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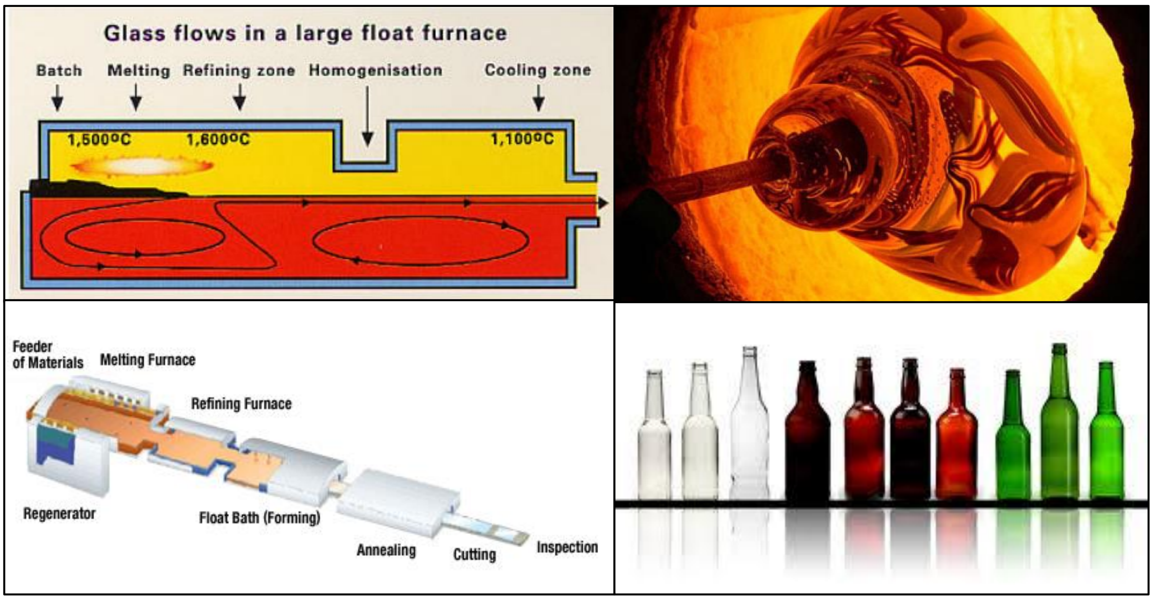
Final Report:

Widening the coverage of PAT Scheme

Sectoral Manual-Glass industry



Prepared for

Shakti Sustainable Energy Foundation

The Energy and Resources Institute

...towards global sustainable development

SHAKTI SUSTAINABLE ENERGY FOUNDATION

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Preface

The industrial sector represents more than one third of both global primary energy use and energy-related carbon dioxide emissions. In developing countries, the portion of the energy supply consumed by the industrial sector is frequently in excess of 50% and can create tension between economic development goals and a constrained energy supply. Further, countries like India, with an emerging and rapidly expanding industrial infrastructure, have a particular opportunity to increase their competitiveness by applying energy-efficient best practices from the outset in new industrial facilities.

Despite the potential, policymakers frequently overlook the opportunities presented by industrial energy efficiency to make a significant impact on climate change mitigation, energy security and sustainability. The common perception is that achieving energy efficiency of the industrial sector is too complex to be addressed through public policy and, further, that industrial facilities will achieve energy efficiency through competitive pressures of the marketplace alone. One such initiative under the National Mission on Enhanced Energy Efficiency (NMEEE) is the Perform Achieve and Trade (PAT) scheme. This is a market based mechanism having the objective to enhance energy efficiency (target based) in the country with an option to trade the additional energy savings, in the form of energy saving certificates.

In the first phase eight industrial subsectors were covered under the PAT scheme. There are further plans to widen the coverage by adding more new industrial subsectors depending upon the energy consumption. Shakti Sustainable Energy Foundation (SSEF) and The Energy and Resources Institute (TERI) intend to assist the Bureau of Energy Efficiency (BEE) in expanding the PAT scheme to new sectors for subsequent phases.

As a part of this exercise, the country profile of a few selected subsectors along with its energy intensity has been tried to establish. It has been done after interactions with respective industrial associations / industry heads and compiling data from secondary sources. For this report on the Glass sector, the discussions were carried out with The All India Glass Manufacturers' Federation (AIGMF). Secondary data available in public sources were used for preparing this report.

We believe that this sector manual will act as a guide for next steps and establish a need to study the energy consumption in detail to set the threshold limit for eligibility for designated consumers.

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Abbreviations

AIGMF	:	All India Glass Manufacturers' Federation
BEE	:	Bureau of Energy Efficiency
CAGR	:	Compound Annual Growth Rage
CGCRI	:	Central Glass and Ceramic Research Institute
CLCSS	:	Credit Linked Capital Subsidy Scheme
CO	:	Carbon monoxide
CO_2	:	Carbon dioxide
FO	:	Furnace Oil
GAIL	:	Gas Authority of India Ltd
GCV	:	Gross Calorific Value
HNG	:	Hindustan National Glass
HSD	:	High Speed Diesel
KJ	:	Kilo Joule
kWh	:	Kilo Watt Hour
LDO	:	Light Diesel Oil
LPG	:	Liquefied Petroleum Gas
MSME	:	Micro, Small and Medium Enterprises
mtoe	:	Million tonne of oil equivalent
NG	:	Natural Gas
NIC	:	National Informatics Centre
NMEEE	:	National Mission on Enhanced Energy Efficiency
PAT	:	Perform, Achieve and Trade
SEC	:	Specific Energy Consumption
SSEF	:	Shakti Sustainable Energy Foundation
Sq.m.	:	Square metre
TERI	:	The Energy and Resources Institute
toe	:	tonnes of oil equivalent
tpd	:	tonne per day
UNIDO	:	United Nations Industrial Development Organisation

Executive summary

Glass is one of the most useful materials in our daily life. Today glass is so commonly used that its presence often goes unnoticed. The Indian glass industry consists of seven segments namely, sheet and flat glass (NIC[1]-26101), glass fibre and glass wool (NIC-26102), hollow glassware (NIC- 26103), laboratory glassware (NIC- 26104), table and kitchen glassware (NIC- 26105), glass bangles (NIC- 26106) and other glass wares (NIC – 26109). India is among the top 15 markets for glass packaging globally and is 3rd fastest growing market after Turkey and Brazil. The global market for Indian glassware is fragmented and spread across several countries. Most of the glass demand in the country comes from container glass which accounts for 50% of the country's glass consumption by value. Apart from few big manufacturers, it is estimated that there are more than 1000 manufacturers in MSME segment. There is no specific glass sector related policy in the country.

The Indian glass sector is growing across all segments. This growth has been driven primarily by India's booming automotive and construction sectors which have been key drivers of the economy for the past few years. The glass industry is highly energy intensive and energy consumption is major cost driver. The total energy consumption in Indian glass industry is about 1.17 million tonnes of oil equivalent. The average energy cost as a percentage of manufacturing cost is about 40 per cent. Melting and refining are most energy-intensive portion of the glass making process and accounts for 60–70% of total energy use in the glass industry. Thermal energy consumption contributes to about 80% of total energy consumption in the glass industry. The performance of a large number of glass industries shows that (1) the energy consumptions of the individual units are relatively high, and (2) there are wide variations in the performance of the units in terms of energy consumption of the furnaces thereby offering scope for energy efficiency improvements. It would be beneficial for the Indian glass industry to evolve glass-sector specific schemes that would enable them to identify technology options, access to finance and adopt technology modernisation in a methodical manner.

The energy consumption in glass industry shows that substantial share of energy consumption is accounted by thermal energy and there exists significant scope for energy efficiency improvements both in process and utility areas. There are few large players in glass industry engaged in the production of float and container glass accounting for major energy consumption in glass sector. The total annual energy consumption of these major players is estimated to be 0.78 mtoe, which is about 66 % of the total energy consumption of glass sector. The energy consumption by glass industries is quite significant for different group companies and a number of plants involved in the production of float glass and container glass would qualify to be 'Designated Consumers' (DCs). However, for a number of such major players (e.g. Saint Gobain, Hindustan National Glass, Asahi Glass and Gold Plus Glass), details like installed capacity, production and energy consumption of their individual glass plants are not readily available. Energy consumption of individual plants would be required to propose threshold limits and consider them as DCs. Therefore, it is suggested to undertake a glass-sector specific study to estimate energy consumption and set threshold limit for the glass sector.

[1] NIC 26101 - Division 26 represents National Informatics Centre classification for manufacture of other non-metallic mineral products, group 261 and class 2610 represents manufacture of glass and glass products and 26101, 26102,26103,26104,26105, 26109 represents sub-class for manufacture of different types of glass

1.0 Introduction

Glass is one of the most useful materials in our daily life. It has been produced for thousands of years, dating from as early as 7000 B.C. A form of natural glass - obsidian - formed within the mouth of a volcano as a result of the intense heat of an eruption melting sand - was first used by man as tips for spears. Today glass is so commonly used that its presence often goes unnoticed. Glass is used in myriad of products, primarily because it is inexpensive and has many desirable properties (table 1.0).

Table 1.0 : Properties of Glass

Property	Unique characteristics of glass
Chemical	Glass is highly resistant to chemical attack, and many chemicals and foods/ beverages can be stored for decades without corrosion of the glass. Only a few chemicals aggressively attack glass (hydrofluoric acid, phosphoric acid, hot alkali solutions, superheated water).
Elasticity	Glass is perfectly elastic. After bending or stretching it returns exactly to its original shape when the force is removed. Glass will break, however, when the force applied exceeds the ultimate strength of the glass.
Strength	Glass is brittle, and will break rather than deform when subjected to severe impacts. However, in compression, glass is very strong (e.g., glass spheres are used in undersea applications where they are subjected to intense compressive forces). The tensile strength of glass can be increased by thermal tempering, chemical modification, or laminating.
Hardness	Glass is a hard material, with hardness values comparable to steel, and can withstand significant abrasion over its lifetime. Glasses with aluminum oxide are some of the hardest.
Optical	Glass is transparent or translucent to light, and some glasses are selectively transparent, transmitting light of one wavelength or colour more efficiently than any other. Other glasses are designed to absorb infrared light and transmit visible light, or to transmit either ultraviolet or infrared while absorbing visible light. Glass can also bend light (as in a lens).
Electrical	Glass is a good insulator, and provides high resistance to the passage of electricity.
Thermal	Glasses with low thermal expansion have high thermal shock resistance.

1.1 Product categorization

The Indian glass industry comprises seven segments namely, sheet and flat glass, glass fibre and glass wool, hollow glassware, laboratory glassware, table and kitchen glassware, glass bangles and other glass wares. In general, the glass production can be categorized broadly into following four segments:

1.1.1 Container glass

This is one of the largest segments in the glass sector and comprises of glass packaging for beverages, food, perfumes and pharmaceuticals.

1.1.2 Flat glass

This segment comprises of sheet plate float glass for residential and commercial construction, rolled glass, cast glass and other flat glasses which are used mainly for architectural and automotive applications. Flat glass, commonly called float glass after the process by which most of it is made, plays a dominate role in today's building construction and vehicles manufacturing industries. Since the development of the float glass process and thin film coating technology, flat glass has remained the transparent material of choice for automotive and construction applications.

