass forming batch
Glass melting – Pot furnace	GJ/tonne molten glass	11.3 (glass bangle)	8.44-16.9@ (discontinuous glass melting for table glassware)	No data for similar products
Toughened glass processing	GJ/tonne product	1.6-1.7	No data	-
Glass blowing - Borosilicate glass	GJ/tonne product	24.7-29.7	No data	Wide range of product categories

** Energy Efficiency Benchmarking of Glass Furnaces (Beerkens, Ruud, van Limpt, Hans 2008)*

@ Energy and environment profile of U.S. glass industry, U.S. Department of Energy (https://www.energy.gov/sites/prod/files/2013/11/f4/glass2002 profile.pdf)

Energy benchmarking of refractory industries

The cluster level production, energy consumption profile and benchmarking in terms of specific energy consumption of different manufacturing technologies of refractory industries are provided below. This section also provides comparison of SECs with international benchmarks.

Product and production profile

A large range of products is manufactured by the refractory industries in MSME sector with an objective to cater to the requirements of other industry sub-sectors such as steel, cement, glass industries, etc. A few important and generic products manufactured in refractory industry include refractory bricks, bottom pouring sections, high temperature alumina bricks, etc. The cluster wise production profile using different firing technologies are shown in Figure 9.

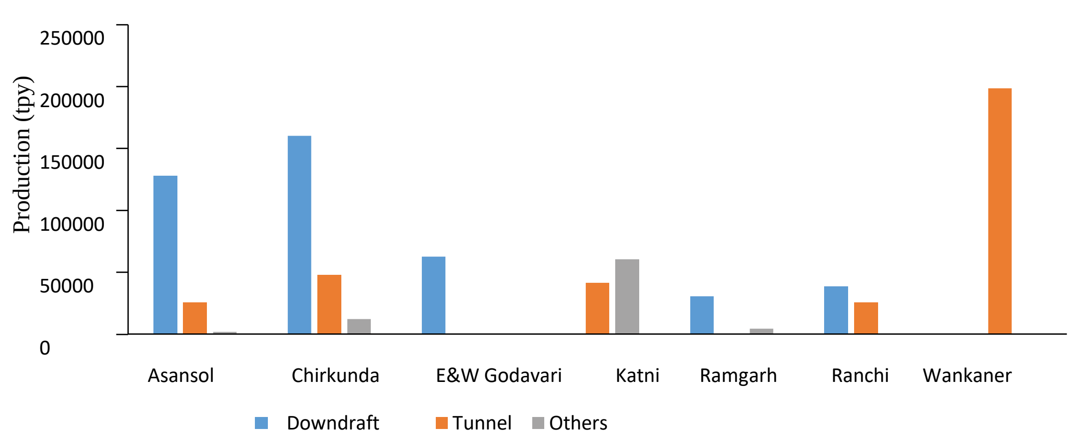


Figure 9: Production profile using major firing technologies in refractory clusters

The cumulative refractory production of the major MSME clusters in India is estimated to be 0.84 million tonne during FY 2019-20. A major share of refractory production is accounted by eastern region (57%) (Figure 10). Downdraft kilns accounted for about 50% of total production, while the share of tunnel kiln is about 41%. Other kilns such as chamber kilns and rotary kilns accounted for about 9% of the total production in the refractory sector (Figure 11).

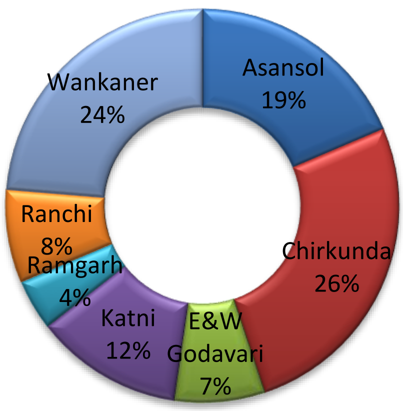


Figure 10: Production profile of refractory sector

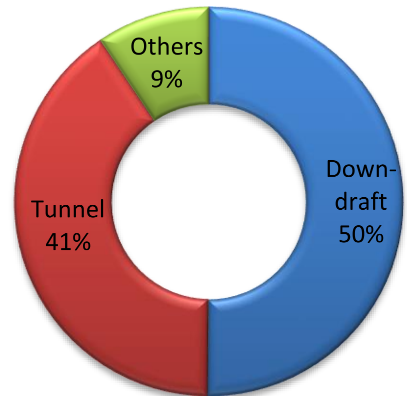
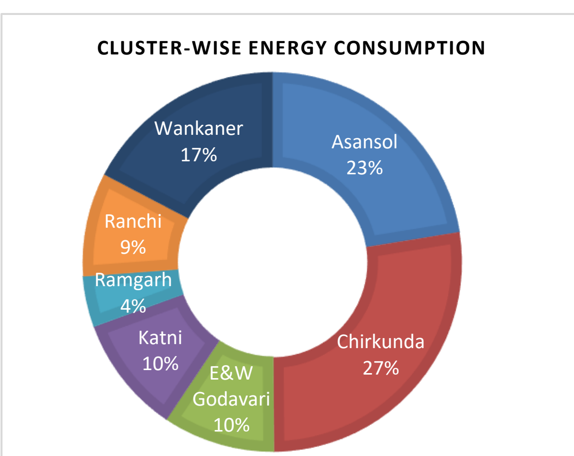


Figure 11: Technology wise production share

Energy consumption profile

The refractory manufacturing process uses both thermal energy and electricity. Thermal energy is used for process heating in kilns to transform the raw mass of green products into final sintered products i.e. refractory bricks and blocks. Coal is used as fuel in downdraft kilns while petcoke is widely used in tunnel kilns. Electricity is used in raw material preparation and green refractory forming.

The total estimated energy consumption of refractory clusters in the MSME sector is estimated to be 1,05,446 toe per year (Table 7). About 99% of energy consumption is accounted by kilns, whereas green refractory processing accounts for only 1% of total energy consumption (Figure 12).



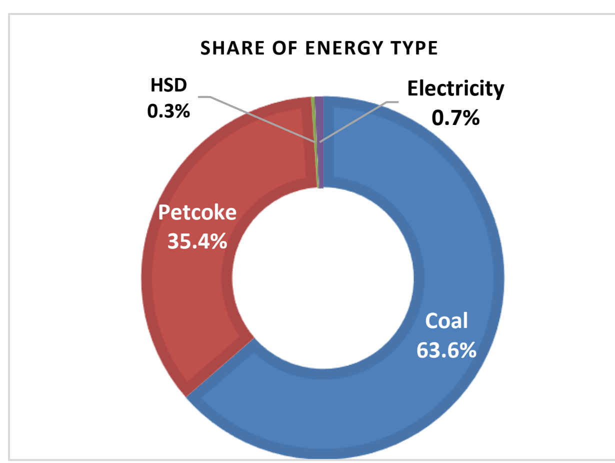


Figure 12: Share of energy consumption in refractory sector

The total GHG emissions of refractory sector are estimated to be 4,29,318 tonne CO_2 per year. Downdraft kilns account for about 62% of total energy consumption, tunnel kilns 31% and others are about 7% (Figure 13).

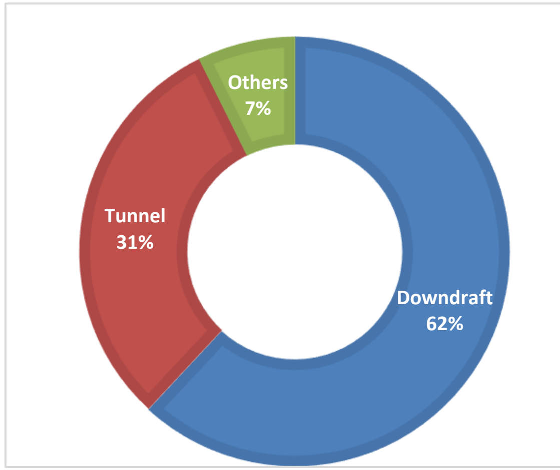


Figure 13: Energy consumption share by technologies

Table 7: Energy consumption and GHG emissions in refractory sector

Energy type	Energy consumption	Equivalent toe	GHG emissions (t-CO_2)
Coal (tonne)	1,48,578	67,068	2,69,818
Petcoke (tonne)	44720	37,296	1,51,421
HSD (kL)	385	336	976
Electricity Million kWh	8.7	745	7,103
Total		1,05,446	4,29,318

Specific energy consumption

The average SEC of downdraft kiln is 6.59 GJ per tonne varying from 6.23 GJ per tonne to 7.04 GJ per tonne of product (Figure 14). The average SEC of tunnel kiln is 4.23 GJ per tonne varying from 3.81 GJ per tonne to 4.51 GJ per tonne of product (Figure 15).

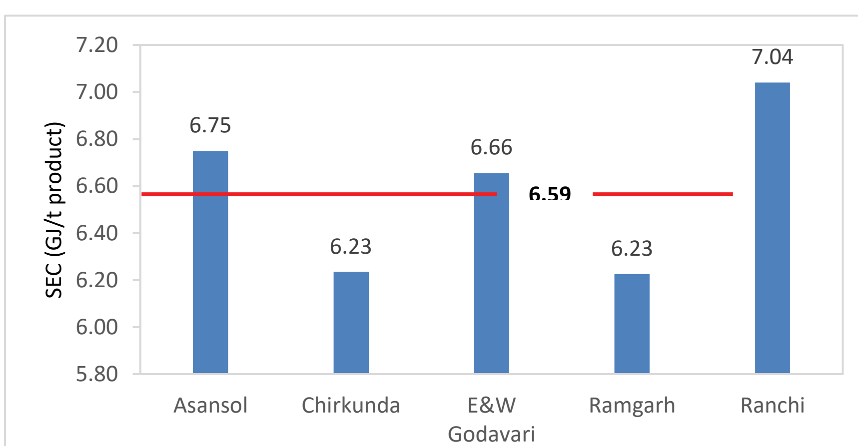


Figure 14: SEC variations in downdraft kilns

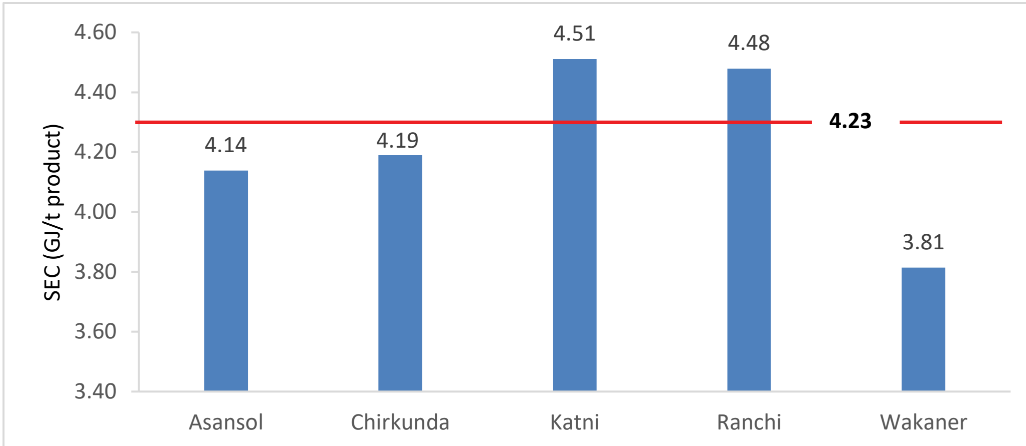


Figure 15: SEC variations in tunnel kilns

The present SEC levels can be improved by adopting best operating practices in different refractory industries (table 8).

Table 8: Target values and best operating practices in refractory industries

Parameter	Present value	Target value	Best operating practices
Downdraft kiln - coal fired (kg coal per tonne product)	345	303	• Install on-line kiln monitoring and control system • Improve insulation of crown and structure • Minimise flue gas losses through waste heat recovery
Tunnel kiln - petcoke fired (kg petcoke per tonne product)	213	192	• Maintain air ratio • Use low thermal mass cars • Minimise flue gas losses through waste heat recovery
Motors	85-88%	92%	• Avoid rewinding of motors • Ensure correct size of motors • Use of IE3 motors

SEC comparison with international benchmarks

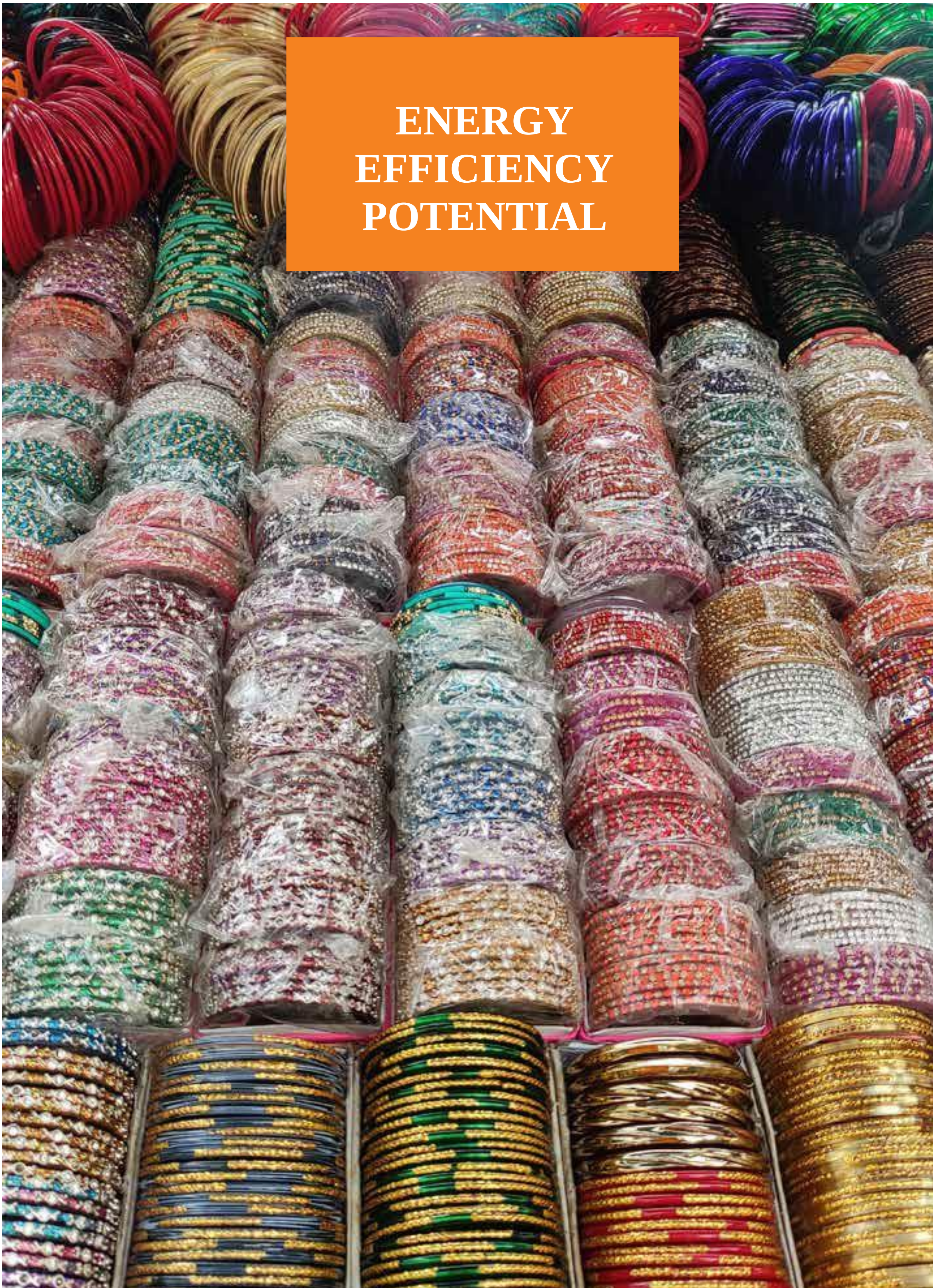
The SEC range of Indian refractory industries (MSMEs) was observed to be 3.8GJ per tonne to 7.0 GJ per tonne as against the reported global value of 3.27 GJ per tonne (Table 9).

Table 9: Performance comparison of MSME refractory industries with global level

Energy performance indicator	Unit	Indian MSME units	Global levels
Specific energy consumption	GJ/tonne product	3.8-7.0	3.27#

For natural gas fired tunnel kiln manufacturing magnesia spinel refractory products fired at 1760–1850 ^{0}C. Life cycle assessment and life cycle cost analysis of magnesia spinel brick production, Özkan, et al, 2016. (Sustainability 2016, 8, 662; doi:10.3390/su8070662, http://www.mdpi.com/journal/sustainability)

ENERGY EFFICIENCY POTENTIAL



Energy efficiency potential in glass sector

The Indian glass industries in the MSME sector play an important role in catering to the customized product requirements of various end-users. Firozabad is the largest MSME cluster in the glass sector involved in container glass and bangle production. The other glass clusters are mainly involved in processing glass products using glass sheets or borosilicate glass tubes. Thermal energy is predominant in glass manufacturing process in which melting units account for about 99 % and processing units about 66 % of total energy consumption. Electricity has a significant share in toughened glass industries.

An analysis of glass units in the MSME sector indicates several energy efficiency, technology upgradation and resource saving options can be adopted. The energy saving potential of container glass and bangle manufacturing segments is estimated to be 9-14 %; the potential in glass products processing sector is about 3-5 %. In addition to the above, cross cutting technologies and resource efficiency options will further help in reducing the operating costs in glass industry. Table 10 to Table 14 summarises the various options and their potential impacts.

Table 10: Summary of EE options and potential impacts in container glass (tank furnace units)

Energy and resource efficiency option	Energy saving potential (%)	Replication potential (%)	Replication potential in short-term (2024-25)	Replication potential in long-term (2030-31)	Energy saving (toe/yr)	Monetary benefits (Rs lakh/yr)	Investments (Rs lakh)	Payback period (year)	GHG emissions (t CO_2/yr)
Furnace automation and control system	4	100	Medium	High	5,537	1,233	4,830	3.9	10,901
Air ingression control in regenerator system	3	50	Medium	High	2,500	770	557	0.7	4,921
Energy efficiency in compressed air system	9	30	Low	Medium	2,278	508	966	1.9	4,487
Total					10,315	2,511	6,353	2.5	20,310
Technology up-gradation: Switch over to electrical annealing lehr	23	100	Low	Medium	2,788	621	1,022	1.6	5,488

Table 11: Summary of EE options and potential impacts in glass bangles (pot furnace units)

Energy and resource efficiency option	Energy saving potential (%)	Replication potential (%)	Replication potential in short-term (2024-25)	Replication potential in long-term (2030-31)	Energy saving (toe/yr)	Monetary benefits (Rs lakh/yr)	Investments (Rs lakh)	Payback period (year)	GHG emissions (t CO_2/yr)
Crown insulation improvement in pot furnace	7	100	Medium	High	3,940	878	474	0.5	7,934
Crown insulation improvement in reheating	3	65	Medium	High	217	48	20	0.4	5,443

Energy and resource efficiency option	Energy saving potential (%)	Replication potential (%)	Replication potential in short-term (2024-25)	Replication potential in long-term (2030-31)	Energy saving (toe/yr)	Monetary benefits (Rs lakh/yr)	Investments (Rs lakh)	Payback period (year)	GHG emissions (t CO_2/yr)
furnace									
Waste heat recovery in reheating furnace	15	65	Low	High	1,400	312	462	1.5	5,971
Total					5,557	1,238	956	0.8	19,348
Technology up-gradation: Electrification of reheating furnace	17	67	Low	Medium	8,373	573	1,580	2.8	-53

Table 12: Summary of EE options and potential impacts in glass processing industries

Energy and resource efficiency option	Energy saving potential (%)	Replication potential (%)	Replication potential in short-term (2024-25)	Replication potential in long-term (2030-31)	Energy saving (toe/yr)	Monetary benefits (Rs lakh/yr)	Investments (Rs lakh)	Payback period (year)	GHG emissions (t CO_2/yr)
Electrification of LPG annealing furnace	7.5	25	Low	Medium	180	118	138	1.2	-1,601
Energy efficiency in LPG annealing furnace	1.0	25	Low	Medium	20	19	38	2.0	68
Energy efficiency in electrical annealing furnace	2.8	25	Low	Medium	67	55	197	3.6	641
Total					267	192	373	1.9	-893
Total					**267**	**192**	**373**	**1.9**	**-893**

Table 13: Summary of cross cutting technology options and potential impacts in glass industries

Energy and resource efficiency option	Energy saving potential (%)	Replication potential (%)	Replication potential in short-term (2024-25)	Replication potential in long-term (2030-31)	Energy saving (toe/yr)	Monetary benefits (Rs lakh/yr)	Investments (Rs lakh)	Payback period (year)	GHG emissions (t CO_2/yr)
Energy efficient motors	6	100	Low	Medium	231	52	139	2.7	456
EE air compressor	35	15	Low	Medium	21	17	55	3.2	197
Total					251	68	194	2.8	653

Table 14: Summary of resource conservation options and potential impacts in glass industries

Energy and resource efficiency option	Energy saving potential (%)	Replication potential	Replication potential in short-term (2024-25)	Replication potential in long-term (2030-31)	Energy saving (toe/yr)	Monetary benefits (Rs lakh/yr)	Investments (Rs lakh)	Payback period (year)	GHG emissions (t CO_2/yr)
Improved pot arching in pot furnace units	18	100	Medium	High	1,102	1,164	2,607	2.2	-2,023
Centralised LPG distribution system in glass blowing units	6.5	30	Low	Medium	98	94	116	1.2	334
Total					1,200	1,258	2,723	2.2	-1,688

The share of energy saving, investments and GHG emission reductions in different glass product categories are provided in Figure 16.

