# Energy Mapping of MSME Foundry Sector

**Bureau of Energy Efficiency,**
**(Ministry of Power, Govt. of India)**

# Imprints

**Commissioned on behalf of:**

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Ministry of Power, Govt. of India
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**Version:**

New Delhi, October 2021

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# Acknowledgement

PricewaterhouseCoopers Pvt. Ltd. (PwC) places on record our sincere thanks to the Bureau of Energy Efficiency (BEE) for vesting its confidence in PwC for carrying out this prestigious assignment on “Energy and Resource Mapping for the MSME Foundry Sector in India”.

The team extends its profound thanks to Mr. Abhay Bakre, Director General (BEE),for his leadership and guidance during the execution of the assignment. The team recognizes and extends its sincere gratitude to Mr. R.K Rai, Secretary (BEE), for his invaluable inputs provided during the many interactions and deliberations. PwC acknowledges the co-operation and the support extended by Mr. Milind Deore, Director (BEE) and Mr. Palraj Shyam Sunder, Joint Director (BEE) in providing their inputs, thoughtful comments and directions throughout the execution of the assignment. The team appreciates the valuable inputs received from Mr. Jitendra Sood (Technical consultant, BEE) during the entire project. Team also places on record, our sincere thanks to Mr. Bibek Ranjan, Project Engineer (BEE) for his support and gratefully acknowledges the support provided by the SDAs (PEDA, UPNEDA, WBSEDCL, GEDA, KREDL) and industry associations during the various consultations.

We extend our sincere gratitude to the industry associations consulted during the assignment – Institute of Indian Foundrymen (IIF), the national association representing the foundry fraternity, along with their regional chapters for their unstinted support throughout all phases of our study. We are also grateful to the various local and regional associations including Machenahalli Industry Association (Shimoga), Agra Iron Founder’s Association (Agra), Howrah Foundry Association (Howrah), Rajkot Engineering Association (Rajkot), Kolhapur engineering Association (Kolhapur), Belgaum foundry cluster (Belgaum).

We are also grateful to the esteemed foundry units who participated in the study, technology suppliers, and various institutions including NSIC and NIFFT for their wholehearted support and cooperation for the various consultations and deliberations during the study and preparation of detailed energy audit reports.

Last but not the least, PwC is grateful to our in-house team for their consistent efforts in bringing this report to fruition.

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# Abbreviations

| | |
|---|---|
| AI | Artificial Intelligence |
| AIFA | Agra Iron Founder's Association |
| BEE | Bureau of Energy Efficiency |
| BOP | Best Operating Practices |
| CAD/E/M | Computer Aided Design/ Engineering/ Manufacturing |
| CAGR | Compound Annual Growth Rate |
| CEA | Central Electricity Authority |
| cfm | Cubic Feet per Minute |
| CI | Cast Iron |
| CLCSS | Credit Linked Capital Subsidy Scheme |
| CNC | Computer Numerical Control |
| COC | Cycle of Concentration |
| DBC | Divided Blast Cupola |
| DG | Diesel Generator |
| DHI | Department of Heavy Industries |
| DIC | District Industries Centre |
| DISCOM | Distribution Companies |
| DPR | Detailed Project Report |
| ECM | Energy Conservation Measures |
| EE | Energy Efficiency/ Energy Efficient |
| EET | Energy Efficient Technology |
| EnMS | Energy Management System |
| EnPI | Energy Performance Index |
| EPS | Expanded Polystyrene |
| ESCO | Energy Services Company |
| FO | Furnace Oil |
| FRP | Fiber Reinforced Plastic |
| GCV | Gross Calorific Value |
| GEF | Global Environment Facility |
| GST | Goods and Services Tax |
| HFA | Howrah Foundry Association |
| HSD | High Speed Diesel |
| HT | Heat Treatment |
| HVAC | Heating, Ventilation and Air Conditioning |
| IA | Industry Associations |
| IE | International Efficiency standard |
| IGBT | Insulated Gate Bi-polar Transistor |
| IIF | Indian Institute of Foundrymen |
| IoT | Internet of Things |
| IRR | Internal Rate of Return |
| ITI | Industrial Training Institute |
| KEA | Kolhapur Engineering Association |
| kgoe | Kilogram of Oil Equivalent |
| KPI | Key Performance Indicator |
| kWh | Kilowatt-hour |
| LDO | Light Diesel Oil |
| LM | Lean Manufacturing |
| LMCS | Lean Manufacturing Competitiveness Scheme |
| LNG | Liquified Natural Gas |
| LPG | Liquified Petroleum Gas |

# Abbreviations

| | |
|---|---|
| LSHS | Low Sulphur Heavy Stock Oil |
| LSP | Logistics Service Provider |
| ML | Machine Learning |
| mmWC | Millimetre of Water Column |
| MoMSME | Ministry of Micro, Small and Medium Enterprises |
| MoP | Ministry of Power |
| MOSPI | Ministry of Statistics and Programme Implementation |
| MSME | Micro, Small and Medium Enterprises |
| MU | Million Units |
| MWh | Megawatt-hour |
| NCTS | National Centre for Technical Services |
| NG | Natural Gas |
| NIFFT | National Institute of Foundry and Forge Technology, Ranchi |
| NIP | National Infrastructure Pipeline |
| NPV | Net Present Value |
| NSIC | National Small Industries Corporation |
| PID | Proportional Integral Differential Control |
| PLC | Programmable Logic Control |
| PLI | Performance Linked Incentive scheme |
| PPAC | Petroleum Planning and Analysis Cell |
| PRGFEE | Partial Risk Guarantee Fund for Energy Efficiency |
| RE | Renewable Energy |
| REA | Rajkot Engineering Association |
| SCM | Standard Cubic Meter |
| SCR | Silicon Controlled Rectifier |
| SDA | State Designated Agency |
| SEC | Specific Energy Consumption |
| SGI | Spheroidal Graphite Iron (Ductile Iron) |
| SLM | Selective Laser Melting |
| SOP | Standard Operating Procedures |
| TEQUP | Technology and Quality Upgradation Programme |
| toe | Tonne of Oil Equivalent |
| UNIDO | United Nations Industrial Development Organization |
| VFD | Variable Frequency Drive |
| VMC | Vertical Milling Centre |
| VSD | Variable Speed Drive |
| WB | World Bank |
| WHR | Waste Heat Recovery |
| ZED | Zero Defect Zero Effect |

# 1. Introduction

# 1. Introduction

Bureau of Energy Efficiency (BEE*), a statutory body under the Ministry of Power, Govt. of India*, has notified broad policies for promotion of Energy Efficiency (EE) in India. Industrial segment including MSME sector has remained one of the focus sectors of the BEE to enhance energy efficiency. Several initiatives have been taken by BEE from time to time to promote the competitiveness of MSME sector through sustainable use of energy, *such as BEE SME program and support for WB-GEF & UNIDO-GEF programmatic interventions*.

These and similar initiatives have contributed to improve efficiency of MSME clusters in the country. However, in quantitative terms, there is not much authentic information and data available with respect to MSME's energy consumption and energy saving opportunities. Also, prior interventions in MSME sector were limited to specific clusters, and do not comprehensively cover sector specific policy and implementation aspects.

In this context BEE has devised the "Energy and Resource Mapping Study" for various energy intensive MSME sectors including Foundry MSME sector. The study aims to identify the present scenario of the foundry sector in terms of energy consumption, applicable EE technologies, readiness of the sector in adopting EE solutions and develop a sector level EE policy roadmap for the Foundry MSME sector. Following activities have been envisaged to execute this assignment:

**Field Studies**

Review of Energy consuming processes & technologies
Calculated Specific Energy Consumtion benchmarks at process level
Identifying EE solutions, technologies and best pratices relevant to sector

**Sector level energy mapping**

Calculating energy consumption at sector level and future projections
Benchmarking Energy Consumption with other clusters & international benchmarks
Estimating technology penetration level and Identifying EE potential at sector level

**Energy efficiency policy roadmap**

Mapping needs of the foundry sector stakeholders at sector /cluster level
Technical, financial and capacity building interventions required
Policy and regulatory level recommnedations for foundry MSME sector

Towards that objective, BEE has appointed PwC India to establish energy consumption patterns, highlight opportunities for EE technology upgradation along with policy recommendations and implementation plan for pacing up the EE initiatives in foundry clusters across India including Howrah, Agra, Batala, Shimoga, Rajkot and others. To conduct this study, several initiatives are carried out by PwC India which directly and indirectly benefitted the foundry sector stakeholders:

- Detailed Energy Studies in 50 foundry units along with recommendations for energy improvement
- Analysed the Specific Energy Consumption benchmarks at sectoral/ sub-sectoral level
- Identified Energy efficient technologies relevant to the sector and developed technology roadmap
- Disseminated the learnings and created awareness on EE across Foundry MSME sector & clusters
- Mapped the readiness of sector in adopting EE solutions and developed EE policy roadmap

## *Approach and Methodology*

Based on our understanding of the objectives, we adopted a structured methodology that comprised of desk research, field studies, stakeholder consultations followed by assessment and analysis. Given the limitations associated with this desk-based study, the primary surveys and field studies were primarily targeted to collect data on the sector and best practices that could assist in EE projections.

We have followed the *mixed approach of primary surveys, one-to-one consultations, workshops, energy studies & secondary research* as shown in below section to achieve the project outcomes:

1. **Primary Surveys in 220 Foundries** covering 8 MSME clusters to collect information on
    - Type of products manufactured and type of metal
    - Metal melting technology and type of casting
    - Annual production and fuel-wise energy consumption
2. **Field studies in 50 MSME Foundries** covering 5 MSME clusters to analyze the following
    - Review of energy consuming processes & operations
    - Calculate Specific energy consumption for processes
    - Identify Energy Efficiency solutions to the MSME foundry unit
3. **Secondary research on energy benchmarks and relevant EE technologies**
    - Identified process specific national and international energy benchmarks
    - Identified EE technologies relevant to the sector, techno-commercial feasibility
    - Estimation of technology penetration levels and projections for EE potential
4. **10 Awareness creation workshops and 2 Stakeholder consultations**
    - 5 Inception workshops to explain about assignment objectives and project features
    - 5 Dissemination workshops to share project learnings and understand cluster needs
    - 2 Stakeholder consultations to understand sector needs & develop EE policy roadmap
5. **One-to-one consultations with industry stakeholders** to understand foundry sector needs
    - Detailed discussions with IIF regional and national chapters
    - One-to-one consultations with cluster level associations- Howrah Foundry Association; Agra Iron Founder's Association (AIFA); Association of Small Industries Batala; Rajkot Engineering Association; Machenahalli Industries Association Shimoga
    - Consultations with technology suppliers, and local service providers

Building on the data collected, a deep dive analysis of sectoral energy outlook and EE reduction potential was conducted. A dynamic excel model was developed to undertake the sub-sector level analysis based on *metal casting and metal melting technique* from 2021 to 2031 to estimate energy consumption in BAU scenario and energy intensity reductions in EE moderate and ambitious scenario.

**Estimating sub-sector level production**

- India's GDP growth from 2021 to 2031
- Historical sectoral production statistics
- Current share and projections of metal- CI, SGI, Steel and investment casting
- Share of cupola & induction and projections based on fuel switch

**Estimating sub-sector level SECs**

- Estimaitng SEC based on field studies
- Subsectoral SECs based on type of metal and metal melting technique
- Validation of data inputs from industry experts
- Revising SEC and other assumptionn

**EE Projections in different scenarios**

- Defining Business as Usual (BAU) and alternate scenarios-
  - EE scenario (moderate)
  - EE+State-of-art scenario (ambitious)
- Estimating EE penetration levels in alternate scenarios at sectoral level
- Changes in SEC in alternate scenarios

**Recommendations**

- Estimating emissions reduction potential at sectoral level and opportutines for EE improvement
- Mapping needs of the foundry sector in achieving identified EE potential
- Technical, financial and capacity building interventions required for EE adoptions

Energy demand for the foundry sector is evaluated based on various contributing factors, which includes sectoral production/service demand, specific energy consumption, energy efficiency improvement, etc.

This “BEE Energy mapping study” ultimately aims to generate a sector level energy efficiency roadmap for the Foundry MSME sector. Findings of this study will also help to formulate policies and prepare the implementation plan for pacing up the EE initiatives in the foundry clusters across India.

# 2. Foundry Sector Overview

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In recent years, Industrial energy consumption is being dominated by emerging markets and economies in transition, and this dominance will increase further in the coming decades. This pattern of development has, for example, been very clearly seen in India and China in recent decades.

Expansion of infrastructure in these emerging economies will generate demand for a wide variety of machinery and equipment such as construction equipment, automotive, motors, appliances, machinery, pumps, conveyor equipment, etc. which, in turn, will create demand for metal castings

The foundry (casting) market is also directly linked with the development of the overall automobile sector and with growth of the automobile industry it is expected to generate huge demand for castings producers.

The global iron cast production rose from 50 million metric tons in the year 2000 to over 90 million tons in 2020.

During the same time, while some of the leading producers in the western world (e.g., USA, Japan, France) lost market shares the production in some emerging markets (e.g., China, India, Brazil, Mexico) expanded. In recent years, global castings production witnessed an increase of ~7.75% from 2016 and reached a value of ~90 Mn tonne in 2020.

Based on total output, India had the highest growth in recent years, with an increase of ~26% in production from 2016 (Figure 2) and reached a value of ~12 Mn tonne.

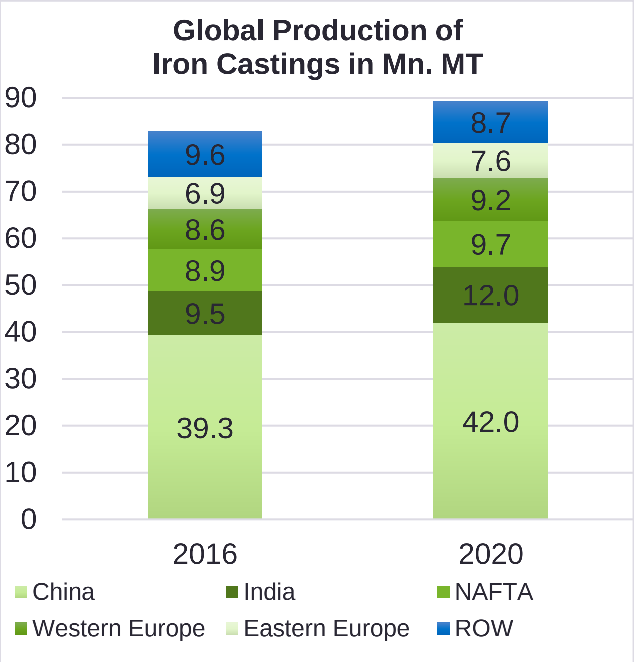



*Figure 1: Global Casting production[1]*

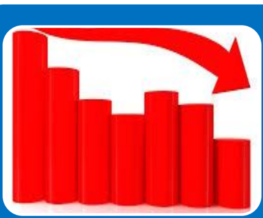
**Major Insights of foundry industry**[1]

- Asia accounts for 65% of total casting production, North America is the third-largest market for metal casting after Asia and Europe.
- Between 2000 and 2018 the output of grey iron cast rose by around 40 % while the production volume of ductile iron cast doubled worldwide to around 27 million tons. The steel cast production grew by 65%
- While the markets for Iron and copper castings have stagnated; there is a significant growth for light metal castings owing to increasing production of light vehicles
- The growth in production of light vehicles is expected to increase demand for new cast metal parts, across the world, and also lead to the replacement of old metal casting products with more energy efficient metal casting solutions.

[1] https://www.worldsteel.org/en and https://www.statista.com/statistics/237526/casting-production-worldwide-by-country/

***Dominance of Asian foundries***

1. China manufactures ~ 49 Mn Tonnes (43% of global); India manufactures ~13 Mn Tonnes
2. China exports ~USD 18 Bn. worth of castings annually whereas India exports ~USD 3.5 Bn.
3. China will continue to dominate the world foundry market but India is expected to catch up



***Stagnant markets in developed countries***

1. The metal castings markets in Europe have stagnated
2. Tough environmental norms and climate issues have closed down many foundries
3. Germany is expected to perform better relative to other European countries

***Shift towards finished and value added castings***

1. Customers are increasingly demanding for completely finished castings and just-in-time
2. Increasing complexity of casting alloys for improved material handling performance
3. Investments in technological competence to maintain improved performance

***Shift to lightweight components***

1. Stricter emission regulations & higher efficiency boost the production of lightweight vehicle and electric vehicles
2. Result in reduction in the weight of castings & substitution of iron castings by other light metals

*Figure 2: Global Mega trends for foundry*

## 2.1. *Indian Foundry Sector*

India is the second largest producer of castings, globally. Casting production in India reached a value of 12 Mn tonnes in 2019 and is expected to expand at a compound annual growth rate (CAGR) of ~12% from 2020 until 2025 (Figure 3)[2].

Indian Foundry industry has a turnover of ~USD 20 billion with export share of USD 3.5 billion. The industry employs 2 million people, out of which 0.5 million are directly employed and rest are indirectly employed mainly from socially and economically weaker sections of society.

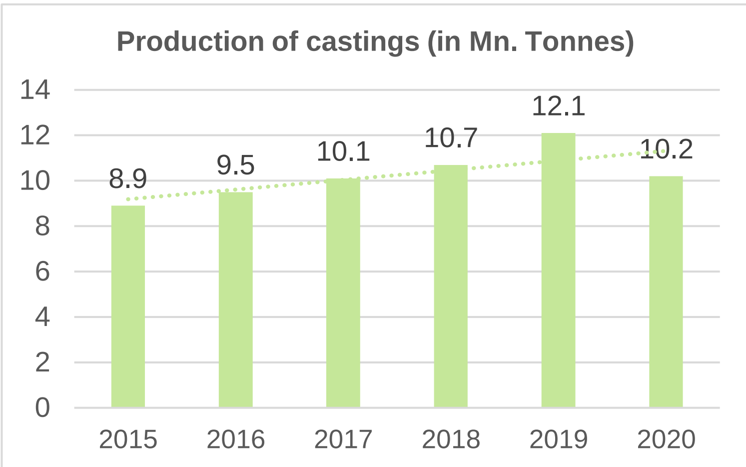



*Figure 3: Casting production in India*

**Major exports of Indian Castings are- 27.8% to USA, 7.5% to Germany, 6.4% to UK**

***Products manufactured***: Indian foundry industry produces various types of metal castings and cast components for application in automotive, railways, machine tools, agro-machinery, power, defense, earth-moving and mining machinery, electrical machinery, and oil and natural gas industries.

[2] http://foundryinfo-india.org/profile_of_indian.aspx

The automobile sector is a major consumer of castings produced in the country (Figure 4).

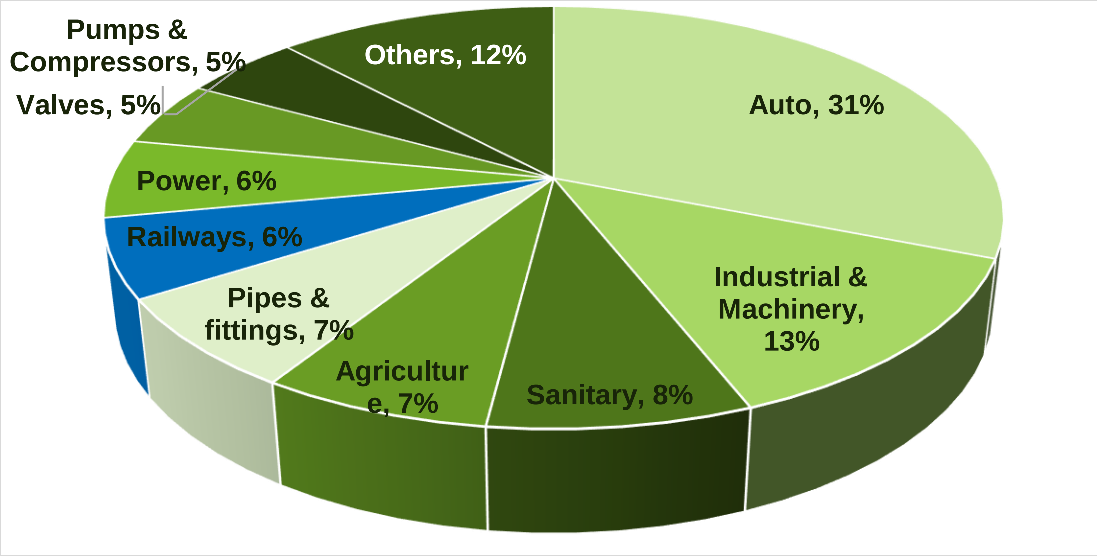



*Figure 4: Share of the casted products in different sector[3]*

**Metal melting technique:** Most of the Foundry units, specially the MSMEs use cupola as the melting furnaces, with coke as the fuel; Most of the Cupolas installed are sub-optimal types which are generally less energy efficient as compared to optimally designed Divided Blast Cupola (DBC) or electric induction furnace. However, there is growing awareness about cost and environment benefits of electric furnaces and many foundries are switching over to induction furnaces.

**Type of metal castings:** Indian foundry industry is capable of producing various grades of value-added castings as per various international standards. The foundries manufacture various types of castings which can be divided into following categories: (1) cast iron, (2) ductile iron, (3) steel and others.

Production of gray iron castings account for the major share of about 70 per cent of total castings produced, while ductile iron and steel castings each contribute around 10% of the total castings production in the country. The share of different metal castings in India, shown in (Figure 5)[3].

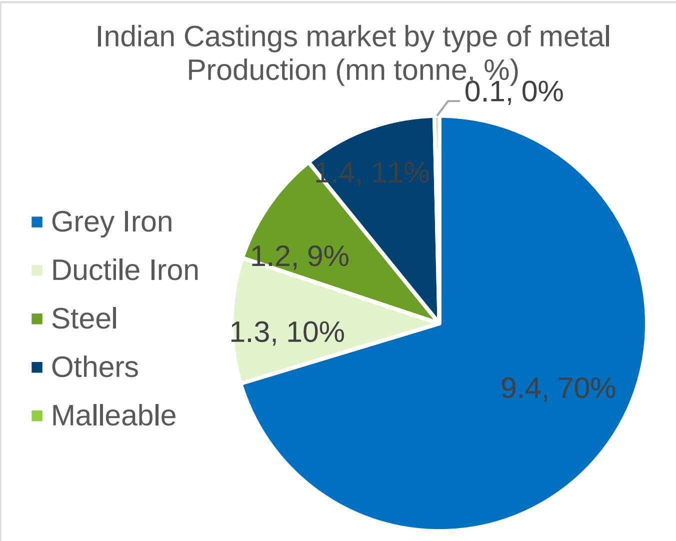



*Figure 5: Share of different metal in total castings*

The share of light metal castings is expected to increase considerably, owing to a shift in demand from iron to lighter castings materials for manufacturing fuel-efficient automobiles. Infrastructure development by the government is expected to generate demand for a wide variety of machinery and equipment. which, in turn, will create fresh demand for iron castings.

## 2.2. *Key growth drivers of the market: End-user segment insights:*

With Government focusing on “Make In India”, and new manufacturing policy which envisages the increase in the share of manufacturing in the GDP to 25%, the role of foundry industry to support

[3] http://foundryinfo-india.org/profile_of_indian.aspx

manufacturing is vital. As all engineering & machining sectors use metal castings in their manufacturing.

**Automotive:** Based on volume, India is currently the fourth largest automobile industry, globally. Steady growth of the automotive sector has also led to the steady development of other subsidiary industries like the auto component industry, indicating demand for castings.

- Demand likely to pick up with steady rate due to increase in disposable income
- Spare parts consumption could drive demand
- Demand for electric vehicles is likely to go up with more thrust for a cleaner environment

**Power:** Consistent power supply and availability of quality electrical equipment are necessary for the growth of the Indian economy from a global perspective. "Power for All" will generate huge demand for power transmission and distribution equipment-

- Ageing equipment will require replacement
- The foundry industry is expected to benefit from such power generation installations

**Pipes and fittings:** The piping sector in India is poised for steady growth due to substantial investments and capacity additions. Demand for castings is expected to expand with the growth of the pipes and fittings market in India.

National Infrastructure Pipeline (NIP) has also set plans to help take India to USD 5 Tn economy and there is a planned budget of USD 1.4 Tn. on infra projects for next 5 years

**Export market** presents a great opportunity for the industry to tap into, India's share of export in global Import of castings stood at 2.4 percent in 2019. This translates to a potential 97% market opportunity for India to grow its share of pie (The USA imports about 7 Mn tonnes of castings every year, while India's contribution to USA's import is comparatively miniscule)

Re-implementation of Public Procurement Policy, **Startup India, and Skill India** initiatives will help in the growth of the MSME foundry sector in the country.