1.1.3 Speciality glass

Specialty glass is mainly used for technical applications such as optics, electronics, lighting, engineering, ophthalmic lenses, etc. Borosilicate glasses are also included in this category.

1.1.4 Fibre glass

Fibre glass consists of thin filaments of glass fibre that are used primarily as reinforcement material in polymer products. The resultant composite is called Fibre Reinforced Polymer (FRP) or Glass Reinforced Plastic (GRP), commonly referred to as fibre glass. The products in this category also include fiberglass (glass wool) insulation for buildings, roofing and panels.

1.2 Production data

Most of the glass demand in the country comes from container glass which accounts for 50% of the country's glass consumption by value. The production of various types of glass in the country is shown in table 1.2.1.

Table 1.2.1: Production of various types of glass

		Production		
Type of glass	Unit	2010-11	2011-12	2012-13 (upto Nov 2012)
Glass sheet	Thousand Sq. m	96,770	1,06,144	73,043
Toughened Glass	Sq.m	26,04,340	26,78,263	22,31,388
Fibre Glass	tonne	39,217	42,670	29,356
Glass Bottles	tonne	11,56,830	1,27,19,208	8,79,733

Source: DIPP 2012-13

1.3 Sectoral importance

The glass industry in India is quite old and well established. The Indian glass industry represents one of the largest markets and the manufacturing capacity for glass products in Asia region. The first glass plant in India was set up in 1908. The glass industry remained largely a cottage industry for a long time. From rudimentary mouth blown and hand working processes, the industry in recent years has evolved to adopt modern processes and automation in a large way. However, mouth blown processes and handcrafted glassware continue to play a role in developing innovative designs in decorative and table glassware products that are exported in large quantities. Indian glass industry is involved in the production of different types of glass products as elaborated in section 1.1 and section 1.2.

The Indian glass market was worth about USD 2.7 billion during 2011-12. The per capita glass consumption was 1.2 kg compared with 8–9 kg in developed countries and 30–35 kg in USA.

During the same period the flat glass market was 4500 tpd (tonnes per day) and was growing at 16%. The market for container glass was about 7000 tpd which has a share of 55-60% of overall market share in the country. The market for other glass products such as lighting, bangle, beads, etc is about 1500 tpd.

1.4 International scenario

The major glass producing countries in the world are Germany, USA, UK, China and Japan. The main glass consuming regions are Europe, China and North America. Together, these regions/ countries account for more than 74% of global demand for glass. Europe is the most mature[2] glass market followed by Japan and North America. Europe has the highest proportion of value-added products. One of the main reasons for the growth of glass industry is that it provides a very attractive packaging alternative. In Europe, the world's largest producer of container glass (bottles, jars, etc.), glass stands for 34% of total packaging market for beverages and has an annual growth rate of 4.2%.

The global glass industry is quite concentrated with four companies – Nippon Sheet Glass (NSG)/ Pilkington (base at Japan/ United Kingdom) , Saint-Gobain (base at France), Asahi (base at Japan) and Guardian (base at USA), producing 67% of the total high quality float glass in the world. Lower quality float and sheet glass production is gradually being replaced by high quality float glass across the globe. For automotive glazing, there are three major players – NSG/ Pilkington, Asahi and Saint-Gobain, who along with their respective associates meet nearly 75% of the world's original equipment glazing requirements.

Flat glass with about 30% of the total glass production is the second largest sector in the glass industry in the European Union after container glass. The Flat glass sector covers the production of float glass and rolled glass. In the European Union, about 97% of flat glass is produced using the float process. The manufacturing facilities using Float process are located across 16 countries in the European Union (EU), but three quarters of EU production originates from Germany, France, Italy, Belgium, UK, Spain and Poland. The flat glass production by different countries in European Union is provided in figure 1.4 (Source: Glass for Europe)

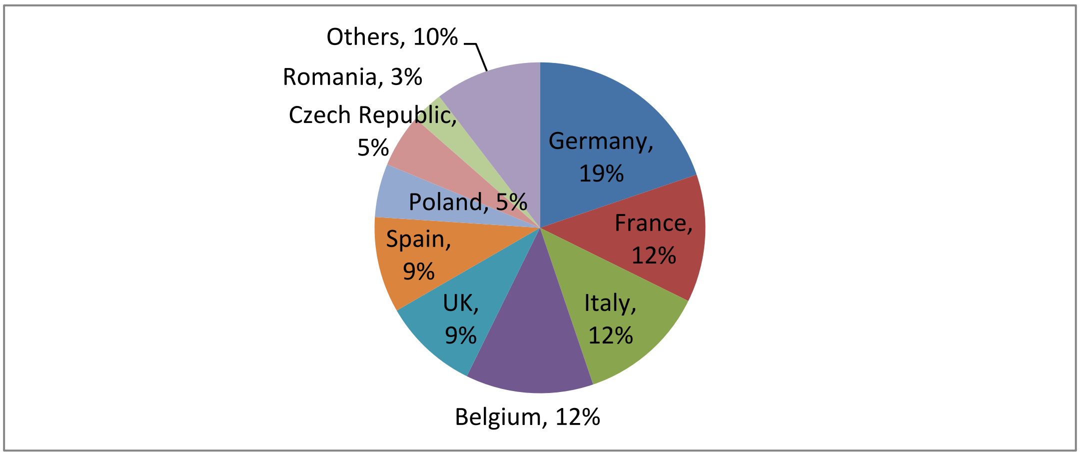

Figure 1.4: Flat glass production by different countries in EU

2 Maturity of a market is indicated by a higher demand for value-added glass, stringent regulations for glass usage and minimum percentage of glass being used for refurbishment projects (Source: Glass Market Intelligence report).

China is the largest consumer of glass in the world, accounting for 50 % of global demand in 2009. China is also the largest producer of glass and glass products, producing over 50%of the global output of flat glass in 2009. It has the greatest number of glass producing enterprises, and has the largest number of float-glass production lines in the world.

1.5 International standing of sub-sector

India is among the top 15 markets for glass packaging globally and is among the fastest growing market along with Turkey and Brazil. The global market for Indian glassware is fragmented and spread across several countries (Table 1.5.1), with no dominant market. USA is the biggest market for Indian glass products and accounted for 14 per cent of exports in 2006-07. UAE with 8 per cent and Poland with 6 per cent, were the other key markets for Indian Glass.

Table 1.5.1: Country wise exports from India (2006–07)

Country	Export share
USA	14%
UAE	8%
Poland	6%
Italy	5%
Belgium	5%
PRP China	5%
Brazil	4%
Turkey	3%
Saudi Arabia	3%
Mexico	3%
Spain	3%
UK	3%
Others	38%

Source: IBEF

The value of exports and imports of different glass types for the years 2010-11 and 2011-12 are provided in table 1.5.2.

Table 1.5.2: Value of export and import of glass items

(Rs million)

	2010-11		2011-12	
Type of glass	Export	Import	Export	Import
Glass & glassware	17,972	27,716	25,559	33,818
Float glass / sheet	1,119	3,634	1,400	3,643

Source: DIPP 2012-13

1.6 Growth in past and future perspective

The Indian glass industry has been growing across all segments. Sheet and float glass have recorded the fastest growth, at nearly 67 per cent CAGR (Compound Annual Growth Rate) between 2001 and 2005. Other glassware such as bottles and fibre glass has recorded more modest growth rates of about 5-6 per cent CAGR, over the same period. The sale of domestic float glass in domestic market is provided in table 1.6.1. The market share of differ flat glass products in India during 2012–13 is given in table 1.6.2.

Table 1.6.1: Sale of float glass in domestic market

Year	Sale of float glass (MT/day)	Growth (%)
2004 – 05	1,427	
2005 – 06	1,402	-2
2006 – 07	1,695	21
2007 – 08	2,043	21
2008 – 09	1,942	-5
2009 – 10	2,684	38
2010 - 11	3,400	27
2011 - 12	4,000	18

Source: Glass Yug;TERI analysis

Table 1.6.2: Market share of flat glass products in India during 2012–13

Type of flat glass	Quantity (tonne)	Share (%)
Clear float / Sheet glass	2,160	60
Tinted float / Sheet glass	540	15
Reflective glass	612	17
Mirror glass	288	8
Total	3,600	100

Source: Glass Yug

Different drivers that influence the glass industry are the following:

- Expansion of construction and automotive industries
  - Increased acceptance of green building concept
  - Global concerns about energy conservation and environment
  - Decorative glasses with digital print technology.
  - Use of 'nano' technology – The future in world of glass
- Architects and car designers continue to increase the glass content in buildings and vehicles
  - Demand for value-added products is growing at a faster rate than demand for basic glass, enriching the product mix and boosting the sales line
- Value-added products are delivering greater functionality to vehicle glazing and adding a further growth dimension to automotive glazing sales

It is expected that in future, glass consumption will grow in construction, automotive, consumer goods and pharmaceutical sectors.

1.7 Important stakeholders

The glass industry has a federation that act as a representative of its members and apart from promoting study and research in glass technology, the Federation also safeguard the interest of glass industry and glassware business in India. There are also few academic institutes/ research organisations in India that are undertaking various research activities related to glass sector in the country. Major stakeholders of the glass industry in the country are:

1.7.1 The All India Glass Manufacturers Federation, New Delhi

The federation was founded in the year 1944 and was incorporated under the Companies Act 1956 as a Limited Company in 1970. The All India Glass Manufacturers association is made up of five regional associations representing Northern, Southern, Western and Eastern region of the country. The contact details of the regional associations are provided in Annexure 1.7.1.

1.7.2 Central Glass and Ceramic Research Institute (CGCRI)

Central Glass and Ceramic Research Institute (CGCRI) is one of the first four laboratories decided to be set up under the Council of Scientific & Industrial Research. Development of various types of optical glasses brought CGCRI into limelight in the international arena.

1.7.3 Centre for the Development of Glass Industry, Firozabad (Uttar Pradesh)

Center for the Development of Glass Industry(CDGI) has been set up at Firozabad in India in collaboration with UNDP/ UNIDO and Government of UP. CDGI aims to assist the glass industry for improving its overall performance particularly in the areas of technology upgradation, energy conservation, introduction of value added glass articles and skill development.

1.7.4 Department of Ceramic Engineering, Indian Institute of Technology (Banaras Hindu University), Varanasi

The course of ceramic technology was instituted in the year 1924 to advance the glass and ceramic technology in India. The Department is pursuing active research in the emerging areas of glass, glass - ceramics, refractories and other ceramic materials. Apart from these institutes/ organisations, construction sector, automobile sector and glass packaging industry like pharmaceuticals, perfumery, food and beverage etc. are also important stakeholder in this sector.

1.8 Major players

Glass industry is a de-licenced industry.Apart from few major manufacturers, there are more than 1000 medium and small manufacturers. Majority of the glass manufacturing units are located in Firozabad, Baroda, Ahmedabad, Mumbai, Kolkata, Bengaluru and Hyderabad. In industry clusters such as Firozabad, Baroda and Kolkata, the glass industry has evolved from cottage industry to the level of organized industry. A brief highlight of the major players in the glass industry is provided in the following sub-sections:

1.8.1 Saint Gobain

With the presence in 64 countries, Saint Gobain is a dominant player in the global glass sector. In India, Saint Gobain has established two companies- Saint Gobain Glass India Ltd. and Saint Gobain Sekurit India Ltd. to manufacture and market glass. Saint Gobain Glass India Ltd. manufactures and markets float glass and mirrors. The manufacturing facilities are located at Sriperumbudur (Tamil nadu), Tada (Andhra Pradesh) and Jhagadia (Gujarat). The manufacturing facility at Sriperumbudur has two float glass plants with cumulative production capacity of 1500 tonnes per day. Saint Gobain Sekurit India Ltd. produces laminated windshields and tempered glazing for the Indian automotive market. The manufacturing facilities are located at Bhosari & Chakan near Pune (Maharashtra) and Sriperumbudur.