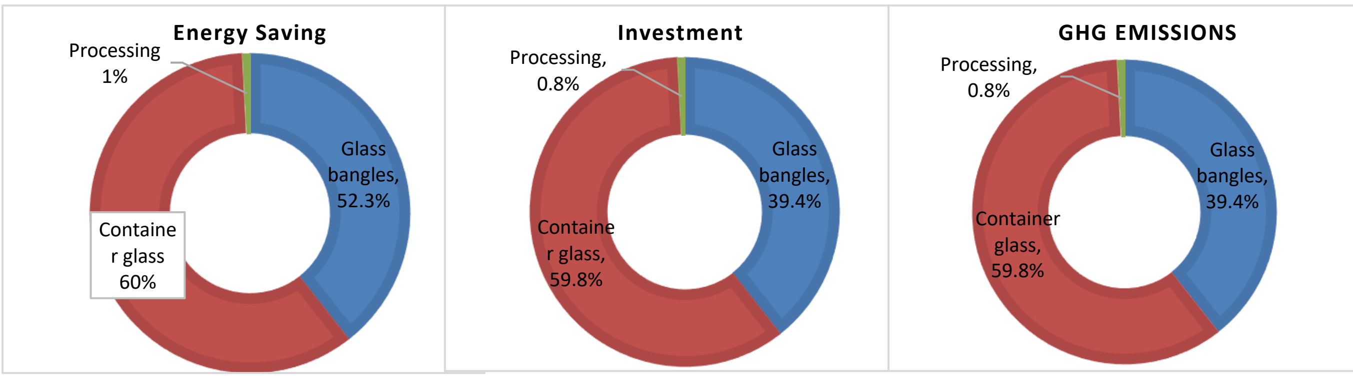


Figure 16: Share of energy, investments and GHG emission reduction in glass products

The glass manufacturing units in the MSME sector offer huge energy and resource saving and GHG emission reduction potential. However, to implement various EE options and realize energy savings, the industry needs to address several barriers. A sectoral roadmap is prepared to spell out the existing barriers and recommend policy/ regulatory instruments for adoption of energy and resource efficiency options in glass industries in the MSME sector.

Impacts of energy efficiency in glass industries

The potential energy saving in glass sector is about 9% for glass melting industries manufacturing assorted container glass (Figure 17). The corresponding GHG emissions are shown in figure 18.

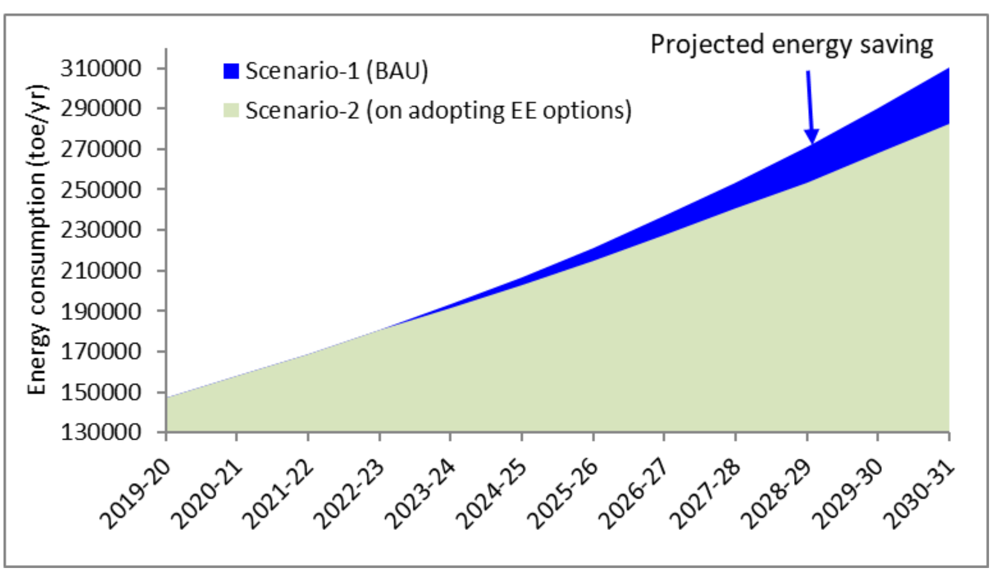


Figure 17: GHG emission projections in glass melting (container glass)

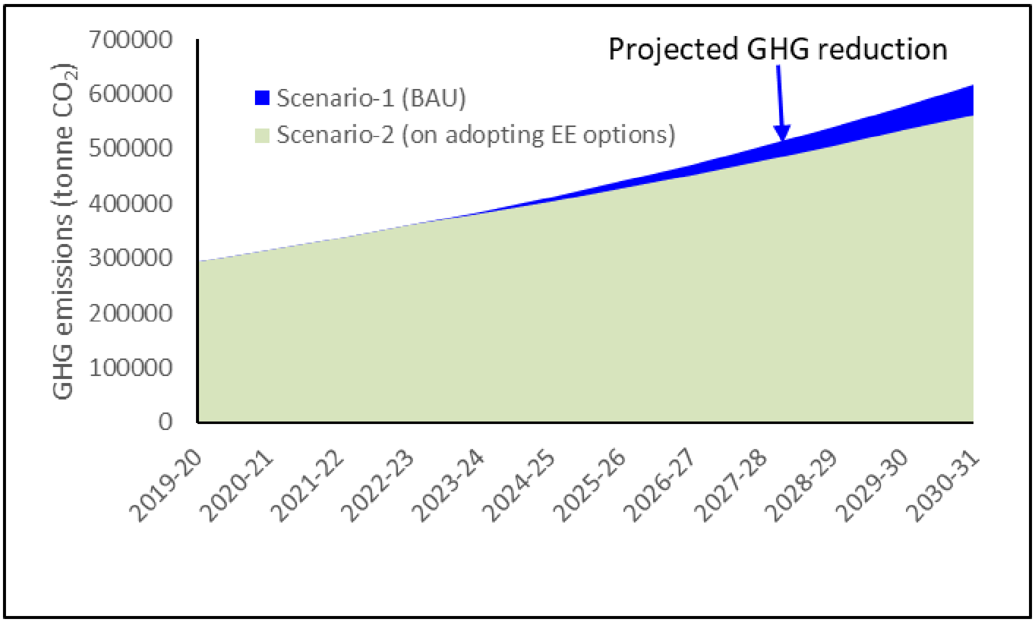


Figure 18: GHG emission projections in glass melting (container glass)

Similarly, the energy saving potential is around 13% for glass melting units producing bangles (Figure 19). The corresponding GHG emissions are shown in figure 20.

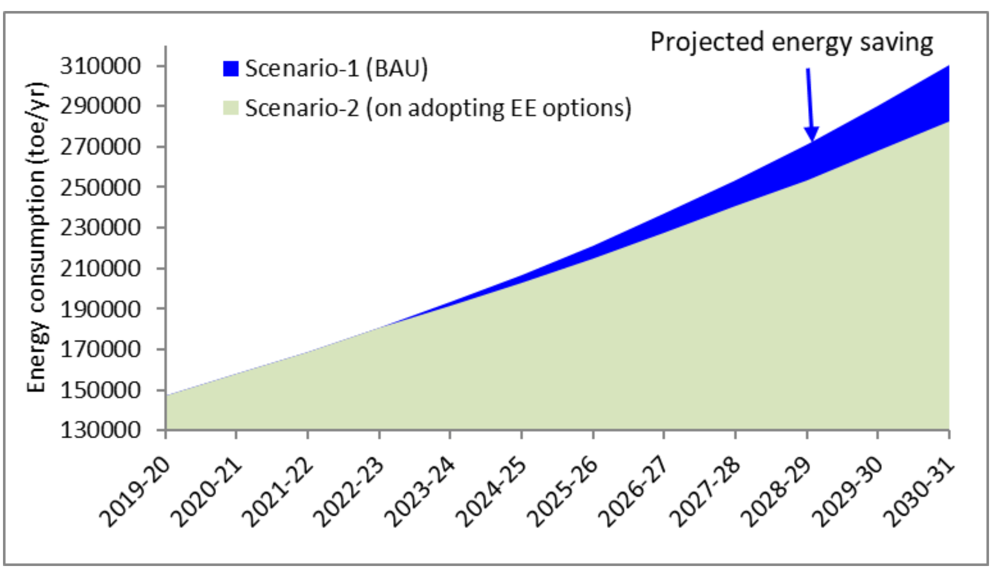


Figure 19: Energy saving projections in glass melting (Glass bangles)

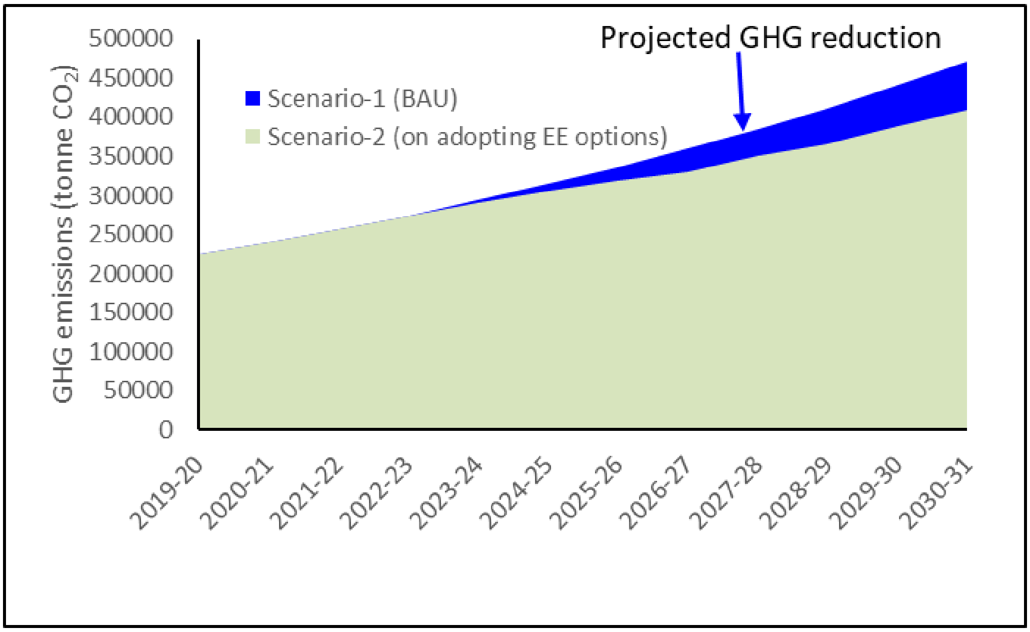


Figure 20: GHG emission projections in glass melting (Glass bangles)

Unlike glass melting industries, the potential is only 3% for glass processing industries such as glass blowing and toughening by adopting identified energy efficiency options (Figure 21). The corresponding GHG emissions are shown in figure 22. The total estimated energy saving in glass industries by 2030-31 is about 60,517 toe assuming a CAGR of 7% in the sector.

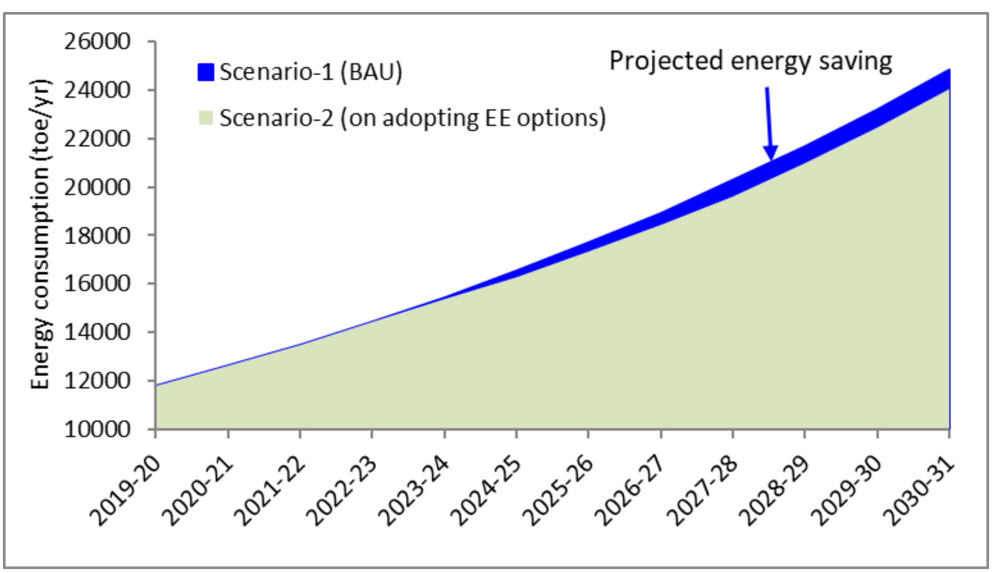


Figure 21: Energy saving projections in glass processing

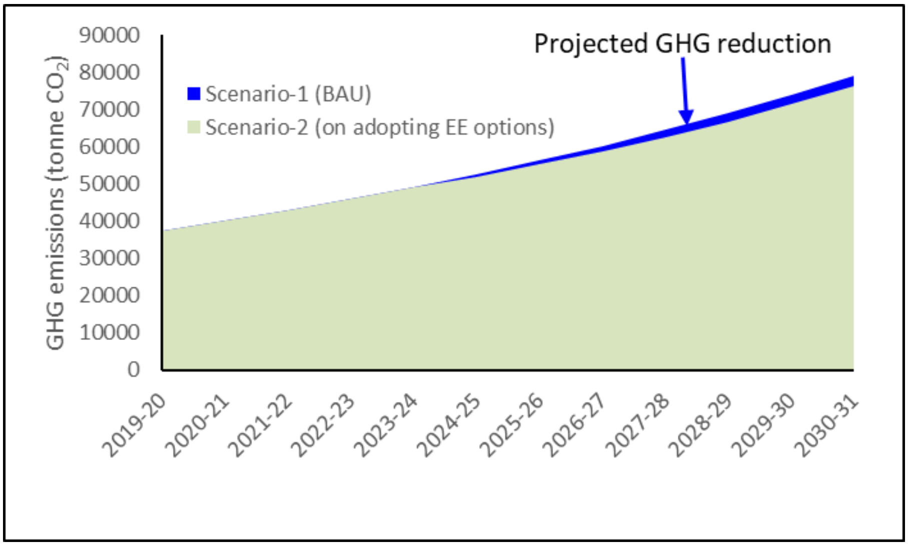


Figure 22: GHG emission projections in glass processing

Energy efficiency potential in refractory sector

The Indian refractory industries in the MSME sector are an important sector catering to the refractory product requirements of various end-use sectors. The MSME sector uses mainly two technologies namely, downdraft (DD) kiln and (2) tunnel kiln, with downdraft having a production share of about 60%. Thermal energy is predominant (98-99%) in the overall manufacturing process of refractories. Energy audit studies and energy performance evaluation through questionnaire based surveys indicate that the downdraft kilns are inefficient and consume at least 40% more energy per unit of production as compared to tunnel kilns. Summary of EE options and potential impacts in DD kiln units are given in Table 15.

Table 15: Summary of EE options and potential impacts in downdraft kiln units

Energy efficiency option	Energy saving potential (%)	Replication potential (%)	Replication potential in short-term (2024-25)	Replication potential in long-term (2030-31)	Energy saving (toe/yr)	Monetary benefits (Rs lakh/yr)	Invest-ments (Rs lakh)	Payback period (year)	GHG emissions reduction (t CO_2/yr)
Enhancing insulation of crown and doors	7	100	Low	Low	2,654	412	243	0.6	10,676
Kiln monitoring and control tool	9	100	Low	Medium	5,490	851	284	0.3	22,087
Installation of kiln waste heat recovery system	10	17	Low	Low	1,268	197	473	2.4	5,103
	Total				9,412	1,460	999	0.7	37,866
Technology Upgradation: Switch over to tunnel kiln technology	25	100	Medium	High	26,897	4,171	7,444	1.8	1,08,207

Several energy efficient options can be implemented by downdraft kiln units with an overall energy saving potential of up to 8-10%. However, a substantial reduction in energy consumption is possible in downdraft kiln based units by only switching over to tunnel kiln technology. The energy performance of tunnel kiln based units can be enhanced by switching over to gaseous fuels, which however depends on the availability of NG at cluster level with the costs comparable to existing fuel use. Table 16 summarises the energy efficiency options and potential impacts in tunnel kiln units. The summary of cross-cutting and resource efficiency options in the refractory industries is given in Table 17.

Table 16: Summary of EE options and potential impacts in tunnel kiln units

Energy efficiency option	Energy saving potential (%)	Replication potential (%)	Replication potential in short-term (2024-25)	Replication potential in long-term (2030-31)	Energy saving (toe/yr)	Monetary benefits (Rs lakh/yr)	Investments (Rs lakh)	Payback period (year)	GHG emissions reduction (t CO_2/yr)
Enhancing insulation of tunnel kilns	5	100	Medium	High	1,954	410	80	0.2	7,934
Low thermal mass cars	5	100	Medium	High	1,341	281	300	1.1	5,443
Fuel switch over solid fuel to gaseous fuel[4]	10	100	Low	Medium	15,334	185	915	5.0	5,971
Total					18,629	876	1,295	1.5	19,348

Table 17: Summary of cross-cutting and resource efficiency options in refractory industries

Energy efficiency option	Energy saving potential (%)	Replication potential	Replication potential in short-term (2024-25)	Replication potential in long-term (2030-31)	Energy saving (toe/yr)	Monetary benefits (Rs lakh/yr)	Investments (Rs lakh)	Payback period (year)	GHG emissions reduction (t CO_2/yr)
Cross-cutting technology									
Energy efficient motors	6	100%	Low	Medium	38	29	95	3.3	363
Resource efficiency options									
Productivity enhancement in downdraft kiln	-	100%	Low	Medium	-466	460	985	2.1	-4439
Installation of material feeding conveyor system	-	100%	Medium	High	196	903	1129	1.2	1867
Total					-270	1,363	2,113	1.5	-2,572

The refractory industries in the MSME sector, thus offer huge potential for energy saving. However, to implement various EE options and realize energy saving, the industry needs to address several barriers. A sectoral roadmap is prepared to spell out the existing barriers and recommend policy/ regulatory instruments for adoption of energy and resource efficiency options in refractory industries in the MSME sector.

[4] includes natural gas, LPG, hydrogen, producer gas (from gasification of sustainable biomass), etc.

Impacts of energy efficiency in refractory industries

The roadmap envisages that the existing DD kiln technology will be completely phased out and replaced by energy efficient tunnel kiln technology by the 2030 and the phenomenon of gradual switch over is depicted in the figure 23. The energy saving is limited to about 12% for DD kilns and 10% for tunnel kiln on retrofitting feasible energy conservation measures.

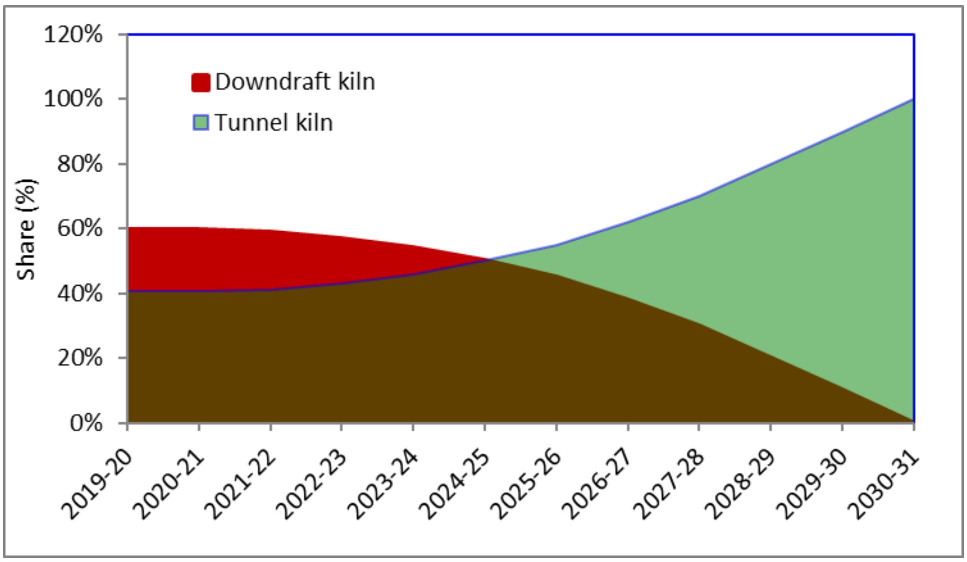


Figure 23: Projection of technology share

The energy saving can be maximized in DD kiln units to the tune of 45% by switching over to tunnel kiln technology. The total estimated energy saving in refractory industries by 2030-31 is about 79,846 toe assuming a CAGR of 7% in the sector (Figure 24). The corresponding GHG reductions are shown in figure 25.