## 2.3. *Key Challenges*

Since most of the castings manufacturing units fall under small and medium enterprises (MSMEs), they cannot use advanced technological equipment or automation due to high costs, thus limiting their marketing strength. The inability to supply high quality products to large domestic and global market players, act as a huge barrier for the industry to grow further.

In addition, ever rising fuel prices and non-reliable availability of fossil fuels, has become a major problem for the MSMEs in the foundry sector. These MSMEs also have limited knowledge capabilities to evaluate production technologies relevant to their unit, and limited capacities to access finance.

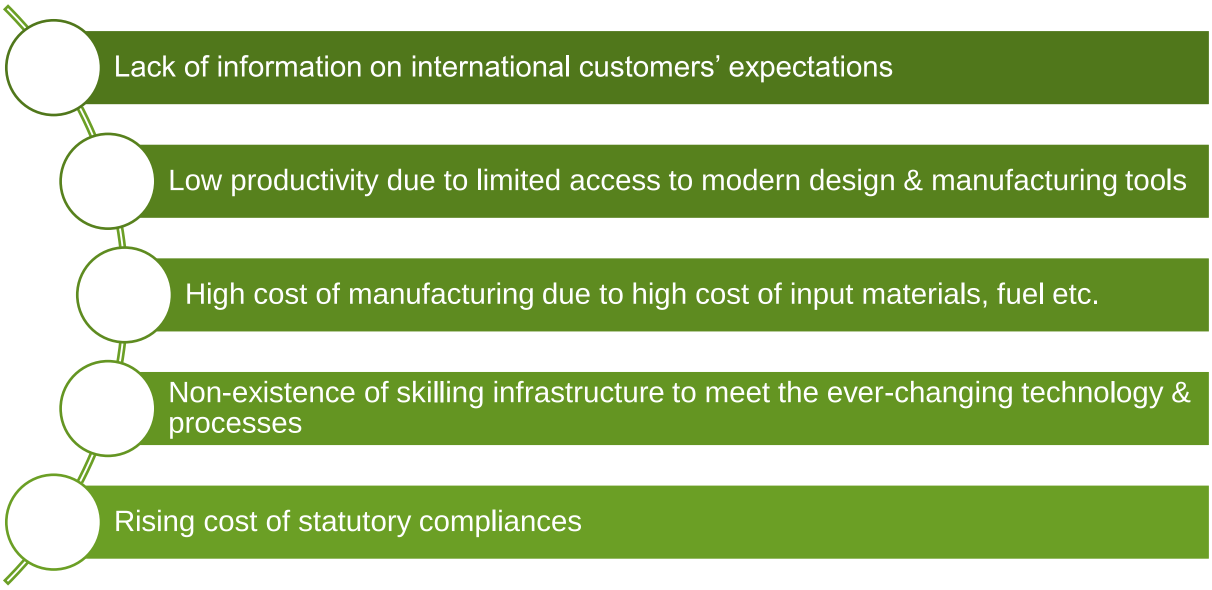



Figure 6: Key challenges for the foundry industry

## 2.4. *Geographical Coverage*

There are about 4,500 foundry units in India, out of these, about 1500 units have international quality accreditation. The majority (nearly 90%) of the foundry units in India falls under the category of medium and small-scale industry.

A peculiarity of the foundry industry in India is its geographical clustering. Some of the major foundry clusters in the country are shown in Figure 7. The major foundry clusters are located in Batala, Agra, Pune, Kolhapur, Rajkot, Shimoga, Howrah, Ahmedabad, Belgaum, Coimbatore, Jalandhar, Ludhiana, Ranchi, and Chennai, among other Indian cities.

Each of these foundry clusters caters to some specific end-use market. Many of the foundry clusters cater to some specific markets. For example, the Coimbatore cluster is famous for pump-set castings, the Kolhapur and the Belgaum clusters for automotive castings, and the Rajkot cluster for diesel engine castings. Major foundry clusters in the country are shown in below section.

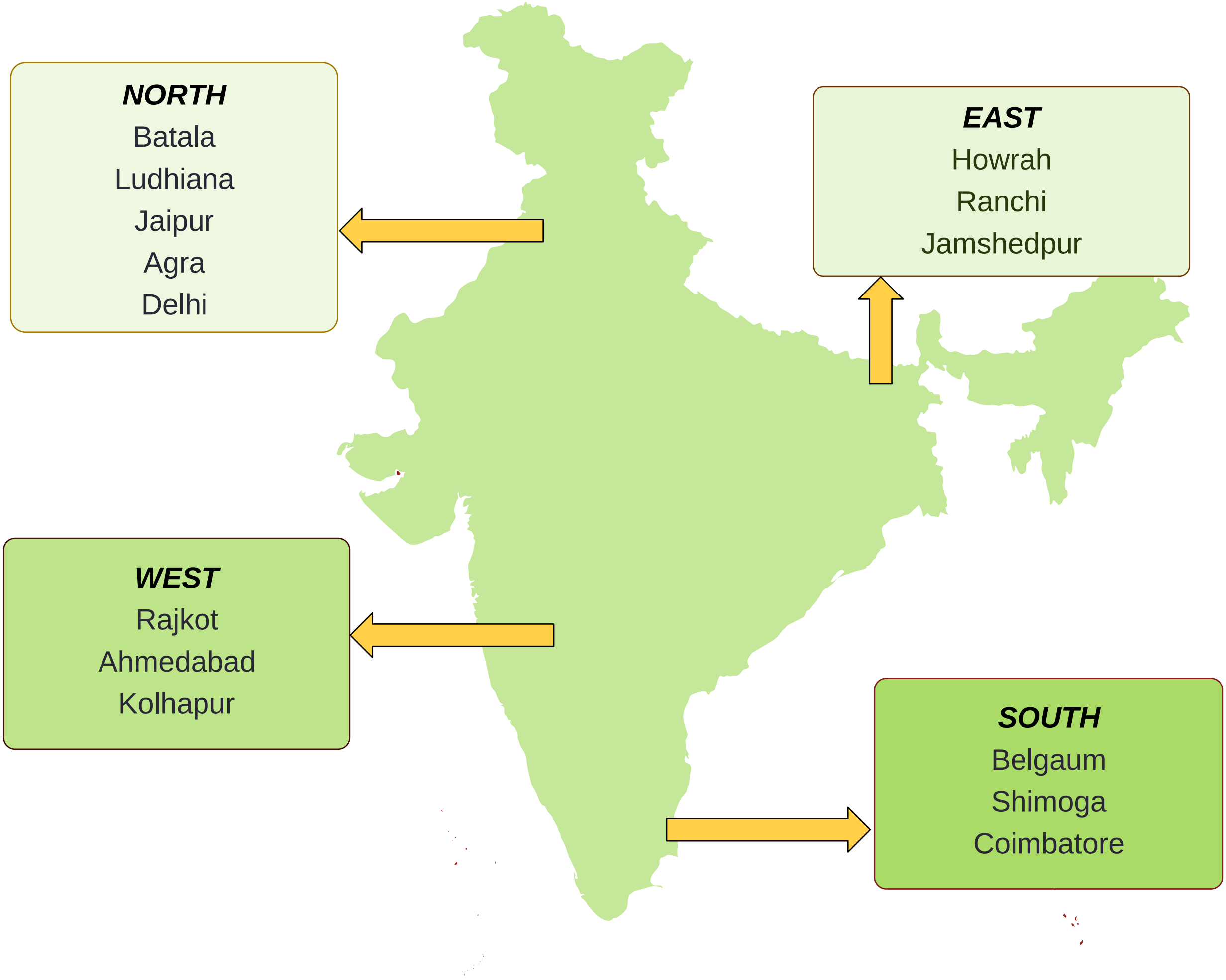



*Figure 7: Foundry clusters across India*

## *Foundry Industry in Northern Region*

**Agra** has over 90 foundry units in the cluster with a production capacity of 0.14 million tonnes per annum. These industries are spread across three localities namely: Rambagh, Nunhai and Foundrynagar. Agra foundry units cater to the casting requirements for automotive, agriculture implements, railways and other engineering sectors.

**Many foundry units in Agra have shifted to induction melting furnace while others are still using natural gas fired cupola furnaces.** These NG cupola based foundries are also struggling hard to make ends meet because of the high manufacturing costs required for running CNG-based furnaces. About 35% production is accounted by cupola furnace-based foundries. The balance 65% of production comes from induction furnace-based foundries.

Cluster has predominantly green sand moulding for castings. Cluster produces mainly Gray Iron (CI) castings, while few units also produce ductile (SGI) and steel castings. The Institute of Indian Foundrymen (IIF) Agra Chapter and Agra Iron Founder's Association (AIFA) are the two prominent foundry industry associations in the cluster.

Table 1 Details of the Agra foundry cluster

| Description | Details |
|---|---|
| **Location** | Uttar Pradesh |
| **Number of foundry units** | ~120 |

| Description | Details |
|---|---|
| **Major foundry products** | Diesel generator-set, Automotive |
| **Type of fuel used in cluster** | Electricity, Natural Gas |
| **Prominent melting Technologies used** | Induction furnace, Gas Cupola |
| **Prominent Industry association** | IIF (Agra chapter), Agra Iron Founder's Association |
| **Prominent Institutes** | DIC, Government Industrial Training Institute Agra |
| **SDA** | Uttar Pradesh New & Renewable Development Agency |

**Batala** is one of the oldest foundry clusters in the Northern India, comprising about 80 MSME foundries and producing around 93,000 tonnes of castings per annum. The majority of the foundries are micro to small-scale units and produce grey iron castings. The industries in Batala are spread across namely: G.T. Road, Industrial area, Focal Point.

Batala foundry units cater to the casting requirements for automobile parts, agricultural implements, machine tools, diesel engine components, manhole covers, sewing machine stands, pump-sets, decorative gates, and valves. Foundry units in Batala also produce the castings for Rail Coach Factory, Kapurthala.

Cupola is the predominant melting technology deployed by around 95% of the foundry units in the cluster, and only few units have switched to induction based melting technology in the recent past. Most of the foundries use green sand moulding for the core preparation, very few units use the cold resin and no bake moulds for the casting. The Institute of Indian Foundrymen (IIF) Batala Chapter and Association of Batala Small Industries are the two prominent foundry industry associations in the cluster.

Table 2 Details of the Batala foundry cluster

| Description | Details |
|---|---|
| **Location** | Punjab |
| **Number of foundry units** | ~100 |
| **Major foundry products** | Automotive casting, Agriculture, and machine parts |
| **Type of fuel used in cluster** | Coke, Electricity, Diesel |
| **Prominent melting Technologies used** | Conventional Cupola |
| **Prominent Industry association** | IIF (Batala chapter), Association of Batala Small Industries |
| **Prominent Institutes** | DIC, Govt Industrial Training Institute Batala, Gurdaspur |
| **SDA** | Punjab Energy Development Agency |

**Jaipur** is the capital of Rajasthan and is known as the Pink City. There are over 110 foundry units in the cluster. The cluster has foundries which mainly use green sand moulding. A few foundries employ investment casting. foundries. Jaipur foundry cluster comprises 80 cupola-based foundries and 30 induction furnace based. Foundries in the cluster caters to the requirements of automobile, general engineering parts, valves and pumps, agricultural sectors and demands of PHED.

Agriculture implements account for about 40% of total production followed by the requirements of PHED (25%). Cluster produces over 2 lakh tonne of the casted products, cupola unit accounts for the 35% of the annual production and Induction furnaces account for 66% of the casting production.

SEC of cluster varies in range of 600–750 kWh per tonne for induction furnace and 100–150 kg coke per tonne in cupola.

Table 3 Details of the Jaipur foundry cluster

| Description | Details |
|---|---|
| **Location** | Rajasthan |
| **Number of foundry units** | ~130 |
| **Major foundry products** | Agriculture, Automobile, Pumping & fittings |
| **Type of fuel used in cluster** | Coke, Electricity, Diesel |
| **Prominent melting Technologies used** | Conventional Cupola , DBC, Induction melting |
| **Prominent Industry association** | IIF (Northern chapter), Foundry Owners Association Vishwakarma Industries Association |
| **Prominent Institutes** | DIC, Government Industrial Training Institute Jaipur |
| **SDA** | Rajasthan Renewable Energy Corporation Limited |

***Sand Preparation***

*Intensive sand mixers are widely used in the Batala, Agra foundry clusters.*

*Foundries with higher production volumes in the Batala and Agra foundry clusters have installed the sand plants for sand preparation with capacity of 1- 5 tonnes per hour.*

*Chemical bonded sand moulding is being adopted by a very few units across Batala foundry cluster for preparing the higher finished quality castings.*

***Core baking***

*Gas is being used as fuel for the core baking in all the units in the Agra foundry cluster. Oil is also used as fuel for thermal heating by few units in Batala foundry cluster.*

***Melting technology***

*Gas based cupola and Induction melting is widely adopted in Agra foundry cluster, conventional cupola is used by majority of units in Batala; other clusters have mix of the conventional cupola DBC and induction melting.*

***State of art technologies***

*A few progressive foundries in the* ***Agra*** *have already adopted the modern state of the art technology for sand preparation and core making.*

## *Foundry Industry in Western Region*

**Rajkot** is one of the largest industrial clusters in India comprising foundry, forging, general engineering industries that cater to the requirements of manufacturing sector. The cluster is spread within Rajkot and neighbouring Gujarat Industrial Development Corporation (GIDC) industrial estates.

There are about 900 foundry industries in the Rajkot and producing around 1,340,000 tonnes of castings per annum. Most of the foundries in Rajkot cluster cater to diverse sectors such as like Auto components, pump sets, heavy engineering, motors, air compressors, earth movers, railways and agricultural machines, and other engineering applications etc.

In recent years, the production has been shifted to induction furnaces which contribute roughly 83% of the production . Cluster has predominantly green sand moulding casting as well as many units with shell moulding and investment castings. Majority of the foundry units at Rajkot produces cast iron castings for the domestic market. The Institute of Indian Foundrymen (IIF) Rajkot Chapter and Rajkot Engineering Association (REA) are the two prominent foundry industry associations in the cluster.

Table 4 Details of the Rajkot foundry cluster

| Description | Details |
|---|---|
| **Location** | Gujarat |
| **Number of foundry units** | ~800 |
| **Major foundry products** | Oil Engines, Auto components, Heavy machine parts, Pump set and valves, Steel and SS casting, Precision casting |
| **Type of fuel used in cluster** | Electricity, Coke, Gas, Oil |
| **Prominent melting Technologies used** | Divided blast Cupola, Conventional Cupola, Induction furnace, Precision casting (Wax and Lost foam based) |
| **Prominent Industry association** | IIF (Rajkot chapter) |
| **Prominent Institutes** | NSIC - Rajkot , DIC, Rajkot Engineering Association (REW) |
| **SDA** | Gujarat Energy Development Agency |

**Ahmedabad** is cluster in the western region, there are about 500 foundry units in Ahmedabad cluster, Ahmedabad foundry manufacturers traditionally cater to the requirements of textile sectors. Over 50% of the casted products supports the requirement of the textile sector. Castings for other sectors include agriculture machinery and sanitary shares 20% share of the casted products: pump and valve body shares about 20% of the casted products.

Cluster have the mix of the green sand molding, investment casting units. Over 70% of the units uses the cupola for melting the metal, penetration of the Induction based melting Is lesser in the cluster. The foundries employ close to 30,000 direct employees. The estimated annual turnover of the foundry cluster is nearly 2,600 crores from the foundries in the cluster. Cluster have the mix of the green sand molding, investment casting units. The SEC varies considerably in a foundry depending on the type and grade of casting manufactured, Average, the Specific Energy Consumption (SEC) varies between 95–125 kgoe per tonne in this cluster.

Table 5 Details of the Ahmedabad foundry cluster

| **Description** | **Details** |
|---|---|
| **Location** | Gujarat |
| **Number of foundry units** | ~450 |
| **Major foundry products** | Textiles, Agriculture, Pumps & Valves |
| **Type of fuel used in cluster** | Electricity, Coke, Diesel, Gas |
| **Prominent melting Technologies used** | Induction melting, Cupola |
| **Prominent Industry association** | IIF (Western region chapter) |
| **Prominent Institutes** | NSIC - Rajkot , DIC |
| **SDA** | Gujarat Energy Development Agency |

**Kolhapur,** located in the state of Maharashtra, is an important foundry cluster for automotive castings. Historically, the foundry cluster came up to cater to the casting requirements of the local industries like oil engine manufacturing, sugar mills and machine tool industry. There are about 250 foundry units at Kolhapur. The geographical spread of the cluster includes Kolhapur, Sangli, Ichalkaranji and Hatkanangale areas. A significant percentage of foundry units (about 25%) at Kolhapur are exporting castings.

Cupola is the predominant melting furnace employed by about 75% of the foundry units. The majority of cupolas in the cluster are of conventional type. Divided blast cupola (DBC) can be found in some of the foundry units. Most of the foundries use low ash coke. A number of foundry units have electric induction furnace, which is used to manufacture graded castings and for duplexing with cupola.

Table 6 Details of the Kolhapur foundry cluster

| Description | Details |
|---|---|
| **Location** | Maharashtra |
| **Number of foundry units** | ~250 |
| **Major foundry products** | Automotive & Engines, Sugar mill parts |
| **Type of fuel used in cluster** | Electricity, Coke |
| **Prominent melting Technologies used** | Induction melting, Divided blast Cupola |
| **Prominent Industry association** | IIF (Kolhapur Chapter) |
| **Prominent Institutes** | DIC, Govt. ITI, Kolhapur Engineering Association (KEA), Ichalkaranji Engineering Association (IEA) |
| **SDA** | Maharashtra Energy Development Agency |

***Sand Preparation***
*Intensive sand mixers are widely used in the Rajkot and Kolhapur foundry clusters.*

*Chemical bonded sand moulding is being adopted by few units across Kolhapur, Rajkot, foundry clusters for preparing the higher finished quality castings.*

***Core baking***
*Gas is being used as fuel for the core baking in most of the units in Rajkot foundry cluster. Oil is also used as fuel for thermal heating by few units across the clusters of Rajkot, Kolhapur, etc.*

***Melting technology***
*DBC finds the highest pentation in the Rajkot and Kolhapur foundry clusters, Indore foundry clusters and other foundry clusters in still have mix of the conventional Cupola and DBC for metal melting.*

***State of art technologies***
*A few progressive foundries in the* ***Rajkot, Kolhapur*** *have already adopted the modern state of the art technology for sand preparation and core making.*

*A few units in the Rajkot have also adopted the modern state of art Permanent magnet screw compressor to meet the process air requirement.*

## Foundry Industry in Southern Region

***Shimoga,*** is situated in the heart of Karnataka, located about 300 km from Karnataka's capital Bengaluru. The foundry units in the district have been very successful in producing quality products for domestic and international market. There are about 45 foundry and allied units in the cluster producing about 100,000 tonnes of saleable casting annually.

Shimoga foundries are predominately supplying castings for heavy engineering (such as railways, earth movers), engine parts (diesel engine and generators), machine components, automotive parts, and pumps & valves. The Institute of Indian Foundrymen (IIF) Shimoga Chapter and Machenahalli Industry Association are the two prominent foundry industry associations in the cluster.

Induction based melting technology is predominate in the cluster with almost 100% units have the induction based melting furnace installed in their unit. Cluster has predominantly green sand moulding casting as well as few units resin bonded shell moulding and centrifugal castings. Cluster produces equal quantities of steel and iron (both SGI, CI) castings.

Table 7 Details of the Shimoga foundry cluster

| Description | Details |
|---|---|
| **Location** | Karnataka |
| **Number of foundry units** | ~50 |
| **Major foundry products** | Auto parts, Earth moving equipment |
| **Type of fuel used in cluster** | Electricity, LPG |
| **Prominent melting Technologies used** | Induction melting furnace |
| **Prominent Industry association** | IIF (Shimoga chapter) |
| **Prominent Institutes** | DIC, ITI , Machenahalli Industries Association |
| **SDA** | Karnataka Renewable Energy Development Limited |

**Belgaum is** located in the state of Karnataka, is an important foundry cluster. There are about 100 foundry units at Belgaum. The geographical spread of the cluster includes Udyambag and Macche industrial areas. The foundry industry at Belgaum came up primarily to cater to the needs of the automobile industry at Pune. Belgaum is recognized to be a reliable source of high precision, high volume, and economical castings. A significant percentage (almost 20%) of the foundry units at Belgaum has ISO 9000 certification and export casting.

Cupola is the most common melting furnace at Belgaum. Three out of every four foundry use cupola as their main melting furnace. Most of the cupolas are of conventional designs. Divided blast cupola is not very common yet in the cluster. Low ash coke is commonly used in the cupolas.

About 40% of the foundry units in the cluster uses electric induction furnace, which are used either as the main melting furnace or for duplexing with cupola. A relatively small percentage (about 5%) of the foundry units use rotary furnaces.

Table 8 Details of the Belgaum foundry cluster

| Description | Details |
|---|---|
| **Location** | Maharashtra |
| **Number of foundry units** | ~120 |
| **Major foundry products** | Automotive castings, Electric motors |
| **Type of fuel used in cluster** | Electricity, Coke, Diesel |
| **Prominent melting Technologies used** | Induction melting, Divided blast Cupola, Conventional Cupola |
| **Prominent Industry association** | IIF (Belgaum Chapter), Belgaum Foundry Cluster |
| **Prominent Institutes** | DIC, ITI , Belgaum Small Scale Industries Association, MSME -DI, Karnataka German Multi Skill Development Centre |
| **SDA** | Karnataka Renewable Energy Development Limited |

**Coimbatore, located in the state of Tamil Nadu,** is an important foundry cluster in Southern India. The foundry industry at Coimbatore came up mainly to cater to the needs of the local textile and pump-set industries. There are about 600 foundry units in Coimbatore. The geographical spread of the cluster includes Thanneer Pandal / Peelamedu, Ganapathy, SIDCO, Singanallur, Mettupalayam Road and Arasur Village.

Most of the foundry units cater to the needs of the domestic market. A small percentage (about 10%) of the foundry units are also exporting castings. Nearly half the number of foundry units are manufacturing castings for the pump-set industry. The distribution of the foundry units by end-use markets is given below.

Cupola is the predominant melting furnace employed by the foundry units in the cluster. Majority (about 70%) of the cupolas in the cluster are of conventional designs. Electric induction furnaces are used by just 10% of the foundry units, mainly to manufacture graded castings and for duplexing operation with cupola.

Table 9 Details of the Coimbatore foundry cluster

| Description | Details |
|---|---|
| **Location** | Tamil Nadu |
| **Number of foundry units** | ~500 |
| **Major foundry products** | Pump-sets, Machinery, Textile machine parts, Grinders |
| **Type of fuel used in cluster** | Electricity, Coke |
| **Prominent melting Technologies used** | Induction melting , Divided blast cupola, Conventional Cupola |
| **Prominent Industry association** | IIF (Coimbatore chapter), Coimbatore Industrial Infrastructure Association |
| **Prominent Institutes** | DIC, |
| **SDA** | Tamil Nadu Generation and Distribution Corporation Limited |

***Sand Preparation***

*Intensive sand mixers are widely used in the Shimoga foundry cluster.*

*Foundries with higher production volumes in the Shimoga, Belgaum foundry clusters have installed the sand plants for sand preparation with capacity of 1- 5 tonnes per hour.*

*Chemical bonded sand moulding is being adopted by few units across Shimoga foundry cluster for preparing the higher finished quality castings.*

*Belgaum foundry cluster have established modern common facility centre for sand reclamation.*

***Core baking***

*Gas and oil are being used as fuel for the core baking in most of the units in Shimoga foundry cluster.*

***Melting technology***

*Shimoga cluster has highest penetration of the IGBT based induction furnaces across the different foundry clusters. Shimoga is only cluster to have 100% penetration of Induction melting technology.*

***State of art technologies***

*A few progressive foundries in the* ***Shimoga foundry cluster*** *have already adopted the modern state of the art technology for sand preparation and core making.*

*A few units in the Shimoga have also adopted the modern state of art Permanent magnet screw compressor to meet the process air requirement*

## *Foundry Industry in Eastern Region*

The industrial city of **Howrah** hosts about 300 foundries, with an installed capacity of almost 0.8 Million tonnes. Majority of foundry units in Howrah foundry cluster fall under the micro & small category of MSMEs and majority of existing foundries in the cluster are 3-4 decades old and very little investment towards modernization of the plant is done after initial commissioning.

Cupola based melting technology is predominate in the cluster, which consumes more energy and produce higher GHG emissions. Almost 80% units have the Divided Blast Cupola (DBC) furnace installed in their unit. Cluster has predominantly green sand moulding casting as well as few units with shell moulding and investment castings. Majority of the foundry units at Howrah produces cast iron castings for the domestic market.