1.8.2 Hindustan National Glass & Industries Ltd (HNG)

The company founded in 1946 is a key player in India's container glass industry. HNG is the largest container glass producer in India and occupies 55% market share in India. With an installed capacity of 4395 tonnes per day, the plants of HNG are located at Rishra, Bahadurgarh, Rishikesh, Neemrana, Nashik and Puducherry. The company has started one of the largest end-fired container glass furnace of 650 tonnes per day capacity at Nasik in 2012. HNG Float Glass Limited is a HNG group company incorporated in Halol (Gujarat) in 2006. The company has an installed capacity of 600 tonnes per day.

1.8.3 AGI Glaspac

AGI Glaspac was established in the year 1972 and manufactures glass containers to meet the packaging needs of the food, pharmaceuticals beverage, soft drink, liquor, cosmetic and other industries. The manufacturing facilities are located in Hyderabad and Bhongir (Andhra Pradesh) near to the raw-material sources. The Bhongir plant with two furnaces of 500 tonnes per day melting capacity each is largest container glass plant in the country at single location. With four furnaces in two plants the AGI's melting capacity is 1600 tonnes per day in flint, green and amber colour.

1.8.4 Piramal Glass

Piramal Glass with an installed capacity of 1115 tonnes per day is one of the largest manufacturers of flacconage glass for the pharmaceuticals and perfumery and is among the top five manufacturers of perfumery bottles in the world. Piramal glass also manu facture glass bottles for specialty food and beverages. In India, Piramal glass has two major facilities at Kosamba and Jambusar (Gujarat). The Kosamba facility with 6 furnaces has combined capacity of 340 tones per day. The Jambusar facility with a capacity of 355 tonnes per day is one of the world's largest installed capacity for pharmaceutical packaging in amber glass.

1.8.5 Gujarat Guardian Limited

Gujarat Guardian Ltd. manufacturer of float glass and other allied products is a member of Guardian Industries Corporation (U.S.A). The manufacturing facility is located at Ankleshwar (Gujarat).

1.8.6 AIS / Asahi India

AIS is one of the largest manufacturer and supplier of automotive and float glass in the country. The manufacturing facilities are located at Bawal (Haryana), Roorkee (Uttarakhand), Chennai (Tamil Nadu) and Taloja (Maharashtra).

1.8.7 Gold Plus Glass

Gold Plus Glass is the first 100% Indian owned company to manufacturing float glass in country. The company has one float glass manufacturing unit (capacity 470 tonnes per day) at Rorkee (Uttrakhand) and two processing units at Sonipat (Haryana) and Kala Amb (Himachal Pradesh).

The installed capacity and the utilisation factor of the major glass manufacturers in India during 2009-10 are shown in table 1.8.7.

Table 1.8.7: Installed capacity and utilisation of float glass units

Manufacturers	Installed capacity (tonnes per day)	Capacity utilisation (%)
Gujarat Guardian Ltd.	550	95
Asahi India Glass Ltd (Two plants: 500+700)	1,200	80
Saint- Gobain Glass India Ltd (Two plants: 600+800)	1,950	80
Gold Plus Float Glass Industry Ltd	460	85
HNG Float Glass Ltd	600	75
Total	4760	

Source: Glass Yug, Jan-Mar 2010

The company-wise market share of float glass in Indian market during 2009-10 is shown in figure 1.8.1 (Source: Glass Yug).

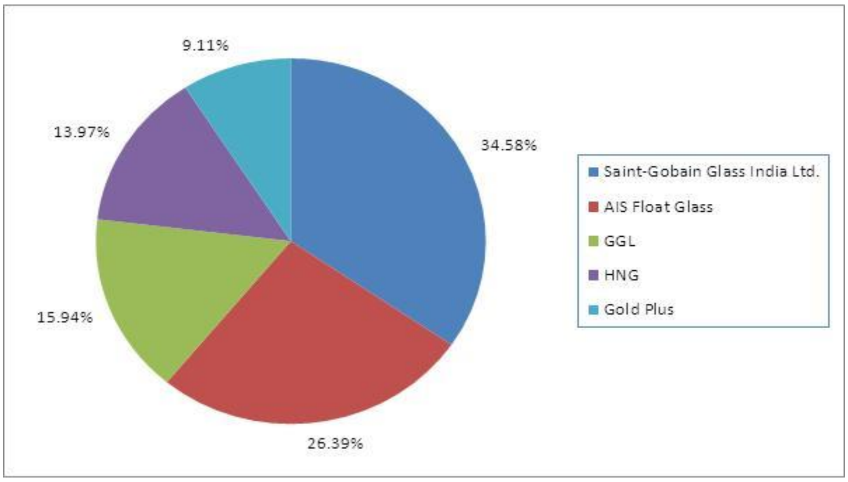

Figure 1.8.1: Company wise market share of Float Glass

1.9 Current regulatory / policy scenario

There are no specific policies that focus on glass industries. The general industrial policy of the Government of India is applicable to the glass industry as well. It may be noted that few energy efficient technologies that are related to fibre glass reinforced products, glass melting and forming have been included under the 'Credit Linked Capital Subsidy Scheme' (CLCSS) of the Ministry of Micro, Small and Medium Enterprises (MSME). Further, the Confederation of Construction Products and Services have brought out "Guidelines on use of glass in buildings-human safety" during November 2007 which is aimed to reduce risks related to accidents in glass sector.

2.0 Energy performance

2.1 Glass manufacturing process

Glass manufacture, regardless of the final product, requires four major processing steps (i) batch preparation, (ii) melting and refining (iii) forming, and (iv) post forming. An overview of the general flow of glass manufacture is illustrated in figure 2.1.1. The detail glass manufacturing process is provided in Annexure 2.1.1.

Source: U.S. Department of Energy

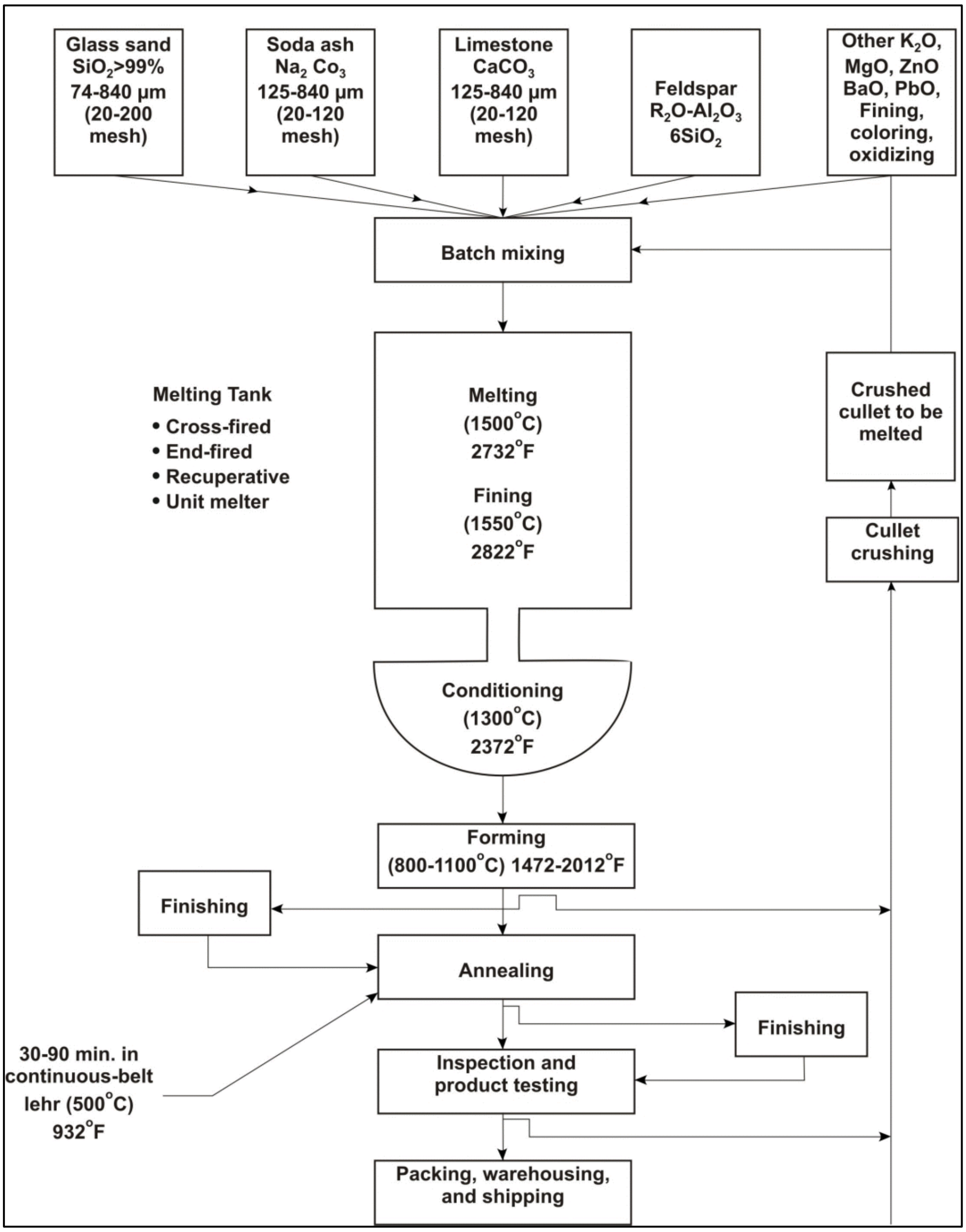

Figure 2.1.1: Overview of Glass Manufacture

2.2 Energy consumption in glass industry

The glass industry is highly energy intensive and energy consumption is a major cost driver. Energy costs include power consumption and running cost of furnaces. The average energy cost as a percentage of manufacturing cost is about 40 percent.

2.2.1 Major energy consuming areas in glass manufacturing

The most energy intensive portion of the glass-making process, regardless of product type, is melting and refining. This portion of glass manufacturing accounts for 60–70% of the total energy use in the glass industry.

i) Batch preparation

Electricity is mainly used in batch preparation for different equipment's like bucket elevators, pneumatic conveyors, batch mixers or blenders and agglomeration of materials. The blender or batch mixer accounts for the greatest share of electricity use in both batch preparation and charging of the furnace.

ii) Melting and refining

Melting and refining of the glass batch is the most energy-intensive part of glass manufacture as high temperature chemistry is involved in glass formation. Melting of raw materials consumes about 60-70 percent of the total energy used in glass production. In general, about 40 percent of the energy consumed in melting goes toward heating the batch and for the chemical conversion of the batch constituents.

Theoretically, 645 kWh are required to melt one short ton of glass. In reality, however, most modern furnaces consume significantly more energy, depending on the percentage of cullet in the feed. In general, only about 33-40% of the energy consumed by a continuous furnace goes toward melting the glass. Up to 30% of the energy consumed by a furnace can be lost through its structure, while another 30% can be lost through flue gas exiting the stack.