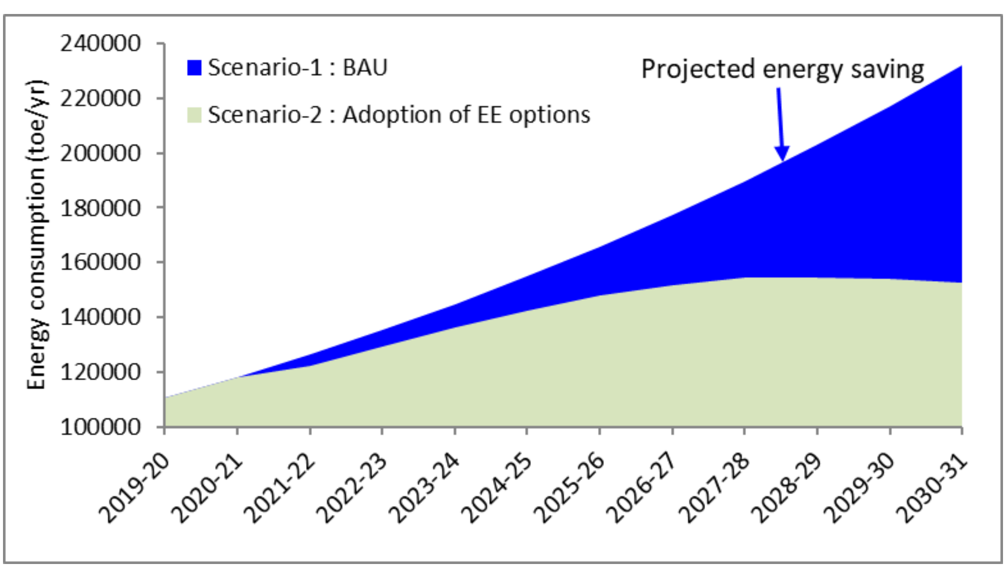


Figure 24: Energy saving projections in refractory sector

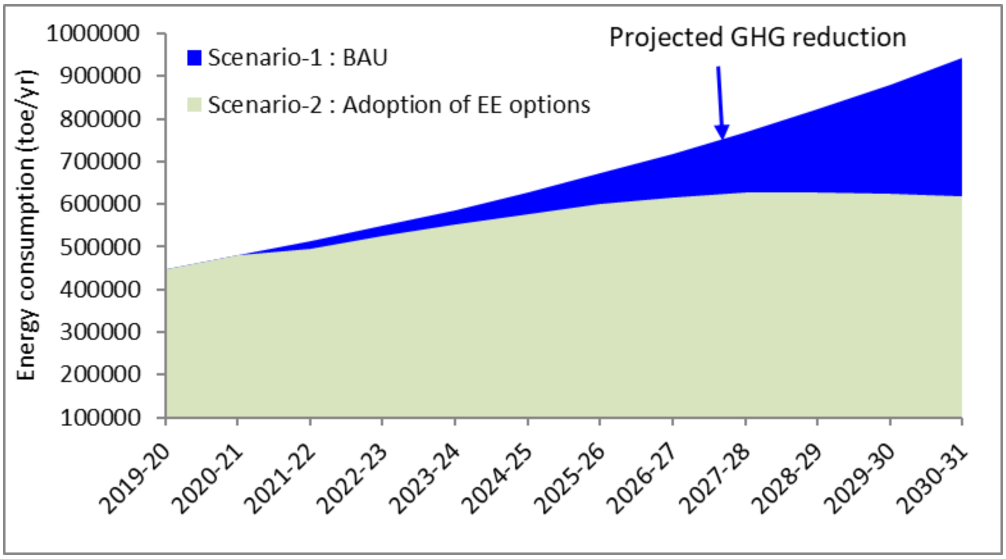
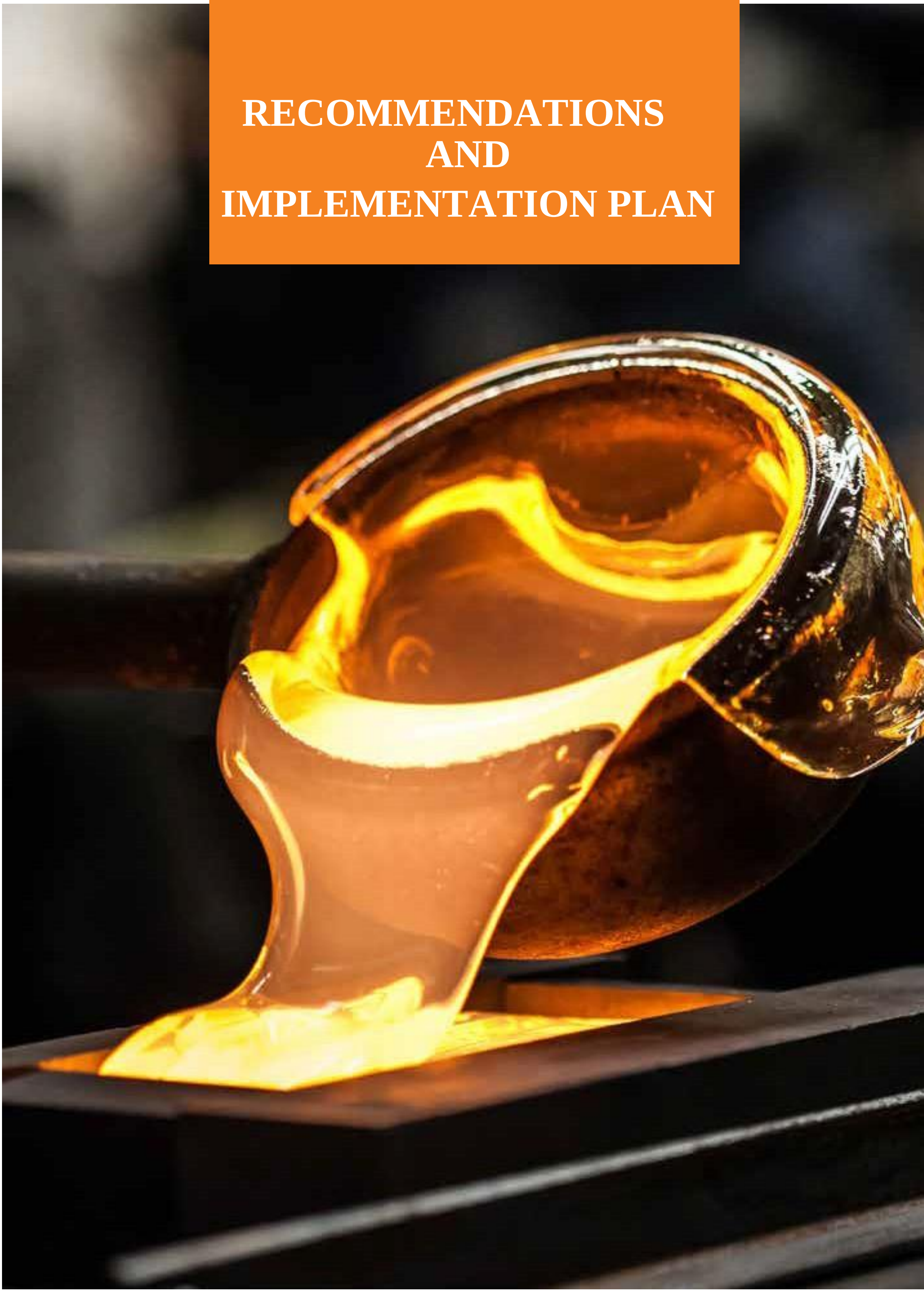


Figure 25: GHG emission projections in refractory sector

RECOMMENDATIONS AND IMPLEMENTATION PLAN



Glass and refractory manufacturing is one of the highest energy intensive industry sub-sectors and has shown sustained growth with increasing demands in steel, construction and other end-use sectors. The continuous use of conventional manufacturing technologies and associated auxiliaries in this sector have led to stagnant production levels, higher SECs, increased O&M and thus higher overall production cost, which make them non-competitive in domestic as well as international markets.

A sectoral analysis shows that there is a significant scope for enhancing efficiency levels as well as conserving resources in the glass and refractory manufacturing industries. In addition, skill development is also one of the vital measures towards sustainability of the sector. However, the glass and refractory sector faces a number of challenges viz. technological, financial, policies and infrastructural barriers, which have slowed down their progress of modernization and energy performance improvements.

By addressing the barriers in a holistic manner through appropriate strategies, the glass and refractory sector will be able to overcome the existing barriers. This section provides a set of recommendations and implementation plan along with way forward focusing on glass and refractory sector. The recommendations are collated into cluster level strategies and policy level strategies aimed to improve the overall energy performance and competitiveness.

Recommendations for energy efficiency improvements

The recommended strategies outlining the specific interventions required in glass and refractory sector along with implementation plan are discussed in this section. The implementation plan includes the list of potential implementing agencies with their roles and responsibilities and envisaged financial assistance. The proposed strategies are shown in Figure 26.

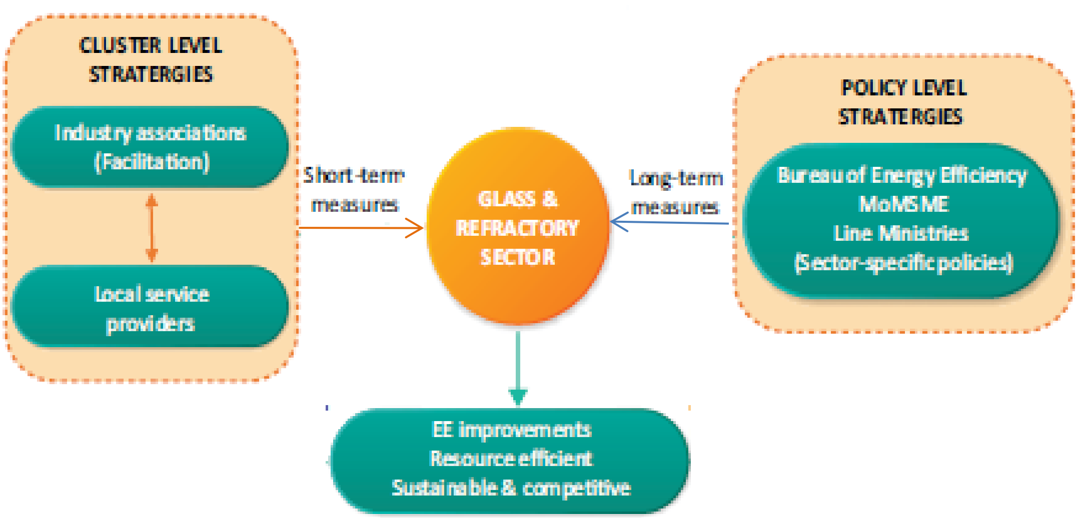


Figure 26: Proposed roadmap for glass and refractory sector

Cluster level strategies

There are several technology-specific energy and resource conservation opportunities that have already been successfully demonstrated and would require low initial investments. The implementation of these conservation measures largely does not require facilitation through specific government policies and can be facilitated directly by cluster level industry associations and/or apex bodies.

The sectoral analysis revealed the need for improvement in the efficiency level of basic utilities and equipment such as electric motors, insulation, lighting, air circulation fans, air compressors, etc. envisaging low investment and periodic replacement. The cluster-specific interventions to be facilitated and promoted by "cluster level energy management cell" established and operated through industry associations, development institutes, special purpose vehicle for cluster development programmes (SPV-CDP), etc. The cell will facilitate adoption of energy and resource conservation measures requiring minimum knowledge support of subject-matter experts and lower financial implications. The board scope of services of cluster level energy management cell (EMC) is depicted in Figure 27. The details of the recommended EMC covering financial assistant needed, functional aspect, main implementing agencies and time frame are provided in Table 18.

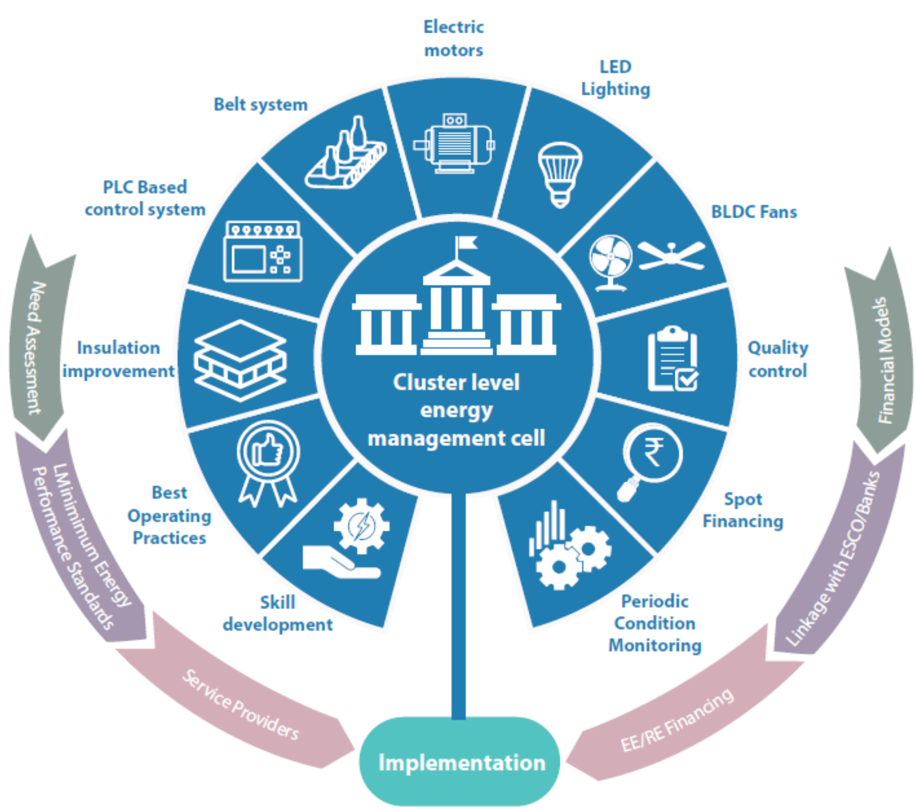


Figure 27: Scope of cluster level energy management cell

Table 18: Details of cluster level energy management cell

Recommendation/ interventions	Financial assistance	Objective	Key suggestions	Implementing agencies	Timeframe
Establishment of Energy Management Cell	Development of infrastructure: Rs. 25 lakh (max) per MSME cluster Total Budget: Rs. 5 crore	Facilitating the adoption of EE technologies/ equipment (self-sustainable model) to ensure minimum EE levels at competitive prices	1. Development of financial models for self-sustainable operation 2. Establishment of linkage with technology/ equipment OEMs 3. Setting up minimum efficiency and quality levels for equipment/system and spare parts. 4. Rate contract under bulk procurement model 5. Inventory management for spare parts 6. Establishment of linkages with Banks/FIs for single-window financing	1. Bureau of Energy Efficiency and SDAs 1.1 Supporting establishment and coordination with cluster level "Energy Management Cell" 2. Industry associations/ apex bodies 2.1 Coordination and facilitation of programme 2.2 Periodic need assessment, review and customisation 3 Ministry of Micro Small and medium enterprises 3.1 Development of basic infrastructure for local bodies 4. Energy Efficiency Services Limited (EESL) 4.1 Linkage with existing national level programme 5. SIDBI, FIs and Banks 5.1 Single window financing	1. Identification and development of local bodies: 1st year 2. Development of energy management cell: 2nd year 2.1 Rate contract with OEMs: 2nd year onwards 2.2 Awareness & outreach: 2nd year onwards

Policy level strategies

The energy and resource efficient manufacturing sector not only requires change in the technology use, but also needs strengthening of infrastructure such as fuel supply network, skilled workforce and financing mechanism. Sustainable development of glass and refractory sector using low carbon path demands mass production and high productivity. Thus, availability of cost-competitive raw materials, product testing facilities at doorsteps and product development & promotion also need strong policy level support.

The key stakeholders for implementing the policy level strategies include government agencies, infrastructure development agencies, development institutions, and financial institutions / ESCOs (Figure 28). The major policy level strategies are (1) upgradation fund, (2) common facility centres (CFCs), and (3) development of new industrial zones (Table 19).

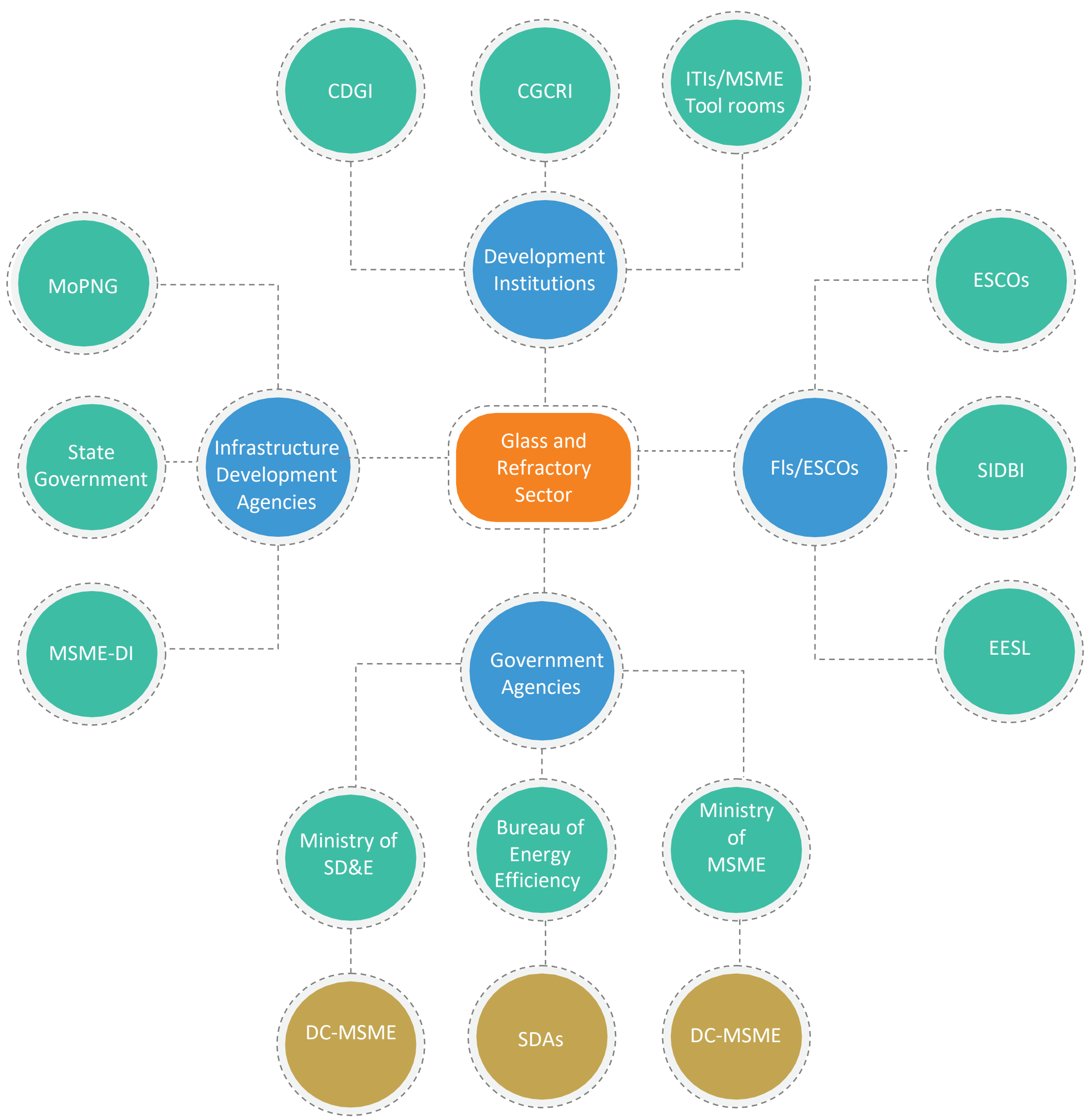


Figure 28: Key stakeholders for policy implementation

Table 19: Details of policy level strategies

Recommendation/ interventions	Financial assistance	Objective	Key suggestions	Implementing agencies	Timeframe
Upgradation fund for glass & refractory sector	1. Technology upgradation 1.1 Glass • Capital subsidy for EE and Tech-up (@ 25% upfront subsidy): Rs. 35 Crore 1.2 Refractory • Capital subsidy for EE and Tech-up (@ 25% upfront subsidy): Rs. 25 Crore 2 Technology and product development centres 2.1 Glass • 5 centres in major clusters like Firozabad[5], Ambala, Vadodara, etc. • DPRs and establishment investment: Rs. 15 Crore	Enabling MSMEs to adopt energy efficient technologies in manufacturing processes and strengthening skillsets	1 Glass industries 1.1 Energy efficient technologies in glass melting unit (tank furnace and pot furnace) 1.2 Electrification of melting and associated process technologies 1.3 Development of product promotion centres at cluster level to enhance competiveness in domestic & international markets 1.4 Technology, product and skillset development centres in glass blowing and artisans based clusters 1.5 Dissemination of best operating practices (BOP) through cluster level experts	**1** Bureau of Energy Efficiency and SDAs 1.1 Facilitate preparation of technology specific DPRs 1.2 Technology demonstration through pilot projects in PPP /ESCO modes 1.3 Develop/ strengthen technology providers and LSPs at cluster level 1.4 Create awareness 2 Ministry of MSME/ DC-MSME/MSME- DI 2.1 Implementation of scheme in MSMEs 2.2 Establishment of cluster level technology and product development centres	1 Technology upgradation 1.1 Launch of scheme: 1st year 1.2 Implementation: 2nd – 5th year 1.3 M&V/ reassessment: 5th year 1.4 Amendment & relaunch: 6th year onward 2 Skill development 2.1 Need assessment study: 1st year 2.2 Development of centres: 2nd year 2.3 Imparting skill development programme: 3rd year onward
Upgradation fund for glass & refractory sector	2.2 Refractory: • 5 centres in major clusters like Asansol, Chirkunda, Wankaner, etc. • DPRs and establishment investment: Rs. 15 Crore 3.3 Skill development[6] • Development and operation of skill development facilities in the major clusters (glass and		2 Refractory industries 2.1 Energy efficient technologies like tunnel kilns and raw material processing 2.2 Technology and product development centres in refractory product manufacturing 2.3 Dissemination of BOPs through cluster level experts	**3** SIDBI/FIs/Banks 3.1 Provide financial assistance 3.2 Linkage with partial risk guarantee fund 4 Ministry of Commerce and Industry 4.1 Assistance for development and promotion of brands 5 Ministry of Skill Development & Entrepreneurship 5.1 Skill certification	**3** Product promotion 3.1 Need assessment study: 1st year 3.2 Development of brands and promotion: 2nd year onward