Most of the foundries in Howrah cater to diverse sectors such as sanitary casting, machinery bodies, counterweights, pump and valve bodies, jute mill spares, railway, defence, and mining, etc. The Institute of Indian Foundrymen (IIF) Howrah Chapter and Howrah Foundry Association (HFA) are the two prominent foundry industry associations in the cluster.

Table 10 Details of the Howrah foundry cluster

| Description | Details |
|---|---|
| **Location** | West Bengal |
| **Number of foundry units** | ~350 |
| **Major foundry products** | Sanitary pipes, Machinery bodies |
| **Type of fuel used in cluster** | Coke, Electricity, Gas, Diesel |
| **Prominent melting Technologies used** | Divided blast Cupola, Induction melting furnace, Conventional Cupola |
| **Prominent Industry association** | IIF (Eastern region), Howrah Foundry Association) |
| **Prominent Institutes** | DIC, ITI , |
| **SDA** | West Bengal State Electricity Distribution Company Limited |

***Sand Preparation***
*Intensive sand mixers are widely used in the Howrah foundry cluster.*

***Core baking***
*Gas and oil are being used as fuel for the core baking in a few units in Howrah foundry cluster.*

***Melting technology***
*DBC finds the highest pentation in the Howrah foundry cluster and other foundry clusters in north still use the conventional Cupola for metal melting.*

## 2.5. *Sector level stakeholders*

In context of our existing working relationships in a number of MSME clusters, the local level stakeholders show great interest and enthusiasm for energy efficiency initiatives and technical cooperation activities. These stakeholders can be positioned as opinion influencers among the local industrial community during project activities in any particular cluster.

The primary stakeholders in the cluster are the industry associations, individual foundry units and MSME DI. The other stakeholders include the technology suppliers, government agencies, financial institutions, and academic/training institutes.

### *Industry Association*

Industry Associations are increasingly becoming more professionally managed with dedicated staff for day-to-day operations. These associations serve as the first avenue to understand cluster dynamics such as energy efficiency technology needs, disseminate best practices among member units and also assist in organizing various cluster level awareness programmes on EE. Leveraging these industry associations from the initial stage of the study would be quite valuable in:

- Understand the membership profile of MSMEs in the cluster
- Cluster profile of Industrial association including number of MSMEs, size of MSME units
- Present business scenario, barriers for energy efficiency
- Support in reaching out to member industries for project activities

The major industry associations in the Indian foundry sector are presented next.

Table 11 List of key industry associations

| Organization | Email | Telephone |
|---|---|---|
| **IIF National Chapter** | fic@indianfoundry.org | 7428022869 |
| **IIF Howrah Chapter** | addl.ed@indianfoundry.org | 9830027955 |
| **IIF Shimoga Chapter** | benakappadgsmg@gmail.com | 9880276455 |
| **IIF Agra Chapter** | agra@indianfoundry.org | NA |
| **IIF Rajkot Chapter** | info@fbc24x7.com | 9978224704 |
| **IIF Batala Chapter** | vinesh.vks@gmail.com | 9814220418 |
| **Howrah Foundry Association** | satyajitkundu@yahoo.co.in | 9830213686 |
| **Machenahalli Industry Association** | shreyonidhientp@gmail.com | 9845416616 |
| **Association of Batala Small Industries** | rashtriy@rediffmail.com | 9216763954 |
| **Rajkot Engineering Association** | info@reaindia.com | 9824490444 |
| **Agra Iron Founder's Association** | amarmittalagra@gmail.com | 9319137829 |

**Government Institutes:**

There are government support bodies, such as District Industries Centre (DIC)–Howrah in the cluster which also work towards the development of the cluster particularly for MSME industries.

Key national and regional stakeholders associated with foundries are presented next-

**Indian Institute of Foundrymen (IIF)** is the national level foundry association incorporated in 1950. IIF is a one-point nodal agency initiating the government interface on behalf of the national foundries. *Association has a headquarters in Kolkata*, with regional offices in Delhi, Mumbai, and Chennai. IIF is also a member of the World foundrymen organization

*IIF has 26 regional chapters* across Northern, Western, Central, Southern and Eastern regions. IIF not only provides support on technical issues and work towards addressing various issues faced by the foundry MSMEs regarding raw materials, labour, etc, but also organizes a number of events for the foundry units and support for dissemination of knowledge products.

Association is supporting the foundries with multiple programmers and initiatives for the research and training skill development, business development, knowledge dissemination programme of new and EE technologies. IIF hosts an annual national level technology exhibition (Indian Foundry Congress), seminars, technical session, B2B interface for industries, technology providers and other stakeholders.

IIF has instituted three main centers of excellence to provide multiple solutions to foundries in the country - *Foundry Informatics Centre in Delhi, National center for technical services in Pune, Center of education and Training in Kolkata*.

**Foundry Informatics Centre (FIC) –** FIC is one of the centers of excellence of IIF supporting the development and continuously update the information system on Foundry & Allied industry. Other broad objective of the FIC is to support the foundries to generate information of special plant machinery & technology; identification of identify suitable sources of cast component, foundry materials equipment's, consultants etc. FIC maintains the list of the on-going schemes and provide the hand holding support to the industries to avail the different on-going schemes.

**National Centre for Technical Services (NCTS) –** NCTS in Pune is center of excellence of the providing the technical support and disseminating the information to foundries. Technical experts at the center also support and provide the technical solutions for different foundries. NCTS has also created the data base of video tutorials, and multimedia videos for the EE technologies related to foundries. NCTS also regularly publish the Technical articles from various Journals and magazines.

**The Centre for Education and Training (CET) –** CET is one of the other centers of excellence providing the training and skill development programs for the foundries. Some of the prominent training includes - human resources, education of the foundrymen for new EE technologies. CET also conduct the six-month certification - training curriculum for the foundrymen (including – pattern making, heat treatment, surface finishing of the castings, operational aspects to reduce the losses etc.). These solutions help the foundrymen to upskilling the staff which help foundries to optimize the skills and resources.

**Belgaum Foundry Cluster (BFC) - Belgaum** was established IN 2004 to provide the foundries in Belgaum region with state-of-the-Art Infrastructure facilities to the foundry units in and around Belgaum, and to make them internationally competitive. Institute provides the multiple skill development programmers for foundries, testing lab and tool room facilities for foundries, training on casting simulations, CAD/CAM modeling etc. BFC has installed the common sand reclamation plant to support the foundries. Institute also has an energy management cell to promote the EE technologies, to carry out energy audits etc.

**Machenahalli Industries Association -Shimoga** was established in 2012 to provide the foundries in the region with state-of-the-Art Infrastructure facilities to the foundry units in and around Shimoga region. Association has supported multiple initiatives to promote the energy efficiency in foundries.

Association support foundries with multiple activities like - skill development, training, energy conservation, product development etc. Association supports industries for dialog with state government and regional institutes.

**Howrah Foundry Association (HFA)**

Howrah Foundry Association is the leading industry association in the cluster comprising about 150 members representing both micro and small industry units comprising mainly cupola-based foundries.

Howrah Foundry Association is quite active in the cluster. The association provides support on addressing various cluster specific issues. In addition, activities of the association include seminars, workshops, technical programmes and training for shop-floor workers and dissemination of newsletters.

**Agra Iron Founder's Association**

Agra Iron Founder's Association (AIFA) is the leading industry association in the cluster comprising about 90 members representing both micro and small industry foundry units. AIFA is quite active in the cluster. The chapter not only provides support on technical issues and work towards addressing various issues faced by the cluster regarding raw materials, labour, etc, but also organizes a number of events for the foundry units and support for dissemination of knowledge products.

**Rajkot Engineering Association (REA)**

Rajkot Engineering Association is the biggest and oldest industrial association of Rajkot and nearby region having more than 1100 units members comprising various engineering sectors like automobiles, pumps & valves, heavy engineering, earth moving and electric motors etc.

Rajkot Engineering Association is quite active in the cluster. The association provides support on addressing various cluster specific issues. The association also supplies raw materials like pig iron to its members on „no-profit-no-loss" basis. REA is having affiliation with renowned Indian organization like, C.I.I., MSME, FICCI, NSIC, CMTI, FASSI, EEPCINDIA, IIF, IDEMA, DIC, etc.

In addition, activities of the association include seminars, workshops, technical programmes and training for shop-floor workers and dissemination of newsletters. The association is centrally located in Bhaktinagar Industrial Area of Rajkot and has its own building and conference facilities. It regularly arranges meetings, seminars and workshops for its members

**Association of Batala Small Industries**

Association of Batala Small Industries is the leading industry association in the cluster comprising about 50 members representing both micro and small industry units comprising mainly cupola-based foundries. Association of Batala Small Industries is quite active in the cluster. The association provides support on addressing various cluster specific issues. In addition, activities of the association include seminars, workshops, technical programmes and training for shop-floor workers and dissemination of newsletters.

Other regional associations supporting the foundries indirectly across the different clusters are – Kolhapur engineering Association (Kolhapur), Shapar Veraval Industry Association and IamSME of India.

## Institutions supporting foundries

**National Institute of Foundry and Forge Technology (NIIFT)** is one of the pioneer institutes for the foundry and forging is located in Ranchi and was instituted in 1966. Since inception NIIFT has been supporting the R&D, training programmes for the foundry and forging industries. Institute providers multiple education and training courses related to Foundry Technology, Foundry Technology, Manufacturing Engineering, Materials and Metallurgical Engineering etc. Institute has world class infrastructure to promote the R&D activities, key facilities offered by NIIFT are - Sand laboratory, Metallography, FMS, Non-destructive and mechanical Testing Non-destructive and mechanical Testing, Ceramic lab, Spectroscopy, Environmental and Pollution Control Lab, Metrology, Electronics etc.

**Process and Product Development Centre (PPDC), Agra** was established with assistance from UNDP/ UNIDO and Government of UP to support Micro, Small, and Medium Enterprises across the country with special focus on Foundry, Forging, and Engineering Clusters.

PPDC functions under the administrative control of the Governing Council. Development Commissioner (MSME), Ministry of MSME, Govt. of India is the Chairman of the Governing Council. It provides following services for the development of MSMEs.

- Product & Process Development- Development of & intricate cast components of ferrous & non-ferrous metals, low & high alloy steels. Investment casting of Foundry & Forging Shop, HT Shop
- Testing division - Chemical, metallurgical & non-destructive testing of ferrous & non-ferrous metals and engineering components. Defect investigation and failure analysis of engineering components
- Training- NSQF approved training courses, NCVT approved training courses in technical trades like Modular, Mechanical Draughtsman. Training in advance CAD Software – Auto-Cad, Pro-E etc.

**National Small Industry Corporation (NSIC)** is one of the oldest institutes in the country, instituted in 1955. Broader objective of NSIC is to promote, aid and foster the growth of MSME enterprises in the country. NSIC have been working on multiple programmes for skill development, training etc. NSIC has multiple regional centers supporting different MSME clusters. Institute supports common facility services for MSME industries, to enhance their competitiveness and quality. NSIC provides multiple facility to the industries – material testing facilities, energy auditing, chemical testing, energy efficiency, environment management training etc. Key activities supported by NISC relevant to foundries are-

- Conduct hand-on trainings for skill enhancement of shop-floor workforce around energy efficiency and management.
- Develop curriculum for professional courses in forging and foundry technologies through consultation with stakeholders
- Establishing of facilities such as for casting testing, Computer Aided Design for Casting


# 3. Energy Consumption and Benchmarks

# 3. Energy consumption and benchmarks

Foundry industry is energy intensive and energy cost accounts for about 15–20 per cent of total production cost. The primary process steps in metal casting method are preparation, melting, pouring, and finishing. Induction furnace and cupola are the two main melting furnaces used by foundries. In induction-based furnaces melting itself accounts for 75–80% of the energy consumption, whereas in cupola-based furnaces it is between 90-95%[4]. The remaining balance is used in auxiliary operations.

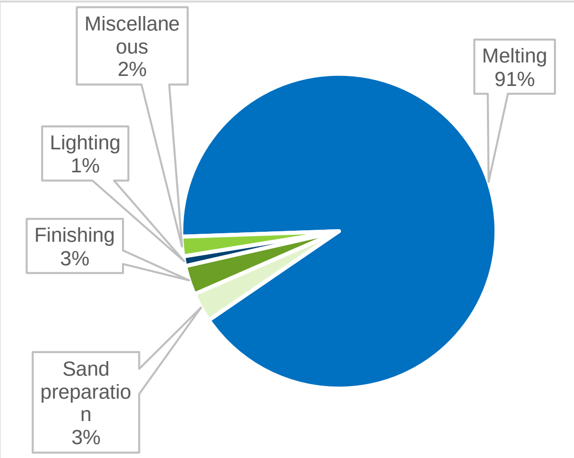



*Figure 9 a. Typical energy consumption in Cupola based furnaces*

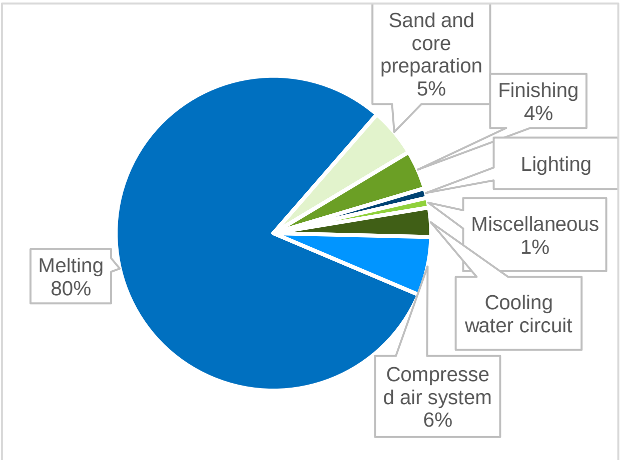



*Figure 9 b. Typical energy consumption in Induction based furnace*

- Metal melting and core preparation accounts for 80-95% of the total energy consumption in the foundry industries. Apart from this other major energy consumption area is compressed air systems.
- *Specific Energy Consumption (SEC)[5] for the induction-based melting furnace range between 580-800 kWh per tonne of liquid metal*
- *Specific Energy Consumption for convention cupola has SEC in range of 100-300 kg of coke per tonne of metal*.

Furnaces and auxiliaries have a huge potential for energy conservation, around 10-35% of the energy can be saved - by selecting right type and size of equipment, maintaining the air fuel ratio, complete combustion, waste heat recovery, automation of processes, periodical maintenance, and by adopting best operational practices.

In Indian foundry context, some clusters are doing better than others. Within the clusters some foundries are doing better than others. These units have identified and implemented energy efficient technologies and practices. Thus, there is need for benchmarking (SEC in kgoe/tonne of final product) and energy mapping. This shall further improve the efficiency and competitiveness of the Indian foundry industry.

[4] Source: Foundry cluster profile reports, sameeeksha.org and SIDHIEE

[5] *SEC is defined for MS, based upon the team experience of the similar assignments in the past.*

## 3.1. *Energy Benchmarking*

The term benchmarking involves “comparing actual or planned practices, such as processes and operations, to those of comparable organizations to identify best practices, generate ideas for improvement”[6] which form the basis for measuring performance in an industry.

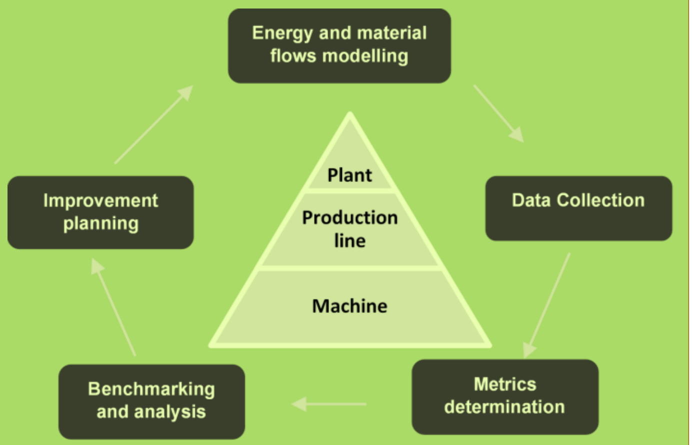
Energy efficiency (EE) benchmarking can be defined as the technique to identify the best practices and achievable EE improvement targets in companies and industries. The management in an industry can compare their baseline values with benchmark and take steps to ensure improvements in EE.

Energy efficiency benchmarking can be divided into internal (including SEC, historical trends oof production, energy consumption inside plant boundary) and external benchmarking (benchmarking with industry best SEC level etc.). Internal benchmarking is the comparisons within one company to establish the baseline and best practice. External benchmarking is to compare companies in the same or similar industry sector to establish the best-in-class performance. Additionally, general benchmarking is the comparisons of practices regardless of the industry field.

Benchmarking as defined above is process of searching for best practices that lead to excellence in performance. Baseline can be established by comparing the best practices practiced and subsequently, areas of potential improvement, and areas of focus can be identified. A variety of methods and studies have been carried across industry to come up with the best practices of energy efficiency benchmarking.

**Example: A five step energy benchmarking method ($E^2$BM method)**

$E^2$BM method can be applied at each individual process (e.g., machine), interrelated processes (e.g., production line), and a plant. This method relates energy consumption in manufacturing process to material flows to visualise the effectiveness and variations of energy usage. The inputs received from the prior step are used for developing strategies to improve energy efficiency. It consists of five steps and takes three levels of hierarchy into consideration i.e., plant, production line and machine.




### *Energy Performance Indicators for the sector*

**Key Performance Indicator (KPI)** can be defined as a quantifiable/measurable value that demonstrates how effectively the industry or equipment or process is performing. KPIs can be financial and non-financial. A pictorial representation defining KPI’s is presented next.


The four challenges in defining and maintaining KPIs are: (a) understanding industry’s strategy and key objectives, (b) measure is deemed important to area/process of the industry, (c) targets of KPI

[6] Source: Guide to the project Management body of knowledge, PMBOK, 2013.

improvement must be realistic and (d) in case, accurately measuring and reporting indicators is difficult, internal process or SOP should be defined.[7]

*Table 12 EnPI related terms and definitions*

| Term | Definition | Notes |
|---|---|---|
| **Energy baseline** | Quantitative reference(s) providing a basis for comparison of energy performance | An energy baseline reflects a specified period of time |
| **Energy consumption** | Quantity of energy consumed | - |
| **Energy efficiency** | Ratio or other quantitative relationship between an output of performance, service, goods or energy, and an input of energy | Conversion efficiency; energy required/energy used; output/input; theoretical energy used to operate/energy used to operate |
| **Energy performance** | Measurable results related to energy efficiency, energy use and energy consumption | Results can be measured against organization's energy targets and energy performance requirements |
| **Energy performance indicator** | Quantitative value or measure of energy performance, as defined by the organization | EnPIs could be expressed as a simple metric, ratio, or a more complex model[8] |

EnPIs can be a simple parameter, a simple ratio, or a complex model. Examples of EnPIs can include energy consumption per time, energy consumption per unit of production, and multi-variable models. The organization can choose EnPIs that inform the energy performance of their operation and can update the EnPIs when business activities or baselines change that affect the relevance of the EnPI, as applicable.

Energy performance indicator of a foundry industry as a whole is represented as energy consumed per tonne of casting produced (kWh/tonne), the indicator can be further divided to arrive at sub-process/equipment-wise EnPI such as induction melting furnace (kWh/tonne), air compressor (kW/cfm). The EnPI for any equipment varies depending on end application, usage pattern and a number of variable parameters.

EnPIs can further be classified as direct or indirect. Direct EnPIs are the internal factors for comparison within an industry to come up with best practices and establish baselines. Indirect EnPIs is comparison of companies or industries in a similar sector to establish best in class practice the infographic below [9]., depicts a study that was conducted by IFC in Russian foundries. The KPIs shown here are indirect, wherein monitoring and improving these KPIs will in-turn improve the EnPIs.

## 3.2. *SEC comparison across various clusters across India*[10]

The specific energy consumption (SEC) of any foundry varies considerably depending on the type of foundry and the degree of mechanization used. For example, induction-based foundry units across India consume about 700–2000 kWh per tonne for finished final casting (CI, DI, SGI Steel) and Investment casting units consume over 3000 kWh per tonne for the multiple finished final castings.

[7] Source: The Basics of Key Performance Indicators, https://www.thebalancecareers.com/key-performance-indicators-2275156
[8] Source: International Standard, ISO 50001 - Energy Management Systems - Requirements with guidance for use, 1st edition 2011-06-15
[9] Source: Resource Efficiency in ferrous foundries in Russia, IFC
[10] SEC of the different clusters based on different melting technologies and production is presented in annexure.

Out of this, about 580–850 kWh is consumed per tonne in the melting process whereas the balance is consumed in other associated operations. On the other hand, in cupola-based foundry the melting process requires 7-17% of coke per tonne of metal melted and 7-12% on good castings. Average SECs of foundries in some of the prominent clusters are represented in the bar graph below.

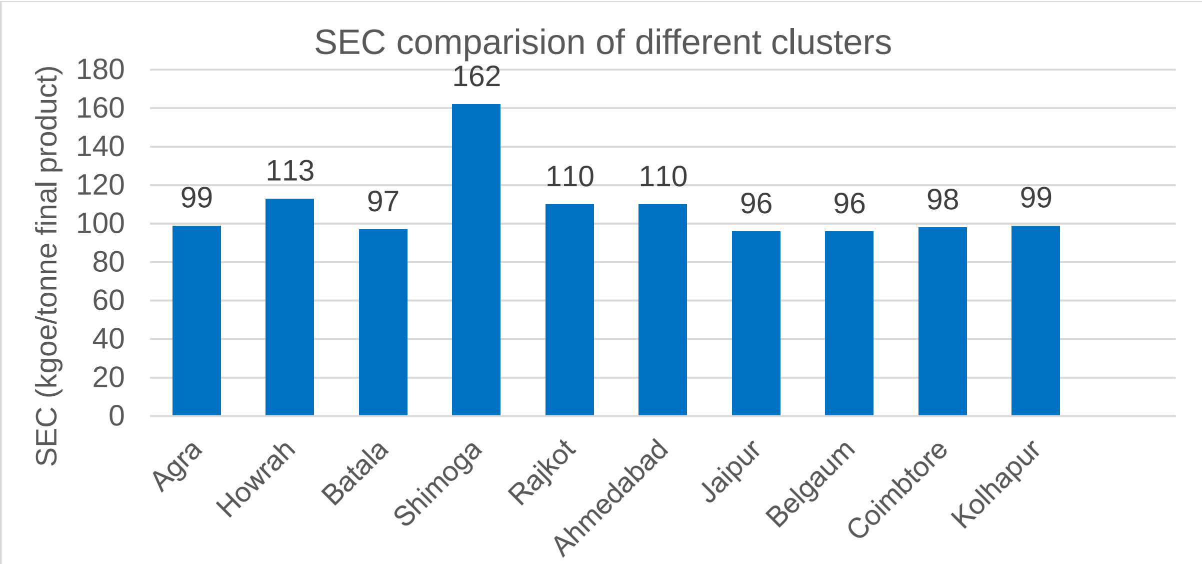



*Figure 10: SEC benchmarks for different foundry clusters across the country*

SEC variation across the different clusters[11] on the basis of the melting technology is presented in Figure 11 and Figure 12. Details of the variation in the SEC is presented in the section after the graphs.

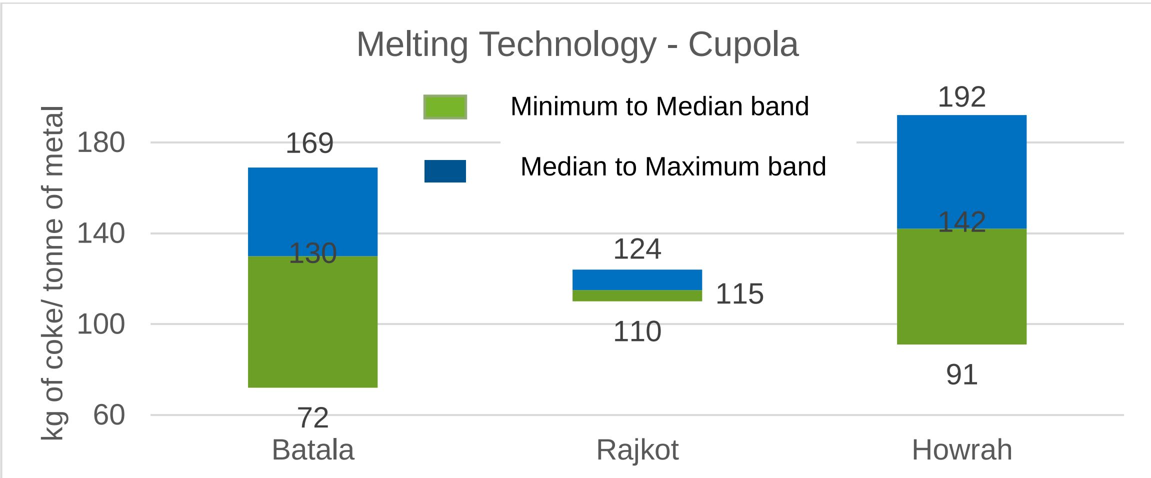



*Figure 11: SEC for different foundry units using the cupola melting technology*

[11] Details are based on the energy audit and filed studies carried out under BEE energy and resources mapping assignment across different foundry clusters. SEC of the different clusters based on different melting technologies and production is presented in annexure.