Melting furnaces are fired with fossil fuels (mostly natural gas) or by electricity (electrical resistance heating). In some cases a combination of both is used. Most large continuous furnaces are fuelled with natural gas. Many of these melters also use electrical boosting, where the melt is "boosted" by being resistively heated rather than by adding a resistive heater. Electric boost and other techniques such as oxygen-enriched combustion air, cullet preheating, better combustion control, or increased insulation, can lower fuel requirements or increase glass production at the same fuel load.

iii) Glass forming

The energy used in forming is highly product dependent and can account from 12 % (flat glass) to 34% (for fiber forming) of total primary energy consumed in glass production. In flat glass production, electricity is used to maintain the molten state of the tin bath and to drive rollers. In the production of glass containers, final form is obtained using either compressed air (blow and blow method) or a combination of compressed air and electricity-driven mechanical pressing (press and blow method). The primary forming processes used in specialty glass production—press and blow, press-forming, lamp-forming, spinning, and drawing—are also electricity-driven. In the production of glass wool, both electricity (for rotary spinners and conveyors) and fuels (for steam blowing or flame attenuation) can be consumed.

iv) Post forming and finishing operations

Annealing process typically consume 2 - 5% of the total final energy in a glass plant. Tempering can occur in either an electric or natural gas-fired furnace. Automotive flat glass typically undergoes mechanical bending prior to tempering to attain desired curvature. Autoclaves are mostly powered with electricity.

2.2.2 International scenario in energy consumption

The energy consumption of float glass production is higher than container glass production. The specific energy consumption (SEC) for speciality glass products such as TV panel glass is even higher due to higher quality requirements. The comparison of physical aspects of typical Indian float glass manufacturing company with a typical overseas float glass manufacturing company is provided in table 2.2.2a (Source: Kanch, April–June 2012). It may be seen that the melting capacity of overseas company is about 2.4 times of Indian company.

Table 2.2.2a: Comparison of float glass manufacturing process–India vs overseas company

Item	Overseas company	Indian company
Furnace type	Side port regenerative	Side port regenerative
Furnace capacity	1600 tpd	650 tpd
Furnace fuel	Natural gas / furnace oil	Furnace oil
Electrical boosting	Yes	Yes
Melting temperature	1593 °C	1580 °C
Exit temperature-tin bath	1093 °C	1050 °C
Furnace area	53.1 x 9.1 m^2	33.6 x 8.5 m^2
Glass level	1.22 m	1.05 m
Tin bath entrance	1038 °C	1005 °C
Tin bath exit	68 8°C	650 °C
Tin bath length	48 m	58 m
Width (front/ back)	6.1m / 4.3m	6.0m/ 4.2m
Volume of tin	150m^3	165m^3
Depth of tin	5.1 – 7.6 cm	5.5 – 7.5cm
Bath atmosphere	94% N_2 + 6% H_2	94% N_2 + 6% H_2
Number of rolls	6 on each side	7 on each side
Roll-to-roll	1.5m	1.5m
Lehr entrance	607 °C	610 °C
Lehr exit	282 °C	285 °C
Lehr length	116 m	110m

The SEC reported through a benchmark survey carried out in 1999 including 123 container glass furnaces and 23 flat glass furnaces operated world-wide is provided in table 2.2.2b. The variation in SEC is shown in figure 2.2.2 (Source: UNIDO 2010).

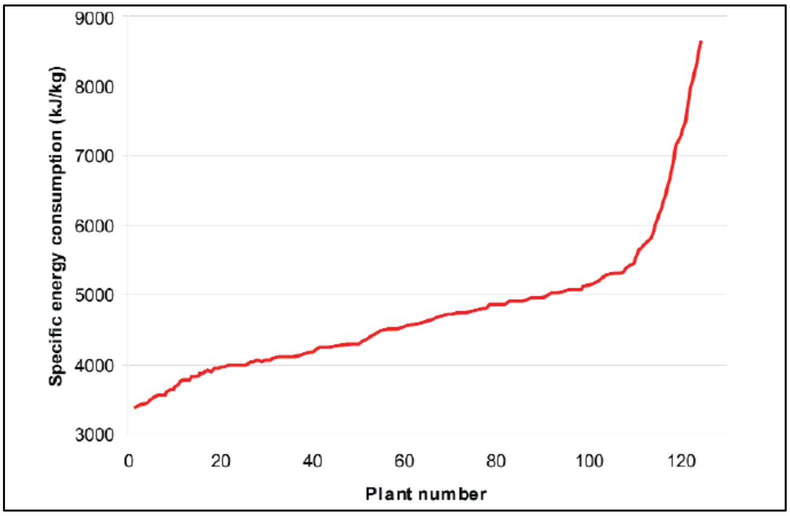

Figure 2.2.2: SEC range of continuous container glass furnaces (normalized for 50% cullet)

Table 2.2.2b: Specific Energy Consumption

Type of furnace	Specific energy consumption (KJ of glass produced)
Best operating furnace	3,850
Least efficient furnace	8,000
Average	5,200

The energy consumption in different processes in glass manufacturing process in US industry is provided in table 2.2.2c. The corresponding figures for Indian glass industry are not readily available.

Table 2.2.2c: Average SEC of glass industry in USA

S. No.			Batch Preparation SEC (kWh / tonne)	Melting Furnace SEC (kWh / tonne)	Forming SEC (kWh / tonne)	Post-forming and Finishing SEC – NG/ FO (kWh / tonne)	Post-forming and Finishing SEC– Electricity (kWh/ tonne)
1	Flat Glass						
			79	-	440	-	-
	Furnace Type	▪ Regenerative		2491	-	-	-
		▪ Electric boost		1905	-	-	-
		▪ Oxy-fuel		1377	-	-	-
	Process	▪ Annealing	-	-	-	117	2.93
		▪ Tempering (gas)	-	-	-	1172	56
		▪ Tempering (electric)	-	-	-	-	542
		▪ Laminating	-	-	-	293	-
		▪ Autoclave	-	-	-	147	41
2	Container Glass						
			155	-	105	-	-
	Furnace	▪ Regenerative	-	2286	-	-	-

S. No.			Batch Preparation	Melting Furnace	Forming	Post-forming and Finishing	
	Type	▪ Electric boost	-	1377	-	-	-
		▪ Oxy-fuel	-	1172	-	-	-
		▪ Electric melter	-	821	-	-	-
		▪ Direct melter	-	2491	-	-	-
	Process	Annealing and Finishing	-	-	-	469	67
3	Pressed and Blown Glass						
			223	-	1553	-	-
	Furnace Type	▪ Regenerative	-	1612	-	-	-
		▪ Direct Melters	-	3517	-	-	-
		▪ Oxy-fuel fired	-	1055	-	-	-
		▪ Electric melters	-	3019	-	-	-
	Process	Annealing and Polishing	-	-	-	879	15
4	Fibrous Glass						
			337	-	2110	-	-
	Furnace Type	▪ Electric melters	-	2198	-	-	-
		▪ Recuperative melters	-	2051	-	-	-
		▪ Oxy-fuel fired	-	1641	-	-	-
		▪ Glass wool	-	-	-	1290	-
		▪ Textile Fibre	-	-	-	961	-
5	Textile / reinforcement fibers						
	Furnace Type	▪ Recuperative melters	-	3077	-	-	-
		▪ Oxy-fuel fired	-	1641	-	-	-

Source: U.S. Department of Energy, 2002

2.2.3 Energy saving opportunities in glass industry

Melting process accounts for more than 60% of the total energy consumption in glass industry. The share of energy consumption of different processes in glass industry is shown in figure 2.2.3a (Source: Kanch, Vol 5, No 4, Jul-Sep 2012). Other major processes such as forming and refining & conditioning are other major energy consuming areas.

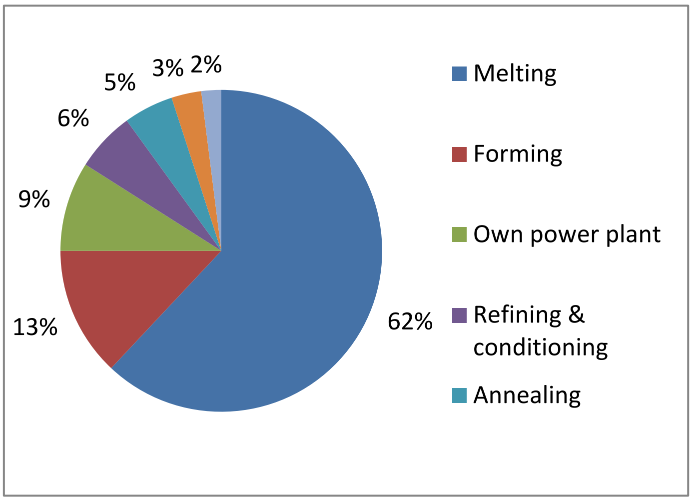

Figure 2.2.3a: Energy consumption in glass manufacturing industry

The energy balance of a glass manufacturing unit in Vietnam engaged in the production of fluorescent lights is shown in figure 2.2.3b. The heat balance figure shows various heat loss areas in a melting furnace that could be reduced effectively.

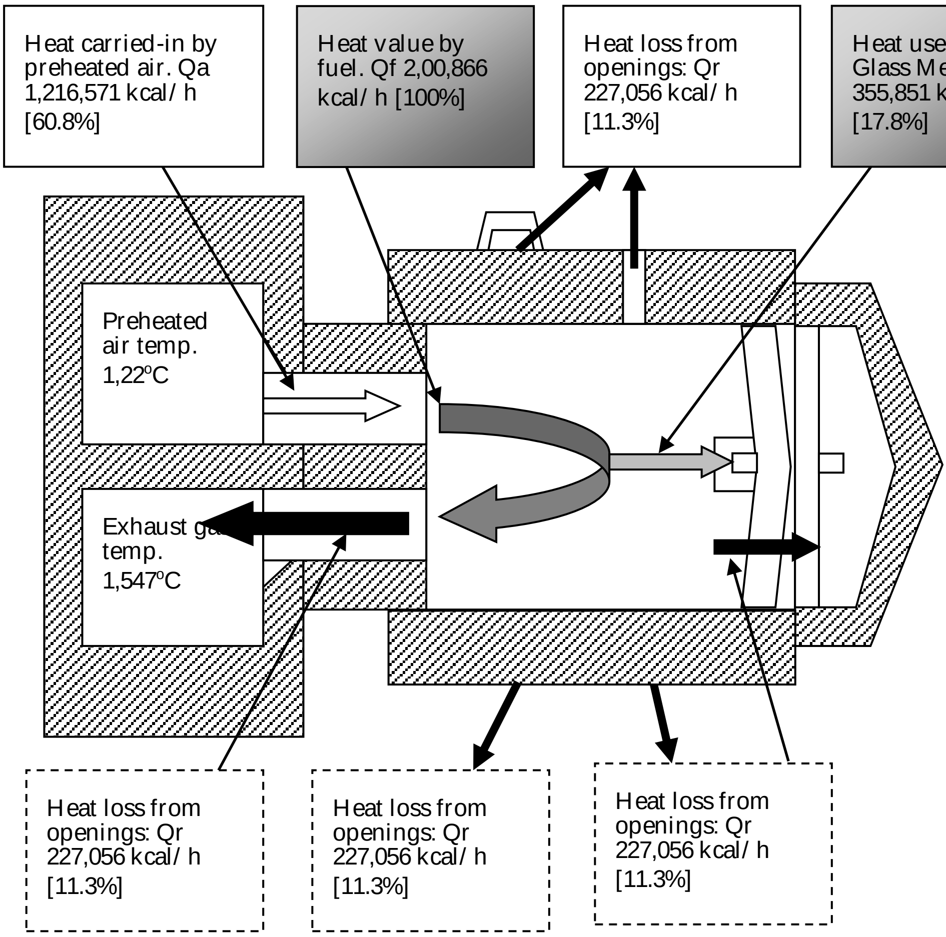

Figure 2.2.3b: Energy balance of glass melting furnace

2.2.4 Melting furnace

A glass melting furnace that is commonly known as 'tank' is a large box built of accurately shaped refractory pieces bound together by a steel structure outside. Most furnaces are fuel fired with flame being burned over the surface of the melt. The residence time in the glass tank is an important factor in the energy intensity of glass production; therefore, the pull rate of the furnace should be optimized. Improvements in annealing and forming of the product may affect the pull rate, reduce reject rates, and hence reduce the energy intensity of the glass tank and final product. Therefore, while evaluating energy efficiency measures, the interactions between the different production steps should be carefully considered. Figure 2.2.4 shows the seven steps to good melting process.