[5] Strengthening of CDGI Firozabad

[6] Estimated based on the current employment level in glass and refractory clusters

Recommendation/ interventions	Financial assistance	Objective	Key suggestions	Implementing agencies	Timeframe
	refractory): Rs 20 crore (Annual expenditure: Rs 4 crore)			programme focusing industry-relevant skill development courses	
Common facility centres	To be estimated[7] (Estimated cost for feasibility studies and DPRs: Rs. 4 crore)	Supporting sustainability and growth of MSMEs by addressing common issues like high end technology, market access, financing, etc.	**1** Glass industries 1.1 Cooperative societies for annealing of glassware products in Ambala cluster 1.2 Raw material bank for borosilicate glass tubes bulk procurement (imported) in Ambala and Vadodara clusters 1.3 Product testing facility for glassware in Ambala cluster 2 Refractory industries 2.1 Common tunnel kiln for firing of refractory in Chirkunda and E&W Godavari cluster	**1.** Ministry of MSME/DC-MSME/ MSME-DI **2.** State governments **3.** Cluster level associations	1. Pre-feasibility study & DPR preparation: 1st year 2. Development of CFCs: 2nd – 3rd year 3. Operation of CFCs: 3rd year onward
Development of new industrial zones	To be estimated[8] (Estimated cost for feasibility studies and DPRs: Rs. 10 crore)	Enabling common facilities and green fuel supply system in MSME clusters	1 Glass industries 1.1 Development of industrial sheds for relocation of small scale household glass blowing units of Ambala and Vadodara clusters 2 Refractory industries 2.1 Development of industrial zone/ industrial park for refractory manufacturing units of Chirkunda, Asansol, E&W Godavari cluster, willing to adopt new tunnel kilns	**1.** Ministry of MSME/DC-MSME/MSME-DI **2.** State government **3.** Cluster level associations	1. Pre-feasibility study & DPR preparation: 1st year 2. Development of zones: 2nd – 5th year

[7] Detailed project reports for each cluster are required for total budget estimates
[8] Detailed project reports for each cluster are required for total budget estimates

Way forward

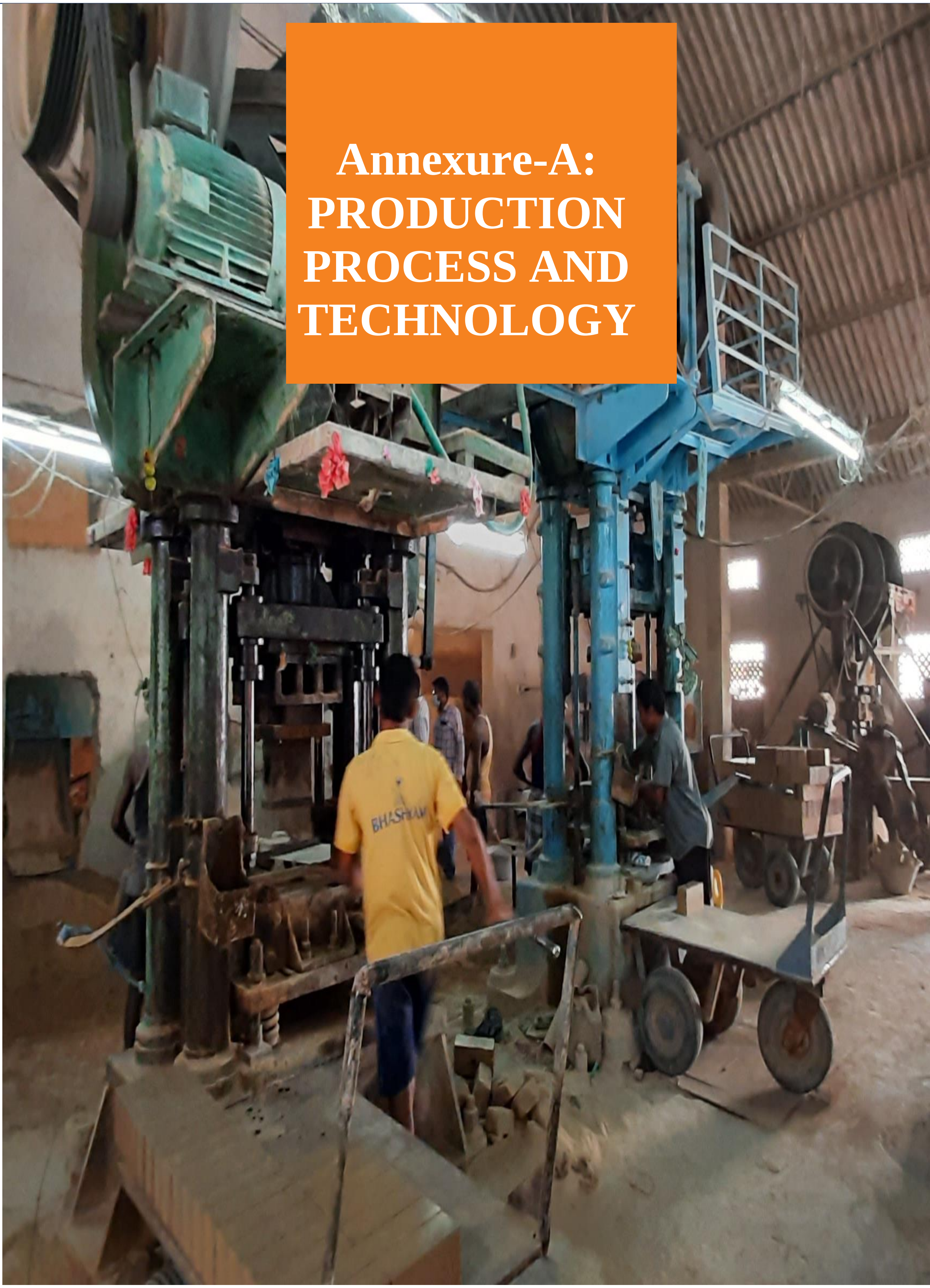
The energy and resource conservation measures in the glass and refractory sector are intended to reduce the energy intensity and improve competitiveness to a significant extent. These options would require both new and innovative technological solutions as well as skillsets to sustain the performance close to the global level. To sustain the pace of growth and development of the sector, barriers such as technical, financial, infrastructure, etc. need to be addressed holistically through cluster level initiatives and deploying suitable sector specific policies. Thus this road map provides inclusive strategies for short-term and long-term solutions for the glass and refractory sector.

There is a specific need to demonstrate successful models of collaboration by bringing together all stakeholders including Bureau of Energy Efficiency, Ministry of Micro, Small and Medium Enterprises, Ministry of Skill Development & Entrepreneurship, Ministry of Commerce and Industry, banks & financial institutions, cluster level industry associations, sector specific apex bodies, etc. on a common platform.

Since most of the glass and refractory units are located in clusters, industry associations are expected to play an important role in demonstrating collaborative approaches to address cluster-specific issues. Cluster level initiatives will not only help in minimising the transaction costs but also mitigate the risk of investment.

These recommendations include (1) cluster level strategies which may be facilitated by cluster level bodies, requiring short term and/or minimum support through government policies and (2) policy level strategies requiring long-term, inter-ministerial collaborative approach to mitigate the sectoral barriers. Both the strategies would complement each other in achieving energy efficiency and sustainability goal of glass and refractory sector.

Annexure-A: PRODUCTION PROCESS AND TECHNOLOGY



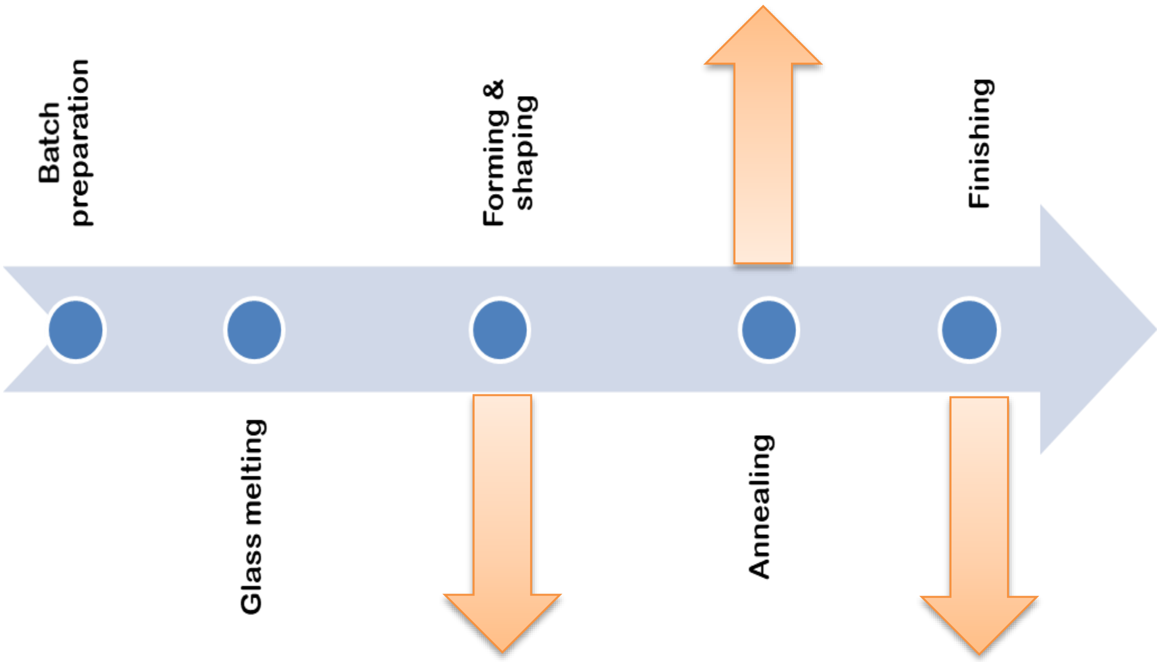
The production processes and technologies used in glass and refractory industries in the MSME sectors are given below.

Glass industries

The glass manufacturing process varies with the products and production capacities. The industries use regenerative tank furnaces for container glass production whereas it uses the pot furnaces and day-tank furnaces for production of glass bangles and decorative glass. However, the technology used for glass products processing is different and dependent on processing e.g. glass blowing, toughened glass, etc. The manufacturing process and technologies/ equipment used in the glass units in the MSME sector are discussed in this section.

Container glass

The process followed and technologies used in container glass production are discussed below.



Container glass manufacturing process

Production process

The production process of container glass involves batch preparation, melting, forming, annealing, and finishing, which are briefed below.

Batch preparation

The batch charge for glass making consists of raw materials such as silica sand, soda ash, calcium carbonate, and cullet (recycled glass). The composition of raw materials may vary depending on the type of products being manufactured. The preparation of the batch material (weighing and mixing) may be manual or mechanized. Smaller tank furnace units generally use manual processes whereas large tank furnaces say use mechanized systems. The batch material is fed to the doghouse through a belt conveyor arrangement.

Glass melting

An end-fired tank furnace is used for the continuous melting of glass. Melting is the most energy intensive operation in a tank furnace unit, which uses thermal energy. The temperature of the glass melt is maintained at about 1450 ^{o}C. The molten glass is flown through the refiner zone to get rid of air bubbles. The melt is tapped from the feeder chamber for shaping and forming.

Forming & shaping

The glass melt is used to produce various glass products either in automatic presses or blowing machines. In some of the units, mouth blowing is also practiced for specialized glass products. The press machines are powered either by electricity or by compressed air (pneumatic systems).

Annealing

The shaping and forming operations will induce stress in the glass products. It is necessary to remove these stains from the glass products so that their brittleness can be removed. The annealing process removes this stress through gradual heating, soaking, and cooling of the products.

Finishing

The glass products after annealing are sent for finishing operations like cleaning, grinding, polishing, cutting, painting, and grading as per requirements. The final products are packed after inspection for defects. Electrical energy is used for different finishing operations.

Technology use

The main process equipment in the container glass units is the melting furnace i.e. end-port fired regenerative tank furnaces. The other downstream process equipment include moulding machines and annealing lehr. Air compressors and blowers are the auxiliaries used in these units.

Tank furnace

The tank furnace accounts for about 50-55 percent of total energy consumption in container glass production. An end-port-fired regenerative tank furnace consists of a melting chamber, refining chamber, distributors and regenerative type air preheater. The auxiliaries associated with the tank furnace consist of combustion air blower, furnace side cooling blower, venturi fan, etc.

Tank furnace

The combustion air is preheated at close to 1000 ^{o}C in the regenerator, a waste heat recovery (WHR) system before entering into the furnace. The regenerator is made up of an array of refractory bricks and comprises two separate chambers. It recovers heat from flue gases and uses to preheat combustion air. The supply of secondary air and the hot flue gases at the regenerator is controlled using a reversing valve. The molten glass flows down to the feeder chamber for the production of the glass products.

Annealing lehr

Lehr is used for the heat treatment of glass products to relieve induced stresses during shaping and forming operations, which otherwise would make glass products more brittle. Annealing helps in strengthening glass products. Annealing lehrs associated with the tank furnace are continuous and in line with the shaping machine. Natural gas is used for heating and electricity is used for the operation of air circulation fans and conveyor systems.

Annealing lehr

Glass bangles

The pot furnace used for melting and other associated auxiliary furnaces including reheating furnace is part of the formation & shaping of glass bangles. The production process followed and technologies used in an open pot furnace unit producing glass bangles is described below.

Production process

The production process followed in bangle manufacturing is described below.

Batch preparation

Raw materials such as silica sand, soda ash and cullet are sieved, weighed, and mixed in required proportions. The composition required for pots containing transparent glass is different from that required for pots containing coloured glass.

Glass melting

Bangle making uses open pot furnaces. Preheated pots are placed within the furnace along its circumference. The charge is fed into the pots and heated to the required temperature of 1,350 -1,400 ºC. The quality and colour of melt glass in a pot are dependent on raw material composition and colouring additives in a charge batch.

Glass drawing and shaping

Ready to process molten glass is taken out using handheld iron rods. The operator provides the required shape using trowel. The glass loom is transferred manually to the colouring section to apply molten colour.

Reheating

The temperature of the glass loom drops during the shaping process and is therefore heated again in reheating furnace to maintain the desired temperature levels required for bangle making.

Bangle making

The reheated glass loom is fed manually in bangle making furnace to produce a spiral of the bangle. The required rotation and speed of bangle making shaft are controlled using an electric motor. The size and thickness of the bangle are controlled manually by a skilled operator.

Cutting and bundling

The spiral of the bangle is cut, counted, and packed like a bunch of 320 bangle pieces manually. These semi-finished bangles are sent for downstream operations.

Bangle making process

Technology use

The main process equipment in bangle making units is the pot type glass melting furnace. The other associated furnaces include reheating furnaces and bangle making furnaces. Pot arching furnaces are used for sintering of green pots required to replace broken pots during melting operation. The muffle furnace is also used for the heat treatment of the glass bangles, however, these are located outside the premises of pot furnace units.

Pot furnace

The pot furnace accounts for about 60% of the total energy consumption in a bangle making unit. A pot furnace consists of multiple pots (10-12 pots), each of 500-550 kg capacity and placed in a circular furnace. This pot furnace is heated using a natural gas-fired burner to maintain the required temperature of about 1400 ºC. A majority of the pot furnaces are equipped with metallic recuperators to preheat the combustion air.

Pot furnace

Auxiliary furnaces

The auxiliary furnaces used in bangle manufacturing process include reheating furnace, bangle making furnace and pot arch furnace.

Reheating furnace

These furnaces are used to rise and maintain the temperature of the glass loom during the shaping process. Reheating furnaces are heated up to 1250-1300 ºC using natural gas fired burner and some of the furnaces are equipped with metallic type recuperator to preheat the combustion air.

Reheating furnace

Bangle making furnace

A bangle making furnace has a rotating shaft that is driven in a manner to have both linear forward movement and rotary motion along the same axis simultaneously. The shaft is rotated using an electric motor. The reheated glass loom is fed manually to form a glass spiral around the rotating shaft.

Pot arching furnace

The glass melting units using the pot furnace are equipped with a natural gas-fired pot arch furnace which is used to prepare pots (preheating / short duration sintering) for replacing broken pots. The pot furnace units use a short sintering cycle (8-12 hours) leading to poor campaign life of pots of 15-20 days.

Laboratory glassware

The glass blowing technique consists of inflating molten glass with a blowpipe to forma glass bubble that can be moulded into a laboratory or industrial process glass. Borosilicate glass is a common base material for laboratory glassware, mainly because of its chemical and thermal stabilities.

Production process

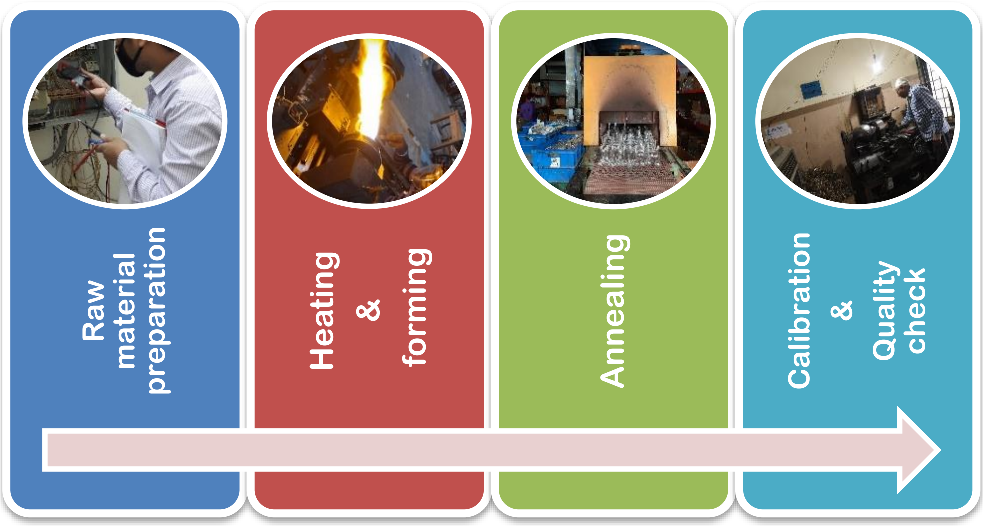
The manufacturing of laboratory and industrial glassware process commonly called glass blowing involves heating of borosilicate glass tubes of different dimensions (thickness and diameter) using an open flame burner and followed by blowing into providing the desired shape and size.

Glass blowing

The blowing units employ an open flame burner using liquefied petroleum gas (LPG) and oxygen to provide a suitable flame temperature for forming of borosilicate glass. The blowing is either mouth blowing or paddle blowing depending upon the size of ware being produced. The glass blowing process requires skilled manpower to produce glassware using traditional equipment such as single chuck and double chuck lathe.

Annealing

The processed glassware is heat-treated before and after the scaling and printing as per the end-use requirements. During the annealing process, the finished piece must be put to bed in the annealing oven to allow it to cool down to room temperature. The MSME units are using both continuous type (LPG fired) and batch type (electric and annealing) furnaces.



Glass blowing process

Technology use

The equipment use in glass blowing operation is given below.

Glass blowing lathe

The glass bowing lathe is the most commonly used technology in the glass blowing industries. These lathes are electric driven and most common capacity is ½ hp single phase induction motor or brushless DC motor. Lathe machines are locally made and having common drive in single and double chuck shaft rotation.

Glass blowing lathe

Annealing furnace

Annealing furnace is used for the heat treatment of laboratory glass products to relieve induced stresses during shaping and forming operations, which otherwise would make glass products more brittle. Annealing helps in strengthening glass products. Most of the laboratory glassware units employ batch type annealing furnaces using LPG or electricity. A few units having large production capacities are equipped with continuous type annealing furnaces using LPG for the heating and electricity is used for the operation of air circulation fans and conveyor systems.

Annealing furnace

Toughened glass

Toughened glass or safety glass is made from annealed glass sheets treated with a thermal tempering process. The glass surfaces are then rapidly quenched while the inner portion of the glass remains hot. The variation in cooling rates between the surfaces and core produces results in different physical properties and compressive stresses in the surface balanced by tensile stresses in the body of the glass. These counteracting stresses provide increased mechanical resistance to toughened glass.

Production process

The production process of toughened glass includes two primary steps such as washing & drying and toughening.