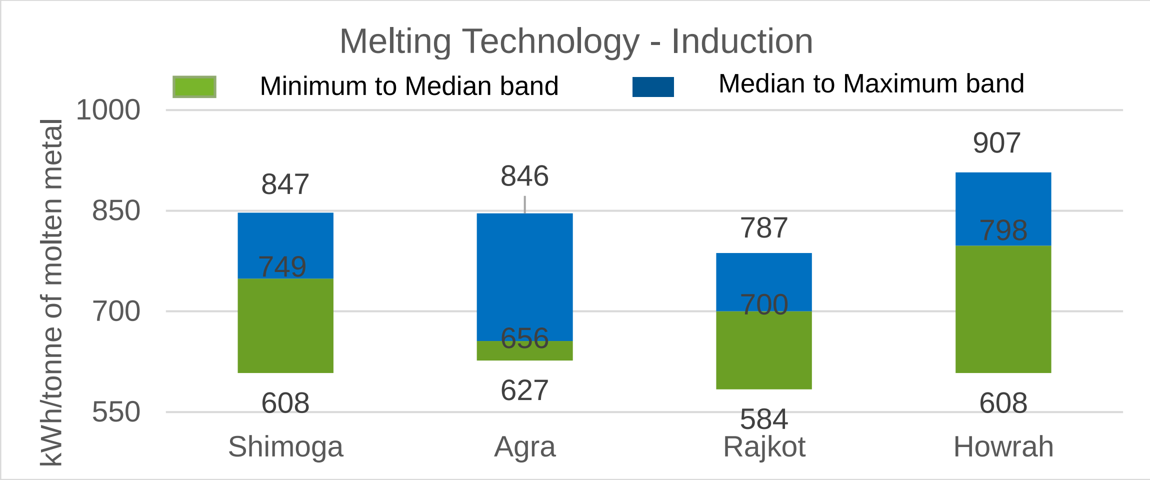



*Figure 12: SEC for different foundry units using the Induction melting technology*[12]

There is a considerable variation in the SEC of Indian foundry clusters. Some clusters are doing better than the others. There can be multiple reasons for the varied SEC values in different clusters. It depends on the varied types of products manufactured by these foundries. Further, many of the foundry's clusters use the conventional single blast cupola furnace crude design of divided blast cupola (DBC). Majority of the furnaces also lack lid mechanism in them resulting in higher heat losses due to radiation and convection

*SEC comparison for different foundry clusters might not represent the true scenario as Shimoga is the only cluster which has 100% penetration of induction melting furnaces and also has the highest share of the modern technologies. Despite all these modern technologies the cluster has the highest SEC. Reason for the same is cluster produces higher quality steel and alloy castings, also cluster produces the final finished products which requires the extensive machining and allied operations. Similar type of high value casting is not predominantly produced in other clusters.*

In order to carry out the better comparison the SEC should be monitored on the basis on melting technology and metal, or alloy being melted. Variation of the SEC for different metals melted by use of the different melting technologies is presented in Table 13.

*Table 13: SEC benchmark data for Indian MSME foundries*

| **Metal** | **Melting technology** | **SEC (kgoe/tonne of final product)** | | |
|---|---|---|---|---|
| | | Minimum | Maximum | Median |
| **CI** | Cupola | 72 | 126 | 101 |
| | DBC | 67 | 111 | 87 |
| | Gas Cupola | 71 | 90 | 81 |
| | Induction | 62 | 308 | 98 |
| **SGI** | Gas Cupola | 64 | 66 | 65 |
| | Induction | 77 | 149 | 96 |
| **Steel and Alloy** | Induction | 125 | 308 | 137 |
| **Investment Casting** | Induction | 288 | 400 | 350 |

[12] SEC of the different clusters based on different melting technologies and production is presented in annexure.
[13] Most widely adopted technology based on the survey and EA carried out during the BEE energy and resource mapping assignment

***Variation in the SEC can be broadly classified in the four main parameters –***

- ***Type of metal***
- ***Type of melting technology***
- ***Degree of allied operations***
- ***BOPs***

Details of each category mentioned above is presented in detail next-

- ***Type of metal***
- *Difference in the melting temperature of metal and alloys, higher melting temperature require the higher quality of heating*
    - *Melting temperature for the CI* is lowest among all the grades of metals meting temperature for CI casting varies in range of 1400-1450 degree centigrade.
    - *Melting temperature of the SGI* varies in rang of 1450-1520 degree centigrade
    - *Melting temperature for steel and alloys* varies in range of 1550-1600 degree centigrade
    - *Melting temperature of Stainless steel* varies in range of 1600-1650 degree centigrade

      *Shimoga, Rajkot, are progressive clusters to produce the larger volumes of the high-end alloys and investment casting. Batala is predominantly CI casting producing cluster, Agra and Howrah produce mix of CI, SGI products. Kolhapur, Belgaum, Coimbatore, have mix of the units producing CI, SGI, alloy castings.*
- ***Type of melting technology***
    - ***Conventional cupola** is most widely adopted melting technology for lower grade castings (CI), due to inherent characteristics of the conventional cupola SEC varies in range of 60-120 kgoe/tonne, the variation is primarily due to the SOPs adopted by the different units across the foundry clusters. Median SEC for conventional cupola based on the BEE's energy and resource mapping study is estimated for the Indian foundry is 101 kgoe/tonne*

      *Batala, Jaipur, Indore etc., are the clusters where the conventional cupola is predominantly used as melting technology.*
    - ***Divided blast cupola** provided the better air to fuel control which support the better combustion of in the cupola furnace thus helping in lowering the SEC. Median SEC of DBC based on the BEE's energy and resource mapping study is estimated for the Indian foundry is 87 kgoe/tonne*

      *Howrah, Rajkot, Ahmedabad etc., are the clusters where the DB cupola is predominantly used as melting technology.*
    - ***Gas Cupola** provided the added advantage of the cleaner fuel and better controlling of air fuel ratio can be precisely controlled, thus helps in eliminating the losses. Median SEC of gas cupola based on the BEE's energy and resource mapping study is estimated for the Indian foundry is 81 kgoe/tonne*

      *Gas cupola is predominately used across Agra foundry cluster and find few installations in Indore cluster*
    - ***Induction melting furnaces provided** the added advantage of the cleaner fuel (electricity) and better controlling of precise temperature control can be possible by adjusting the current and frequency of the current in the coils, thus helps in eliminating the losses. Median SEC of induction melting based on the BEE's energy and resource mapping study is estimated for the Indian foundry is 98 kgoe/tonne for CI and 137 kgoe / tonne for Steel and 350 kgoe/tonne for Investment casting*

      *Induction is predominately used across Shimoga foundry cluster and used as major melting technology across the clusters of Kolhapur, Belgaum, Coimbatore, Ahmadabad etc.*

- ***Degree of allied applications***
    - ***<u>Units using the cupola and producing the CI casting</u>*** *doesn't involve in the machining and Heat treatment applications. CI casting produced by these units after minimal fettling is sent to the customers as the end products. Most the products are lower grade of castings used for main-holed, agriculture implements, Toka machines, saintly pipe and fittings etc.*
      *Most of foundries in the Batala, Agra, Jaipur, Howrah clusters produce the CI casting that require the lower machining and allied operations – thus SEC of these clusters are lower despite of predominantly using the Conventional cupola technology for metal melting.*
    - ***<u>Modern units involved in producing the CI castings (induction melting)</u>*** *carry out the multiple machining operations and heat treatment applications to produce the high-quality CI and DI castings. Most of the units in this category are medium units and used Induction based melting technologies for better and precise temperature control; use of advance machining operations; high end technology for sand – mould making; units also carry out the heat treatment for the specified products. End products produced by these units are directly used by end consumers. Major products – machinery components, Pumpset parts, textile, and sugar industry components etc.*
      *Foundry clusters of Kolhapur, Belgaum, Ahmedabad, Rajkot, Shimoga, Coimbatore despite of using the mix of Induction melting furnaces and DBC have slightly higher SEC due to allied operations carried out along with casting operations.*
    - ***<u>SEC of the Alloy steel / Stainless steel / investment casting</u>*** *are very high due to the additional processes such as shell preparation, de-waxing application shell baking etc. Also, investment casting is generally done for the higher grade of alloys and are produced with highest level of precision and tolerance. Higher grade of alloys has higher melting points and higher precision and surface finish require the higher end process technologies and machining and finishing applications- which possess the additional energy requirements. Heat treatment is also one of the most processes in these castings. Major components produced are – high quality surgical equipment, Oil and Gas components, Components for aviation, defense, and high-end automobiles.*
      *Foundry clusters of Rajkot, Shimoga, Coimbatore despite of using the modern state of at induction melting technologies have higher SEC as compared with other foundry clusters.*

- ***<u>Best operating practices and EE technologies</u>*** *for the different processes used in foundries play is vital role in optimization of the energy consumption in the units. Summary of key BOP's and technologies is presented in Table 14*

*Table 14: Summary of BoPs and EE technologies for different foundry processes 14*

| Particulars | Best | Major Area of Improvement Required to meet the Benchmark values | Best operating practices |
|---|---|---|---|
| **Induction based furnace (kWh/tonne)** | CI: 509<br>SGI: 575<br>Steel & alloys: 608<br>Investment Casting: 620 | • Use of an IGBT based induction furnace.<br>• Use of Lid based mechanism<br>• Use of the good quality lining for the furnace | • Optimizing the charging time<br>• Optimizing the holding time during Spectro analysis<br>• Optimizing the poring time |

[14] Elaborative details of ah technology and BOP is presented in technology compendium section

| Particulars | Best | Major Area of Improvement Required to meet the Benchmark values | Best operating practices |
|---|---|---|---|
| **Gas fired cupola (SCM / tonne)** | CI: 74 | • Maintaining proper blast in cupola controlling the draft and air flow.<br>• Improving operating practices, Proper sizing of the blower (pressure and volume)<br>• Installing gas flow meter | • Weighment of the coke and metal<br>• Optimizing the size of the coke size<br>• Use of the adequate size of the metallic scrap.<br>• Monitoring bulk density of the coke |
| **Cupola based furnace (coke : metal)** | 1:10 | | |
| **Divided blast cupola (coke : metal)** | 1:14 | | |
| **Screw Air compressors (Pressure 7 bar)** | 0.15 | • Use of IPM screw compressors<br>• Technology shift to screw compressors with integrated control systems | • Optimizing the pressure drop in pipeline and arresting air leakages |
| **Reciprocating Air compressors (Pressure 7 bar)** | 0.20 | | |
| **Pump set (efficiency) up to 10 kW** | 80% | • Selection of adequate pump with appropriate flow and head, Proper maintenance | • Monitoring the water quality and operating parament's periodically |
| **Motors and Drives** | 96% | • IE4/ Permanent Magnet, Replacement of rewound motor | • Avoid multiple time re-winding<br>• Avoid installing higher capacity (rated than required) motors |
| **Lighting** | 135 | • Use of higher efficient Star rated LEDs, use of adequate lux level in different areas | • Use of the motion sensors and automatic switching of lights |

## 3.3. *Comparison with International benchmarks*

Foundry sector produces cast metal products based desired requirements. Although there are reliable statistics for a number of foundries, the foundry sector is not separately reported in international energy statistics. Foundries are dispersed across a number of sectors against which their activities are accounted for, such as the iron and steel, non-ferrous metals, and machinery sectors.

A survey of Canadian foundries covering a total of 45 foundries found that the melting process in iron foundries accounts for 54% - 84% (average 66%) of the total final energy use, according to a study conducted by UNIDO. The remaining energy use results from electricity consumption by motors (30%) and lighting (4%). 12% is consumed in air compression systems which account for around 100 kWh to 200 kWh per tonne of cast product, for example in sand casting. Although lighting demand is very similar in steel and bronze and copper foundries, the energy demand for motors is higher at around 57% in bronze and copper foundries than in steel foundries (around 47%). The share of electricity demand for the melting process is however higher in steel foundries at around 45% - 65% (average 49%) than in bronze and copper foundries at around 38%.[15] The table below shows foundry benchmarks in terms of electricity use (kWh per tonne of melted product). The table does not represent the electricity benchmarks of the overall foundry plant.

[15] Source: Global Industrial Energy Efficiency Benchmarking, UNIDO, Nov 2010

*Table 15 Best SEC benchmarks for foundry (CI melting) globally (kWh/t of molten metal)* [16]

| Metal | EU | Canada | Russia | USA | India[17] |
|---|---|---|---|---|---|
| **Cast iron consumption** | 500 | 595 | 543 | 500 | 509 |

Indian foundries (processing CI) have best SEC value of about 584 kWh/tonne for induction furnace and average SEC value about 681 kWh. There is a considerable gap between best and average values. In the case of European and USA foundries have their best SEC as 500 kWh per tonne and Russian foundries have best SEC of about 543 kWh/tonne. Best SEC levels for Canadian foundries are 595 kWh/tonne slightly higher than Indian foundries. This further elaborates the gap in efficient use of foundries in India and abroad and need to introduce best practices and technologies to increase their efficiency. SEC comparison for CI melting in induction furnace is shown in Figure 13[18]

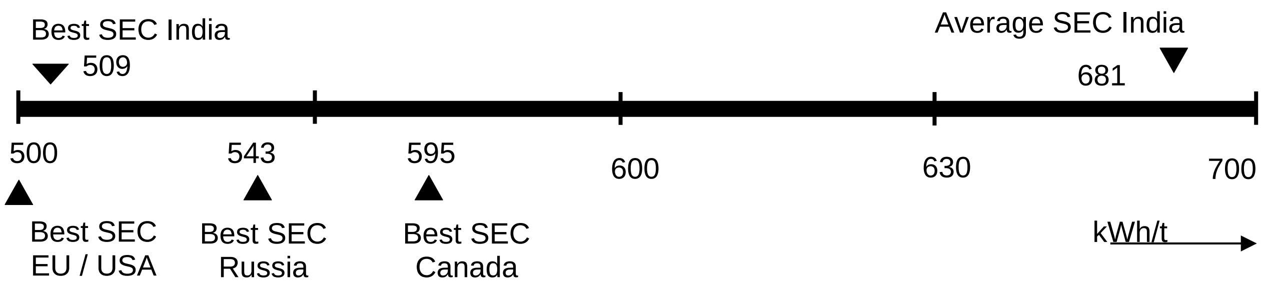



*Figure 13: Comparison of Indian foundry with Global foundries (Induction melting – CI metal)*

*Table 16 Best SEC benchmarks for foundry (Steel and alloys) melting globally (kWh/t of molten metal)*

| Metal | EU | Canada | India[19] |
|---|---|---|---|
| **Steel and Alloys** | 520 | 620 | 608 |

Indian foundries processing steel and alloys have best SEC value of around 608 kWh/tonne for induction furnace and average SEC value about 731 kWh per tonne. There is a considerable gap between best and average values. In the case of European foundries have their best SEC as 520 kWh per tonne. However, the best Canadian foundries have best SEC level slightly higher than Indian foundries. SEC comparison for steel and alloys melting in induction furnace is shown in Figure 14.[20]

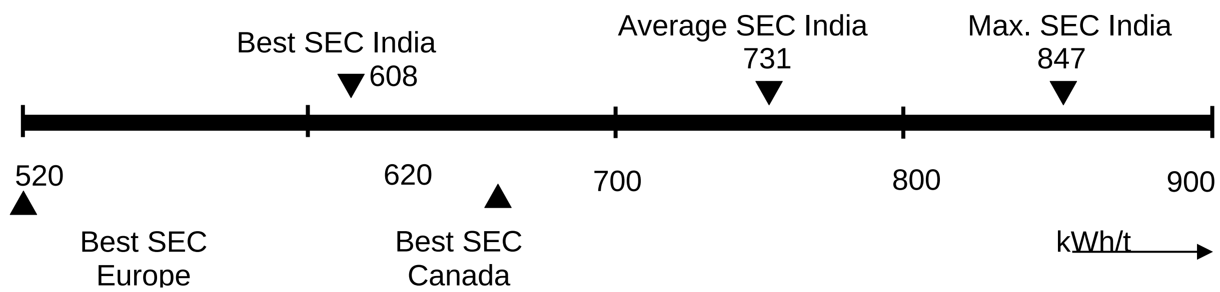



*Figure 14: Comparison of Indian foundry with Global foundries (Induction melting – Steel and alloys)*

[16] Comparison of SEC is plotted based upon the type of metal being metal to form the castings, SEC is also function of the type of end product, type of raw material, processes adopted and scale of operations (Global leaders in foundries have higher scale of operations and larger foundries thus helping them to have the lower SEC)
[17] Few of the unit processing CI uses the old SCR based Induction, thus SEC is slightly for the few units
[18] Source: Cleaner production strategies in small scale foundries, 2013
[19] Few of the unit processing CI uses the old SCR based Induction, thus SEC is slightly for the few units
[20] Source: Cleaner production strategies in small scale foundries, 2013

# 4. Energy Efficiency Potential in foundry sector

# 4. Energy Efficiency Potential in foundry sector

Foundry is one of the most energy intensive sectors, the majority of the energy is consumed in melting and allied operations depending upon the type of the castings and type of metal. Melting contributes considerable share in the energy pie for the foundry units, followed by the mould preparation and other processes.

Energy saving potential is a function of the present efficiency levels, type of fuel used, energy efficiency measures applicable for different foundry clusters, and readiness of the foundry clusters in adopting the new state of art technologies. Details of the present fuel mix, penetration level of different technologies, EE potential for the different foundry clusters and national level projections is presented in this section.

The Foundry sector mainly uses coke and electricity for meeting the energy requirements. Gas is used as fuel in limited operations in limited clusters, oil is used for HT in some clusters and used as fuel in DG for back power. Major application of the different fuels is presented next.

**Coke**
- Metal melting in cupola furnaces

**Electricity**
- Metal melting in induction furnace
- Sand preparation, machining, shot blasting, air compressor


**Oil**
- HT furanaces
- DG back up power


**Gas**
- NG is used for metal melting in gas cupola
- LPG is mainly used in heat treatment furnaces
- LPG is fired in shell baking processes

During the BEE- *"Energy and resource mapping assignment"* detailed primary survey (EoI forms 250+) and secondary stakeholder consultations (390+), field visits (70+), energy audits (50), review of the past reports and interventions carried out across foundry clusters, discussion with IA (12+) and technology providers - were carried out to evaluate the penetration level of different technologies and shar of the different fuels etc.

Summary of the cluster level and sector level findings based on the elaborative and extensive study is presented in section next.

## 4.1. *Energy consumption at cluster level*

Different foundry industries use the mix of the conventional and modern melting technologies. Based on the different technologies and operations predominantly three forms of the energy are used by the sector i.e., electricity, coke, and gas. Share of the energy varies for the different foundry clusters based upon the type of the technology and different operations catered during the formation of the final product.

During the BEE energy and resource mapping study, the share of the fuel mix for five foundry clusters ***(Rajkot, Shimoga, Howrah, Agra, Batala)*** is calculated based on the energy audits and stakeholder consultations with industries and multiple industries associations in these clusters (physical meetings, workshops, webinars).

*Findings for these clusters have been thoroughly discussed with prominent industry associations and industries through workshops / physical meetings and one-one interactions with multiple industries. Five cluster level workshops were conducted across – Batala, Shimoga, Rajkot, Agra, Howrah foundry clusters to validate the findings. Regional consultations across the prominent foundry clusters (western region, central region, and southern region) were also conducted to validate the findings.*

Summary of the different forms of energy used in different foundry clusters is presented in Table 17 and share of the energy (toe) for different clusters is presented in Table 18.

*Table 17: Fuel mix for the different foundry clusters (five clusters)*

| Energy type | Unit | Batala | Shimoga | Rajkot | Agra | Howrah | Overall |
|---|---|---|---|---|---|---|---|
| Electricity | million kWh | 9.27 | 146 | 1189 | 123 | 331 | 1798 |
| Coke | tonnes | 11,858 | | 47,640 | | 84,774 | 144,272 |
| Gas | tonnes | | 749 | 22,553 | 3959 | | 27,262 |
| Oil | tonnes | | 557 | | | 8247 | 8,804 |

*Table 18: Energy share of different fuels in five foundry clusters (Units - **toe**)*[21]

| Energy type | Batala | Shimoga | Rajkot | Agra | Howrah | Overall |
|---|---|---|---|---|---|---|
| Electricity | 797 | 12,513 | 102224 | 10,587 | 28,462 | 154,583 |
| Coke | 8,301 | | 30,030 | | 57,223 | 95,554 |
| Gas | | 862 | 14943 | 2495 | | 18,300 |
| Oil | | 665 | | | 8533 | 9,198 |
| Total | 9,098 | 14,040 | 147,197 | 13,082 | 94,218 | 277,635 |

Share of electricity in fuel mix for the Batala, Shimoga, Rajkot, Agra, Howrah are – 9%, 89%, 69%, 81%,30% respectively. Share of coke in fuel mix for the Batala, Rajkot, Howrah are – 91%, 20%, 61% respectively. Share of gas in fuel mix for the foundry clusters in Shimoga, Rajkot, Agra are – 6%, 10%, 19% respectively. Share of oil in fuel mix for the foundry clusters in Shimoga, and Howrah – are 5%, 9% respectively.

[21] Appropriate GCV values of the different fuel based upon the discussion with Industries review of the GCV reports at different audited units, across different clusters have been used to convert the different form of fuel to oil equivalent units.

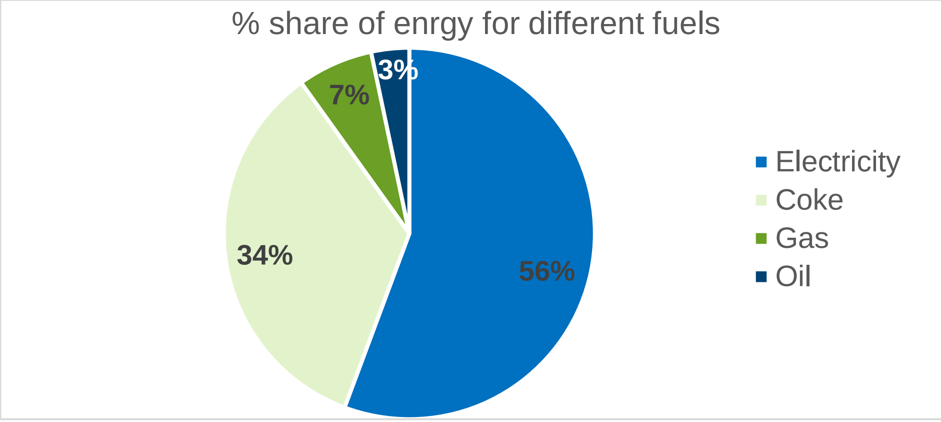



*Figure 15: Energy share of different fuels across five clusters*

Electricity is the prominent fuel in the five clusters (*Rajkot, Shimoga, Howrah, Agra, Batala)* accounts for around 56% of total energy demand in these clusters. Coke is the second largest used fuel in these clusters and contributes 34% to energy pie. Gas and oil contribute to around 10% share in these clusters. *However, the gas is predominantly used in Rajkot and Agra clusters only.*

### 4.1.1. *Prominent melting technologies adopted in foundry sector*

Different technologies are used in different foundry clusters, based upon the type of the metal being processed and type of the final product produced. *Summary of the technology level penetrations is carried out on the basis of the primary survey, field visits, energy studies and stakeholder consultations across different foundry clusters.*

Summary of the predominant melting technologies (Cupola, Gas Cupola, Induction melting) adopted among the different foundry clusters is presented in Table 19.