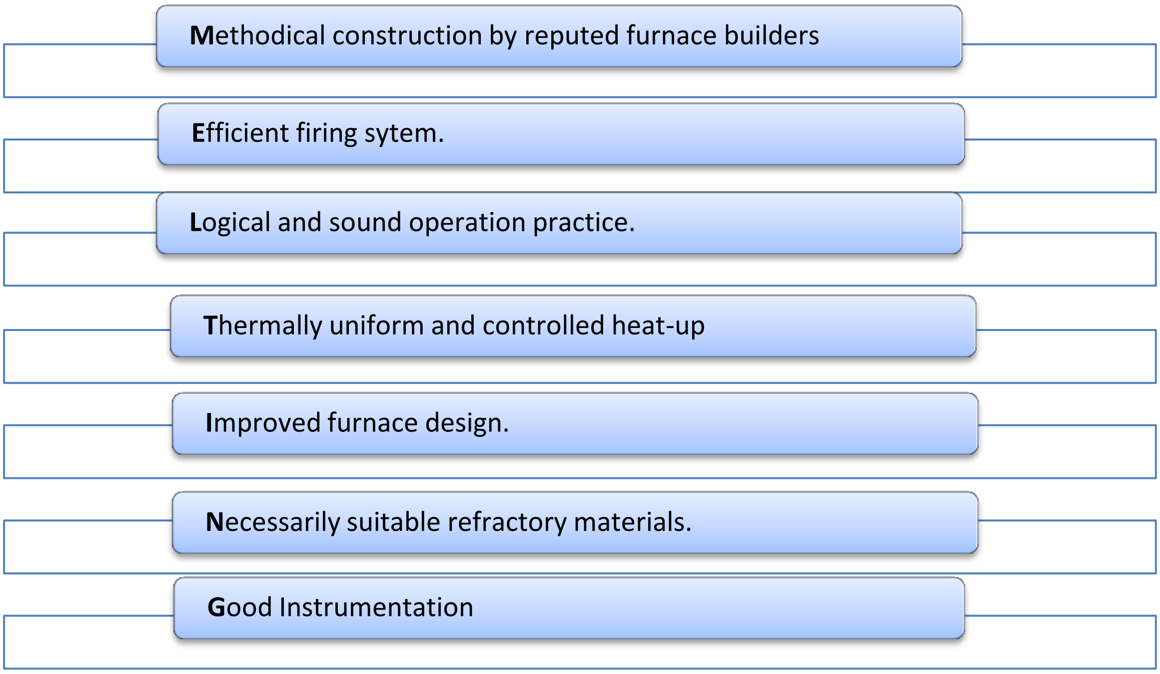

Figure 2.2.4: Seven steps to good melting process

i) Improvement in combustion control

Combustion in glass tank furnace takes place above the glass level and most of the heat is transferred to the glass melt by radiation. The efficacy of combustion depends upon various parameters such as furnace and burner design, burner position, fuel-air proportion, flame length etc. The three most important factors that influence an efficient combustion are excess air, preheat air temperature and cold air infiltration. Combustion can be checked by measuring the limits of carbon-di-oxide (CO_2), carbon monoxide (CO) and oxygen (O_2) in the exhaust gas.

ii) Minimum excess air

Theoretically, the percentage of CO_2 in oil-fired systems ranges from 14 – 16% depending on the type of oil. However, in practice, the optimum level of CO_2 is around 12 – 13%. This can be used as a criteria for judging the efficiency of combustion, as lower O_2 values are obtained by burning a fuel-rich mixture. Optimum CO_2 values should be achieved with a brown hazy smoke. The ratio of primary air to total air should be around 8% and secondary air to total air around 92%.

iii) Preheating combustion air

Exhaust gases leave the furnace at high temperatures between 1500°C and 1580°C, a substantial part of the latent heat of these gases can be used to pre-heat the air supplied for combustion.

v) Influence of cold air

The secondary air used for combustion is preheated by the heat exchanger. The primary air for spraying and air intruding from the clearance of the burner tiles enter the furnace in cold conditions. Reduction in volume of intruding cold air helps to conserve energy. It has been observed that a cold air reduction by 1% results in fuel savings by 0.5%.

vi) Refractories/ insulation

Refractory materials and refractory engineering plays a very important role in performance of glass melting furnaces. Due to the improvement in the quality of refractory materials used for construction of glass melting furnaces the average life of modern glass melting tank furnaces has continuously improved. Insulation reduces heat losses by about 55 to 65%. General problem that exist with the furnace insulation are higher corrosion rates and rat-holes in the silica crown. Over the life-time of furnace, insulation material wears off and increases the heat loses. The deteriorating refractories may lead to increase in energy losses by 0.1 – 0.2%/ month. The common refractory materials used for various parts of the furnace are shown in table 2.2.4.

Table 2.2.4: Common refractory materials

Furnace area	Material
Glass contact area	Alumina, zirconia
Melter area	Silica fused cast material
Excessive corrosion areas such as throat, barrier walls, dog house corners	Chromic oxide containing fused cast blocks
Refining area or distributor	Alumina blocks for minimal exudation and quality problem
Furnace superstructure	Alumina Zirconia silica electrocast or super silica bricks
Crown	Super silica bricks
Bottom	Multi layered with flux blocks, zircon bricks, special refractory cement or concrete and finally alumina zirconia silica electrocast paving tiles

vii) Proper burner positions

Furnaces should have the proper angle between the burner axis and the glass surface. The burner angle not only affects the efficiency of heat transfer to the melt, but may also affect NO_x formation and dust emissions. The burner angle should be optimized for heat transfer to the melt.

viii) Burner sealing

Burners may be sealed in the furnace burner block to avert outside air that is normally drawn into the furnace through the furnace block. This air can make up as much as 15% of the total stoichiometric air, but is typically 3 to 5%. If 5% cold air is eliminated, 2 to 3% of energy can be saved.

ix) Oxygen enrichment

During combustion, oxygen combines with carbon and hydrogen of fuel to liberate heat. The inert gases of air absorb heat from the combustion and carry it out of the furnace resulting in heat loss in addition to reduction in flame temperature and reduced rate of heat transfer to stock. Reduction in inert content of the air can result in more efficient combustion. This can be done by addition of oxygen to combustion air. With the same fuel input, enriched air helps in raising the flame temperature, increasing heat transfer and enhancing production rate. It is reported that additional 1.6% oxygen in combustion air can result in fuel savings of 8 to 10%.

x) Furnace operation

The furnace should be operated at a slightly positive pressure. Negative pressure leads to air infiltration, affecting air-fuel ratio and furnace temperature resulting in increased fuel consumption. However, excessive positive pressure lead to exfiltration resulting in leaping out of flames, overheating of furnace refractories, reduced brick life and other associated problems. A reasonable pressure would be 0.25 mm wg.

xi) Exhaust recovery by regeneration

The regenerator is commonly used with glass melting tank furnaces. The regenerator comprises chequer bricks to absorb the heat of exhaust gas. After combustion, gas is fed to the regenerator for 15 to 20 minutes to heat the bricks. Combustion air is then fed to absorb heat from the chequer bricks. This procedure is repeated at specific intervals known as reversal time. Hence, two regenerators are required for each furnace. With an effectiveness of 85-90%, the regenerators produce extremely high levels of air preheat (about 85% of process temperature) bring about substantial fuel savings of up to 65%.

3.2.5 Glass recycling

Recycling implies the substitution of some raw materials with used glass or cullet. Since no chemical reactions takes place in melting the cullet, recycling reduces consumption of raw materials and saves energy. Higher thermal conductivity of scarp glass compared to the basic raw materials also ensures improvement in melting. Glass containers are 100% recyclable. In container glass manufacturing, cullet use can vary from 10% to over 90%. In the European Union, the average cullet use in container glass production is 60% and ranges from 95% for Belgium and 90% for Germany to 34% for UK and 27% for Greece (Glass Gazette 2003). For flat glass production, cullet can be as high as 20–40% for green flat glass and lower for clear flat glass. Increasing the cullet share by 10% (weight basis) the net energy consumption is reduced by 2–3.5%. The end of life route for container glass in India is provided in table 2.2.5.

Table 2.2.5: End of life route of container glass in India

Type of flat glass	Recycling rate	Landfill rate	Reuse
Container glass	32%	38%	30%

2.2.6 Batch and cullet preheating

In a cullet preheater, the waste heat of the fuel-fired furnace is used to preheat the incoming cullet batch. Batch preheating is more difficult than cullet preheating, as clumping of incoming materials can affect the product quality and melting efficiency. In theory, any system with over 50% cullet in the batch can install preheaters. Energy saving of cullet preheaters is estimated to be around 12 – 20%.

3.0 Analysis of energy consumption data

3.1 Methodology

The following methodology has been adopted to analyze the energy consumption data:

- Analysis of energy consumption data measured and collected during energy audits of different types of major glass industries by TERI
- Analysis of data collected during energy efficiency study in MSME units involved in glass manufacturing in Firozabad glass cluster
- Collation of data from annual reports of major glass manufacturing units

3.1.1 Gross calorific value of fuels

Different type of fuels are used in glass manufacturing process in India. The gross calorific value (GCV) and conversion factors used during analysis of energy consumption are provided in table 3.1.1 and table 3.1.2 respectively.

Table 3.1.1: Gross calorific value of various fuels

Fuel	Gross calorific value	Unit	Specific gravity (kg/unit)
Electricity	860	kcal/ kWh	–
LPG	12500	kcal/ kg	1.287
Furnace Oil (FO)	10050	kcal/ kg	0.9337
High Speed Diesel (HSD)	11840	kcal/ kg	0.8263
Light Diesel Oil (LDO)	10700	kcal/ kg	0.8600
LSHS	10600	kCal/ kg	0.93

Table 3.1.2: Conversion factors

1 kwh	0.00009	toe
1 Kcal	0.0000001	toe

3.2 Energy consumption in major Indian glass industries

Glass manufacturing consumes a sizeable portion of energy in the process. The energy consumption of few major Indian glass industries based on annual reports and energy audits carried out by TERI are shown in table 3.2a and 3.2b respectively. It is evident from the tables that the thermal energy consumption in glass industry accounts for significant share of the total energy consumption, which is about 80%. Furnace oil and Natural Gas are the major fuels used in Indian glass industry.