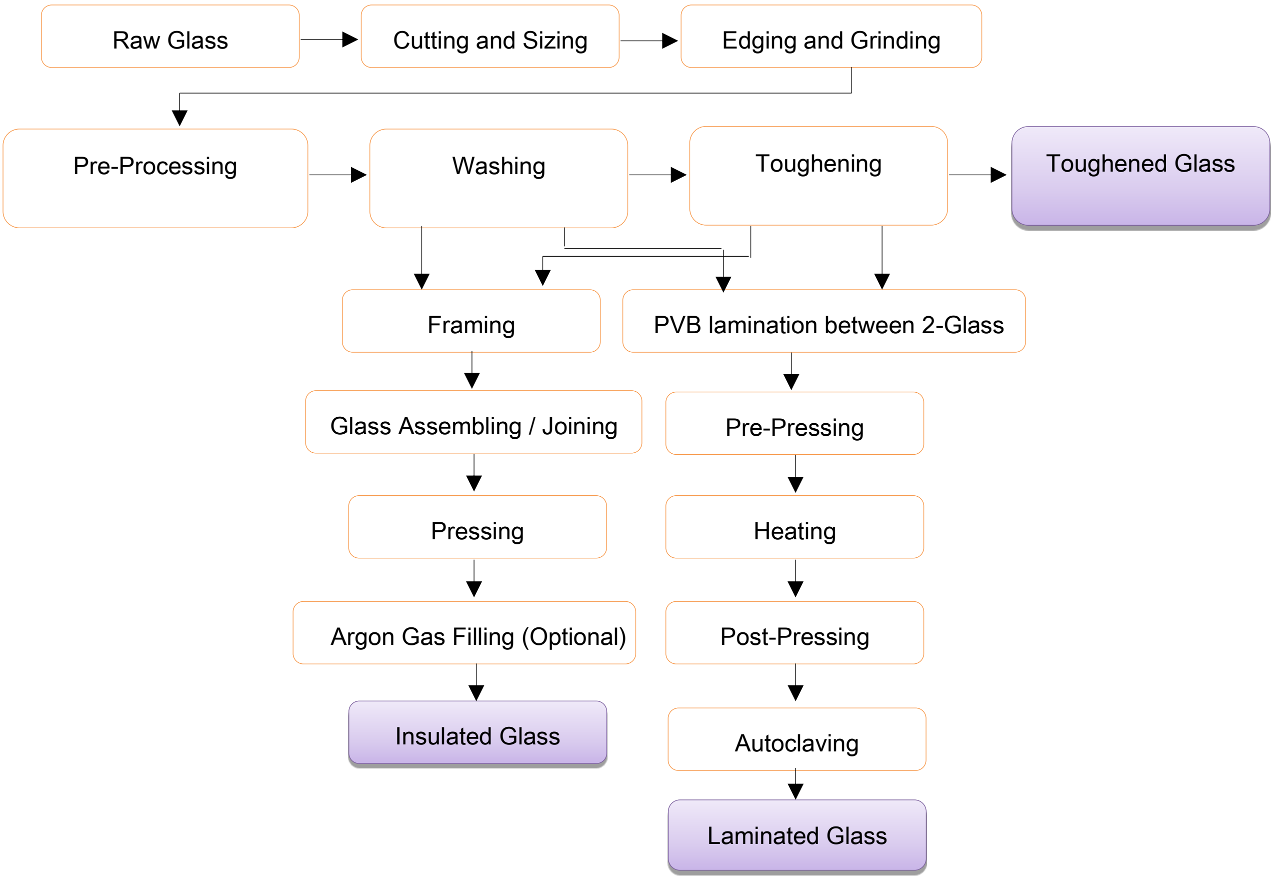
Washing and drying

The annealed glass sheet is cleaned to make it free from waviness, distortion, and cut to the required size as per end-use of the product. The edge grinding and polishing is an important process for toughening as it may lead to breakages.

Toughening process

The glass sheets are fed into the electric furnace for increasing the temperature to the softening point. The toughening process involves heating glass above its annealing point of about 600 °C. After attaining the required temperature, the glass sheets are shifted to air-blowing quenching boxes for toughening.

Most of the MSME units further process toughened glass into end-use products such as laminated glass, insulated glass, etc. A process flow diagram for toughened glass as well as insulated and laminated glass is provided below.



Production process of toughened glass and associated products

Technology use

The main process equipment in toughened glass manufacturing is reheating furnace. The other auxiliaries include quenching blowers, air compressors, and process cooling water, and raw water pumps. CNC machines are mainly used in the sizing and edge grinding process.

Refractory industries

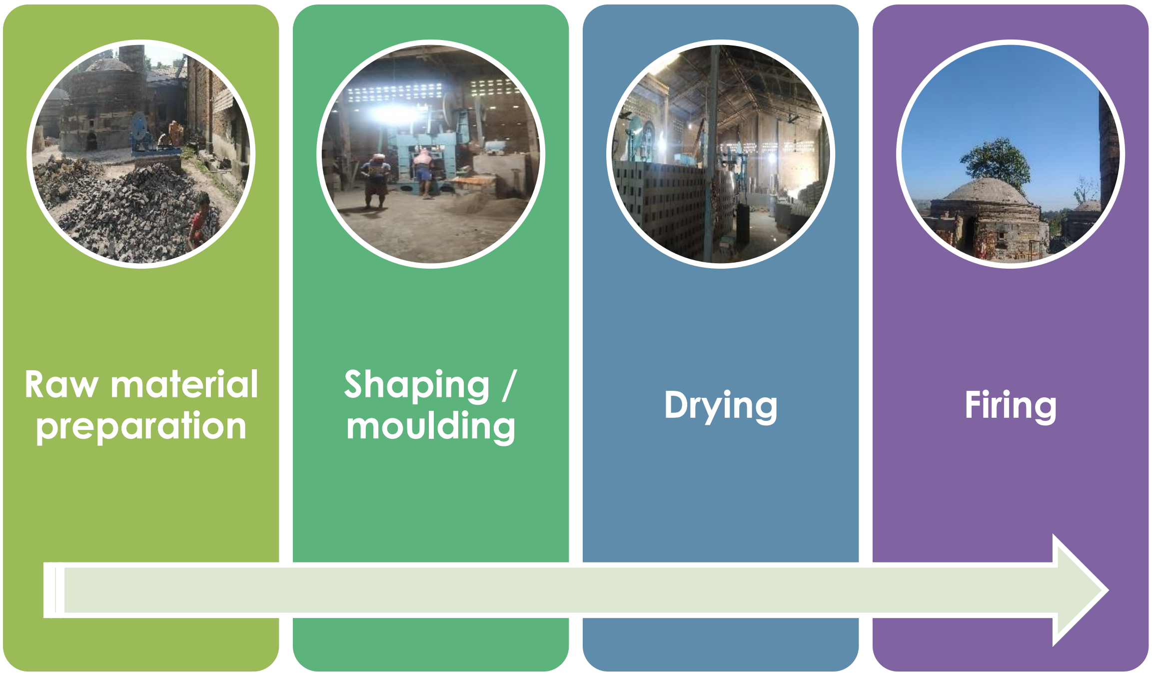
The production process in refractory industries includes raw material preparation, shaping, and firing. The technologies and equipment used in different process steps of refractory products manufacturing is discussed in this section.

Production process

The refractory manufacturing process broadly consists of raw material preparation, shaping of green products, drying to remove the moisture and firing to provide the strength and impart required properties. The raw materials include fire clays (plastic and non-plastic varieties), refractory grog (broken fire bricks) and other high alumina minerals like kyanite, sillimanite and bauxite. A typical manufacturing process followed in the cluster for the production of refractory products is shown below.

Raw material preparation

The refractory units procure basic raw materials such as plastic clay and other ingredients as lumps or powder which are generally tested in the laboratories to match customer requirement. Jaw crushers are used to reduce the size of lumps before they are sent for grinding.



Typical production process in a refractory industry

Grinding is a batch process for reducing the size of batch materials. It ensures the homogeneity of the material being processed. Ball mills are used for the grinding process. In ball mills, the raw materials are grinded to reduce their size as per requirements for pressing. Screening is done to ensure the required size of raw materials for the milling process.

Mixing of raw materials is carried out in Muller machines. It is done in batches of fixed quantity. These machines are used for the uniform and quick mixing of a heterogeneous mass of two or more materials of varying aggregate size mechanically into a uniformly blended batch of raw materials. Mullers are fitted with large mulling rollers for the mixing of raw materials. Water is added to raw materials in required proportions and loaded in Muller machines to have homogeneous mass of raw material.

Shaping and moulding

Pressing machines are used to provide shape to the product. Each refractory unit uses multiple press machines. The press machines are operated manually. Two types of press machines are commonly used namely (1) hydraulic press and (2) friction press. The type of press used is dependent on the type of product being produced by the unit. For large size products, friction press is used whereas for others hydraulic press is used. The required quantity of homogeneously mixed raw material in Muller is loaded manually in hydraulic or friction press based on the type of product. The press is operated manually to provide shape and strength to the products. The pressed product is manually removed for further drying.

Drying

The moisture level of the green refractory products is in the range of 7-8% which must be reduced to 3-5% before firing. The shaped products from shaping/formation process are stacked inside an open sheds to allow slow and uniform drying. Tunnel kiln based refractory units are equipped with dryers utilizing the waste heat available in flue gases for the removal of moisture from moulded products.

Firing

Firing is the process by which refractories are thermally consolidated into a dense, cohesive body composed of fine and uniform grains. This process also is referred to as sintering or densification. Refractories are generally fired at 50-75% of the absolute melting temperature of the body material. The temperature profile of the refractory bricks varies in the range of 1150-1300 ^{o}C.

Technology use

The refractory manufacturing industries in India use both traditional and modern technologies. The technology and equipment used in different refectories manufacturing processes are described below.

Crusher

Crusher

The raw materials are crushed and sieved to achieve defined particle-size distribution according to the recipe. The raw material crushing process uses jaw crusher and disintegrator. Jaw crusher is used to reduce the input feed sizes into 50 mm (maximum). An electric motor driven disintegrator used to achieve defined particle size of batch products. Most of MSME units are manpower intensive and use manual conveying of the raw material. About 10-15 manpower is required for the raw material preparation in a typical size MSME unit.

The grinded /prepared powder stored in a chamber underneath the disintegrator, which requires additional manpower for material transfer as well as significant wastage of ready to use recipe. However, some of the progressive units use bucket elevators and silo reducing manpower requirements and minimizing wastage.

Muller machine and press machine

Water is added to the mixture in Muller machines to prepare homogeneous batches as per requirements of final product composition. Press machines are used to provide shape to the product. Friction press and hydraulic screw press are primarily used in the shaping/moulding process of the products. The type of press used is dependent on type of products being manufactured, density and strength.

Muller machine and press machines

Friction press is suitable for large size refractory products. The common capacity of electric motors friction in the studied clusters is varying in the range of 80-250 tonne. However some of the medium and large units are using multiple cavities, friction press of up to 800 tonne capacity. The hydraulic press is more suitable for refractory products that can be shaped generally within 30-180 tonne in single stroke.

Electricity is primarily used in the raw material preparation and shaping sections. More than 90% of the total electricity used in the electric motors is associated with jaw crushers, disintegrators, U-mixer, Muller machines and press machines. The installed electric motors are standard efficiency class and more than 60% of the motors are old and multiple times rewound.

Drying

The refractory sector uses natural drying process for removal of moisture from green refractory product. Due to natural drying process, the drying duration and the final moisture level are generally dependent on ambient conditions. For example, the firing cycle and the associated energy consumption of the kilns increase significantly during rainy season. Hence, most of the refractory kilns are generally not operated during rainy season.

Natural drying

A few tunnel kilns in the sector have been equipped with waste heat based dryers for removal of moisture. However, due to non-availability of local service providers and skilled operators, the refractory units have bypassed the dryer in refractory manufacturing process.

Tunnel dryer

Firing

Different types of firing technologies are used by refractory industries in India. It includes downdraft (DD) kiln, tunnel kiln, and chamber kiln. DD kiln and chamber kiln use batch type process whereas tunnel kiln and rotary kiln use a continuous type of firing process.

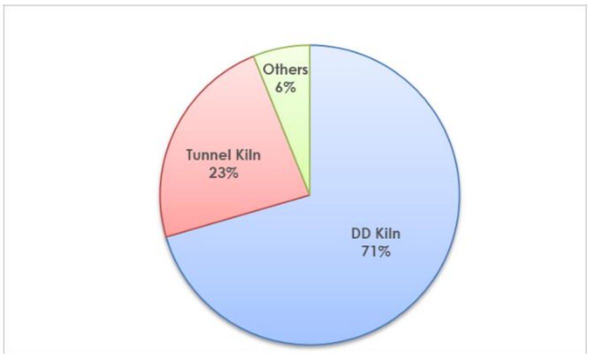
Down draft Kiln

Tunnel Kiln

Chamber Kiln

Rotary Kiln

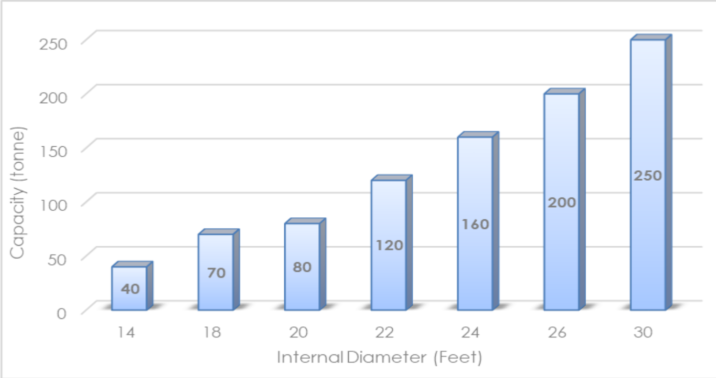
A vast majority of refractory industries uses traditional DD kiln technology (71%) in the firing process. The refractory clusters in the eastern region primarily use DD kiln for firing whereas tunnel kiln is the main technology used in western region. Tunnel kiln is a continuous firing process and offers high production rate. It is gradually being adopted in clusters such as Ranchi, Chirkunda, Asansol, etc. A very few units are using chamber kiln and rotary kiln for manufacturing of specific product categories. Rotary kilns are continuous type furnace used to process minerals for calcination to convert base mineral material to a target product.



Share of firing technologies

Downdraft kiln

The production capacities of downdraft kiln vary in the range of 40 tonne to 250 tonne per batch depending of internal diameter of kiln. Coal is used as the major fuel in downdraft kilns; however, a few units also use firewood along with coal. A typical batch cycle of downdraft kiln unit includes the following steps.



Downdraft kiln: Diameter vs capacity

Loading: Green refractory products are being stacked inside the chamber. Most of the units transfer green products manually from production shed to kiln chamber which takes almost 2-3 days using 10-15 manpower. A few units have installed motorised flexible conveyor system.

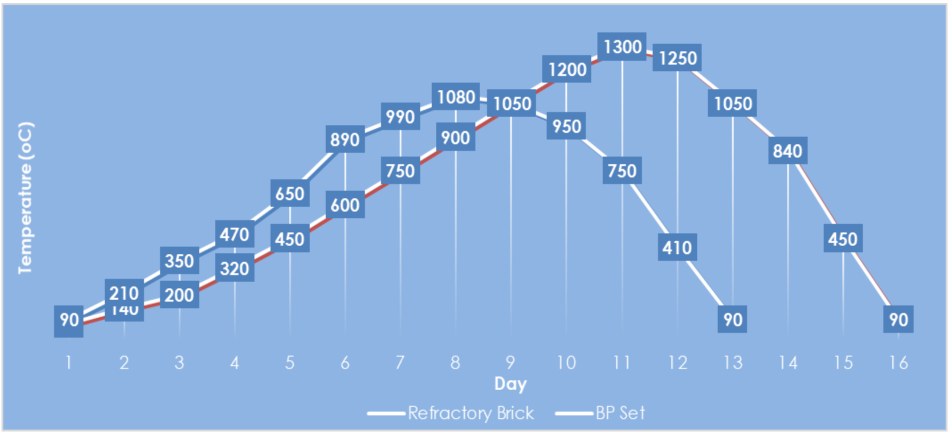
Smoking: Slow firing is initiated in the kiln for removal of moisture from green products (initial moisture level of stacked products is in the range of 3-5%).The duration of slow firing is about 2-3 days.

Firing: The firing takes about 5-7 days wherein a temperature level of about 1150-1300 ºC is achieved. Coal is generally fed at set intervals but without weighing. The downdraft kilns also do not have provision for temperature monitoring in order to maintain standard temperature profile of the kiln.

Soaking: On achieving the desired temperature, the kiln is sealed completely for soaking of products to attain uniform temperature and required physical and chemical properties.

Cooling and unloading: Cooling of the kiln is carried out for about 2-3 days which includes upto 1 day for natural draft cooling and 2 days for forced cooling using fans.

A typical temperature profile for refractory brick and bottom pouring set (BP set) during the complete batch is provided in figure. Since downdraft kilns are batch based, their specific energy consumption (SEC) levels are generally observed to be higher than continuous type kilns.

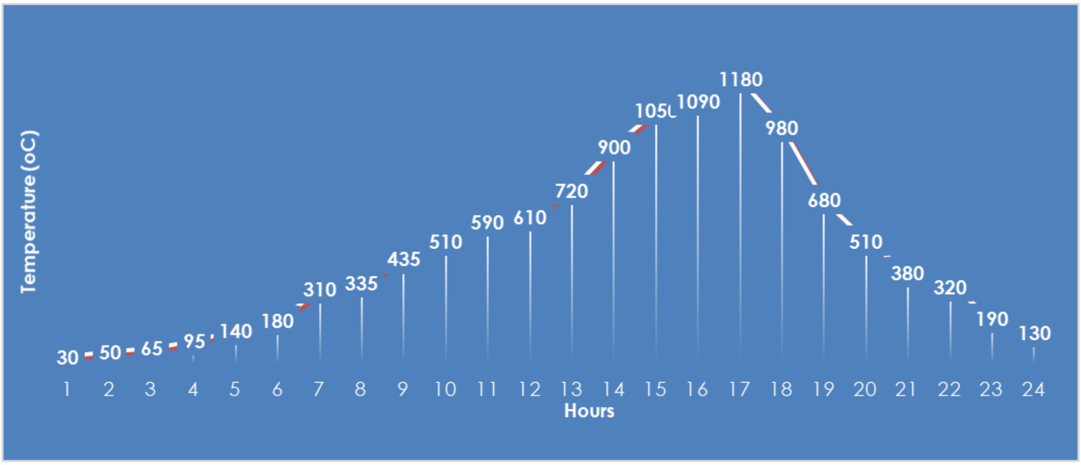


Typical temperature profile of downdraft kiln

Tunnel kiln

Tunnel kilns are continuous type kilns. Tunnel kilns in the refractory sector use mainly petcoke as fuel. A few refractory kiln units use gaseous fuels (natural gas and coal bed methane) and liquid fuels. The capacity of tunnel kilns used in the studied clusters is in the range of 10-20 tonne per day (tpd).

A typical tunnel kiln has three zones, namely, preheating, firing and cooling zones. The green products are stacked on trolleys, and moved on rails inside the kiln. The product carrying capacity of each trolley is about 1.5-2.5 tonne. The movement of the trolleys is controlled using an electrically operated pusher. The pushing time is adjusted to maintain the retention time. A typical temperature profile of a trolley is provided in the figure.



Typical temperature profile of tunnel kiln

Other kilns

Apart from downdraft kilns and tunnel kilns, a few refractory units also use other firing technologies such as chamber kiln and rotary kiln. The details of these kilns are provided in this section.

Chamber kiln

A chamber kiln consists of number of rooms or chambers with permanent side wall and roof that are arranged in series with provision of coal grate for firing stacked refractory products for vitrification. Each chamber is connected to the next chamber and with the central chimney in a manner that would help in directing flue gas from source to chimney after it travels through next chamber by appropriately positioning damper in flue path and passageway in partition wall.

During firing cycle, hot exhaust gases from room under fire will be directed through passageway provided in partition wall to following adjacent two rooms in series that are scheduled to be fired next. While hot gases pass through the kiln circuit, they transfer heat to the stacked refractories thereby preheating stack materials.

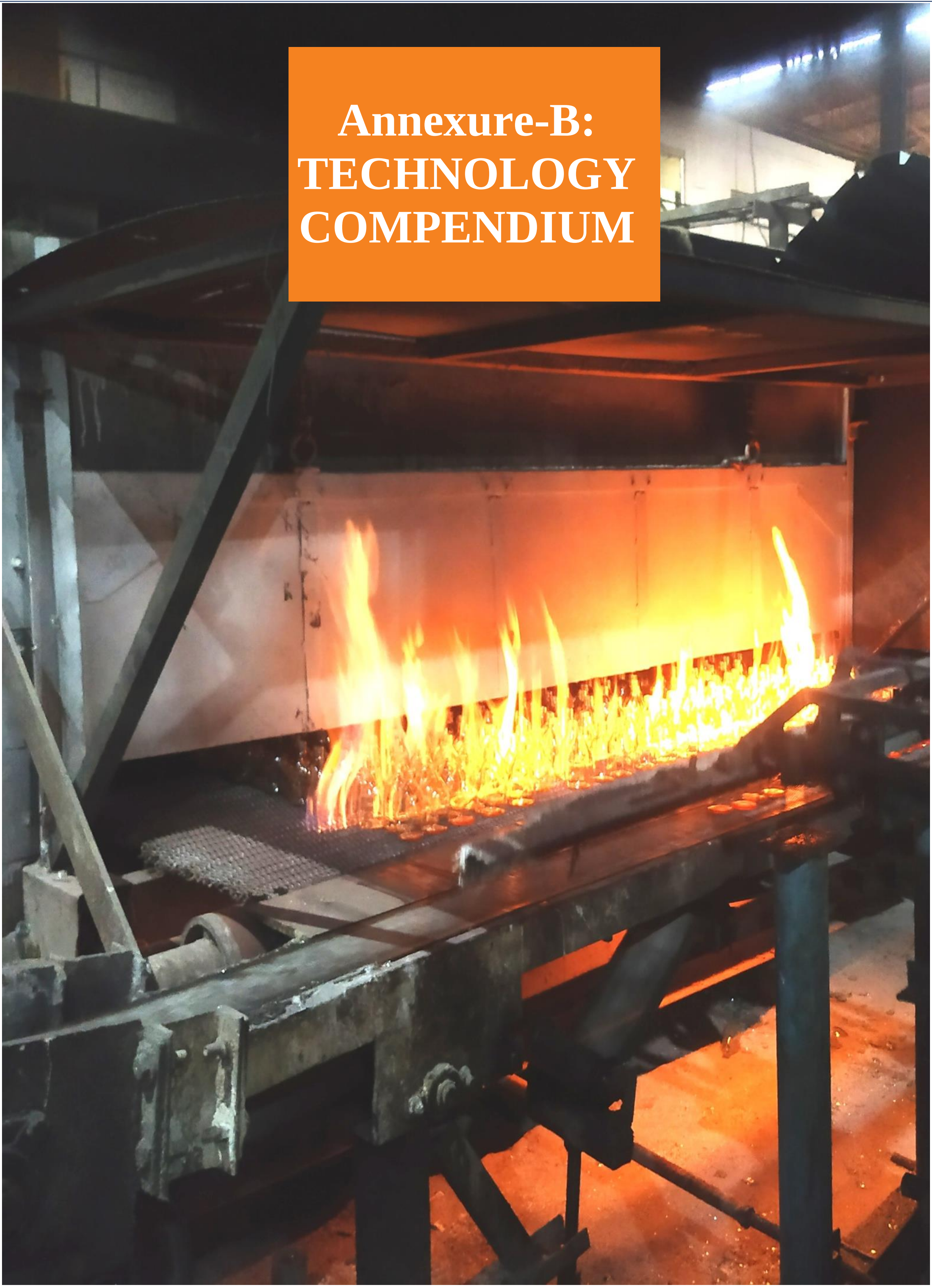
Finally, flue gases at reduced temperatures will be dispersed through the chimney. This arrangement recovers sensible heat of hot exhaust gases thereby making chamber kilns more efficient than downdraft kilns. Chamber kilns are also batch type kilns, wherein loading and unloading of refractory products and firing is carried out manually. Coal is the primary fuel used in chamber kilns.