*Table 19: Share of the prominent melting technologies during FY 22*

| Metal ↓/ Melting technology → | Sectoral production (Mn tonne) | Cupola | Gas Cupola | Induction |
|---|---|---|---|---|
| **Cast Iron (CI)** | 9.06 | 49.6% | 0.2% | 50.2% |
| **SGI Iron (SGI)** | 1.35 | - | 1.2% | 98.8% |
| **Steel and Alloy** | 1.27 | - | - | 100% |
| **Investment casting** | | - | - | |

**Cupola** is predominately used to produce the CI castings; Gas cupola is used for CI and SGI castings but is limited to a few clusters only. Conventional cupola is predominantly used across different clusters (*Batala, Jaipur, Ahmedabad, Indore foundry clusters)* which use higher coke per tonne of molten metal. Modern designed Divided blast cupola provides the better efficiency and have lower SEC level *(Used widely across Rajkot, Howrah Coimbatore, Kolhapur, Belgaum foundry clusters)*

**Induction melting furnace** is predominantly used for higher value castings (steel and investment) and also shares a considerable share in the CI and SGI castings. Around 60% of the units use the *conventional (SCR)* based induction which consumes significantly higher energy per tonne of molten metal as compared with *modern state of art IGBT based induction furnaces* with IOT based control *(Adopted by front runners across the different foundry clusters).*

### 4.1.2. *Sector level production details and SEC*

Production data for the different grade of metal taken from the national level foundry association (IIF). Based upon the historical production data CAGR is calculated for different metallic castings and

CAGR growth is used to project the future production levels. SEC data for the different melting technologies is calculated from the multiple energy audits carried out under the BEE energy and resource mapping assignment, SEC data has been validated thought multiple consultations carried out different foundry cluster. Details of the present level production, SEC are presented in Figure 16.

*Table 20: Production data for the FY 22*[22]

| Metal | Melting technology | Mn tonnes | SEC (toe/tonne) |
|---|---|---|---|
| **Cast Iron (CI)** | Cupola | 3.335 | 0.104 |
| | Gas Cupola | 0.040 | 0.077 |
| | Induction melting furnace | 5.686 | 0.107 |
| **SGI** | Gas Cupola | 0.023 | 0.065 |
| | Induction melting furnace | 1.326 | 0.112 |
| **Steel & alloys** | Induction melting furnace | 1.032 | 0.195 |
| **Investment casting (Steel & alloys)** | Induction melting furnace | 0.243 | 0.332 |
| ***Total*** | | ***11.69*** | |

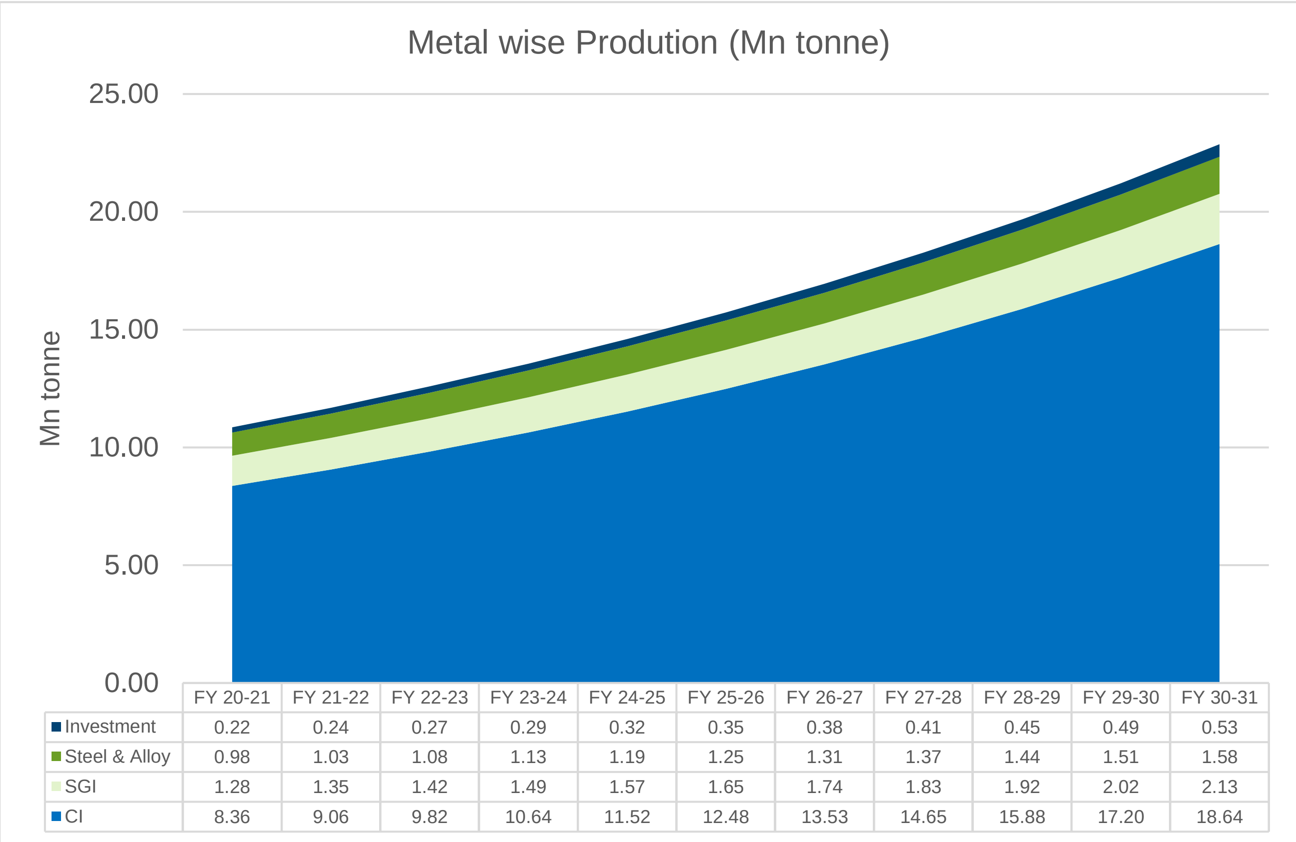



*Figure 16: Share of production of different metals (projections)*

### 4.1.3. *Sector level energy consumption*

Benchmark SEC data for the different metal and type of operations in foundry validated though multiple consultations is used for calculating the sector level energy consumption data. Energy

[22] Thermal energy is predominantly used DBC cupola, Gas Cupola for metal melting, Modern Induction based units have highest % shar of electrical energy only. Investment casting units have mix of thermal energy for core preparation and electrical energy for metal melting.

consumption for different types of casting is calculated by product of the SEC and production volume. Summary of the sector level energy consumption for different metals is presented in Table 21.

*Table 21: Sector level energy consumption of the different metal and melting technology (FY 22)*

| Metal | Melting technology | Energy consumption (Mn toe) |
|---|---|---|
| **Cast Iron (CI)** | Cupola | 0.35 |
| | Gas Cupola | 0.00 |
| | Induction melting furnace | 0.61 |
| **SGI** | Gas Cupola | 0.00 |
| | Induction melting furnace | 0.15 |
| **Steel & alloys** | Induction melting furnace | 0.20 |
| **Investment casting (Steel & alloys)** | Induction melting furnace | 0.08 |
| ***Total energy consumption (Sector level)*** | ***Mn toe*** | ***1.39*** |

Share of the different fuels used by the different foundries at the sector level is presented in the Figure 17.

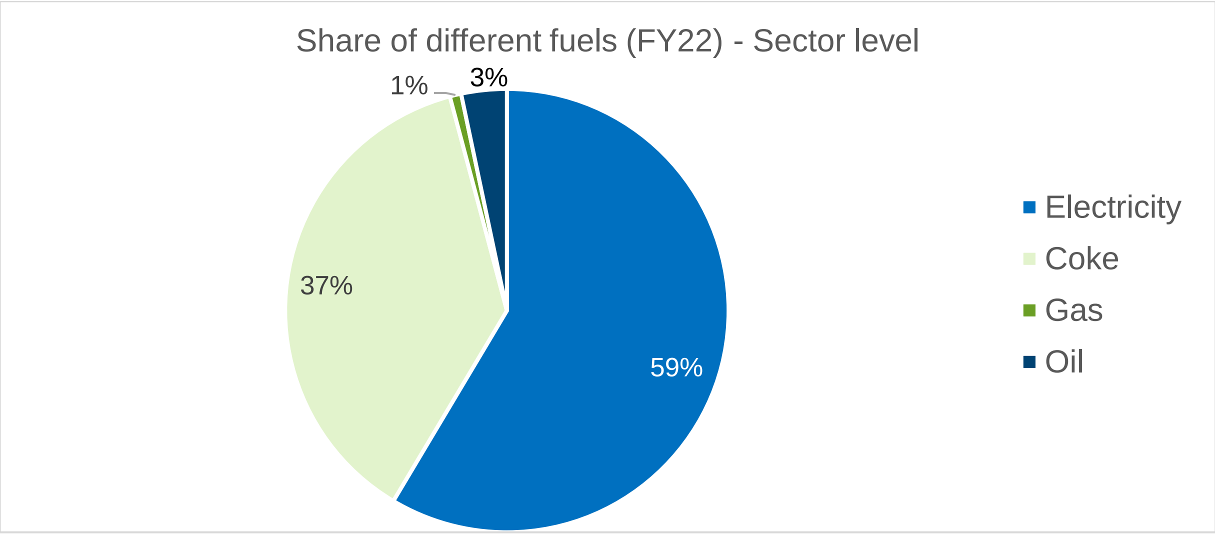



*Figure 17: Sectoral level share of different fuels (FY22)*[23]

Electrical energy has the highest share (59%) among the different forms of the energy. Electricity followed by the coke (37%) which is predominantly used as the source of the fuel in Cupola

## 4.2. ***Projections of energy saving potential***

In order to evaluate the energy saving potential at the sector level, mapping of energy efficiency technologies, state of art technologies, EE technologies for utilities is required along with energy saving potential.

Mapping of the technologies for the different foundry clusters were done though field studies, primarily survey, discussion with IA and technology vendors. Long list of the technologies was mapped during multiple tasks and activities under BEE energy and resource mapping study.

Replication potential for different technologies in short term and long term is evaluated in closed consultations with multiple stakeholders across different *leading foundry clusters* – **Kolhapur** foundry

[23] Gas consumption is limited to few clusters link – Rajkot, Shimoga, and Agra

cluster, **Belgaum** foundry cluster, **Shimoga** foundry cluster, **Batala** foundry cluster, **Agra** foundry cluster, **Rajkot** foundry cluster, **Howrah,** and **nearby foundry clusters**.

***Over 390+ foundries***[24] ***and 12+ industry association****s (including regional chapters of IIF, regional cluster level associations) were consulted to fine tune the recommendations of different technologies and repletion potential.* Summary of different energy efficient and state of art technologies is presented in Table 22 and Table 23..

[24] Including the post audit workshop and cross cluster consultations

**Potential of technology penetration levels across[25]**

*Table 22: Process specific replication potential of ECM across foundry clusters*

| S. No | Technologies | Energy savings potential | Replication Potential in short-term (till 2025) | | | Replication Potential in long-term (till 2030) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Micro | Small | Medium | Micro | Small | Medium |
| 1. | Induction melting Furnace with IGBT control and pyrometer | 10-30% | Low | Low | Medium | Saturation | Saturation | Saturation |
| 2. | Insulation & Lid cover to avoid radiation losses | 5% | Low | Low | Low | Saturation | Saturation | Saturation |
| 3. | DBC with optimized air control | 10-25% | High | High | Saturation | Saturation | Saturation | Saturation |
| 4. | Cupola with optimized air control | 10-25% | Low | Medium | High | Saturation | | |
| 5. | Gas based copula with PLC based control | 5-15% | | Low | Low | Low | Saturation | Saturation |
| 6. | Relining of furnaces / Insulation | 5-10% | Low | Medium | High | Saturation | Saturation | Saturation |
| 7. | Electrically operated Heat treatment / Annealing / Normalization furnaces | 20-30% | | Low | Low | Low | Medium | Saturation |
| 8. | Fuel switch in furnace FO- NG for core baking | 10-15% | | Low | Low | Low | Medium | Saturation |
| 9. | IoT based EMS | 2-5% | Low | Low | Medium | Low | Medium | Saturation |
| **State of Art Technologies** | | | | | | | | |
| 10. | Auto poring of molten metal for induction furnace | 5% | | | Low | | Low | Medium |
| 11. | Centralised sand plant | 5% | | Low | Low | | Low | Saturation |
| 12. | Automated core and Sand Plant with conveyor system | 5-10% | | | Low | | Low | Medium |
| 13. | Installation of high pressure moulding line in moulding area | 5% | | | Low | | Low | Medium |
| 14. | Multi axis Machining centre ( 5 / 6 Axis) | 5-10% | Low | Low | High | Medium | Saturation | Saturation |

[25] Indicative list not comprehensive, saving envisaged in the table only represents the energy saving, productivity saving from different technologies is not factored in this table. Most of the units globally having best SEC level had already implemented the ECMs indicated in point 1-9. Cost for the stat of art technology varies from 25 lakhs – over 300 lakhs depending upon the scale of the unit and type of operations performed in the unit.

## Utility specific Energy conservation measures

*Table 23: Utility specific replication potential of ECM across foundry clusters*[26]

| S. No | Technologies | Energy savings potential | Replication Potential in short-term (till 2025) | | | Replication Potential in long-term (till 2030) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Micro | Small | Medium | Micro | Small | Medium |
| 1. | IE3/IE4 motors | 5-15% | | Low | Low | Low | Medium | High |
| 2. | EE FRP Cooling towers with temperature control / Fan less natural draft cooling tower | 5-10% | | Low | Low | | Low | High |
| 3. | Appropriate size of air compressor / Arresting air leakage and pressure optimization | 10-30% | | Low | Low | Low | Medium | Saturation |
| 4. | EE retrofit of low friction metallic pipe for compressed air system | 10-30% | | | Low | Low | Medium | High |
| 5. | Energy Efficient Transformers | 20-50% | Low | Low | Low | Saturation | Saturation | Saturation |
| 6. | EE Air conditioner / Chillers | 10-25% | | Low | Low | Saturation | Saturation | Saturation |
| 7. | Automatic Power factor Controller | 5-10% | Low | Low | High | Saturation | Saturation | Saturation |
| 8. | Energy Efficient Blower | 20-30% | Low | Low | Low | Saturation | Saturation | Saturation |
| 9. | Energy Efficient Pumps | 20-30% | Low | Low | Low | Saturation | Saturation | Saturation |
| 10. | LED lights | 10-50% | Low | Medium | Medium | Saturation | Saturation | Saturation |
| **State of Art Technologies** | | | | | | | | |
| 11. | PM Screw Compressor with waste heat recovery | 20-30% | | | Low | Low | Low | High |
| 12. | Use of Hydraulic power pack (VFD) for Clamping application | 20-40% | | | | Low | Medium | High |

[26] Indicative list not comprehensive, saving envisaged in the table only represents the energy saving, productivity saving from different technologies is not factored in this table

Implementation of the energy saving, and state of art technologies will help in reduction of the energy intensity in the long run. This will help the foundries to become more efficient and competitive globally Summary of the energy saving potential for the different metal is presented in Table 24

*Table 24: Summary of the energy saving potential for different metal*

| Metal | Energy Saving potential (%) | Energy consumption (Mn toe) FY 21-22 | Energy consumption BAU (Mn toe) FY 30-31 | Estimated energy saving (Mn toe) FY 30-31 |
|---|---|---|---|---|
| Cast Iron (CI) | 18% | 0.96 | 1.98 | 0.35 |
| SG Iron | 21% | 0.15 | 0.24 | 0.05 |
| Steel and alloy | 15% | 0.28 | 0.48 | 0.07 |
| ***Total*** | ***18%*** | ***1.39*** | ***2.70*** | ***0.47*** |

Projections of the different scenarios on account of the multiple interventions proposed for the sector are presented in Figure 18. Proposed sector level SEC after implementation of EE and state of art technologies in the long run till FY-2031 is presented in Table 25.

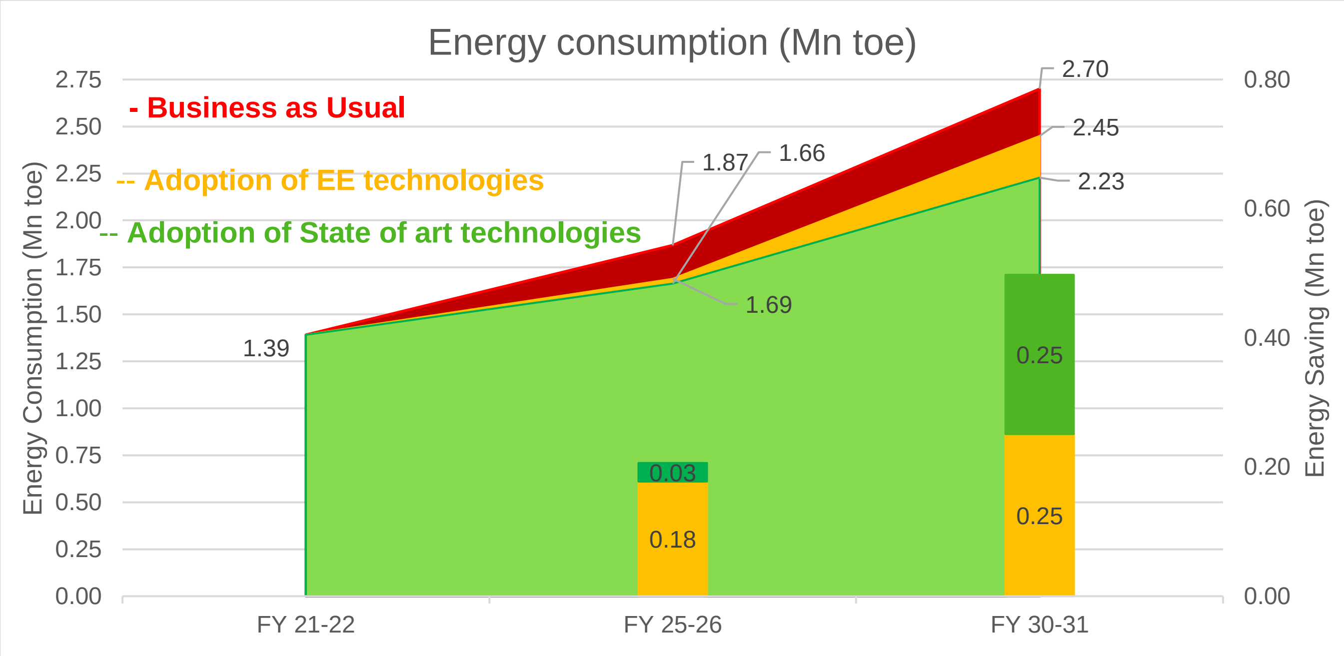



*Figure 18: Projections of energy consumption and savings*

Adoption of the new technologies will help the Indian foundries to reduce the SEC level by over 20% till FY 2031. Faster adoption of the interventions will further help the foundry sector to achieve the saving and lowering the emission faster. List of challenges and proposed solutions to support the sustainable growth of the foundry sector is presented in section 5.

*Table 25: Proposed long term Sector level SEC*

| Overall sector level SEC | FY 21-22 | FY 25-26 | FY 30-31 |
|---|---|---|---|
| **kgoe/tonne** | 119 | 102 | 93 |

Proposed recommendations will help units in the foundry sector to transit from conventional technologies to newer cleaner technologies for the production. Based on the consultations and penetration level of the EE, state of technologies and other cross cutting technologies will lead to change in the fuel mix for the sector. Projected fuel mix, Energy saving potential and SEC for the foundry sector is presented in Figure 22.

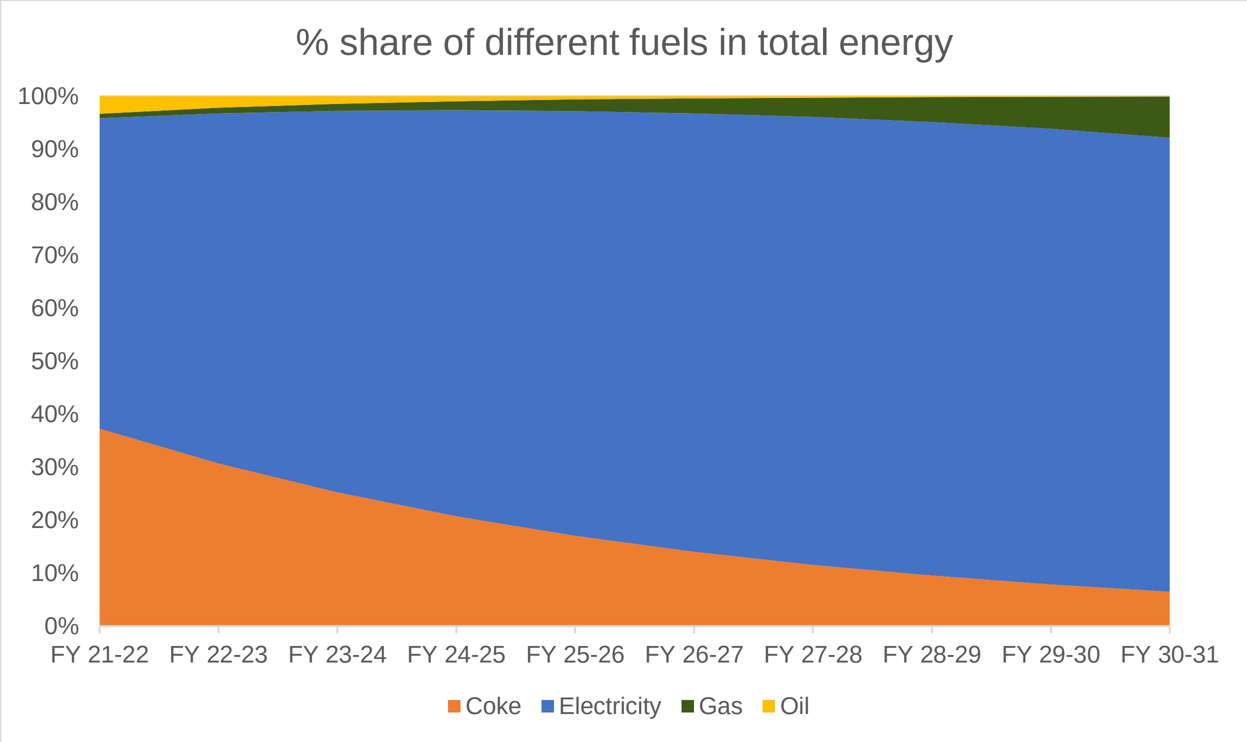



*Figure 19: Projected fuel mix of the sector*[27]

Foundry sector will lower the carbon intensity in long run by adoption of the new EE technologies and transformation of the from conventional cupolas to Induction melting technologies. Dependence on the carbon intensive fuel such as coke will gradually reduce to around 11% during FY 2031 from 37% level at present level. With development of the new technologies the penetration of the gas base cupola will also replace the conventional coke base cupola this will further help in the reduction of the carbon intensity of the foundry sector.