Table 3.2a: Energy Consumption in few Indian Companies (annual reports)

	HNG				Piramal Glass India Ltd.				Sezal Glass Ltd		Asahi India Glass Limited			
Products	Glass containers for liquid and beer, food, pharmaceuticals and cosmetic industries, Float Glass				Flacconage glass for the pharmaceuticals and perfumery, glass bottles for specialty food and beverages				Insulating glass, tempering glass, Laminated glass		Automotive safety glass, float glass and value-added glass like reflective glass, mirror and architectural			
	2010-11		2011-12		2010-11		2011 - 12		2009 - 10		2005-06		2006-07	
Installed capacity	2930 tpd				700 tpd		700 tpd		1725000 sq.m		-		-	
Total production (tonne)	936863		829624		-		-		-		Laminated windshield - 1579721 (pcs); Tempered glass (sqm)-2937861; Float glass (csqm)-24,422,779		Laminated windshield - 2002137 (pcs); Tempered glass (sqm)-3448074; Float glass (csqm)-38,999,031	
	Total	toe	Total	toe	Total	toe	Total	toe	Total	toe	Total	toe	Total	toe
Electricity (mil kWh)	3723	32015	330.9	28461	114.6	9853	111.8	9612	9.257	796	91.7	7,887	121.4	10,445
HSD (kL)	1565	1531	8495	8311	-	-	-	-	-	-	-	-	-	-
LPG (tonne)	8535	10669	77271	96589					31,200	39				
FO/ RFO/ E q.oil (kL)	83456	78312	1402	1316	6,371	5978	2,503	2349			9,620	9,027	22,833	21,426
LNG (MMBTU)	1667616	42056	721773	18202	–	–	–	–	–	–	-	-	-	-
Kerosene oil (lit)	–	–	–	–							96,000	87	24,700	22
LSHS (tonne)	–				–	–	–	–	–	–	22,501	23,851	31,642	33,540
NG (mil	–	–	–	–	65.6	58471	67.9	0.24	4.6	4135				

	HNG				Piramal Glass India Ltd.				Sezal Glass Ltd		Asahi India Glass Limited			
Sm³)														
LDO (kL)	46.8	43.10	-	-	-	-	-	-	-	-	4979	4582	442	407
SEC (toe/ tonne)		0.176		0.184		0.303		0.296		-				
Share-Thermal energy	-	80%	-	76%	-	87%	-	87%	-	83%	-	81%	-	84%
Share - Electrical energy	-	20%	-	24%	-	13%	-	13%	-	16%	-	19%	-	16%

Table 3.2b: Energy Consumption in few Indian Glass manufacturing companies (energy audits)

	Victory Glass Industries Ltd.				AGI Glasspac, Hyderabad				AGI Glasspac, Bhongir		Binani Industries, Glass Fibre Goa		Durgesh Block & China Glass Works Ltd.	
Products	Glass for bottles, liquor industries				High quality glass for packaging industries				High quality glass for packaging industries		Glass fibre products, chopped strand mat woven roving		High quality glass bottles, bulb shells, container glass and assorted glassware items	
	1996-97		1997-98		2009-10		Apr 2010- Sep 2010		2009-10		1997-98		2011	
Installed capacity	110 tpd				300 tpd				450 tpd		6600 tpa		120 tpd	
Total production (tonne/ year)	24354		19527		171607		64632		156585		5746		35700	
	Unit	toe/ t	Unit	toe/ t	Total	toe/ t	Total	toe/ t	Total	toe/ t	Total	toe/ t	Total	toe/ t
Electricity (million kWh)	1.87	0.0007	2.0	0.0009	70.915	0.0036	28.366	0.0038	40.937	00.022	17.42	0.0261	–	–
HSD (KL)	1716.5	0.069	908.3	0.046	199542	1.138	115565	1.749			355	0.060	–	–
LPG (MT)					4234.9	0.031	1672.5	0.032	2941.37	0.023	334	0.073	–	–
Furnace Oil (KL)	3305.8	0.127	2431.8	0.117	7650.12	0.042	145	0.002	14497	0.087	880	0.144	–	–
NG (Sm3/ year)	–	–	–	–	–	–	–	–	–	–	–	–	10150000	0.245
LSHS (KL)	778.4	0.032	NA		14610	0.084	7973.7	0.122						
NG (m^3)	–	–	–	–	–	–	–	–	–	–	–	–	–	–
LDO (KL)	624.7	0.024	446.7	0.021	–	–	–	–	–	–	–	–	–	–
SEC (toe/ tonne)		0.258		0.192		1.330		1.943		0.133		0.538		0.245
Share- Thermal energy		97.4%		95.4%		97.3%		98.1%		83.1%		51.5%	–	100%
Share- electrical Energy		2.6%		4.6%		2.7%		1.9%		16.9%		48.5%	–	–

3.2.1 Energy consumption in Indian Glass Industry

In India, container glass production is more than the float glass production. As per All India Glass Manufacturing Federation, total container and float glass production during 2011-12 was 7500 tonnes per day and 4760 tonnes per day respectively. Considering 80% of the total energy consumption in glass manufacturing is accounted by the thermal energy requirements, the estimated total energy consumption of Indian glass industry is given in table 3.2.1.

Table 3.2.1: Production and energy consumption in Indian glass industry

Type of glass	Production during 2011-12 (million tonne per year*)	Energy consumption per year (mtoe) #			Share
		Thermal	Electrical	Total	
Container	2.74	0.60	0.15	0.75	65%
Float	1.74	0.24	0.06	0.30	26%
Others	0.19	0.07	0.02	0.12	9%
Total	4.66	0.91	0.23	1.17	100%

**Source: All India Glass Manufacturing Federation, Glass Yug and TERI*

 # Energy consumption of 6800 kcal/kg for container glass and 4400 kcal/kg for flat glass are considered for melting (UNIDO 2010)

3.2.2 Energy consumption in Firozabad glass cluster

Firozabad, a small town about 40 kilometres from Agra is one of the leading glass clusters in India. There is a large agglomeration of small-scale units engaged in the manufacture of bangles, hollow wares, decorative items, glass beads and headlight covers etc. The cluster is very important because of the fact that the bangles in India are almost exclusively produced in this cluster.

Closed & open pot furnace and tank furnace are the major glass melting technologies used in the cluster. There are other auxiliary furnaces such as muffle furnace, reheating furnace etc. which are involved in glass processing chain. The major forms of energy used in the cluster are piped natural gas (NG) supplied by Gas Authority of India Limited (GAIL). The total energy consumption of the cluster in producing melt-glass is about 0.19 million tonnes of oil equivalent per year. Considering the importance and high energy consumption in the cluster, possibility of considering the cluster as a 'Designate Cluster' may be explored in the future[3].

3.2.3 Energy consumption by large industries in India

The energy consumption of few large glass manufacturing industries has been provided in table 3.2.2. The energy consumption levels are estimated based on the average Specific Energy Consumption of float and container glass respectively. The actual energy consumption by these industries could be verified by carrying out actual measurements during field visits. However, estimates clearly highlight the large energy consumption by

[3] The idea of 'Designated Cluster' was put forward during the National Summit on 'Energy Efficiency in MSMEs' organized in July 2012 by TERI, SDC, BEE and MoMSME

these industries. The energy consumption by few large glass manufacturing companies in India is provided in table 3.2.2 and figure 3.2.3. It may be noted that the total energy consumption of 28,175 toe per year to about 378,692 toe per year across different glass companies.

Table 3.2.2: Energy consumption by few large glass manufacturing companies

Name of the company	Production (million tonnes per year)*		Total energy consumption (toe per year) #
	Container glass	Float glass	
Hindustan National Glass & Industries Ltd	1.283	0.175	378,692
Saint Gobain	-	0.569	126,673
AGI Glasspac	0.467	-	99,895
Piramal Glass (Indian facilities)	0.203	-	55,024
Gujarat Guardian	-	0.161	28,175
Asahi India Glass Ltd		0.350	61,474
Gold Plus Glass	-	0.137	24,077

**Based on a weighted average capacity utilisation of 80% of the installed capacity (Glass Yug, Jan-Mar 2010)*
 # Energy consumption of 6800 kcal/kg for container glass and 4400 kcal/kg for flat glass are considered for melting (UNIDO 2010)

The cumulative values of energy consumption of different companies (estimated) have been provided in the report since the energy consumption of individual plants of each glass companies are not available. Therefore threshold limit for energy consumption for glass sector is not provided in the report.

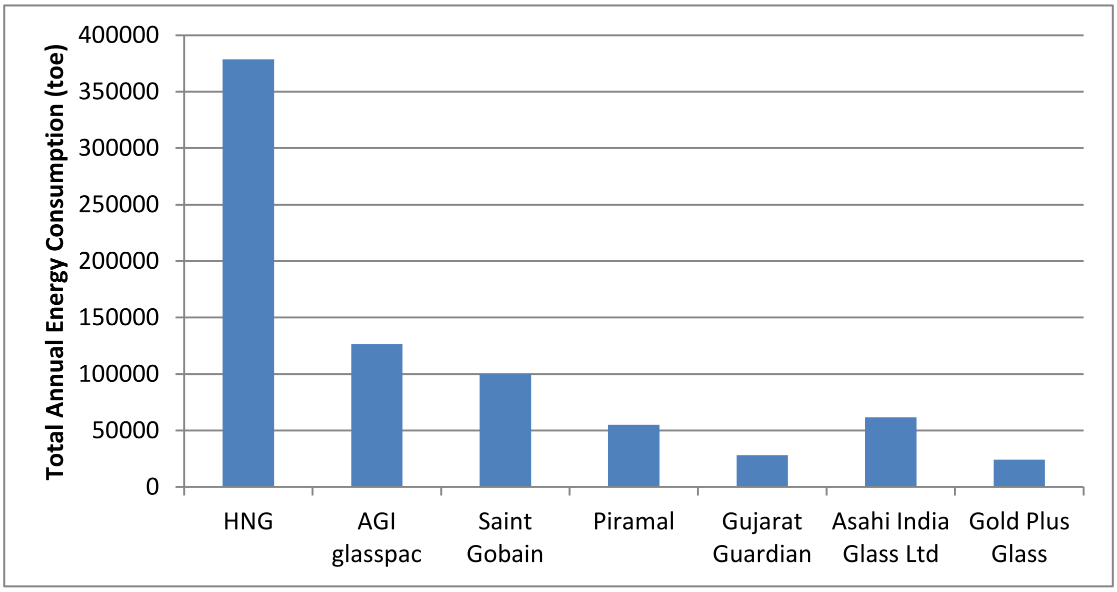

Figure 3.2.2: Estimated energy consumption by few large glass manufacturing companies

4.0 Conclusions

The energy consumption in glass industry shows that substantial share of energy consumption is accounted by thermal energy and there exists significant scope for energy efficiency improvements both in process and utility areas. There are few large players in glass industry engaged in the production of float and container glass accounting for major energy consumption in glass sector. The total annual energy consumption of these major players is estimated to be 0.78 mtoe, which is about 66 % of the total energy consumption of glass sector.