Rotary kiln

Rotary kilns are continuous type furnace used to process minerals for calcination to convert base mineral material to a target product. Generally, these kilns are used in manufacturing processes like cement, refractory, lime etc. Petcoke and pulverised coal are commonly used as fuel in rotary kiln. The rotational speed (rotation per minutes) varies between 0.5 to 5 maximum depending upon its application.

In most of the cases, raw material to be processed and heat source move in opposite direction (counter-current), but sometimes in the same direction as the process material (co-current). It has an outer metallic shell made of mild steel plate, usually between 15 and 30 mm thick, welded to form a cylinder which may be up to 230 metre in length and up to 6 metre in diameter. Inner face of shell is provided with refractory lining to avoid hot spot development on shell side. The thickness of the lining is generally in the range 80-300 mm. It may consist of refractory bricks or cast refractory concrete, or may be absent in zones of the kiln that are below around 250 °C.

Annexure-B: TECHNOLOGY COMPENDIUM



The energy mapping study in glass and refractory sector has identified a range of potential and feasible energy efficient technologies and energy conservation measures to improve energy performance. The identified energy efficient options include (1) technologies, (2) retrofits, (3) state of the art technologies and (4) best operating practices. Theses energy efficient options are described below.

Glass industries

This section provides details of identified energy efficiency options covering glass melting and glass processing industries.

Energy efficient technologies

The energy efficient technology options in process areas of glass industries are provided below.

End-port fired regenerative type tank furnace

The energy efficiency options for tank furnace based industries such as furnace automation and control, air ingression control in regenerator and energy efficient air compressor are provided below.

Furnace automation and control system

The container glass manufacturing industries employ end-port fired regenerative type tank furnaces. These furnaces use basic furnace monitoring and automation system e.g. working end distributors temperature, furnace pressure, glass level and fuel firing regulator & totalizer. To maintain the desired temperature of the melting zone, the furnace operator periodically monitors temperature using a handheld pyrometer and manually revises the set values of fuel firing rate in the digital control system. The manual control of fuel flow rate results in significant variations in the final melting temperature. The units outsource monitoring of flue gas parameters (%O2, CO) on a periodic (weekly) basis. However, these feedback/values are not used for any corrective actions.

Upgradation of furnace monitoring and control system by installing online pyrometers would help in precise control of temperature profile and corresponding fuel firing rate using a close-loop firing system. Also, integration of online combustion analyser would help in real-time monitoring of O_2/ CO in the exhaust before and after the regenerator.

Replication potential (%)	Saving potential (%)	Payback period (months)	Sector Level Energy saving (toe/year)	Sector Level Investment (Rs. lakh)	Sector Level Emission reduction (tCO_2)
100%	3.8%	47	5,537	4,830	10,901

Air ingression control in regenerator system

The tank furnaces in the container glass units use regenerators to recover and recycle sensible heat from high temperature exhaust gases. The flue gases entering the regenerator contain a residual oxygen (O2) level of 2-3%. However, level of residual oxygen in the flue gases increases significantly which is primarily due to air ingression from damaged structure of regenerator.

Installation of on-line combustion analyser would help in real time monitoring of air ingression by measuring the differential oxygen levels for undertaking necessary corrective maintenance, minimising air ingression and optimizing heat recovery in regenerator. Further, this system will provide an additional tool for scheduling the preventing maintenance of regenerator.

Replication potential (%)	Saving potential (%)	Payback period (months)	Energy saving (toe/year)	Investment (Rs. lakh)	Sector Level Emission reduction (tCO_2)
50%	3.4%	9	2,500	557	4,921

Energy efficient air compressor

The air compressor is second highest energy consuming centre in container glass manufacturing units. The moulding section requires large quantities of compressed air at a pressure of 1.5-2.2 kg/cm_2 (g). The glass units use either reciprocating type air compressor or energy efficient compressors (like centrifugal and/or rotary screw type). The specific energy consumption of reciprocating air compressors is in the range of 0.11-0.12 kW per cubic meter per hour (kW/m3/hr), whereas the design SEC of screw type and centrifugal air compressors are 0.07 kW/m3/hr and 0.08 kW/m3/hr respectively.

The installation of optimum capacity centrifugal air compressors and/or a combination of centrifugal air compressor and VFD enabled rotary screw type air compressors would reduce significant consumption of electricity.

Replication potential (%)	Saving potential (%)	Payback period (months)	Energy saving (toe/year)	Sector Level Investment (Rs. lakh)	Emission reduction (tCO_2)
30%	35%	23	2,278	966	4,487

Pot furnace

The energy efficiency options in pot furnace based industries are provided below.

Improved pot arching

The glass melting pot furnaces in bangles and decorative glass manufacturing units are required to change the pot after pot failure. The average life of pots used for glass melting in the cluster is about 15-20 days. The sintering duration (9-12 hours/pot) followed in the unit is relatively short and faster leading to lower operating campaign life of the pots (average life: 15-20 days).

The life of pots largely depends on the sintering cycle followed in the pot arch furnace. Adoption of the recommended cycle of green pots would help in doubling the campaign life of pots as well as minimising the heat and production losses due to pot failure. The suggested temperature and time profile for sintering would lead to gradual heating till the pots attain the required temperature of about 900 0C in a period of 10 days. The NG based pot arching furnace can be replaced with PLC controlled, electrical heating furnace to ensure proper sintering of the green pot as per the recommended practices.

Replication potential (%)	Saving potential (%)	Payback period (months)	Sector Level		
			Energy saving (toe/year)	Investment (Rs. lakh)	Emission reduction (tCO_2)
100%	18%	27	1,102	2,607	-2,023

Crown insulation of pot furnace

The average temperature profile of the crown section of glass melting pot furnace shows that the surface temperatures are in the range of 150-300 ºC. The corresponding structural losses are in the range of 15-20% of the total heat input. The surface temperatures of the crown of the pot furnace are higher than the permissible limits. By applying suitable insulation (ceramic blanket, sheets) the surface temperature of the crown can be reduced.

Replication potential (%)	Saving potential (%)	Payback period (months)	Sector Level		
			Energy saving (toe/year)	Investment (Rs. lakh)	Emission reduction (tCO_2)
100%	7%	6	3,940	474	7,760

Crown insulation of reheating furnace

The temperature of crown surface of reheating furnace in the bangle making process is about 180-390 ºC. The corresponding structural losses are in the range of 3-5% of the total heat input of the furnace. The surface temperatures of the crown of the reheating furnace are higher than the permissible limits. By applying suitable insulation (ceramic blanket, sheets) the surface temperature of the crown can be reduced.

Replication potential (%)	Saving potential (%)	Payback period (months)	Sector Level		
			Energy saving (toe/year)	Investment (Rs. lakh)	Emission reduction (tCO_2)
65%	3%	5	217	20	428

Waste heat recovery in reheating furnace

The reheating furnaces used in the glass bangle making units are using a waste heat recovery system (recuperator) of inferior design to recover the sensible heat from hot flue gases. The temperature of the flue gases at the recuperator inlet is in the range of 600-650 ºC which gets reduced to about 300 ºC after heat recovery. The performance of the heat recovery system can be further enhanced using a 3-stage recuperator system of suitable design and material.

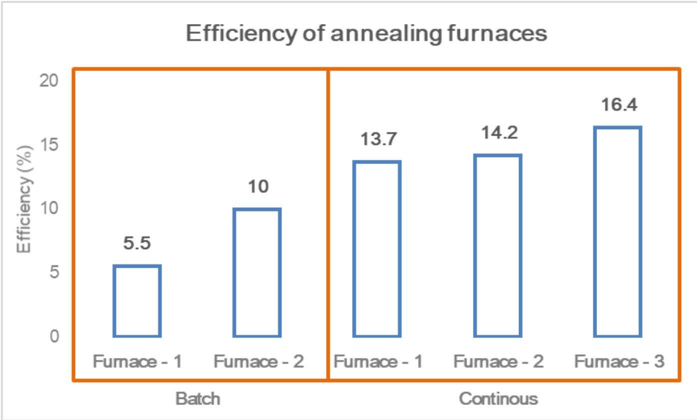
Replication potential (%)	Saving potential (%)	Payback period (months)	Sector Level		
			Energy saving (toe/year)	Investment (Rs. lakh)	Emission reduction (tCO_2)
65%	15%	18	1,400	462	2,758

Glass product processing

The energy efficiency for glass processing industries such as glass blowing and glass toughening units are given below.

Automation of LPG fired annealing furnace

A few laboratory glassware units use LPG fired annealing furnaces-both batch and continuous type for heat treatment process. The thermal efficiency of annealing furnaces varies in the range of 5-10% for batch type and 13-17% for continuous type. A majority of the heat is lost in hot flue gases and furnace structures. Significant heat is also lost in furnace heating during start-up.

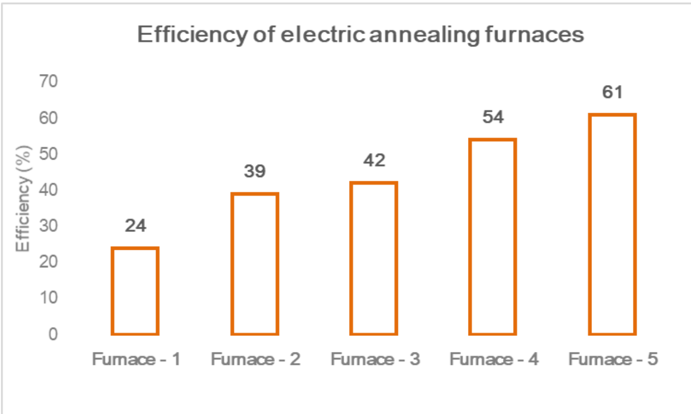


Use of PLC based furnace control system and adoption of preventive maintenance practices such as periodic measurement of flue gas parameters (O_2, CO_2, CO, etc.), insulation survey of furnace structure, periodic calibration of instrumentation, maintenance of burner assembly and air-to-fuel control system, etc. will help in maintaining the efficiency of the furnaces at optimum level.

Replication potential (%)	Saving potential (%)	Payback period (months)	Energy saving (toe/year)	Sector Level Investment (Rs. lakh)	Emission reduction (tCO_2)
25%	1%	24	20	38	68

Improved electric annealing furnace

Most of the apparatus and laboratory glassware units (except small glass blowing units) employ batch-type electrical annealing furnaces catering to heat treatment requirements. The thermal efficiency of electrical furnaces is in the range of 24-61 percent. A majority of the heat in electrical furnaces is lost in overheating due to poor control, the high thermal mass of material handling tray, and inferior furnace structure. Significant heat is also lost in furnace heating during start-up.



Installation of energy efficient furnace with an insulated-gate bipolar transistor (IGBT) control system will help in precise temperature control to avoid overheating and extended batch duration. Improved furnace insulation will help in reducing structural losses. Also, use the low thermal mass trays in the annealing furnaces will reduce the dead weight, thus the reduction in energy consumption.

Replication potential (%)	Saving potential (%)	Payback period (months)	Energy saving (toe/year)	Sector Level Investment (Rs. lakh)	Emission reduction (tCO_2)
25%	2.8%	43	67	197	641

Centralised LPG distribution system

The micro and small category glass blowing units in Ambala cluster use dedicated LPG cylinders to meet the heating requirements. A residual LPG of 1.5-2.0 kg is left behind in each cylinder when the cylinder gets emptied. The main reason is the cylinder pressure is lower than the required minimum pressure to form the desired flame length. The residual LPG in individual cylinder can be optimally utilised by setting up a LPG bank and central distribution network. This will not only avoid the loss of energy as residual in the cylinders, but also reduce the handling and improve safety.

Replication potential (%)	Saving potential (%)	Payback period (months)	Energy saving (toe/year)	Sector Level Investment (Rs. lakh)	Emission reduction (tCO_2)
85%	5-8%	12-15	98	116	334

Energy efficient retrofits in utilities

The most common energy intensive utilities across glass industries are motors and air compressors.

Premium efficiency class (IE3) motors

Electric motors are used mainly in raw material preparation, moulding/shaping of products, and auxiliaries associated with melting and annealing furnaces. The glass industry uses combustion air and air circulation fans & blowers in furnaces; the associated motors are of standard efficiency class. Further, the motors are also rewound a number of times which reduces the overall efficiency of the motor driven system.

These inefficient motors can be replaced with premium efficiency class (IE3) motors. The salient features of high-efficiency motors include the following:

- Longer core lengths of low loss steel laminations to reduce flux densities and iron losses
- Maximum utilization of slots and generous conductor sizes in stator and rotor to reduce copper losses
- Careful selection of slot numbers and tooth/ slot geometry to reduce stray losses
- Generation of less heat leading to a reduction in the size of the cooling fan thereby lowering windage losses and waste power.

Replication potential (%)	Saving potential (%)	Payback period (months)	Energy saving (toe/year)	Sector Level Investment (Rs. lakh)	Emission reduction (tCO_2)
100%	4-8%	32	231	139	456

Energy efficient air compressor in glass processing units

Most of the toughened glass processing units uses fixed capacity screw type air compressors for process and instrumentation air. In many installations, the use of compressed air requirements is intermittent and compressors operate on a low/no-load load conditions. The poor loading increases the specific power consumption of air compressors.

Compressed air is one of the costliest utility in the industries. Therefore, to optimise the power consumption in compressed air system, a suitable capacity control can be installed. This would help to eliminate or minimize low/no-load conditions to the least as unload operation consumes up to 30-35 percent of full load power.

Replication potential (%)	Saving potential (%)	Payback period (months)	Sector Level		
			Energy saving (toe/year)	Investment (Rs. lakh)	Emission reduction (tCO_2)
15%	9%	39	21	55	197

State of the art technologies

The state of the art technologies in glass industries include electrification of fossil fuel fired thermal system and use of rooftop solar system. Some of the potential technology options are described below.

Electrification of thermal process

The state of the art technologies in glass industries focus on electrification of fossil fuel fired thermal system. Some of the potential electrification options are described below.

Annealing lehr

The container glass manufacturing units are equipped with natural gas fired annealing lehr in line with moulding lines. The fresh products are brittle due to induced stress while shaping, which are removed during annealing operation. Almost all the container glass manufacturing units employ multiple moulding/shaping lines and associated lehrs for the heat treatment process. The thermal efficiency of gaseous fuel fired lehrs is in the range of 15 -20 percent attributed to higher heat losses. These can be replaced with energy efficient (up to 70% thermal efficiency) electric lehrs having precise control system and low heat losses.

Replication potential (%)	Saving potential (%)	Payback period (months)	Sector Level		
			Energy saving (toe/year)	Investment (Rs. lakh)	Emission reduction (tCO_2)
100%	23	20	2,788	1,022	5,488

Reheating furnace

All bangle making units use natural gas fired reheating furnace to cater to the reheating requirement of the in-process glass looms. The overall thermal efficiency of this furnace is low (12-14%) due to high heat losses, losses due to furnace openings and idle operation of furnace. These NG fired reheating furnaces can be replaced with energy efficient (up to 60% thermal efficiency) having precise control system, minimum opening of heating mouth and low structural losses.

Replication potential (%)	Saving potential (%)	Payback period (months)	Sector Level Energy saving (toe/year)	Sector Level Investment (Rs. lakh)	Sector Level Emission reduction (tCO_2)
67%	15%	33	8,373	1,580	-53

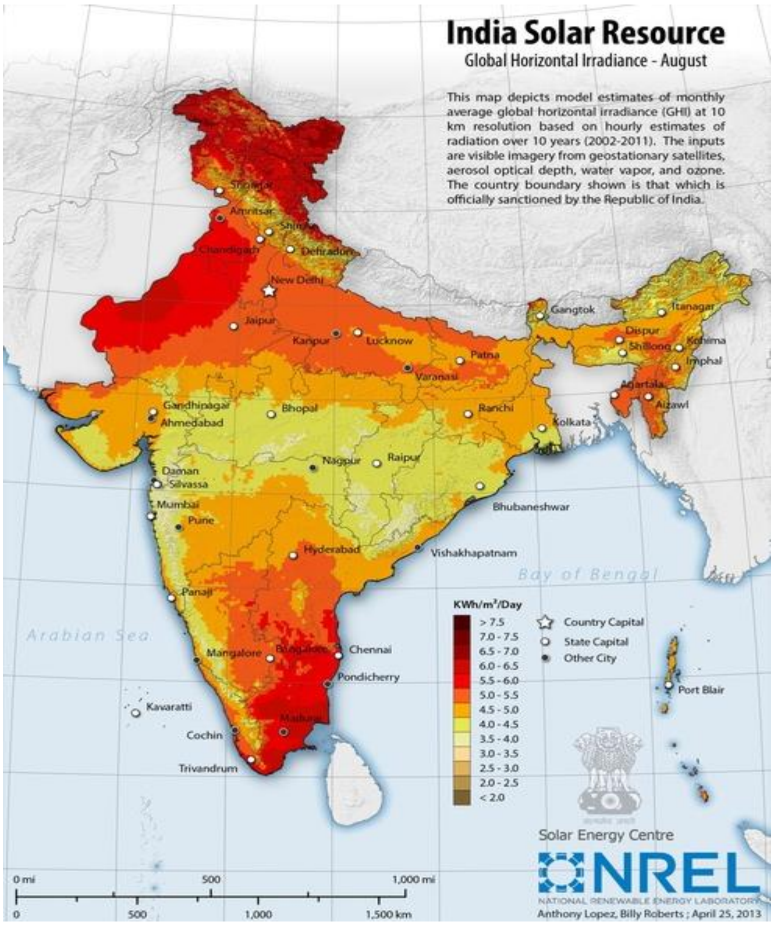
LPG fired annealing furnace

LPG is used in annealing furnaces to cater to heat treatment requirements of the processed laboratory glassware products. The overall thermal efficiency of these furnaces is in the range of 15-18% which is mainly due to high heat losses, losses due to furnace openings and sub-optimal product charging, and low capacity utilisation of the furnace. These LPG-fired reheating furnaces can be replaced with energy efficient electric furnaces (up to 25% thermal efficiency) with having a precise control system, the minimum opening of the heating mouth, and low structural losses.

Replication potential (%)	Saving potential (%)	Payback period (months)	Sector Level Energy saving (toe/year)	Sector Level Investment (Rs. lakh)	Sector Level Emission reduction (tCO_2)
25%	7.5%	14	180	138	-1,601

Rooftop solar photovoltaic (SPV)

Rooftop solar photovoltaic system is one of the options for sourcing green and low cost electricity in glass industries particularly in the glass products processing units. Rooftop solar panels utilize sunlight to generate electricity. Most of the glass processing clusters are situated at ideal geographical locations receiving ample tropical sunlight.



The glass processing units are dust free and therefore the existing shed/roof can be effectively utilised without any additional investment for lands. The landed cost of electricity from solar PV system in comparison to industrial tariff rates is cheaper by 15-25 percent. A significant amount of electricity is used in glass processing units during day time and therefore rooftop panels can supplement grid electricity, thereby saving energy costs.

Best operating practices

The best operating practices for glass industries are given below.

Process temperature

- Maintain furnace temperature to avoid overheating of melt and energy losses.
- Use sufficient number of temperature indicators to monitor the temperature profile.

Air ratio

- Maintain suitable air-fuel ratio based on type of fuel used in firing
- Use online or portable oxygen (O_2) analyser for monitoring.
- Minimize air ingression using suitable measures such as minimizing openings, proper sealing, etc.
- Install on-line measurement and recording equipment to monitor and control key operating parameters.

Flue gas temperature

- Maintain minimize exhaust flue gas temperatures to avoid sensible heat loss.
- Measure and record temperatures of exhaust gases and preheated air.

General

- Use consistent quality of raw materials to minimize the use of fluxing agent for producing glass melt.
- Recycle in-house glass rejects at the maximum possible temperature for reducing energy consumption.
- Maximize use of cullets of consistent quality in melting to minimize energy consumption.
- Use appropriate tools in finishing operations to improve product quality and reduce rejections.
- Arrest leakages from compressed air lines to reduce power consumption.
- Use compressed air only at required pressure to optimize energy consumption.
- Use airguns in place of compressed air for requirements of air at low pressures.

Refractory industries

This section explores various energy efficiency options which would help in substantial energy performance improvement of refractory industries in the MSME sector.

Energy efficient technologies

The energy efficient technology options for the firing process in refractory industries are discussed below.