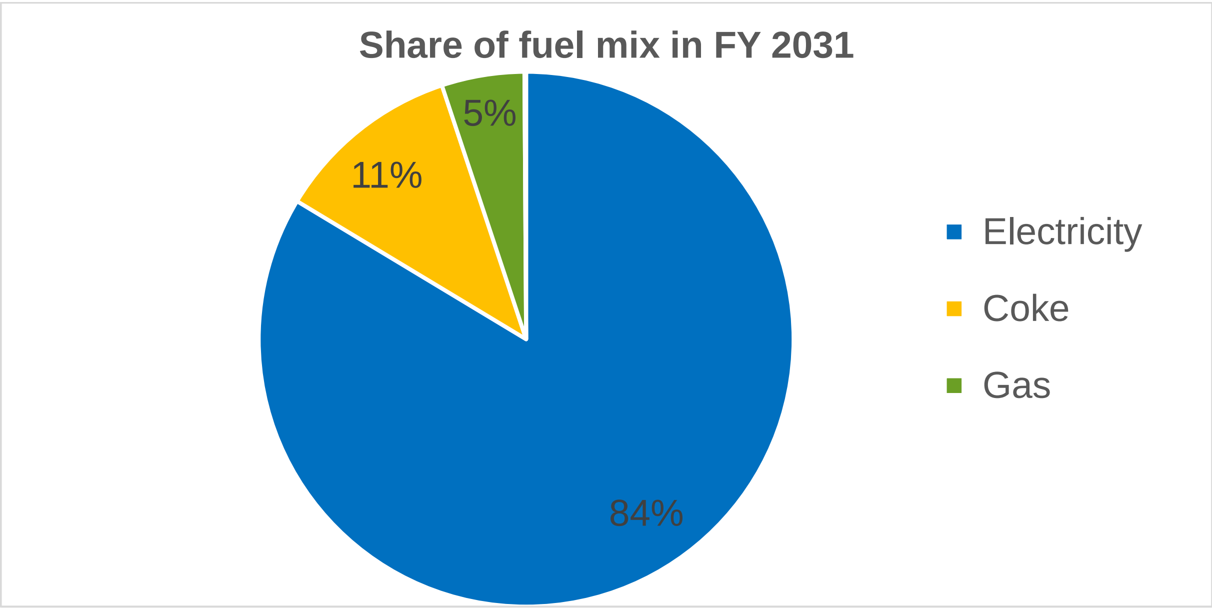



*Figure 20: Projected share of different fuel during FY 2031*

[27] With increase of the electricity share in the sector and growth of the sector will require additional demand of ~14,000 Mn units annually

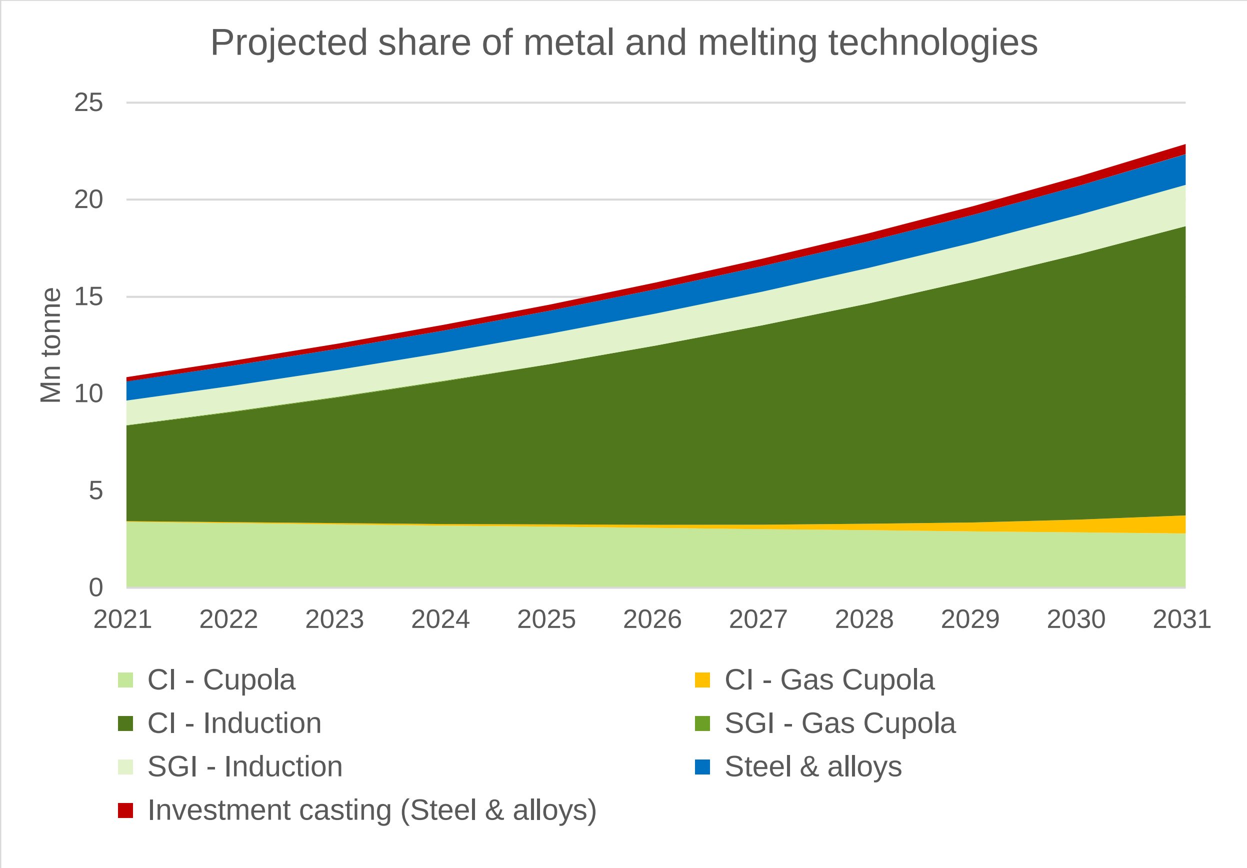



*Figure 21: Projections for Metal and Melting technology*

Cast Iron has the highest share in the casting produced by the foundries in India. Presently the share of the high-end castings (SS, SGI DI etc.). Cupola is the used by the majority of the micro and small units to produce the CI casting. With the adoption of the new technologies in this sub-sector will help the sector to reduce the energy and emission with wider adoption of the EE technologies (Induction melting). Other casting units already adopted the Basic Induction melting technologies can further adopt the higher end state of art technologies and adoption of SOPs and IoT based monitoring and ISO 5001 energy management system in longer run to further conserve the energy. Support required by the foundry sector for reducing the carbon intensity and faster adoption of newer technologies is presented in section 5.

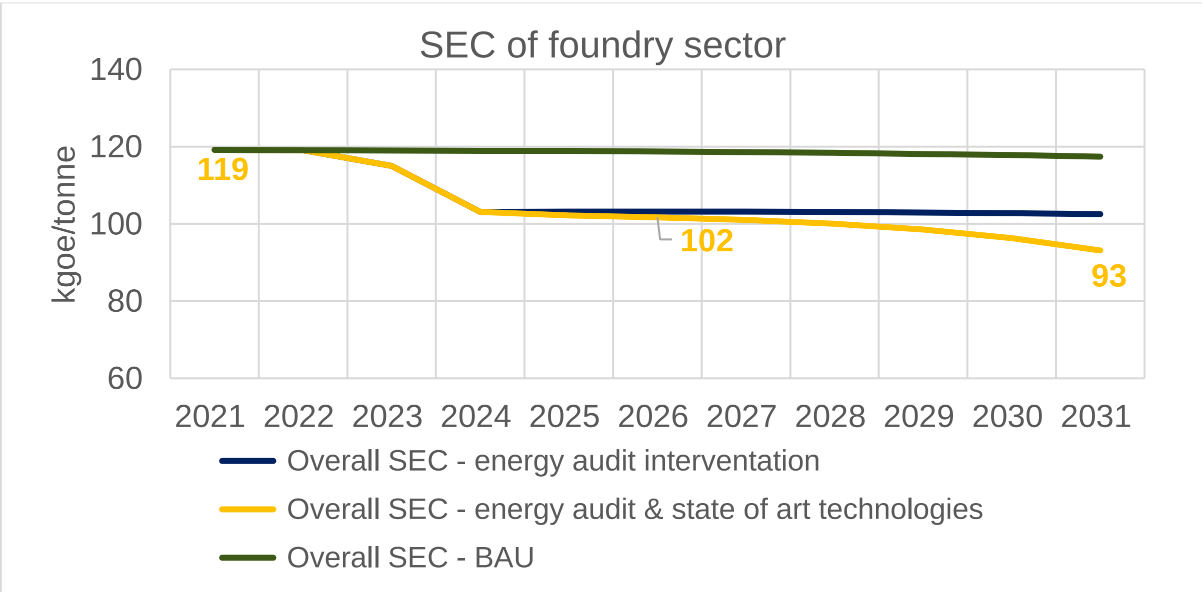



*Figure 22: Change in SEC of the foundry sector by implementation of EETs*

Adoption of the new technologies will help the foundry sector, during the transition to cleaner energy usage in the long run. Rationale for the reduction in the SEC level considered are – EA recommendations will find faster adoption across the foundries and will be implemented by 2024 peer to peer learning will propagate the push for adoption of these technologies). State of art technologies are new and require the support and push from different stakeholders and demonstration projects, acceptance of these technologies will evolve over the time and penetration in MSME level will be completed by 2030. Projections carried out on the basis of adoption of new state of art technologies, advanced energy efficient technologies will help the foundry sector to reduce the carbon intensity in long run.

***The share of electricity (cleaner fuel) is expected to grow up to ~84% during 2030-31 from 59% during FY 22. Share of the fossil fuels (Coke and oil) is expected to drop to less than 11% during 2030-31 from 37% during FY 22.***

### 4.2.1. *Emission reduction and additional power requirement*

Adoption of the new technologies such as Induction melting, and other state of art technologies will help the sector to reduce the carbon emissions and dependance on the coke and oil in the long run. With use of the induction melting for the metal melting and gas and electrical furnaces for heat treatment and core baking will help the reduction of the dependance on the carbon intensive fuels (coke). With the change of the technology and adoption of the energy conservation and state of art technologies the sector will help in lowering the carbon emission. Details of the emission reduction with respect to the base year (2021) with BAU scenario is presented in Table 26 along with the fuel mix during the respective year.

*Table 26: Fuel consumption and Emissions (BAU and proposed)*

| Year | | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fuel Consumption and Emissions BAU** | | | | | | | | | | | |
| **Electricity** | Mn toe | 0.82 | 0.88 | 0.94 | 1.02 | 1.09 | 1.18 | 1.27 | 1.36 | 1.46 | 1.57 |
| **Coke** | Mn toe | 0.52 | 0.56 | 0.60 | 0.65 | 0.70 | 0.75 | 0.81 | 0.87 | 0.93 | 1.00 |
| **Gas** | Mn toe | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| **Oil** | Mn toe | 0.05 | 0.05 | 0.05 | 0.06 | 0.06 | 0.07 | 0.07 | 0.08 | 0.08 | 0.09 |
| **Total** | Mn toe | 1.39 | 1.50 | 1.61 | 1.74 | 1.87 | 2.01 | 2.16 | 2.33 | 2.50 | 2.69 |
| **Emissions** | Mn tonne of $CO_2$ | 10.2 | 10.7 | 11.3 | 11.9 | 12.5 | 13.2 | 13.9 | 14.6 | 15.3 | 16.41 |
| **Proposed Fuel Consumption and Emissions** | | | | | | | | | | | |
| **Electricity** | Mn toe | 0.81 | 0.94 | 1.05 | 1.13 | 1.26 | 1.39 | 1.51 | 1.62 | 1.71 | 1.86 |
| **Coke** | Mn toe | 0.52 | 0.48 | 0.44 | 0.39 | 0.36 | 0.34 | 0.32 | 0.29 | 0.27 | 0.25 |
| **Gas** | Mn toe | 0.01 | 0.01 | 0.02 | 0.02 | 0.03 | 0.04 | 0.05 | 0.07 | 0.08 | 0.11 |
| **Oil** | Mn toe | 0.05 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 |
| **Total** | Mn toe | 1.4 | 1.5 | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 2.0 | 2.1 | 2.22 |
| **Emissions** | Mn tonne of $CO_2$ | 10.2 | 10.9 | 11.5 | 11.6 | 12.3 | 13.0 | 13.5 | 13.9 | 14.1 | 15.15 |

Adoption of the new technologies will help in the reduction of the 0.47 Mtoe during the FY 31. Change in the fuel mix will help in the reduction of the emission level from 16.41 Mn tonne of $CO_2$ (BAU FY2031) to 15.15 Mn tonne of $CO_{2;}$ these interventions will help the sector to reduce over 1.3 Mn tonne of $CO_2$ emission during FY 2031. These transformations and adoption of new technologies will also help the foundry sector to reduce the SEC level by over 20%.

During the transformation phase additional power will be required to support the technology transform from conventional cupola to the modern Induction melting furnaces. During the course adoption of the technologies as described in the section above will help the sector to reduce the energy requirement; also due to the transition from oil fired core baking and heat treatment processes to gas fired and electrical heated oven technologies will increase the electrical energy requirement to meet the transition toward low carbon economy.

Foundry sector will require additional[28] **650 MW** of power (over and above the BAU scenario) during FY 2031 to support the technology transition. Considering the technology penetration levels of 60% and 80% the additional power required by the sector during FY2031 will be 390-520 MW.

Shimoga foundry cluster uses the modern induction melting furnaces for metal melting, Gas and oil-fired furnaces are used for heat treatment and core baking applications. Share of the cleaner fuels in the cluster (gas and electricity) is around 96% for the foundry units in this cluster. There is potential to adopt modern electrical heat treatment furnaces which will help the cluster to reduce the use of oil fuel. Considering the present scenario and discussion with multiple stakeholders during the BEE energy mapping study, it is projected that additional electricity requirement for the cluster till 2031 over and above BAU scenario (after adopting EE measures) will be in range of 3-5 MW.

Howrah foundry cluster uses the mix of the induction melting furnaces for metal melting, DBC, coke cupola and inefficient conventional oil-fired furnaces for heat treatment applications. Share of the cleaner fuels in the cluster (electricity) is around 30% for the foundry's units in this cluster. Conventional coke cupola accounts for over 60% of the energy used for metal melting. There is vast potential for transition of coke cupola to induction melting furnaces and gas fired cupola once infrastructure for gas is available in the cluster in long run. Units are also willing to opt for the gas fired heat treatment applications eventually once gas is available in the cluster. Considering the projected scenario and discussion with multiple stakeholders during the BEE energy mapping study, it is projected that additional electricity requirement for the cluster till 2031 over and above BAU scenario (after adopting EE measures) will be in range of 70-80 MW.

Rajkot foundry cluster uses the mix of the induction melting furnaces for metal melting, DBC, coke cupola and inefficient conventional oil-fired furnaces for heat treatment applications. Some advanced units have adopted gas fired furnaces for core baking and hat treatment applications. Share of the cleaner fuels in the cluster (electricity and gas) is around 80% for the foundry's units in this cluster. Conventional coke cupola and DBC accounts for around 20% of the energy used for metal melting. There is vast potential for transition of conventional cupola to induction melting furnaces and gas fired cupola once infrastructure for gas is available in the across all industrial clusters in the region. Units are also willing to opt for electrical heat treatment applications in the long run. Considering the projected scenario and discussion with multiple stakeholders during the BEE energy mapping study, it is projected that additional electricity requirement for the cluster till 2031 over and above BAU scenario (after adopting EE measures) will be in range of 70-80 MW.

Agra foundry uses modern induction melting furnaces for metal melting, Gas cupola, Gas fired furnaces are used for heat treatment and core baking applications. Agra is the only cluster which has eliminated the use of oil / coke. Cluster has robust infrastructure for the gas supply. Hence with no additional electricity requirement is projected for sustainable growth of the cluster for the cluster till 2031 over and above BAU scenario (after adopting EE measures).

Most of the foundries in the Batala cluster use conventional coke fired cupola, most of the units in the cluster are keen in adopting the gas fired cupola in the long run, gas pipe is available near to Batala and will eventually be extended to the cluster. The majority of units in the cluster are small and operate one or twice a week, hence feasibility for induction melting is not feasible for such lower scale production. Only a fewer units will adopt the induction melting furnaces in the long run. Considering the projected scenario and discussion with multiple stakeholders during the BEE energy

[28] Power required is calculated based on the additional power required by the sector considering the present production CAGR levels and average annual operation of 5400 hours by the foundry units across different scales.

mapping study, it is projected that additional electricity requirement for the cluster till 2031 over and above BAU scenario (after adopting EE measures) will be in range of 1-2 MW.

Cluster level summary for additional electricity requirement over and above BAU scenario till 2031 is presented next.

*Table 27: Additional electricity for technology transition (over and above BAU scenario)*

| Cluster Name | No. of Cupola Furnaces | No. of Induction melting Furnaces | Penetration of Induction melting furnace (%) (present) | Present Electricity consumption (Million units) | Additional Electricity requirement (2031): different technology penetration levels (MW) | | |
|---|---|---|---|---|---|---|---|
| | | | | | 60% | 80% | 100% |
| **Howrah** | 240-260 | 60-70 | ~20% | 331 | 48 | 64 | 80 |
| **Rajkot** | 290-320 | 580-610 | ~67% | 1189 | 48 | 64 | 80 |
| **Agra**# | 50-55 | 45-50 | ~45% | 123 | - | - | - |
| **Batala** | 70-75 | 2-5 | ~4% | 9 | 1.2 | 1.6 | 2 |
| **Shimoga** | - | 45-50 | ~100% | 146 | 3 | 4 | 5 |

**Proposed values represent the additional electricity requirement in the cluster over and above BAU scenario during 2031. Also, the units in the cluster have adopted the proposed EE & State of art recommendations. Units in the different cluster will also adopt the cleaner heating though NG and Hydrogen in cupola, core baking and HT applications in long run.*

*#Units in Agra would like to explore the NG and Cleaner hydrogen for diversification, Cluster also has one of the best developed infrastructures for the gas distribution across different industrial clusters.*

Additionally, technical and financial barriers along with regulatory support required for the transition along with recommendations required to achieve the projections are presented in the next section.

# 5. Recommendations and Implementation Plan

# 5. Recommendations and Implementation Plan

## 5.1. *Barriers and Challenges in adoption of EE technologies*

Despite being recognized for good quality castings, the Indian foundry sector consumes significant energy and highly energy intensive, hence, offers immense scope for energy savings through adoption of state-of-art technologies and operating practices. However, there are several barriers that need to be addressed to realize the full potential of energy savings in MSME industries.

We have segregated those challenges and barriers mainly in 3 categories viz. **a) technical** (covers mainly lack of awareness and capacity building), **b) financial** (covers lack of financial capacities such as weaker balance sheets of MSMEs), and **c) regulatory** (covers mainly lack of support infrastructure and skills). In addition to this, we have highlighted barriers which are pertinent to MSMEs due to their small scale, unpredictability in demand, and widespread across clusters.

### 5.1.1. *Technical barriers*

The use of outdated and outmoded technologies is a major challenge in the MSME foundry sector. Limited availability and weak linkages with suppliers, and low levels of knowledge on modern technologies are the main reasons for lack of technology up gradation in the sector. Indian MSME foundries need to become more energy efficient to increase their competitiveness and maintain profits, however foundry units face following technical barriers in adoption of EE technologies.

- Lack of consistent data on energy consumption and energy savings due to limited scope for energy monitoring
- Inability to understand the complexities of the EE project i.e., baseline, adjustments to baseline, energy performance contracting, M&V procedures, realization of savings etc.
- Fear of underperformance as well as disruption of routine manufacturing cycle due to troubleshooting and change in plant load factors
- Lack of awareness on available EE technologies & limited capacities to evaluate cost-benefit of EE technologies
- Limited access to energy auditors with sound technical knowledge and non-availability testing facilities
- Lack of confidence in modern state-of-art technologies due to higher investment cost
- Force of habits resist any change in routine operating practices and lack of training on importance and necessity of energy conservation
- Limited outreach to technology suppliers of EE technologies and ESCOs

### 5.1.2. *Financial barriers*

Implementation of potential energy conservation measures requires investments, either marginal or substantial in order to realize energy savings. Energy efficiency generally perceived as a secondary aspect when compared to the core business activity or is only considered when it directly links to increase in production/output. This perception is also brought on by lack of awareness about EE.

#### 5.1.2.1. *MSME specific barriers in EE financing:*

- High upfront cost of EE technologies. Host entity (MSME) usually doesn't use internal funds for EE project financing
- Rigid lending policies of banks; there are limited FI's (banks, NBFCs) extending credit to pure EE projects and on merits of project cash flow
- Limited access to capital due to weak balance sheets of MSMEs and requirement for collateral
- The process of availing benefits and subsidy from EE schemes is complex and it takes considerable time to receive the subsidy
- Reluctance to undertake energy study in their unit and bear the energy auditing cost

#### 5.1.2.2. *Financial institutes (Banks, NBFCs) specific barriers:*

Energy efficiency investments usually do not generate additional tangible revenues, but rather contribute to the earnings through a reduction in energy expenditures. This can make it difficult for banks to identify and capture cash flows from such projects and treat energy savings as assets of sufficient market value to justify a loan, despite the overall benefits which will accrue if implemented.

- Concept of EE is still very complex to FIs due to lack of standard project assessment tool, and most FIs show reluctance to develop technical capacities to evaluate projects
- EE projects are considered high risk projects with associated risks like technical risk, performance risk, hence FIs have low confidence in the estimated energy savings
- Relatively small ticket size & high transaction cost of EE projects and FIs instead prefer large investing into large capacity expansion projects
- Limited investment potential for EE at cluster/ sector level as compared to overall MSME portfolio; FIs cater already very large portfolio for MSMEs through WC and business loans
- Lower resale value of assets in energy efficiency project

### 5.1.3. *Regulatory and infrastructure related barriers:*

In addition to technical and financial barriers lack of supporting infrastructure and regulatory interventions also limit the uptake of EE interventions in MSME clusters.

- Though MSMEs fall under the priority lending category, EE does not fall under priority sector lending unlike to RE as per RBI guidelines; hence benefits of low interest rates cannot be transferred due to high-risk factor associated with EE technology and performance risks
- Lack of supporting infrastructure for EE upgradation such as difficulties in getting clearances for HT connection
- Lack of incentives to adopt cleaner fuels such as non-availability of Natural gas pipelines in some clusters and stringent policies for net metering
- Feasibility of the potential EE technology is highly sensitive to the external factors like availability of fuel (biomass, NG etc.), price fluctuations and availability of raw material
- Change in government regulation/policy related to pollution, and taxes and duties can affect the viability of the unit

- Non-existence of skilling infrastructure to meet the ever-changing technology & processes

### 5.1.4. *Miscellaneous*

The above challenges have beleaguered the energy efficiency sector and limited its uptake. Now further when we look specifically at the MSME sector we see that it has its own challenges which has immensely restricted energy efficiency improvement in MSMEs even though there is a high potential.

- Unpredictability of future business due to global economic downturn, which may adversely affect manufacturing activities in end user sectors of foundry products
- MSMEs are spread across in small clusters hence catering to them is itself a difficult task for both technology and capacity building activities
- Low awareness on various schemes of Govt. of India related to energy conservation
- Lack of information on international customers' expectations
- High cost of production due to increase in fuel prices and non-reliable supply of fuels
- Lack of transparency in financial reporting, and unconventional business practices of MSMEs also hinder their capacities to avail benefits of EE schemes
- It is a low priority segment services than large industrial plant due to perceived notion about expected lower scale of business.
- Low priority segment for EE technology suppliers and financial institutes due to smaller ticket size of EE loans and high transaction costs

### 5.1.5. *SWOT Analysis*

Lower productivity, ever rising fuel prices and rising cost of statutory compliances have become major hurdles for the MSMEs. A SWOT (Strength, Weakness, Opportunity, and Threat) analysis of Indian foundry sector is provided below.

| **Strengths** | **Weaknesses** |
|---|---|
| • Steady domestic demands in the sector<br>• Key role played by active industry association i.e., IIF in technology adoption<br>• Availability of technology suppliers of EETs<br>• Forward looking outlook of entrepreneurs | • Lack of information on international customers' expectations<br>• Lower productivity & high manufacturing costs<br>• Use of outmoded and conventional technology<br>• Limited funds for technology upgradations |
| **Opportunities** | **Threats** |
| • Potential for adoption of EE technologies automation and state-of-art technologies<br>• Govt. thrust on auto & manufacturing sector<br>• Increase in domestic and export demand in near-by future post-covid situation | • Severely impacted by cyclical market trends<br>• Non-availability of skilled manpower<br>• Increase in global competition such as China<br>• Increase in energy costs and rising costs of statuary compliances |

## 5.2. *Integrated policy roadmap*

Foundry sector in India offers immense potential for energy savings through technology upgradation, EE retrofits and adoption of operating practices. However, given the current levels of EE technology penetration and the overall health of the MSME sector, there is a need of innovative measures and policy interventions to increase the adoption of EE solutions in foundry MSMEs.

This BEE Energy mapping study" ultimately aims to generate a sector level energy efficiency policy roadmap for the Foundry MSME sector, which is aligned with the country's energy & climate goals and also have high correlation with industry needs. Hence, based on analyses of the various identified barriers to energy efficiency, we have created and recommended an integrated policy roadmap to boost the adoption of EE technologies across the foundry industry.

*We have organized multiples stakeholder consultations with an aim of building consensus on the outcomes and to seek inputs from a diverse set of stakeholders for drafting the recommendations. This study provides a very useful service by putting together the experiences from the diverse set of stakeholders and discussing identified interventions and their appropriateness & relevance.*

This policy roadmap takes into consideration the current situation when the foundry industry is still grappling with challenges due to the ongoing pandemic. This is a time when incentives can play a more significant role; a time when policymakers have the opportunity to place conditions on grants and funding, which could include implementation of EE technologies, achieving benchmarks for EE while supporting technology and process improvements, and so on.