The energy consumption by glass industries is quite significant for different group companies and a number of plants involved in the production of float glass and container glass would qualify to be 'Designated Consumers' (DCs). However, for a number of such major players (e.g. Saint Gobain, Hindustan National Glass, Asahi Glass and Gold Plus Glass), details like installed capacity, production and energy consumption of their individual glass plants are not readily available. Energy consumption of individual plants would be required to propose threshold limits and consider them as DCs. Therefore, it is suggested to undertake a glass-sector specific study to estimate energy consumption and set threshold limit for the glass sector.

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Annexure 1.7.1

Contact details of regional associations of All India Glass Manufacturing Federation

1. Northern India Glass Manufacturers' Association (NIGMA)
   c/ o Universal Glass (A division of Jagatjit Industries Limited), Plot No. 17, Site IV, Industrial Area, Sahibabad, Ghaziabad – 201010 (UP)

2. South India Glass Manufacturers' Association (SIGMA)
   c/ o Universal Glass (An SBU of HSIL Ltd.),
   Glass Factory Road, Off Motinagar,
   P B No. 1930, Sanathnagar, PO Hyderabad – 500018

3. Western India Glass Manufacturers' Association (WIGMA)
   c/ o Pragati Glass Works (P) Ltd.,
   111, Damji Shamji Industrial Complex,
   9, LBS Marg, Kurla (W), Mumbai – 400 070

4. Eastern India Glass Manufacturers' Association (EIGMA)
   c/ o Asoke Enamel & Glass Works (P) Ltd.,
   34-A, Metcalfe Street, 1st Floor,
   Kolkata - 700013

Annexure 2.1.1

Glass Manufacturing Process

2.1 Batch preparation

In this step the raw materials for glass are blended to achieve the desired final glass product. While the main components in glass are high-quality sand (silica), limestone, and soda ash, there are many other components that can be added. The basic ingredients in the glass are called formers. Apart from it, the glass batch contains fluxes, stabilizers and sometimes colorants. Fluxes are added to lower the temperature at which the glass batch melts. Soda ash and potash are commonly used alkali fluxes. Stabilisers are used to make glass chemically more stable and to keep the finished glass from dissolving, crumbling or falling apart. There are number of additives that are used to colour and impart unique properties to glass. Cerium is often used to improve the ultraviolet (UV) absorption properties of optical glass, or to reduce x-ray browning effects. In some cases, small amounts of powdered anthracite coal, or even blast furnace slag, may be added to the batch to improve the melting characteristics of the glass, for reduction-oxidation control, or to replace feldspar. 'Cullet' is another raw materials that is used in the manufacture of glass. Cullet is recycled glass obtained from within the plant (rejects, trim, waste scrap) and from outside recycling firms. The commonly used glass components are shown in table 2.1a.

Table 2.1a: Common glass components

Formers	Silica (SiO_2)
	Boron/ Boric Acid (B_2O_3)
	Lead Oxide (PbO)
	Feldspar
Fluxes	Soda Ash (Na_2CO_3)
	Potash (K_2O)
	Lithium Carbonate
	Lithium Alumino Silicate
Stabilizers	Limestone ($CaCO_3$, CaO)
	Litharge
	Alumina (Al_2O_3)
	Magnesia (MgO
	Barium Carbonate (BaO)
	Strontium Carbonate
	Zinc Oxide
	Zirconia
Colorants	Iron (sulphides or pyrites)
	Cobalt Oxide
	Nickel Oxide
	Selenium

The chemical composition of some of the more commonly used glasses is provided in table 2.1b.

Table 2.1b: Approximate composition of different glass types (weight percent)

Oxide	Container Glass	Float Glass	Fiberglass (E-Glass)	Laboratory Ware
SiO_2	73	72	54	80
B_2O_3	-		10	10
Al_2O_3	1.5	0.3	14	3
CaO	10	9	17.5	1
MgO	0.1	4	4.5	1
Na_2O	14	14	-	5
K_2O	0.6	-	-	-

The summary of inputs and outputs for glass batch process are provided in table 2.1c.

Table 2.1c: Summary of inputs and outputs for glass batch

Inputs	Outputs
Sand/ silica and other formers, Limestone and other stabilisers, Soda ash / potash, Cullets, Colorants, Water, Electricity	Homogeneous batch, Particulates, Unusable raw materials, Filter residues

2.2 Melting

After mixing of raw materials, the batch is charged to a melting furnace. With the exception of few speciality glass manufacturing processes, continuously operated tank furnaces are commonly used for the melting of glass. A typical glass melting furnace (tank) consists of a batch charging area (doghouse) attached to a refractory basin covered by a refractory superstructure. As the batch passes through the melting furnace, it essentially goes through four phases:

- Melting
- Refining
- Homogenizing and
- Heat conditioning

A rough idea of all these processes is shown in figure 2.2a.

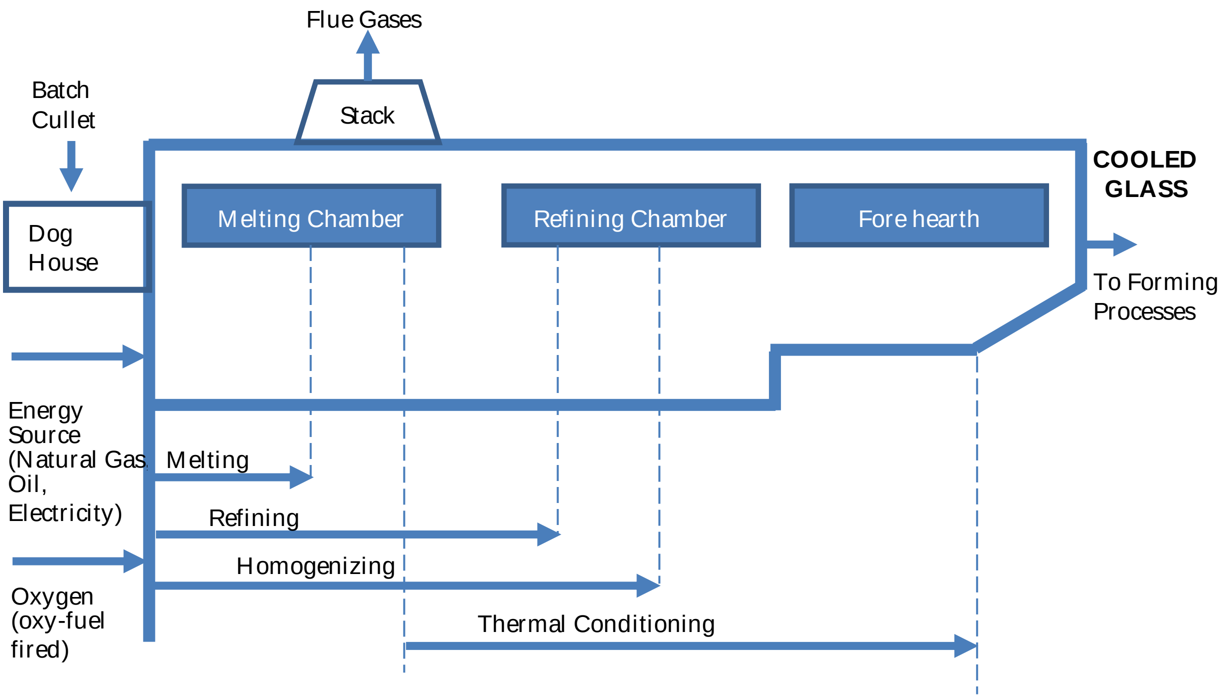

Figure 2.2a Melting and refining processes

Melting of the batch may be accomplished in many different types and sizes of furnaces, depending upon the quantity and type of glass to be produced. The melting step is complete once the glass is free of any crystalline materials. Optimally, melting should be complete before the batch has gone through the first half of the furnace. Melting rate depends on the furnace temperature, composition of the batch, grain size of the batch ingredients, amount and grain size of cullet, and homogeneity of the batch. For example, smaller grain batches will undergo melting quicker; batches with different grain sizes will melt slower. The addition of cullet reduces the amount of time required for melting, while poor homogeneity can seriously affect melting efficiency. This is most energy intensive operation in glass unit using thermal energy. Melting of raw materials consumes 60 – 70 percent of total energy used to produce glass. Various chemical reactions that occurs during glass manufacture are as below:

Dissolution of Sand with Soda Ash as Flux
$Na_2CO_3 + SiO_2$ B $Na_2SiO_3 + CO_2$ (1000EF)

Further Heating
$Na_2SiO_3 + SiO_2$ B $Na_2Si_2O_5$ (1300EF)

Formation of Liquid Eutectic Mixture
$3Na_2SiO_3$ • $SiO_2 + SO_2$ (1400EF+)

Carbonates in Limestone Decompose to Form other Eutectic Glasses
$CaCO_3 + nSiO_2$ B CaO • n $SiO_2 + CO_2$ (1400EF+)

The summary of inputs and outputs for glass melting process are provided in table 2.2a.

Table 2.2a Summary of inputs and outputs for glass melting

Inputs	Outputs
Crushed cullets, Glass batch, Refining agents, Natural gas, Fuel oil, Electricity, Air / Oxygen	Molten glass, Flue gas, Particulates / dust, Furnace slag, Refractory wastes

Refining (often referred to as fining) is the combined physical and chemical process occurring in the melting chamber during which the batch and molten glass are freed of bubbles, homogenized, and heat conditioned. Refining occurs throughout the melting chamber, beginning with the batch charge to the furnace and continuing until the complete dissolution of crystalline materials. The refining section of the furnace is typically separated from the main melting section by a bridgewall, while glass flows through a wall opening called the "throat." The exception is flat glass furnaces, in which case the opening between the furnace and refining area is above the surface of the glass.

While the process of melting and refining is very similar throughout the industry, the type of furnaces used may vary considerably. In general, furnaces are classified as discontinuous or continuous (figure 2.2b).

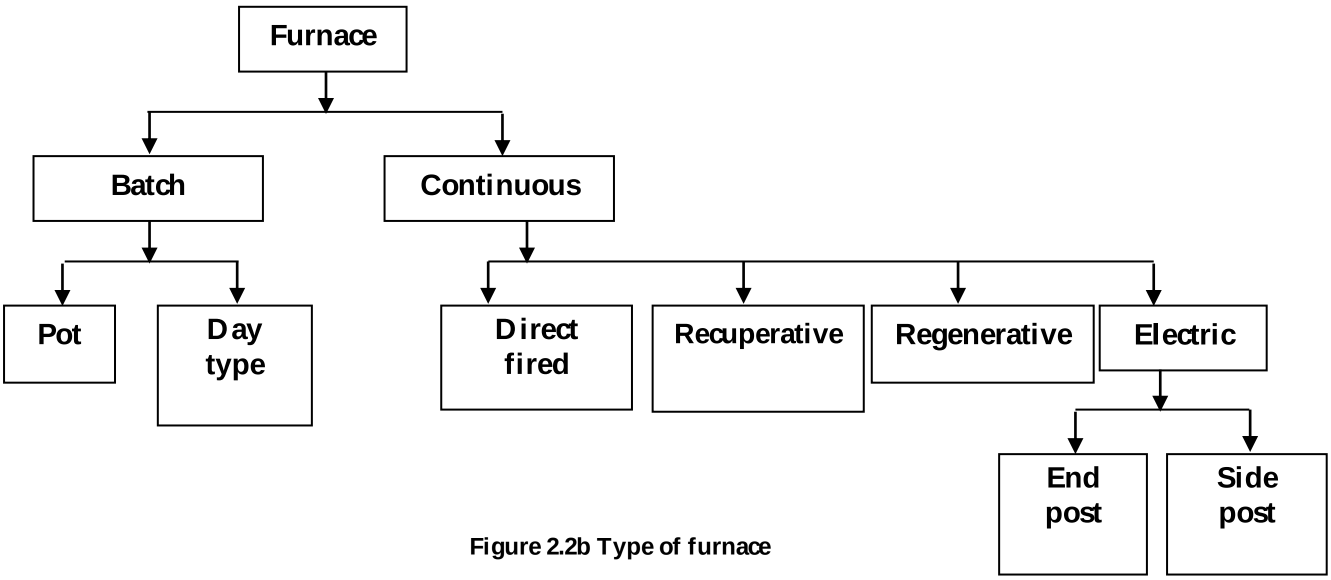

Figure 2.2b Type of furnace

2.2.1 Batch furnaces

Batch furnaces are used in smaller glass melting operations, typically of the order of less than five tons per day. They are operated for a short period of time and can usually go through the entire cycle of charging, melting, and removal of molten glass in a single day. Batch furnaces are either pot furnaces or day tanks. In a pot furnace, the glass is melted in a refractory pot inside the furnace, and the pot is externally heated. Pot furnaces may have single or multiple pots, and these may be open or closed. Day tanks are small units employing semi-manual operations, and the charging/ melting/ removal cycle is repeated daily. Day tanks are used for many types of specialty glass, and most commonly for opal, ruby, crystal, and soda-lime glasses.