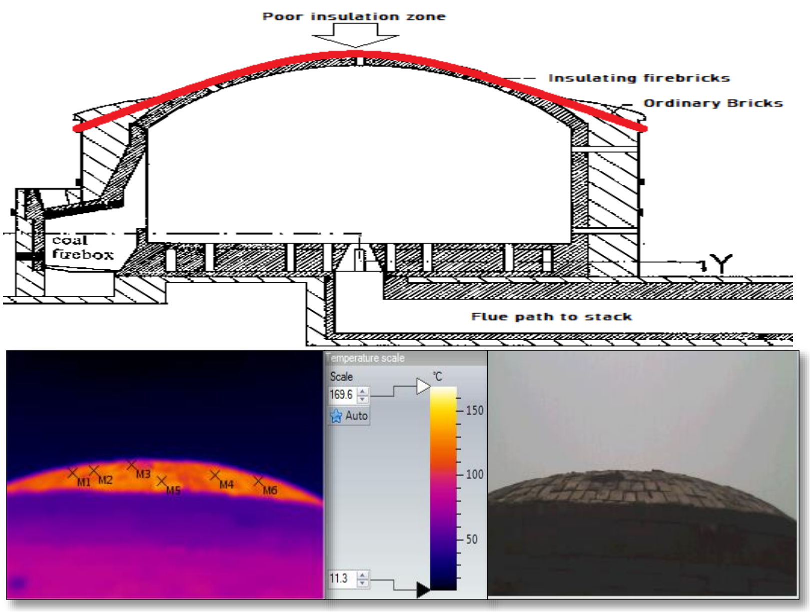
Downdraft kilns

The energy efficiency options in downdraft kiln include (i) enhancing insulation, (ii) use of monitoring and control system for process parameters, and (iii) waste heat recovery system for multi downdraft kiln. While these options help in marginal to medium level improvements in energy efficiency, the most attractive option for DD kiln-based units is to switch over to tunnel kiln technology, which is also discussed in this section.

Enhancing insulation of kiln

In a downdraft kiln, the thickness of the wall is in the range of 36 to 48 inches and is fabricated of refractory bricks. The surface temperature of the wall is in the range of 60-80 ^{o}C during the soaking period. The thickness of the crown (dome) and doors (loading and unloading points) are about 9-12 inches. Due to lower thickness, the surface temperatures of crown and loading doors were observed to be 150-350 °C over the firing cycle. The corresponding heat losses from these surfaces are estimated to be 8-10% of the total heat input.

The high surface temperature of the crown can be reduced by applying hot face insulation with veneering. It involves the application of a low thermal mass module on the hot face of the existing refractory lining. Veneering of internal surfaces leads to a reduction in the exposed mean temperature of the surface. Similarly, suitable insulation can be added to loading doors to reduce the surface temperatures. The envisaged energy saving with insulation improvement in a typical 120 tpd capacity downdraft kiln is about 14 kg coal per tonne of refractory product.



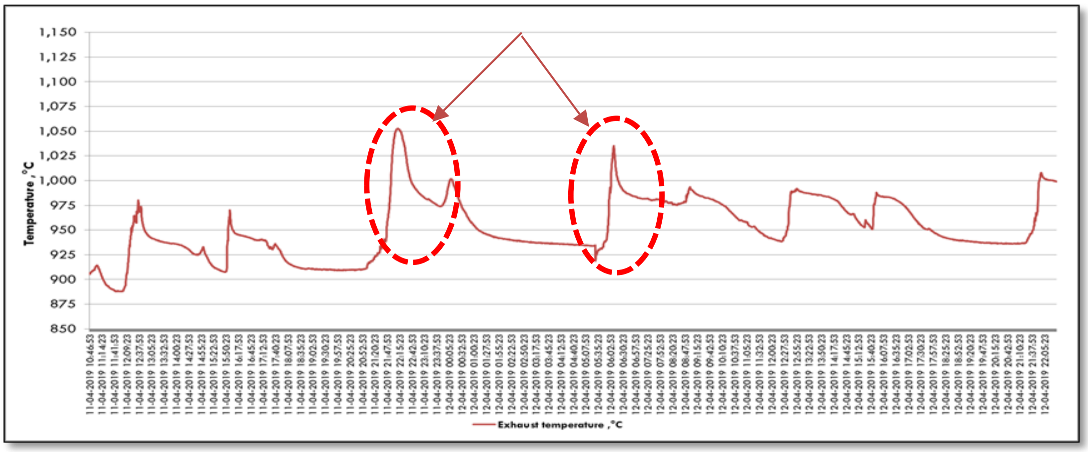
Replication potential (%)	Saving potential (%)	Payback period (month)	Sector level		
			Energy saving (toe/year)	Investment (Rs. lakh)	Emission reduction (tCO_2)
100% of DD kiln units	7%	6-9	2,654	243	10,676

Instrumentation for kiln temperature control

The production cycle of downdraft kilns is generally scheduled based on the experience of entrepreneurs/supervisors, whose instructions are followed by the fireman without monitoring kiln temperature profile or any other variables such as green refractory moisture, ambient conditions, etc. Further, there is the absence of monitoring of operating parameters like fuel firing rate and kiln temperature, which greatly influence the energy consumption (high or low) and/or product quality (over-firing/ under-firing).

The downdraft kilns may install a temperature measurement system to monitor kiln temperature profile and flue gas temperatures to control operating parameters ensuring uniform distribution of heat. Based on the real-time monitoring of kiln and flue gas temperature, coal feeding frequency can be scheduled to maintain the standard temperature profile of downdraft kilns.

Replication potential (%)	Saving potential (%)	Payback period (month)	Sector level		
			Energy saving (toe/year)	Investment (Rs. lakh)	Emission reduction (tCO_2)
100% of DD kiln units	7-10%	3-9	5,490	284	22,087

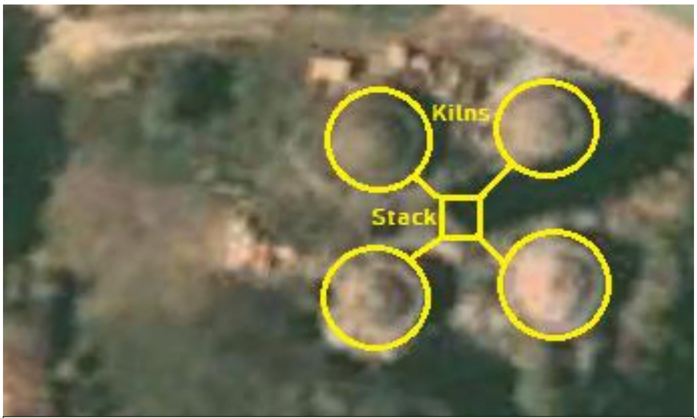


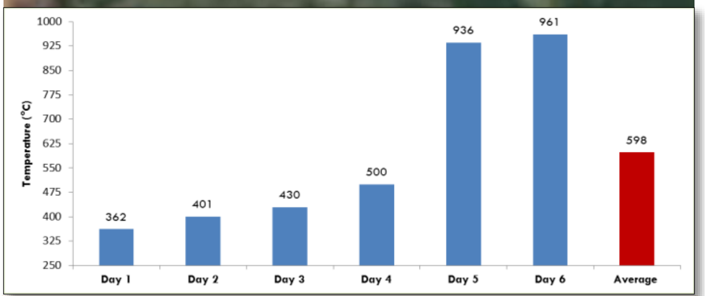
Sudden temperature rise due to high coal feed rate

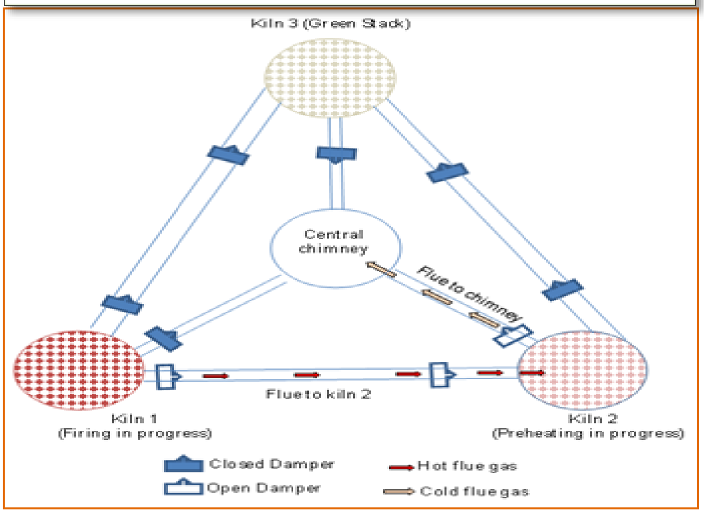
Waste heat recovery in downdraft kilns

In general, a number of refractory units have multiple downdraft kilns (2-4 kilns per unit) with a common stack. During the normal production cycle, one kiln is in operation while the others are kept on standby. The exit flue gas temperature of the downdraft kilns is about 350-950 °C during the firing cycle; high-temperature flue gases from downdraft kilns are left out through the stack without recovering the sensible heat.

The sensible heat in flue gases can be recovered by integrating downdraft kilns in a manner to ensure flue gases are directed from the source kiln to another kiln, which is loaded with green refractory and next in line for firing. The 'waste heat recovery' (WHR) system is more suitable wherein 3 kilns are located close to each other. Hence, the waste heat available in flue gases can be effectively utilized to preheat green refractory without installing any waste heat recovery system which can lead to substantial fuel saving.







Replication potential (%)	Saving potential (%)	Payback period (month)	Sector level		
			Energy saving (toe/year)	Investment (Rs. lakh)	Emission reduction (tCO_2)
17% of DD kiln units	10-12%	24-36	1,268	473	5,103

Tunnel kilns

The major energy efficiency options comprise insulation improvement, use of low thermal mass cars and switch over to gas firing. The details of these options are described below.

Enhancing insulation of tunnel kilns

The set temperature of the firing zone in a tunnel kiln is in the range of 1,000-1,250 ºC and the corresponding surface temperature of the firing zone and the inline preheating zone is in the range of 110-180 ºC. The corresponding surface heat loss is estimated to be 0.2-0.3 GJ per tonne of product which is about 5-8% of total energy input. Further, deterioration of the insulation results in hot spots, cracks, and heat leakage points along the kiln length.

The surface heat loss can be reduced by enhancing the insulation. This includes (i) covering of internal wall surface with ceramic fibre, and (ii) covering the external wall surface with ceramic fibre or rock wool insulation.

Replication potential (%)	Saving potential (%)	Payback period (month)	Sector level		
			Energy saving (toe/year)	Investment (Rs. lakh)	Emission reduction (tCO_2)
100% of tunnel kiln unit	4-6%	3-5	1,954	80	7,934

Low thermal mass cars

The cars/ trollies used to carry the refractory material inside the tunnel kiln comprise a solid refractory brick base and support structure to the green product. The car is also heated up during the firing process along with the product and the energy requirement for heating the solid refractory brick base cars is quite high. The ratio of product to kiln car (trolley) is kept around 1.5:1 leading to higher energy losses.

The weight reduction in kiln cars would save a significant quantity of energy in tunnel kiln. The use of low thermal mass materials in kiln car construction can reduce the weight of kiln cars considerably which enhances the material loading to car weight ratio. The deadweight of car structure can be reduced by about 15 to 25% of the traditional cars. The materials which can be used in kiln car include (1) silicon carbide offering maximum kiln fill and improved performance at high temperatures (2) silicon carbide beams having high strength and resistance to bending (long beams minimize the number of vertical posts) (iii) lightweight, hollow perimeter blocks. The incidental advantages due to low thermal mass materials are less thermal shock resistance, ease of assembly, and good mechanical strength. The modifications proposed to reduce the weight of kiln cars include the following:

- Replacement of refractory bricks with the hollow ceramic coated pipes at the supporting pillars for holding the racks
- Introduction of ceramic fibre blankets at the base of the car instead of the refractory brick base
- Use of low thermal mass materials (cordierite) hollow blocks to hold the raw wares instead of solid refractory mass

Replication potential (%)	Saving potential (%)	Payback period (month)	Sector level		
			Energy saving (toe/year)	Investment (Rs. lakh)	Emission reduction (tCO_2)
100% of tunnel kiln unit	4-7%	12-15	1,340	300	5,443

Switch over to gaseous fuel

A majority of tunnel kilns in the refractory sector use the petcoke (pulverised in powder form) as primary fuel, while only a few units (1-2 units in each cluster) use natural gas/coal bed methane/syngas. The combustion control and precision to maintain the zone temperature will be challenging in petcoke based tunnel kilns. Apart from this, pulverised petcoke requires appropriate handling and storage facility. Non-availability of proper handing and/or storage facilities results in wastage of fuel in the majority of the plant.

The use of gaseous fuel in tunnel kilns improves combustion efficiency as well as helps in precise control of temperature in firing zones. The benefits of conversion from solid/liquid fuel to gaseous fuel have already been realized in tunnel kilns operating in the ceramic and sanitary ware sector. Different gaseous fuel such as natural gas, LPG and producer gas can be used efficiently in tunnel kiln based system in switching over from solid/liquid based fuels. While natural gas and LPG can be used directly, producer gas requires separate system for production and refining treatment. Producer gas arrangement requires availability of suitable supply chain from sustainable biomass. An illustration of cost benefits in switch over of tunnel kiln to natural gas based system is provided.

Natural gas is available in refractory clusters of the western region through a piped distribution network. However, refractory clusters in the eastern region do not have access to PNG due to (i) units are not located in the scheduled industrial areas, and (ii) the PNG distribution network is not developed in industrial zones. Further, coal bed methane (mobile storage system) exists in the eastern region cluster. The fuel switchover would reduce specific energy consumption, reduced fuel handling, operating costs, and improve the environmental performance of the sector.

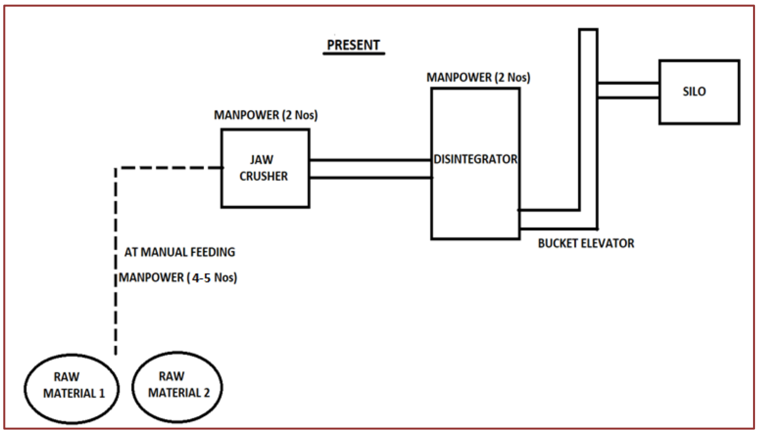
Replication potential (%)	Saving potential (%)	Payback period (month)	Sector level		
			Energy saving (toe/year)	Investment (Rs. lakh)	Emission reduction (tCO_2)
100% of tunnel kiln unit	10%	40	2,931	915	69,206

Common energy efficiency options

A few common energy efficiency options in refractory industries include mechanization of material handling and improvement of drying of green refractory. These options are given below.

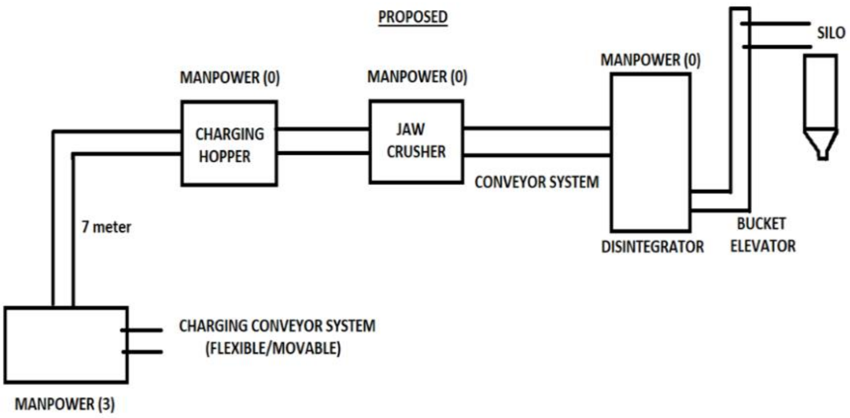
Mechanized material handling system

The raw materials preparation includes grinding and sieving to achieve defined particle-size distribution according to the recipe. Most units are manpower intensive and use manual conveying of the raw materials. About 10-15 manpower is required for the raw material preparation in a typical size MSME unit.



The grinded /prepared powder is stored in a chamber underneath the disintegrator, which requires additional manpower for material transfer as well as significant wastage of ready-to-use recipes. However, some of the progressive units use bucket elevators and silos reducing manpower requirements and minimising wastage.

The productivity of the grinding process is estimated to be about 60-70% of the rated capacity which is mainly due to existing manual material feeding into the primary jaw crusher which is the first step of the grinding process. Manual feeding is not only affecting productivity but also increases the cost of production (electricity and manpower) of the unit.



To maintain the optimum loading as well as minimum production cost, it is recommended to mechanise the material feeding system by installation of material carrying conveyor (from storage to jaw crusher) and feeding hopper to existing jaw crusher.

Replication potential (%)	Saving potential (%)	Payback period (month)	Sector level		
			Energy saving (toe/year)	Investment (Rs. lakh)	Emission reduction (tCO_2)
100% of refractory units	0.1-0.2%	12-18	903	1,129	1,867

***Note** Significant reduction in manpower cost with the use of a mechanical conveying system. Further, it reduces the fatigue of the workforce.*

Productivity enhancement

In the shaping process, the moisture level of the green refractory products is in the range of 7-8% which must be reduced to 3-5% before firing to optimize the specific power consumption. Most of the refractory units use a natural drying process for the removal of moisture. The drying duration and the final moisture level are generally dependants on ambient conditions in natural drying. For example, the firing cycle and the associated energy consumption of the kilns increase significantly during the rainy season. Hence, most of the refractory kilns are generally not operated during this period.

A few tunnel kilns in the sector have been equipped with waste heat-based dryers for the removal of moisture. However, due to the non-availability of local service providers and skilled operators, the refractory units have bypassed the dryer.

To maintain the moisture level of shaped products, the plant may adopt a forced air circulation system in the drying shed by installing ceiling fans to allow uniform drying. This will not only reduce the drying time but also help us in maintaining productivity during the rainy season. Installation of a forced-air circulation system will increase the power consumption marginally.

Tunnel kiln-based refractory units may also employee skilled manpower for operating the dryer system. The improved productivity will help in reduction of fixed cost such as inventory, manpower and O&M cost.

Replication potential (%)	Saving potential (%)	Payback period (month)	Sector level		
			Energy saving (toe/year)*	Investment (Rs. lakh)	Emission reduction (tCO_2)
All refractory units (DD & tunnel)	Productivity improvement	18-30	(465)	985	(4,438)

* *Results in monetary benefits of Rs 460 lakh per year*

Energy efficient retrofits in utilities

The most common energy intensive utilities across refractory industries are motors and air compressors.

Energy efficient motors

Motors are used mainly in raw material preparation, shaping of refractory products, and auxiliaries associated with kilns. Some of the applications of electric motors in the industry include jaw crusher, impact mill, conveyor, bucket elevator, vibrator, disintegrator, screw conveyor, counter-current mixer, Muller machine, friction screw press, and hydraulic press. The refractory industry also uses a cooling fan in downdraft kilns and combustion air blowers and conveyor systems in tunnel kilns. Almost all the motors used in refractory industries are of standard efficiency class with capacities varying from 1 kW to 20 kW having lower energy efficiency levels.

These inefficient motors can be replaced with premium efficiency class (IE3) motors. The salient features of high-efficiency motors include the following:

- Longer core lengths of low loss steel laminations to reduce flux densities and iron losses
- Maximum utilization of slots and generous conductor sizes in stator and rotor to reduce copper losses
- Careful selection of slot numbers and tooth/ slot geometry to reduce stray losses
- Generation of less heat leading to a reduction in the size of the cooling fan thereby lowering windage losses and waste power.

Replication potential (%)	Saving potential (%)	Payback period (month)	Sector level		
			Energy saving (toe/year)	Investment (Rs. lakh)	Emission reduction (tCO_2)
100% of refractory units	5-7.5%	36-48	38	95	362

State of the art technologies

The state of the art technologies which can lead to substantial improvements in refractory industries in MSME sector are discussed below.

Switchover from DD kiln to tunnel kiln

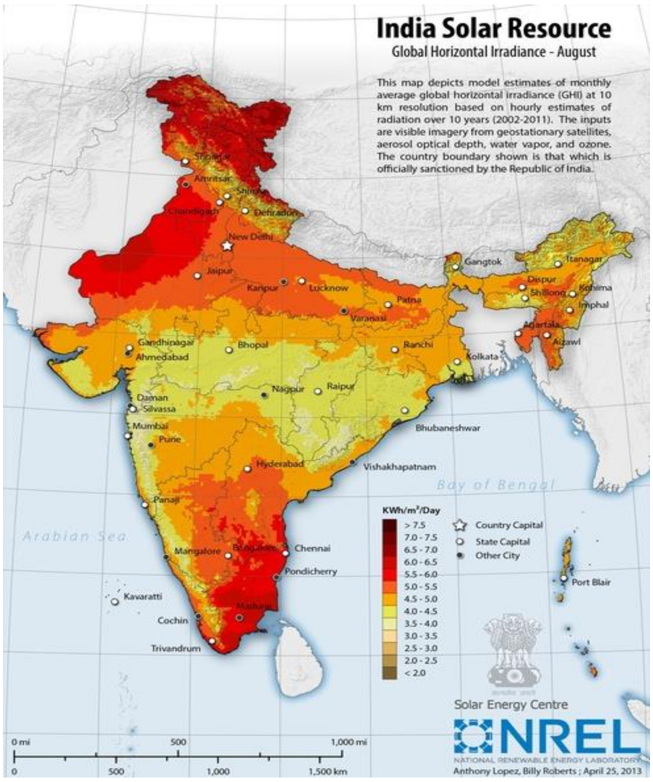
Downdraft kilns account for about 70% of total kilns in refractory industries and 60% of total production in the MSME sector. The SEC of the downdraft kiln is in the range of 6.2-7.0 GJ per tonne of refractory. The higher consumption may be attributed to high thermal mass, batch operation, manual firing, and poor operating practices.