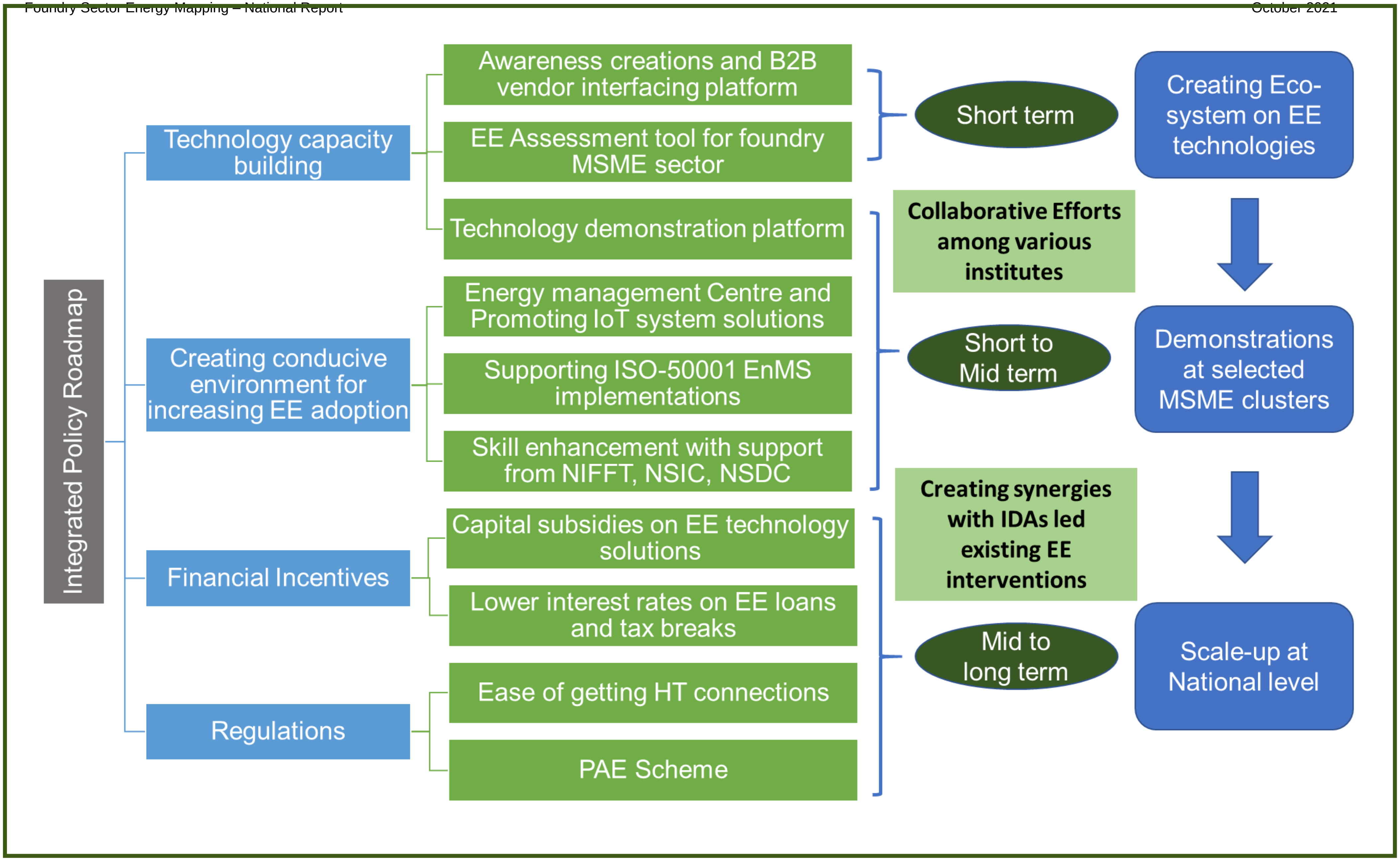
A long list of recommendations, prepared with in-depth consultations with MSME foundry units, Industry Associations, industry specific institutes and other decision makers in various foundry MSME clusters, is provided below. The actionable elements of the policy roadmap are integrated along four broad and parallel tracks (figure 7):

a) Technology capacity building
- Awareness creations & B2B vendor interfacing platform
- EE Assessment tool for foundry MSME sector
- Technology demonstration platform

b) Creating conducive environment for increasing EE adoption
- Energy management Centre
- Supporting ISO-50001 EnMS implementations and Promoting IoT Solutions
- Skill enhancement support from NIFFT, NSIC, NSDC

c) Financial Incentives
- Capital subsidies on EE technology solutions
- Lower interest rates on EE loans and tax breaks

d) Regulations
- Ease of getting HT connections
- PAE Scheme


Integrated Policy Roadmap
Technology capacity building
Awareness creations and B2B vendor interfacing platform
EE Assessment tool for foundry MSME sector
Technology demonstration platform
Creating conducive environment for increasing EE adoption
Energy management Centre and Promoting IoT system solutions
Supporting ISO-50001 EnMS implementations
Skill enhancement with support from NIFFT, NSIC, NSDC
Financial Incentives
Capital subsidies on EE technology solutions
Lower interest rates on EE loans and tax breaks
Regulations
Ease of getting HT connections
PAE Scheme
Short term
Collaborative Efforts among various institutes
Short to Mid term
Creating synergies with IDAs led existing EE interventions
Mid to long term
Creating Eco-system on EE technologies
Demonstrations at selected MSME clusters
Scale-up at National level

**Implementation Roadmap:**

| Proposed Interventions | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Technology capacity building** | | | | | | | | | | |
| Awareness creations & B2B vendor interfacing platform | X | X | | | | | | | | |
| EE Assessment tool for foundry MSME sector | X | X | | | | | | | | |
| Technology demonstration platform | | | X | X | | | | | | |
| **Creating conducive environment for increasing EE adoption** | | | | | | | | | | |
| Energy management Centre | | | X | X | X | X | | | | |
| Supporting ISO-50001 EnMS implementations and Promoting IoT Solutions | | | X | X | X | X | | | | |
| Skill enhancement support from NIFFT, NSIC, NSDC | | | | X | X | X | | | | |
| **Financial Incentives** | | | | | | | | | | |
| Capital subsidies on EE technology solutions | | | | | | | X | X | X | X |
| Lower interest rates on EE loans and tax breaks | | | | | | | X | X | X | X |
| **Regulations** | | | | | | | | | | |
| Ease of getting HT connections | | | | | X | X | X | X | X | |
| PAE Scheme | | | | | X | X | X | X | X | |
| **Scale-up at National level** | | | | | | | | | X | X |

### 5.2.1. *Technology capacity building*

**Need Assessment:**

MSMEs usually have limited technical abilities to evaluate EE technologies and limited outreach to technology suppliers and service providers of EE technologies.

1. Limited technical capacities and weak linkages with suppliers are among the main reasons for lack of technology up gradation in the cluster.

This could be addressed by increasing the frequency of awareness workshops on EE technologies in presence of technology suppliers

2. EE investments are usually considered risky because of the uncertainties associated with the performance of technological interventions and the difficulty in demonstrating savings.

MSME's confidence can be enhanced by establishing replicable contracts for identified EE technologies and building the capacities of local FIs in evaluating EE proposals

3. Many foundry units in this cluster fall under the micro/ small category, hence they have lower confidence on high investment state-of-art technologies

Technology demonstrations with a focus on hands-on training to enhance confidence of MSMEs and provide touch-and-feel experience for state-of-art technologies

#### 5.2.1.1. *Awareness creations & B2B interfacing platform*

We are proposing following interventions for creating awareness on techno-commercial feasibility of EE solutions:

**Proposed interventions:**

a. Increasing MSMEs' awareness through workshops on energy efficiency solutions, by including a generous dose of positive case studies from other successful implementations

b. Provide the simplified case studies with calculations for the most relevant EE technologies based on typical estimation of energy cost savings, payback period & IRR

c. Match making between potential vendors and MSMEs from clusters will help in adoption of new and advanced EE technologies

d. Building the capacities of vendors and local service providers to strengthen the implementation of EE measures and post implementation services and spares

**Implementation roadmap:**

1. Organizing the B2B workshops and focused technical seminars with the IIF regional chapters and technology providers. Technical workshops are to be designed to meet as per the cluster process technology upgradation requirements.
    a) Conducting workshop on state of art technologies (Automated casting lines, high pressure moulding lines etc.) in progressive MSME clusters of Kolhapur, Belgaum, Shimoga, Coimbatore and Rajkot.
    b) Conducting workshops on IGBT induction furnaces, Gas based cupola and DBC furnaces in Batala, Howrah, Agra and Jaipur foundry MSME clusters
    c) Conducting the workshop on new technologies for investment casting (Lost foam) in clusters of Rajkot, Shimoga and Indore.

d) 4 National level workshops on decarbonization solutions in foundry sector with solutions such electric heat treatment furnace, gas-based cupola instead of coke- based cupola and applicability of hydrogen as a fuel for heat treatment and

2. BEE shall also deploy consultant for these awareness and capacity building activities. The consultant will also assist in developing the case studies with support from IIF regional chapters and local industry associations for the new technology implementation
3. Technology workshops should be conducted on regular intervals (Each quarter- one workshop in each cluster, one national workshop) to address the changing needs of the cluster and development of new energy and resource efficient technologies.
4. These workshops shall include minimum 50 foundry MSMEs and will also invite local institutes/ MSME departments. These workshops shall also include the case studies presentations from technology vendors, with minimum 3-4 vendors for each workshop
5. Consultant will also provide support for the capacity development of ESCOs and LSPs in executing EE projects and implementing the ESCO/ RESCO based projects. Consultant will assist in developing the capacities for minimum 2 vendors/ OEMs/ ESCOs in each foundry cluster
6. Post workshop, Consultant will also provide support for dissemination of case studies and these case studies to be circulated to foundry clusters though national/ regional level associations.

#### 5.2.1.2. *Developing EE assessment tool for financial institutes- Short term*

Energy efficiency financing is inherently risky because of the uncertainties associated with the technology risk, performance risk, and re-payment risk based on demonstrated savings. EE assessment tool along with capacity building of local Financial institutions (FIs) can play a crucial role in building the confidence of both MSMEs and FIs in EE technologies.

The tool will provide reliable information about estimate potential energy savings compared to similar MSMEs, sector-wise Energy Efficiency measures implemented by similar MSMEs understand equipment's / utilities' performance, identifying the potential energy savings measures, and associated Investment and payback period.

a) Standard online tool which houses the technology compendium with typical use cases and payback, IRR, NPV analysis.

b) Establishing standard contracts for Energy Efficiency project appraisal through sector specific EE assessment tool

c) Developing the capacities of FIs (Banks and NBFCs) in evaluating EE proposals and sharing standard EE project appraisal documents for faster loan disbursement

**Implementation roadmap:**

1. BEE may hire the consultant to develop this Energy Efficiency assessment tool for foundry sector.
2. This will activity start with by carrying out an analysis of sector with respect to key sub-sectors, energy consuming processes. BEE will leverage the detailed analysis carried out during the mapping study
3. It will also involve Integration of sector/ sub-sector benchmarks SEC benchmarks data for from this energy mapping study will be integrated into this EE assessment tool.

4. It will also involve identification of unit level parameters affecting SEC as an input variable for such as sub-sector, annual production, type of fuel and fuel consumption

5. BEE will also leverage the list of EE technology solutions relevant to sector for suggesting EE measures through assessment tool. BEE jointly with IIF will shortlist the EE technologies based on their techno commercial feasibility and financial viability.

6. The tool will perform the cost payback analysis – NPV, IRR, payback period. Banks / FIs can know about potential EE Measures in MSMEs, attractiveness of the EE investments and the cost savings and payback period,

7. BEE can also leverage the existing tools / or improvising existing tool prepared by SIDBI- ISTCL other tools prepared under SAMEEEKSHA/ other ongoing IDA led interventions

8. BEE will develop the technical capacities of FIs (banks/ NBFCs) through this interactive EE assessment and assisting in evaluating the techno-economics of EE technologies from the tool.

**Role of Industry Associations and local MSME DC/ DIC centers:**

**Industry associations** can be positioned as opinion influencers among the local industrial community, and ensuring ownership of association in all cluster events, workshops, B2B exhibitions etc. and sharing of knowledge material like Case Studies.

**National Institute of MSMEs:** NIMSME, which mainly works in the areas of capacity building, research, and job enrichment training, shall be leveraged for conducting workshops on creating awareness on energy efficient and state-of-art technologies

**Technology Suppliers:** Support for B2B interactions and sharing of knowledge material like technology brochures, and Case Studies

**Project consultants and Financial Institutes:** Developing the standard contracts for project appraisal of EE technologies, developing EE assessment tool with NPV, IRR calculations for faster loan appraisal process

### 5.2.1.3. *Technology demonstration platform*

One of the key findings of cluster level discussions was MSMEs were more likely to invest in EE Technologies specifically in state-of-art technologies on the basis of recommendations from peers. Hence, it has proposed that more demonstrations should be conducted in a front runners and opinion leaders in the MSME clusters to enhance confidence of MSMEs and provide touch-and-feel experience:

a. Technology demonstrations for state-of-art and advanced energy efficient solutions
b. Cross-cluster visit to near-by clusters for building confidence of MSMEs in advanced EETs

**Implementation Roadmap:**

1. BEE will carry out such pilot demonstrations in coordination with cluster stakeholders such as industry associations, technology suppliers

2. Industry associations to ensure participation from foundry MSMEs, this will help in addressing the perceived risks of investing in such EETs

3. BEE shall carry out 3-5 demonstrations in each MSME cluster group and invite participants from near-by clusters for creating outreach and availing the benefits of cross learning.

   For example- foundry participants from Ahmedabad can be invited to Rajkot cluster; also Pune and Belgaum cluster foundries to Kolhapur foundry cluster etc.

4. BEE will identify the demo projects based on clusters needs and product mix, progressive of the cluster, available suppliers in the cluster etc. Below are the list some state-of-art EE technologies relevant to respective MSME clusters:

| EE Technology / solutions for demonstration | Relevance to foundry clusters |
|---|---|
| IGBT based Induction melting furnaces | Howrah, Batala, Agra |
| Automated core and sand Plant with conveyor system | Rajkot, Howrah, Shimoga |
| Installation of high-pressure moulding line in moulding area | Howrah, Batala, Agra, Rajkot, Shimoga, Kolhapur |
| Robotic fettling | Rajkot, Shimoga, Coimbatore, Kolhapur |
| AI based enhancements for technologies and IoT integration | All Clusters |
| Hydrogen as a fuel for heat treatment and other operations | Shimoga, Rajkot, Agra, Howrah |

5. BEE shall identify the other industry decarbonizations such as Solar PV roof-top, biomass, hydrogen as a fuel and various possibilities of electrification in foundry sector for demo projects.
6. BEE will invite local bankers for these technology demonstrations to apprise them about state-of-art technologies. These demo's will help reassure FIs of performance of EETs, which in turn lead to technical capacity building within FIs, enabling them to better appraise such interventions.

### 5.2.2. *Creating conducive environment for increasing the adoption of EE*

MSME foundry units need to become more energy efficient to increase their competitiveness and maintain profits, however due to lack of supporting infrastructure in MSME clusters, foundry owners face various challenges in adoption of EE technologies:

1. Poor practices on energy management, lack of consistent data on energy consumption limits the scope for realizing the benefits of energy efficiency

This could be addressed by promoting ISO 50001 EnMS and IoT technologies, this will help MSME units to adopt the energy monitoring practices

2. Lack of supporting infrastructure such as limited access to energy auditors, non-availability of testing facilities limits the uptake of EE technologies

A permanent Energy Management Centre at cluster level with energy auditing facilities, testing instruments and common utility solutions

3. Non-existence of skilling infrastructure to meet the ever-changing technology needs and lack of standard curriculum on energy conservation

A range of skills with a focus on hands-on training are required to operate new technologies, to adopt best operating practices and comply with minimum EE efficiency standards

### 5.2.2.1. *Developing the ecosystem for the energy monitoring by supporting ISO 50001 EnMS implementations in MSMEs*

**Need Assessment:**

Energy Efficiency efforts are often plagued by lack of consistent data on energy and operations; therefore, push is required to promote energy monitoring practices and technologies. Energy monitoring will also ease out the M&V process where EE implementations are taking place.

*During our study in Agra cluster, it was emerged that submetering of Gas Cupola furnaces could help to enhance their energy efficiency improvement attempts.*

In typical foundry, it is very essential to select proper type & size of furnaces, operate the equipment scientifically with proper measurements by giving due focus to the energy monitoring and by regular energy audits which can highlight the potential areas for energy conservation.

**Proposed interventions:**

ISO 50001 EnMS will help the MSME units to develop the EE culture, adopt the energy monitoring practices and sustain the benefits of energy conservation measures. It will also ease out the Monitoring & Verification process where EE implementations are taking place.

a) Technical consulting services for ISO-50001 certification in selected MSME clusters (10 MSME units in each foundry cluster)

b) Workshops on creating awareness on ISO-50001 and training on ISO-50001 protocols - The frequency of workshops on energy management system must be increased, with a focus on including a generous dose of positive case studies from other successful implementations.

**Implementation roadmap (1 Year timeline):**

a) Market assessment: Identifying progressive MSME clusters and early adopters in each cluster for implementation of EnMS (1-2 Months)
c) Launch Workshop- National level launch workshop in support with IIF and 3-4 cluster level workshops with local industry associations- (3-4 months)
d) Technical consulting services in 5-10 MSMEs in each of identified MSME clusters (3-6 Months)

   a. Energy Review of Facilities, Equipment, Systems, Processes and Personnel.

   b. Energy Baseline Setting, Derivation of EnPIs and Performance Process.

   c. Development of energy policy, implementation, and development of Internal Auditors

e) Support for EnMS certification through accredited bodies and organizations (6-12 Months)
f) Building capacities of local service providers and local consultants for sustenance of EnMS culture at local level and building markets for ISO-50001 (11-12 Months)
g) Dissemination workshop at cluster level for sharing the learnings and felicitations of adopters on EnMS (Month 12)

**Major stakeholders and their responsibilities**

| | | | |
|---|---|---|---|
| Industry Associations | Project consultants | Bureau of Energy Efficiency | National Institute of MSMEs |

- **Industry Associations:** Industry associations can be positioned as opinion influencers among the local industrial community and ensuring ownership of inviting member MSMEs to cluster events, workshops etc. and sharing of knowledge material like Case Studies.
- **Project consultants:**
    - Identification of interested MSME units for ISO 50001 certification
    - Consulting services for EnMS implementations and certifications
    - Carry out awareness workshops on importance of ISO 50001- EnMS
- **National Institute of MSMEs:** NIMSME, which mainly works in the areas of capacity building, research, and job enrichment training, shall be leveraged for conducting workshops on creating awareness on ISO-50001 and training on ISO-50001 protocol
- **Bureau of Energy Efficiency:** BEE can provide services for technical consulting services for ISO-50001 certification in selected MSME clusters. BEE can engage project consultants to provide these consulting services.

**Benefits to sector stakeholders**

- Energy management system will build a culture of sub-process level energy benchmarking
- Ease out the M&V process where EE implementations are taking place.
- Help in strengthening the ESCO based projects, establishing the baselines and also help in better evaluation of the savings.

#### 5.2.2.2. *Promoting Internet of thing (IoT) systems & energy monitoring technologies – Short Term*

These IoT systems provide access to real-time equipment performance, energy consumption, and building l data to support a smarter, data-driven maintenance strategy. Hence, push is required to promote IoT systems and energy monitoring technologies.

a) Linking IoT technologies with ISO-50001 for realizing the energy savings of installed EETs

b) 2-3 demo projects in few progressive MSME clusters on IoT technologies for hands-on-training

c) Providing incentives and subsidies on IoT and energy monitoring solutions

d) B2B matchmaking between MSMEs &vendors and building capacities of LSPs

**Implementation roadmap (2 Year timeline):**

1. BEE will link this activity with ISO-50001 EnMS implementation, BEE will leverage the MSME premises where ISO-50001 implemented for carrying out demo projects on IoT systems
2. BEE will make these IoT systems and energy monitoring equipment mandatory as a pre-requisite for ISO-50001 implementation, however, BEE will provide upfront subsidies on installation of these energy monitoring technologies
3. BEE will carry out these demo projects in 2-3 units in prominent MSME clusters.
4. The timeline for this activity would be 2 year, where first 3 months would be installation and certification of EnMS. Next 9 months would be for monitoring and assessing the benefits of EnMS implementations and IoT installations.

5. Second year onwards, MSME units will be invited for demonstrations. BEE in association with industry associations will invite MSME units for hands-on-training
6. BEE will support in inviting technology vendors of energy monitoring solutions on common platform and creating awareness by sharing case studies on successful implementations
7. BEE will assist in building capacities of local service providers in foundry clusters to implement energy monitoring solutions in MSME foundry units

#### Relevant stakeholders:

| Industry Associations | Technology vendors | India Smart Grid Forum |
|---|---|---|

#### Role of various actors/ stakeholders

**Technology vendors:** Support for B2B interactions and sharing of knowledge material like technology brochures, and Case Studies

**Industry Associations:** Ensuring ownership of foundries in all cluster events, workshops, B2B exhibitions etc.

**India Smart grid forum:** It can help in creating awareness on state-of-art IoT systems and assist in organizing B2B vendor exhibitions for promoting of these technologies. Smart grid forum can also help in identifying IoT technologies eligible for subsidies and incentives.

#### Benefits to sector stakeholders

- Increase awareness on energy monitoring solution and explaining direct and in-direct benefits of IoT system
- Help in strengthening the ESCO based projects and establishing the baselines faster.
- Energy monitoring systems will also help in better evaluation of the savings.

### 5.2.2.3. *Energy Management Centre (EMC) at cluster level- Mid term*

#### Need Assessment:

During energy studies it was identified that limited access to energy auditors and lack of handholding support to MSMEs limits the EE implementations in MSME clusters. Many foundries in the sector fall under micro category with limited financial capacities, hence they have limited funds to invest into energy auditing activities and high-cost investments solutions.

#### Proposed interventions:

We propose to have permanent Energy Management Centre at each major foundry cluster. We propose to establish a common facility, may at Industry Associations premises, to provide services for energy auding, testing facilities and common utility solutions. We are proposing following interventions for creating the ecosystem for EE interventions in MSME clusters through this EMC:

- Demonstrate the direct, in-direct benefits of EE technologies through energy auditing services
- Access to energy auditors and building the capacities of local consultants on carrying out energy auditing activities
- Providing common testing and utility solutions for foundry MSMEs in the cluster.

### Implementation roadmap (2 Year timeline):

1. BEE will provide its support to local associations for developing Energy management Centre at cluster level.
2. Establishment of EMC will be done in 1 year and for the next year BEE will provide handholding for supporting various activities of EMC
3. BEE will support in identifying local auditors, provide them hands-on training followed by sample energy audits through experts with foundry specific energy audit experience
4. BEE will also support in encouraging plant heads and production managers of foundry units to enroll for energy auditor and energy manager examinations
5. BEE will support in reskilling of certified energy auditors for foundry focused audit in each foundry cluster
6. BEE will provide support for establishing standard energy audit template for Energy Efficiency project evaluation
7. BEE will also carry out awareness workshops through energy auditors to be led by EMC in cluster and inviting testimonials from plant managers of foundries

### Functions of Energy Management Centre:

**a. Energy Auditing facilities:**

- Conduct energy audits at subsidized rates for foundry MSMEs. BEE may consider linking these energy auditing activities with PAE scheme for additional benefits
- Provided end-to-end hand holding support to MSMEs for installation of the EE projects
- Developing capacity of local consultants in conducting energy audits, walk-through audits

**b. Common testing facilities:**

- Establishing of a common center for providing services related to Computer Aided Design (CAD), CAM for casting design and simulations for prototype development
- Establishing of a common testing facility to provide services for testing facilities such as casting testing, Coordinate Measuring Machines (CMM) and radiography which will help in reducing rejection rates and increasing production hence increase in SEC.
- Liaison with NSIC, MoMSME, IAs, to hold such facilities at their premises

**c. Community based solutions:**

- Common Sand reclamation facility: Sand recovered from the moulds can be treated in a common sand reclamation facility, which can be able to reuse about 90% of the sand- Applicable in Kolhapur, Howrah, Agra, Shimoga clusters
- Common facility for moulding and fettling operations in auto components related foundry clusters (due to high uniformity) such as Pune, Kolhapur, and Rajkot

### Relevant stakeholders:

| Industry Associations | Technology vendors | DI-MSME & MSME-DIC |
|---|---|---|

### Role of Industry Associations and local MSME DC/ DIC centers:

**Industry associations** can be positioned as opinion influencers among the local industrial community, and ensuring ownership of association in all cluster events, workshops, B2B exhibitions etc. and can also host the common facility center at their premises

**DI-MSME/ MSME-DIC:** Establishment of a common facility center at MSME DIC premises to carry out demonstration/ pilots in coordination with cluster stakeholders.