2.2.2 Continuous furnaces

Continuous furnaces are found in larger operations and are designed to be used continuously over a period of years. In the continuous furnace glass levels remain constant, with new batch materials constantly added as molten glass is removed. Continuous furnaces can be fired by natural gas, electricity, or a combination of both. When both are used, the furnace is said to be fitted with “electric boost.” In natural gas furnaces, the gas is burned in the combustion space above the molten glass and the transfer of energy occurs through radiation and convection. When electricity is the energy source, electrical resistance is introduced using electrodes that are placed directly in the molten glass. Continuous furnaces are classified into four categories: (i) direct-fired (ii) recuperative (iii) regenerative, and (iv) electric. Regenerative furnaces are most commonly used in glass industry. Regenerative furnaces can be end-port or side port, depending on the placement of burner and exhaust ports.

2.3 Forming

Forming is the step in which the molten glass begins its transformation into a final shape. As it moves from the melting tank to the forming machine, the molten glass looks like a thick, red-orange syrup. The forming process may involve casting, blow forming, sheet forming, fiberization, or other processes. Forming processes vary widely, depending on the type of glass being manufactured. Major forming operations include tin float baths for flat glass; blowing and pressing for glass containers; blowing, pressing, casting and drawing for specialty glass; and fiberization with spinners or air for fibrous glass. The greatest amount of diversity is found within the pressed and blown glass sector, where a wide range of products are made, from art ware to glass for lighting and electronics. Glass containers are formed using moulds. Mostly container manufacturers use the IS (individual section) machine to automatically form containers from gobs. The IS machine is capable of handling a variety of types and sizes of moulds, and can produce containers at rates of well over 100 per minute. Two modes of operation are commonly used in IS machines: blow and blow, and press and blow. IS machines can form glass by either method, and can be easily converted from one to the other, allowing for greater flexibility and productivity.

2.3.1 The blow and blow method

Molten ‘gobs’ of glass are delivered into a mould known as a ‘blank’ or parison mould. A puff of compressed air blows the glass down into the base of the mould to form the neck or ‘finish’ part of the bottle or jar. A second blast of compressed air is then applied through the already formed neck of the container to form the ‘parison’ of pre-form for the bottle against the walls of the parison mould cavity. The thick walled parison is then transferred to the final mould during which time the surface of the glass ‘reheats’ and softens again enough to allow the final container shape to be fully formed against the walls of the final mould cavity by the application of either compressed air or vacuum. The container is then removed and transferred to an annealing oven (lehr) where it is reheated to remove the stresses produced during forming and then cooled under carefully controlled conditions. The illustration of this process is provided in figure 2.3.1.

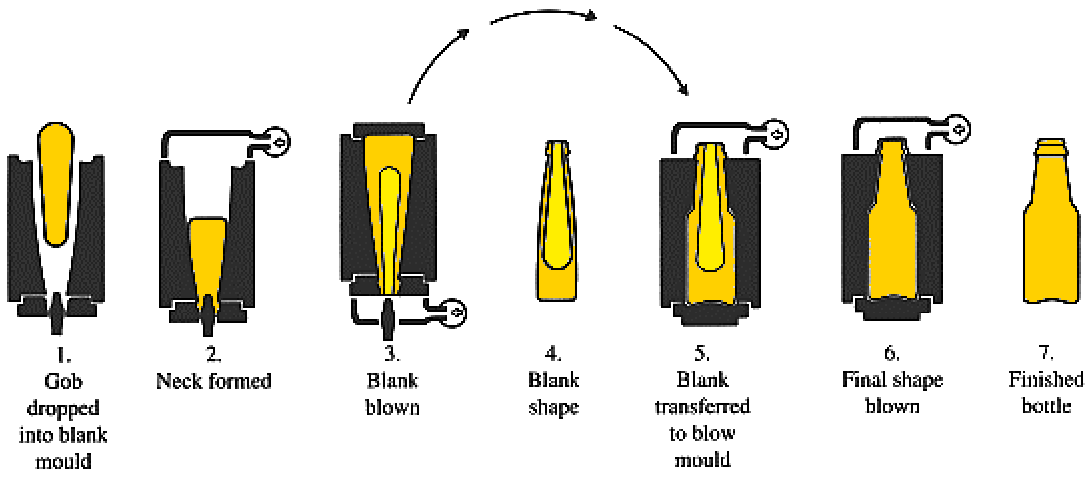

Figure 2.3.1 Blow and Blow Process

2.3.2 The Press and Blow method

In this molten 'gobs' of glass are delivered into the parison mould and a plunge is used to press the glass into the parison shape (Figure 2.3.2). The final mould stage of the process is the same as that described for the Blow and Blow Process.

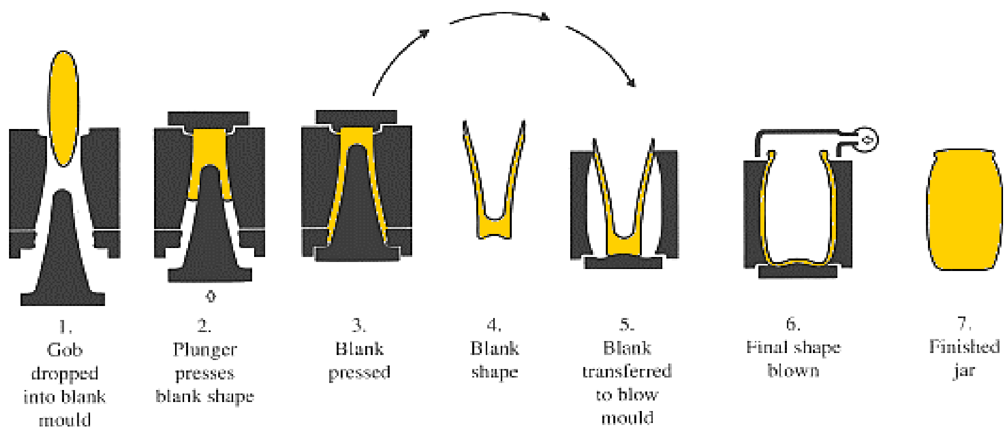

Figure: 2.3.2 Press and Blow Process

The summary of inputs and outputs for glass forming process are provided in table 2.3.2.

Table 2.3.2: Summary of inputs and outputs for glass forming

Inputs	Outputs
Molten Glass, Glass Marbles, Electricity, Tin (float glass), Lubricants, Air, Cooling water, Nitrogen	Formed Glass, Cullet, Contaminated Glass, Spent cooling water , Particulates, Organic Condensable Particulates, Volatile Organics (VOCs)

2.4 Post-forming

These are the processes that alter the properties of the glass, such as annealing, tempering, laminating and coating. The processes may vary widely depending upon the product.

2.4.1 Annealing

Annealing is basically a heat treatment process (slow cooling at a controlled rate) used to remove strains in the glass product. The internal strains in the glass products are induced during the upstream operations. Strain is dependent on how quickly glass passes through a critical temperature range, usually around 449°C. Annealing is done in an oven, called a lehr, through which glass articles pass on a slowly moving conveyor belt (figure 2.4.1). Annealing process is carried out for almost all type of glass products except fibres and very thin- walled products such as light bulbs.

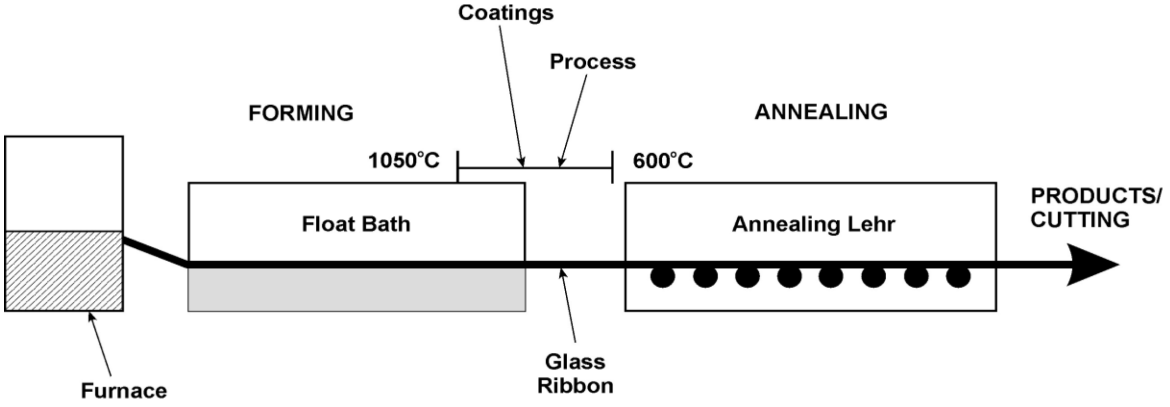

Figure 2.4.1: Flat glass post forming / Annealing in the Lehr

2.4.2 Tempering

Tempering is used to impart strength to glass sheets and oven ware. It is accomplished by first heating annealed glass to just below its softening temperature, and then rapidly quenching it with ambient air. The rapid cooling allows the glass surface to shrink in relation to internal regions which continue to flow and remain stress-free. Continued cooling in this manner creates a uniform temperature profile throughout the glass, and distributes stresses. The result is increased resistance to bending failure.

2.4.3 Coating

Coating of glass surfaces (e.g. mirrors, strengthening of bottles, and colouring) gives glass new physical, chemical, and optical properties. Lightweight glass containers are coated with organic compounds to give the surfaces a degree of lubricity, thus preventing abrasion in handling. This adds strength to the container and has enabled glass manufacturers to make a lighter and better product.

The summary of inputs and outputs for glass post forming process are provided in table 2.4.3.

Table 2.4.3 Summary of inputs and outputs for glass post forming

Inputs	Outputs
Formed Glass, Natural Gas, Electricity, Air, Coating and resins	Finished Products, Cullet, Particulates, Volatile Organics (VOCs), Waste Water