Tunnel kiln is the continuous type and consumes significantly less energy (3.8-4.5 GJ per tonne) for the same product with an added advantage of a higher production rate. The number of downdraft kilns in a refractory unit may be replaced with a single and large capacity tunnel kiln system using petcoke or cleaner fuels (PNG or CBM).

The advantages of tunnel kiln as compared to downdraft kiln include low thermal mass design, closed-loop fuel firing system, temperature monitoring & control system, and waste heat recovery based continuous dryer. In general, the replacement of downdraft kilns with tunnel kiln technology increases the overall energy performance and production capacity.

Replication potential (%)	Saving potential (%)	Payback period (month)	Sector level		
			Energy saving (toe/year)	Investment (Rs. lakh)	Emission reduction (tCO_2)
DD kilns production equivalent	25%	18-30	26,897	7,444	1,08,207

Rooftop solar photovoltaic



Rooftop solar photovoltaic system is one of the options for sourcing green and low cost electricity in refractory industries. Rooftop solar panels utilize sunlight to generate electricity. Most of the refractory clusters are situated at ideal geographical locations receiving ample tropical sunlight.

One of the biggest advantages of installing rooftop solar panels in refractory industries is that it can be installed on any type of roof. Therefore the existing shed/roof can be effectively utilised and investment for additional land will not be required. The landed costs of electricity from solar PV system in comparison to industrial tariff rates are cheaper by 15-25%. The electricity utilisation in refractory units is mainly in the raw material processing and green refractory formation which is operating mainly during the day time and therefore rooftop panels can supply electricity to the units during this period. This would result in reduced grid electricity and backup power consumption, thereby saving on energy costs.

Best operating practices

The best operating practices for refractory industries are given below.

Raw material processing

- Operate ball mill at critical loading point to minimize specific energy consumption.
- Use grinding media of mixed sizes for efficient grinding.
- Use the correct and consistent quality of raw materials.
- Switch off conveyor used to carry the raw material when not in use.
- Use timer for switching off automatically on completion of grinding process.
- Maintain suitable pressure settings in press machine based on type of products.
- Minimize furniture dead mass to product ratio with low thermal mass material.

Downdraft kiln

- Do not use coal lumps to avoid incomplete combustion in firing. Coal use in firing to be sized around 3/4 to 1 inch.
- Feed fuel in small quantities at regular intervals against feeding lumps.
- The frequency of coal feeding may be kept once in 1.5 to 2 hours to ensure complete combustion of the fuel.
- Keep the feeding hole closed after fuel feeding is completed so as to ensure the entry of combustion air through the grate only.
- Use mechanised damper system to control kiln draft.

Tunnel kiln

- Ensure proper layout of burners for even distribution of heat in the firing zone.
- Arrange the products inside the kiln to ensure uniform heat gain by products.
- Avoid direct impingement of flame on products and furnace lining.

General

- Use good and consistent quality of refractory while stacking to improve yield.
- Check dimensions of moulds periodically to avoid rejections.
- Eco natural ventilators may be used to enhance drying process.
- Use in-house rejection of green refractory for recycling.
- Control firing to avoid both overheating and under heating to enhance productivity.
- Ensure proper housekeeping and avoid spillage of fuels to reduce wastage.

Development of new refractory materials

The typical refractory materials include fireclay refractories, high alumina refractories, silica brick, magnesite refractories, chromite refractories, zirconia refractories, insulating materials and monolithic refractory. Any aggregate can potentially be used in the formulation of a monolithic refractory. The material composition is based on stability at the temperature of application, mechanical strength, and corrosion resistance. However, there is a need to develop functional refractories for various end use applications. These include high performance heat insulation refractories, energy saving coatings, high thermal conductivity, fast heat storage refractories, etc.

Developments in the refractory industry have been driven strongly in terms of energy conservation and environmental protection. The development of binders that lead to high strength when refractories are fired at low temperatures, the formation of spinel grain through mechanical alloying, development of non-toxic and environmentally friendly resins for carbon-containing refractory materials, and the replacement of coal tar pitches for impregnation by other benzo-α-pyrene (BaP) free carbonaceous agents. The functional refractories can be produced using different combinations of refractory aggregates like bauxite, calcined and sintered alumina, fused alumina, fused bubble alumina, spinel, magnesia, dolomite, silicon carbide at different proportions. The on-going developments on new refractories at global level focuses on unshaped refractories and low carbon refractories are briefed below.

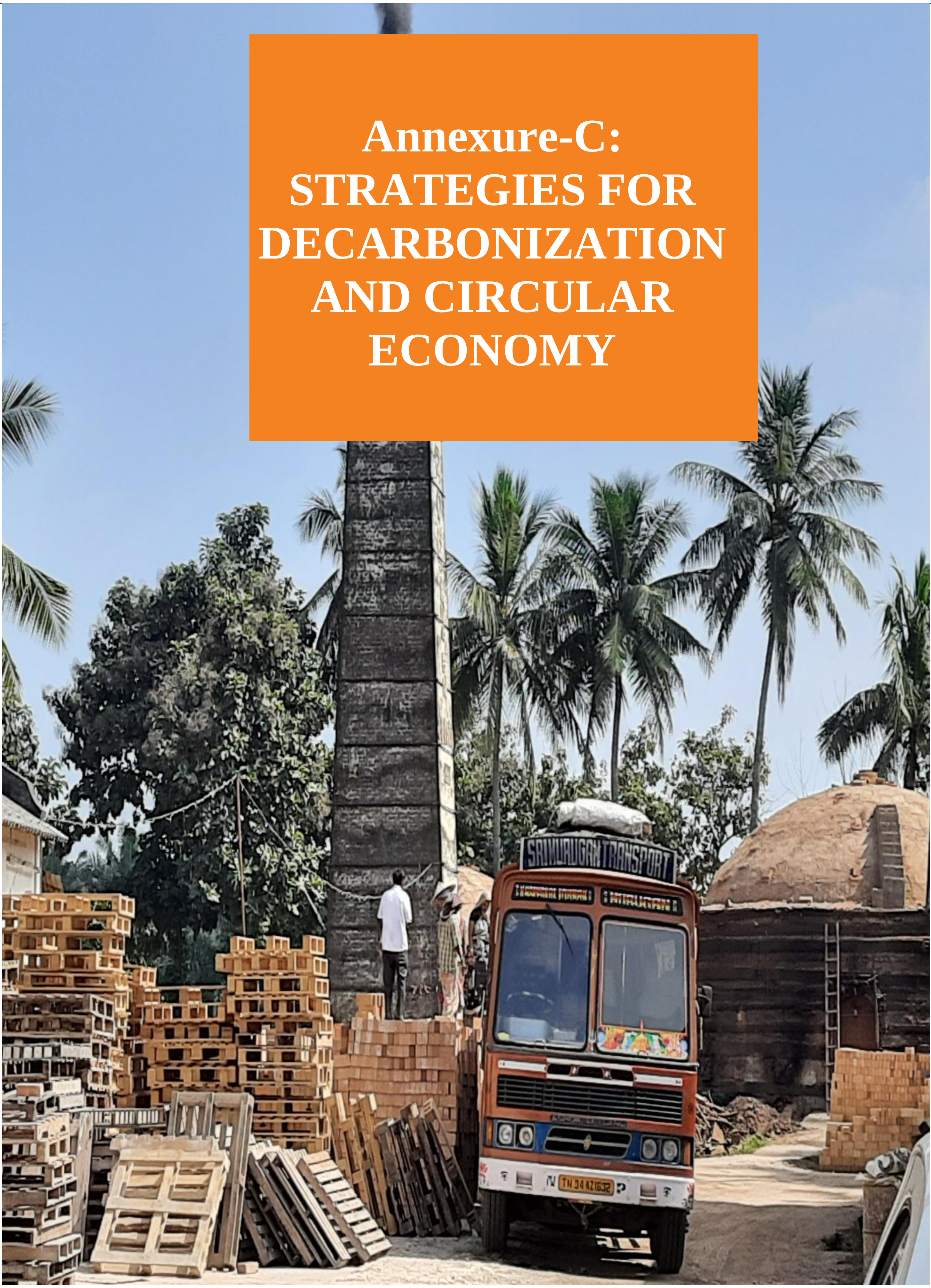
Unshaped refractories

The areas of development in unshaped refractory materials include MgO refractories and SiO2 refractories. In unshaped MgO refractories, cement-free bonding is being developed by producing plate like brucite through hydration of MgO. Refractories for high heat and corrosion resistance processes are under development by reduction of micro silica used as MgO castable binders and addition of synthetic $MgO-SiO_2-H_2O$ binders. Refractories like cement-free 96% silica is being developed for coke ovens and hot stoves which require high purity silica. Unshaped, precast and heat treated castables are required for large and complicated-shaped refractories. There are on-going experiments focusing on grain size and micro structure to improve mechanical properties such as durability, thermal shock, etc. For example, splintered coarse grains are developed which can be applied to unshaped refractories to provide high cohesive power and durability for application such as steel ladles.

Low carbon refractories

Low carbon refractories are being developed for production of clean steel wherein a number of experiments are on-going. A recent experiment in low carbon refractories includes replacement of graphite with a phase of Ti-MAX (a chemical compound having both metal and ceramics properties) which helps in suppression of rapid oxidation of graphite at eroded interfaces. Thermal shock resistant refractory materials are being experimented by adding nano-carbon with MgO-C to improve the micro structure of refractory materials. Carbon-free, unburned alumina-magnesia bricks are being developed for ladle metal lines in ultra low carbon steel production.

Annexure-C: STRATEGIES FOR DECARBONIZATION AND CIRCULAR ECONOMY



Strategies for decarbonization and circular economy

The glass sector and the refractory sector is one of the energy intensive sectors among MSME in India. The share of thermal energy is predominant in both glass melting and refractory firing accounting for more than 95% of the total energy consumption within the factory premises. The sector needs to explore suitable options to transit gradually towards decarbonization. The glass and refractory industries may explore the following.

- Technology switch over from coal / petcoke to natural gas along with promoting circularity in supply chain
- Adoption of best available technology (BAT) at global level
- Electrification of fossil fuel based processes
- Promoting deep decarbonization through research and development
    - Electrification route
    - Hydrogen route

The deep decarbonization would require involvement of stakeholders globally for developing commercial scale technologies and suitable policies.

Strategies for glass sector

The glass industries use coal, oil, natural gas, liquid petroleum gas (LPG) and grid electricity to meet the energy demand for the process. Around 93% of fossil fuel based energy in glass sector is sourced from natural gas. The energy intensity in glass sector can be marginally reduced on adoption of energy efficiency options. The industries may explore the electrification / hydrogen based technology options for the following equipment / processes / technologies for decarbonization of the sector.

- Melting technologies such as tank furnace, pot furnace, day tank furnace, etc. to replace the consumption of natural gas
- Glass toughening process to replace LPG fired furnaces
- Heat treatment processes such as annealing, pot arching, bangle baking, etc. to replace the consumption of natural gas and LPG
- Glass reheating furnaces and bangle making furnaces to replace the consumption of NG

The industries can also reduce the consumption of grid electricity by sourcing renewable based electricity to meet electricity requirement within the plant premises.

Strategies for refractory sector

The refractory sector uses coking coal, petcoke, biomass and grid electricity. More than 95% of energy requirement in refractory sector is met from coking coal and petcoke. The energy intensity in refractory sector can be marginally reduced on adoption of energy efficiency options. The industries may explore the following technology options for decarbonization of the sector.

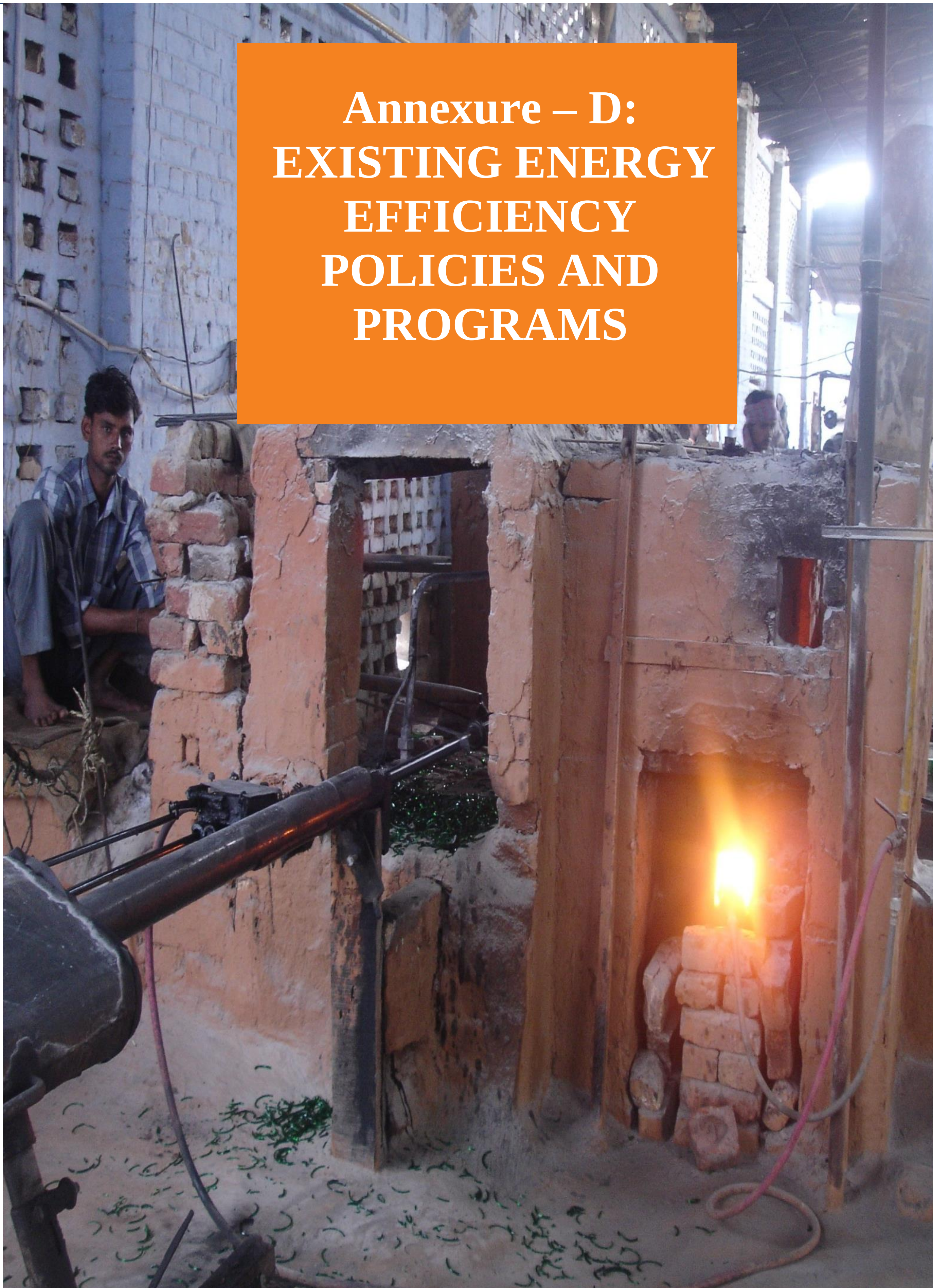
- Switch over from coal based downdraft kiln to natural gas based tunnel kiln
- Fuel switch over from petcoke to natural gas in tunnel kiln
- Electrification/ hydrogen based tunnel kiln for deep decarbonization of the sector

The industries can also reduce the consumption of grid electricity by sourcing renewable based electricity to meet electricity requirement within the plant premises.

Strategies for circular economy

The in-house waste generated in glass and refractory industries are generally recovered, recycled and reused to reduce the dependency on virgin raw material use promoting sustainable consumption and production, which is in-line with circular economy. Further, the industries can enhance the procurement of waste generated after end of life cycle from the open market and reuse in the process.

Annexure – D: EXISTING ENERGY EFFICIENCY POLICIES AND PROGRAMS



This section provides an overview of existing schemes and policies that are applicable for MSME sector. The applicable schemes for glass and refractory sector are also covered in this section.

Existing schemes and policies

It has been well recognized that the MSME sector forms the bedrock of Indian entrepreneurship, and needs to be nurtured appropriately. There are several programs and schemes promoted by the Government of India under the Ministry of Micro Small and Medium Enterprises (MoMSME) as well as by other ministries and state governments. The general industrial policy of the Government of India, as well as the states, is applicable for the glass and refractory sector as well. Some of the relevant schemes are summarized below.

Credit linked capital subsidy scheme

The Credit Linked Capital Subsidy Scheme (CLCSS) was launched in the year 2000 by the MoMSME and is being implemented by Development Commissioner, Micro Small and Medium Enterprises (DC-MSME).

Implementation Agency	Ministry of MSME
Description	The objective of the scheme is to facilitate technology upgradation in MSMEs by providing an upfront capital subsidy of 15% (on institutional finance of up to INR 1 crore availed by them) for induction of well- established and improved technology in the specified 51 industrial sub- sectors/products approved
Nature of assistance	15% upfront capital subsidy to MSMEs, including tiny, khadi, village, and coir industrial units, on institutional finance
Period of implementation	Year 2000 – Present (on-going)

The scheme covers several technologies for the glass sector, however, there are only a few technologies covered for refractory industries. The equipment covered under the CLCSS scheme in the glass and refractory sector is provided in below.

Sector	Equipment	CLCSS coverage
Glass	Glass melting tank furnace	Energy efficient tank furnace Injection moulding machine
	Glass melting pot furnace	Improved glass fired 12-pot furnace Improved single pot arch Insulation, heat recovery system, modification of furnace Spinning machine (1-head, 2-heads and 4 heads) Set up different machines
	General	Improved batch house and batch handling system Automatic controllers and recorders for furnace temperature On-line oxygen analyser Improved muffle furnace IS-machine of capacity 10-12 tpd Small scale laboratory

Sector	Equipment	CLCSS coverage
		LPG fire bead making furnace
Refractory	Tunnel kiln	Gas/oil fired tunnel kiln Refractory decker plate/kiln furniture, etc.
	Refractory kiln	Not covered
	General	Gas/oil fired shuttle kiln Auto on-off burner in shuttle kiln Control instruments for firing in shuttle kiln

Credit guarantee fund trust for micro and small enterprises

Implementation Agency	Ministry of MSME and Small Industrial Development Bank of India (SIDBI)
Description	The trust fund is to implement the Credit Guarantee Scheme for providing collateral-free loans to individual MSE on payment of guarantee fee to the bank by the MSMEs. The corpus of CGTMSE is contributed by the Government of India and SIDBI.
Nature of assistance	Eligible borrower can avail fund and non-fund based credit facilities up to Rs 200 lakh The guarantee covers to the extent of 50-85% of the sanctioned amount of the credit facility. The extent of guarantee cover is 85% for micro enterprises for credit up to Rs 5 lakh. The extent of guarantee cover is 50% of the sanction amount of the credit facility for credit from Rs 10 lakh to Rs 100 lakh per MSME borrower for retail trade activity. The extent of guarantee cover is 80% (i) Micro and Small Enterprises operated and/or owned by women; and (ii) all credits/loans in the North East Region (NER) for credit facilities upto Rs 50 lakh. In case of default, Trust settles the claim up to 75% of the amount in default of the credit facility extended by the lending institution for credit facilities upto Rs 200 lakh.
Period of implementation	Year 2000 – Present (on-going)

Micro and small cluster development program

Implementation Agency	Ministry of MSME
Description	The objective is to improve the competitiveness of MSME clusters (industries working in similar proximity, having similar products) by focusing on common issues such as access to technology, skills, quality, market access, access to capital, etc. It further focuses on capacity development, create/upgrade infrastructural facilities in industrial parks such as training centres, testing centres, effluent treatment plants, etc.

Implementation Agency	Ministry of MSME
Nature of assistance	Common Facility Centres: Grant up to 70% of the cost of the project of a maximum INR 20 crore. Infrastructure Development: Grant up to 60% of the cost of project of maximum INR 10 crore for industrial estate & Rs 15 crore for flatted factory complex.
Period of implementation	Year 2007 – Present (on-going)

Interest subvention scheme for MSMEs 2018

Implementation Agency	Ministry of MSME (Govt. of India)
Description	The objective is to encourage both manufacturing and service enterprises to increase productivity and provide incentives to MSMEs for on-boarding on GST platform.
Nature of assistance	The interest relief will be calculated at two percentage points per annum (2% p.a.), on the outstanding balance from time to time from the date of disbursal/ drawl or the date of notification of this scheme, whichever is later, on the incremental or fresh amount of working capital sanctioned or incremental or new term loan disbursed by eligible institutions.
Period of implementation	Year 2018 – Present (on-going)

State specific schemes and policies

Apart from the policies of different central government ministries/departments, various state governments also provide incentives/ subsidies for energy efficiency and technology upgradation projects and undertaking energy audits. However, there is no sector specific policies/scheme by the state governments.

Technology centres

The technology centres comprise tool rooms and technology development centres. The nature of assistance of these centres includes (i) providing access to MSMEs to tooling facilities for enhancing efficiency, (ii) process and product development, and (iii) skill development. However, there is limited presence of development institutions at cluster level in glass sector; Centre for the Development of Glass Industry (CDGI), Firozabad is providing support to MSME in energy conservation, skill & product development and need assessment for cluster-specific technologies.