**NSIC Technical Services Center (NTSC):** NTSC can assist in developing common testing facilities at their center along with services for stimulation and CAD/ CAM for prototype development

**Technology Suppliers:** Support for B2B interactions and sharing of knowledge material like technology brochures, and Case Studies

## 5.2.2.4. *Skill Development in foundry MSME sector*

### Need Assessment:

Non-existence of skilling infrastructure is the major hurdle in adopting the ever-changing technology & processes. A range of skills are required to operate new technologies, to adopt best operating practices and comply with minimum EE efficiency standards.

### Proposed interventions:

We are proposing to leverage and expand existing center of excellence institutes such as NIFFT Ranchi, IIF - National Centre for Technical Services (NCTS)- Pune and NSIC Technical Services Centre in Rajkot, Pune, New Delhi etc.

- Leveraging National Institute of Foundry and Forge Technology for hands-on-training and holding diploma courses on foundry/ forging technologies
- Leveraging IIF - National Centre for Technical Service- located in Pune for promoting soft interventions such as 5S, Kaizen etc.
- Leveraging NSIC Technical Services Centre and National Skill Development Centre for developing curriculum on skill development on foundry specific technologies

### Implementation roadmap (2 Year timeline):

#### *A.* Leveraging National Institute of Foundry and Forge Technology- (Month 1- Month 12)

National Institute of Foundry and Forge Technology (NIFFT), Ranchi is a public engineering and research institution in Ranchi. *During consultations, there was a need felt across the IIF to leverage this premium institution for preparing the new skillset for the work force in the foundry sector. This institution can play the leading role in developing the new age of the skillset required by the industry to meet next generation of technological advancement.*

1. NIFFT to set up a series of training and diploma courses for the operating level staff on best operating practices in foundry and forging units. These courses can be developed jointly with industry stakeholders, NSDC and BEE, being the nodal agency on EE in India.

2. NIFFT possibly with support from BEE and/or MoMSME can support in conducting hand-on trainings for skill enhancement of shop-floor workforce around energy efficiency technologies.

   Some such technologies include

   a. AI/ ML based enhancements for process technologies and IoT integration
   b. Hydrogen as a fuel for heat treatment and oxyfuel burner operations

3. NIFFT to consider developing various local chapters at key Foundry and Forging clusters across India in consultation / collaboration with prominent industry associations.

**B. Leveraging IIF - National Centre for Technical Service- Pune for promoting soft interventions**

One of four centre of excellence of IIF, National Centre for Technical Services (NCTS) with its office at Pune plays a very important role in providing Technical Services in areas of top-quality systems to reduce costs and improve response time keeping at the same time environmental issues in control.

1. Conducting programs on foundry technology and subjects which indirectly aid efforts to reduce cost / increase productivity e.g., 5S, TPM
2. Conducting customized corporate skill enhancement training program covering various areas of foundry operations, quality, and management
3. Guiding foundries in layouts for smoother material / process flow and efficient operations

**C. Leveraging NSIC Technical Services Centre and National Skill Development Centre**

NSIC through 'NSIC Technical Services Centers' (NTSCs) provides technical support to MSMEs include skill development in Hi-Tech as well as conventional trades, product testing at testing laboratories accredited by NABL, energy audit, environment management etc. NTSC Rajkot is a most credible organization in the field of Energy Audit, testing facilities authorized by Govt. of Gujarat.

*During consultations, NTSC has shown interest in collaborating with BEE for creating knowledge base and ecosystem for scaling up the implementation of EE technologies. We envisage that NSIC, through its extensive experience, to perform the duties and support BEE in:*

1. NSIC in support with NSDC to develop professional training courses and curriculum for the operating level staff on EETs and best operating practices in MSME foundry units.

   These courses can be developed jointly with BEE, being the nodal agency of the Govt. of India on energy efficiency matters in the country.

   **The National Skills Qualification Framework (NSQF) theoretically makes it possible to drive competency-based training for every job role in industry. Framework from NSDC on National Occupational Standards (NOS) will be followed for creating course curriculum.**

   NOS specify the standard of performance an individual must achieve when carrying out a function in the workplace, together with the knowledge and understanding they need to meet a standard consistently.

   - Each NOS defines one key function in a job role.
   - Each NOS must be a concise and readable document,
   - Each NOS usually consisting of no more than five or six pages (some are only 1 or 2)
   - NOS describe functions, standards of performance and knowledge / understanding.

   It is possible for all current vocational courses, like, ITI Courses, or similar vocational courses in polytechnics, to be aligned to job roles (including foundry sector) at specific NSQF Levels. For Example- An ITI Course in Plumbing would say they are training for plumbers at NSQF Level 3. Similarly, a polytechnic, training in fashion design, may say it is training for NSQF Level 5 for Garment Cutters.

2. NSIC possibly with support from BEE can support in creating the ecosystem for scaling up the implementation of some of the state-of-the-art technologies through live demonstrations

- Some such technologies include Automated moulding and pouring technologies in Foundries, AI based enhancements and metal melting technologies, 3D Printing etc.

3. Establishing of facilities such as for casting testing, Computer Aided Design for Casting

**D. Leveraging local universities, ITIs and other institutes for developing EE curriculum**

Leveraging local institutes, universities, and centers for developing courses on Energy management- in Rajkot NSIC-NTSC, Shivaji University in Kolhapur, Engineering Export Promotion Council (EEPC) in Kolkata, PPDC in Agra, Central tool room in Ludhiana etc.

1. Inclusion of the technical courses on energy management and conservations and inclusion of Advanced Diploma courses in local ITIs

2. Develop curriculum for professional courses in foundry processes and technologies through consultation with stakeholders

**Benefits to sector stakeholders**

a. This will prepare the workforce ready to implement best practices and energy efficient technologies in the sectors
b. Different foundry clusters will have easier access to the centers of excellence
c. Skilled labour will empower the units to adopt the new technologies.

**Relevant stakeholders:**

| BEE | National Skill development Corporation | National Institute of MSMEs |
|---|---|---|

**Role of various actors/ stakeholders**

**BEE:** Assist in providing finance for procuring state-of-art technologies for hands-on-training at NSIC center and local skill development institute

**Industry associations** shall ensure inviting member MSMEs to trainings and workshops for capacity development

**National Institute of MSMEs:** NIMSME, which mainly works in the areas of capacity building, research, and job enrichment training, shall be leveraged for developing the technical courses on energy management and conservations

**National Skill development Corporation:** Assist in developing training courses and curriculum on in foundry processes and technologies and deploying local resource for continuous improvement at cluster level

### 5.2.3. *Financial incentives for EE Technology adoption*

**Need Assessment:**

Energy efficiency generally perceived as a secondary aspect when compared to the core business activity or is only considered when it directly links to increase in production/output. Higher cost of energy efficient technologies due to advanced features and lack of upfront capital in MSMEs remained one of the biggest hurdles in adoption of EE technologies

**Proposed interventions:**

Capital Subsidy scheme is most popular and see significant uptake as it offers to reduce the burden of high upfront cost of EE projects along with simplified process of availing subsidies.

#### 5.2.3.1. *Capital subsidies on EE technology solutions*

We are proposing following interventions cater the needs of MSMEs. CLCSS has seen significant uptake in MSMEs and has been operational for two decades

a. Increasing the limit of capital incentives under CLCSS, both maximum subsidy amount (15 lakhs) and applicable loan amount (1 Cr.) under CLCSS
b. Higher % of capital subsidies on EETs for differentiating from productivity improvement
c. Increase the purview of technologies and sectors under existing subsidies schemes
    i. Auto poring of molten metal for induction furnace
    ii. Gas based copula with PLC based control
    iii. Centralized sand reclamation plant
    iv. Automated core and Sand Plant with conveyor system
    v. Installation of high-pressure moulding line in moulding area
    vi. Multi axis Machining center (5/6 Axis)
    vii. IoT based EMS

**Implementation roadmap:**

a) Awareness and cluster level engagement is essential for capital subsidy scheme as well.

b) Some foundry clusters have finds wider adoption of these schemes however majority of the units in the different clusters still lack the knowledge of the different schemes.

- Conducting the workshops for promoting the awareness of the financial schemes across clusters of Batala, Ludhiana, Jaipur, Indore etc.

c) Even though capital subsidy schemes are highly accepted in MSMEs it is vital that it incorporates important features like simple application process, quick approval and disbursement of subsidy, wide coverage of technologies & MSME clusters and awareness of the scheme.

d) Regional level consultations should be conducted across all foundry cluster to draft the possible recommendations for the faster and wider adoption of these schemes.

e) After consolidating the inputs received, IIF along with BEE can conduct the stakeholder consultation with MoMSME for further simplification of the processes.

#### 5.2.3.2. *Lower interest rates on EE loans and fasten disbursement*

The prime objective of this mechanism is to promote ease of financing for the adoption and implementation of energy efficiency measures across all the selected sectors (mainly demand side).

1. List of EE technologies applicable for interest subsidies based on minimum threshold
2. Building the capacities of Financial Institutes in loan appraisal for EETs
3. Quick and fast disbursement for adoption of EE technologies

#### 5.2.3.3. *Differential taxes on EE technologies*

A tax exemption will allow the purchaser of an equipment, such as an energy-efficient technology, to be exempt from paying tax on that purchase. Tax credit can also be provided to allow MSMEs to deduct the tax credit amount from their annual taxes as a percentage of a purchase price.

1. Charging lower GST and differential tax breaks on purchase of EE technologies.
2. Different GST slabs based on EE potential of technologies

**Implementation roadmap:**

Regional level consultations should be conducted across all foundry cluster to draft the possible recommendations for list of technologies that should be included in this scheme.

- We propose one workshop in each Custer for compiling the requirements of the different foundries.
- After consolidating the inputs received, IIF can propose a consolation with BEE and relevant stakeholder consultation for addition of most relevant technologies in the list.

**Benefits to sector stakeholders**

a. Increasing affordability of energy efficient technologies
b. Faster replication and adoption of new & advanced technologies

**Relevant stakeholders:**

| BEE | MoMSME | Commerical Banks | SIDBI |
|---|---|---|---|

**Role of various actors/ stakeholders**

- **BEE:** Providing list of Energy efficient technologies applicable for incentives and subsidies
- **Commercial banks**- Developing in-house capacities on evaluation on EE technologies and ready reckoner for quick sanction & faster loan disbursement
- **MoMSME:** Revised guidelines for capital subsidies schemes and shortlisting EE technologies for GST breaks and differential taxes on EE technology solutions.
- **SIDBI –** Expanding the capacity building of industries and FIs, standardization of the project documents

### 5.2.4. *Collaboratives efforts among institutional stakeholders and IDAs*

**Need Assessment:**

State specific departments and institutes participate minimally in implementing centrally funded support programmes. The wider reach to state specific institutes coupled with increased ownership can significantly improve the outcome of existing schemes. Support from DICs, state ministries and departments are needed to facilitate better implementation.

**Proposed interventions:**

There is a need felt across clusters to leverage other institutes for promoting of EE interventions in the MSME foundry clusters. We are proposing following interventions for institutional capacity building

#### 5.2.4.1. *Collaborative Efforts among various institutes:*

a. Building capacity of SDAs/MSME-DI, to include a full time EE-MSME expert to facilitate MSMEs in availing benefits of existing cluster specific schemes

b. Support from SDAs and DICs is needed to facilitate better implementation and collect timely feedback on the performance of energy efficiency programmes.

c. The wider reach of state government agencies, coupled with increased participation can significantly improve the outcome of existing schemes

#### 5.2.4.2. *Creating synergies with IDAs led existing EE interventions*

a. Identified IDA led (GIZ programme in secondary steel and paper sector) ongoing EE interventions in MSME clusters and exploring options for synergies for capacity building and technology demonstration activities

b. Combining IDA led EE financing schemes and revolving funds (EESL UNIDO EMRF fund) with technical assistance activities of BEE in foundry MSME sector

**Implementation roadmap:**

a) Developing the common platform to map the different initiatives carried out for the foundry sector by the different stakeholders. This will result into propagating the benefits and learning captured in different program though web portal accessible to foundries.

b) Strengthening of SDA, DICs and regional association for wider dissemination of the learning to the foundries in their respective regions.

c) Creating the common platform for exchange of thoughts and ideas among the regional stakeholders to identify the key areas for development.

d) Establishing the long-term programmatic interventions focused for specific cluster led by one IDA or collaborative efforts - including the capacity building programmes, technology demonstration, hand-holding support for implementations.

e) Developing new focused programs for foundry clusters where limited or less program intervention has been carried out in the past. Developing long term energy management centers across clusters of Batala, Agra, Jaipur, Indore etc.

f) Programmatic interventions should leverage cross -cluster learnings and interventions of different IDA in other clusters though knowledge exchange programmers and industry tours and hand-o training in center of excellences.

**Benefits to sector stakeholders**

a. Developing the collaborative ecosystem for wider outreach of programmatic activities
b. Different foundry stakeholders will have increased awareness and access to various cluster specific interventions
c. Removing the duplication of efforts among various stakeholders.

**Relevant stakeholders:**

| BEE | International development agencies | DICs/ MSME DI | SDAs |
|---|---|---|---|

**BEE:** Engaging all stakeholders at the inception of the programme and ensure ownership from them by highlighting mutual benefits and opportunities for synergy

**MSME DI:** Creating awareness on current initiatives among MSMEs at cluster level and support during awareness workshops by inviting MSMEs in the cluster

**International development agencies (IDAs)-** Supporting ongoing BEE interventions through bundling with ongoing EE financing schemes and revolving funds

### 5.2.4.3. *Creating supporting infrastructure for EE technology upgradation-*

In addition to this lack of supporting infrastructure and regulatory support also limit the uptake of EE interventions in various MSME clusters in foundry sector. *For example: MSMEs usually find difficulties in getting regulatory clearances to shift from Low Tension to High Tension connections which limits the uptake of induction furnaces.*

1. **Ease of regulations from DISCOMs**:
   a. Easing the upgradation from LT connections to HT connections, create a bridge between MSME industries & DISCOMs
   b. Additional financial incentives for technology upgradation which wit lower the overall projects costs related infrastructure upgradation
   c. Developing ready reckoner and list of documents required for getting the clearances

BEE appointed project consultant will understand the regulations and need assessment at MSME level.

2. **Extension of Natural Gas Pipelines:**
   *During energy audits in Rajkot cluster, it was emerged that there are some industrial areas where Natural gas pipelines are not available.*
   a. Strengthening & extension of the Natural Gas pipeline within clusters mainly in Batala and some areas in Rajkot
   b. Prioritizing availability of Natural Gas pipelines across all energy intensive foundry MSME clusters

BEE appointed project consultant will do study to identify industrial areas where NG pipelines are not available

3. **Easing the net-metering policies** and wheeling charges support for solar roof-top installations in MSMEs

BEE appointed consultant with the help of MNRE, gap assessment and interventions required

**Benefits to sector stakeholders**

a. Evaluation of technical viability of EE technologies, cost benefit assessment
b. Access to cleaner fuel by switching to electricity and NG, hence reduction of emissions
c. Easy access to energy auditors in the clusters and support during implementations

**Relevant stakeholders:**

| BEE | Industry Associations | Gas Authorities | DISCOM |
|---|---|---|---|

**Role of various actors/ stakeholders**

**Industry Associations:** Holding the energy management cell in the cluster and outreach to foundry MSME industries in the cluster

**DISCOMs:** Easing out the process of upgradation to HT lines and assist MSMEs in providing required documents for clearance and approval

**MSME DI in collaboration with Gas Companies** can assist in getting the clearances for extending Gas pipelines in industrial MSME clusters

**BEE**- Supporting in carrying out regulatory interventions in the cluster for HT connection upgradation and NG lines in the cluster

### 5.2.5. *Performance Achieve and Earn (PAE) Scheme:*

Learnings from the Perform Achieve Trade (PAT) scheme should be extended to the MSME sector. These mandatory programmes should not be perceived by MSMEs as an administrative burden; therefore, the incentives should be provided based on EE potential achieved.

Considering the fact that SMEs already face significant barriers to energy efficiency implementation, proposing a scheme which penalizes SMEs on non-compliance may widen the relationship gap between the government and enterprises and create extra burdens on these enterprises. Therefore, an incentive-oriented compliance mechanism (e.g., offering ESCerts based incentives) is proposed.

**Proposed interventions:**

Programme coverage: In the pilot phase for Foundry across 10 clusters covering over 200. Different clusters that can be considered under the programme include- Rajkot, Belgaum, Kolhapur, Coimbatore, Indore, Batala-Jalandhar-Ludhiana (BLJ), Howrah, Agra, Jaipur, Ahmedabad.

A mandatory audit programme will help policymakers and regulators identify major energy efficiency bottlenecks and opportunities to intervene at scale. However, enterprises may perceive mandatory energy audits as an added administrative burden, hence, they can be incentivized by providing free/ subsidised energy audit services

**Implementation Roadmap:**

As a first step, energy audits must be made mandatory in the next 3-5 years for all energy intensive foundries having an annual turnover of more than INR 50 crore (medium scale units); this can later be extended to enterprises having turnover of more than INR 25 crore.

- The pilot for this program will cover about 10 MSME foundry clusters across India.
- BEE team in close consultation with national foundry association (IIF) will navigate the execution of this programme.
- Interested SMEs can opt for the energy savings programme by reaching out to Industry Association. Industry associations will be given ownership to register the MSMEs for programme and to engage with them in a meaningful and sustainable way
- BEE will promote the voluntary uptake of energy conservation by carrying out the energy audits in MSMEs and assign targets for reduction of their specific energy consumption
- BEE appointed agency will carry out baseline energy audit as per prescribed format of BEE, recommend ECMs for energy saving and techno-commercial feasibility for EE solutions
- BEE will also provide handholding support to MSMEs during implementation phase
- SMEs that achieve or exceed the reduction targets would be issued ESCerts based monetary incentives. MSMEs will be required to achieve a minimum of 30% of the agreed targets

- BEE will also assist in building confidence of MSMEs by technology demonstration and create awareness on EE solutions and technologies.

**Relevant stakeholders:**

| ***Stakeholders*** | ***Key Activities and Task*** |
|---|---|
| *BEE* | *Roll out of the pilot phase of PAE scheme, Selection and procuring services of EA agency for baseline energy audits, issuing ESCerts to MSMEs* |
| *Project Consultants* | *Carry out baseline energy audit as per prescribed format of BEE, recommend ECMs for energy saving and techno-commercial feasibility for EE solutions* |
| *Industry Association* | *Disseminate the programme objectives across different clusters through workshops and collating expression of interest from different foundry clusters* |
| *MSME* | *Support EA agency appointed by BEE, facilitate EA study, sharing of the details and data requirement for baseline study* |

# *Annexure*

# A. Production process and technology adopted

# A. Production process and technology adopted

Foundry is the most energy intensive process and energy cost accounts for about 20–30 percent of the total manufacturing cost. The primary process steps in metal casting method are sand preparation, mould preparation, melting, pouring, and finishing. Of these, melting is the most energy-intensive operation and accounts for 70-90 percent of the total energy consumption in typical foundry while the balance is used in sand mixers, shot blasting, fettling, heat treatment & auxiliary operations.

## Type of production processes in foundry

Different processes in the foundry can be classified under following broad heads, shown in.

- Sand Preparation
- Casting and Moulding
- Core preparation
- Metal charging and melting
- Knock-Out and Shot -Blasting
- Heat treatment
- Machining and Finishing

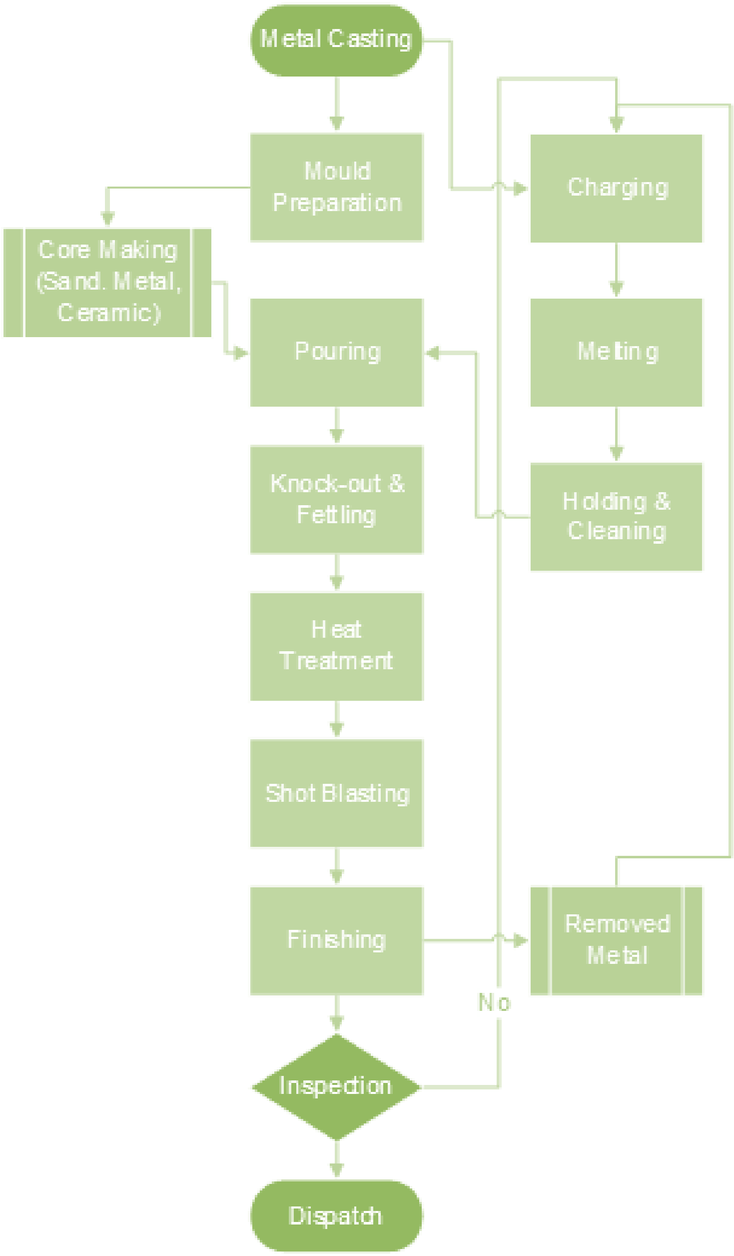



Figure 23 Typical production process in foundry units

### Sand Preparation

Silica sand is mainly used in the foundry for preparation of moulds for the casting, because of the thermal conductivity properties of the sand. Properties of the sand are enhanced with us of the additive materials which are thoroughly mixed with sand. *Major additives used during sand preparation are bentonite clay, water, organic resins etc.*

Additives help in absorption and transmission of heat while allowing the gases generated during the thermal degradation of binders to pass through the grains. *Adequate use of the additives helps in better product quality and lower rejection volumes.*

Green sand is generally prepared in a sand muller, large wheel based muller mixers are used for mixing to maintain the properties of the bentonite clay and other additives.

Screw mixers are preferred for sand moulding in foundry operations if organic binders are used as additives. This process of mixing sand helps to maintain the uniformity of binders, additives, and sand. During the process, the binders are gradually added to the sand so as it is uniformly distributed over the sand grains.

*Average size of the **sand mixers** used across the foundry clusters in Howrah, Batala, Agra, Rajkot Shimoga, Belgaum, Kolhapur for small foundries varies in range of 250-500 kg per batch.*

*Foundries with higher production volumes in the  Shimoga, Batala and Agra clusters have installed the sand plants for sand preparation with capacity of 1- 5 tonnes per hour.*

*Most of the small green sand foundries re-use the sand after the casting operations by adding the additional additives, however* some *of the foundries have implemented a sand reclamation system for retrieve the best quality of the sand for further processing.*

*Intensive sand mixers are also use across the medium size foundry units across Shimoga, Kolhapur.* The sand is blended with suitable binders, water, and other ingredients in intensive mixers. Intensive mixers are generally powered with two motor drives, which are used to rotate the angular blades and other supporting the blending operations in vertical direction. These mixers are having efficiency and higher quality of mixing  as compared with sand mixers. These mixers generally have rated capacities over 10 tonne per hour and adopted by medium to large scale foundry units.

## Casting and Moulding

There are three main types of casting done in India, which includes the most common green sand moulding, shell moulding and precision casting. Details of the different processes are presented in this section.

Over 85% of the foundry units adopt the green sand for the mould preparation, around 5% of the foundries use the chemical bonded sand mould, no – bake sand moulding operations.

### Sand moulding

The mould cavity is formed by packing sand around the pattern (which is a replica of the external shape of the casting). Cores are placed inside the moulds to create void spaces. The sand can be packed manually, but moulding machines that use pressure or impact to pack the sand are commonly used.

*Progressive units in Shimoga, Rajkot, Kolhapur foundry clusters have adopted the state of the art - high pressure moulding lines for mould preparation . A few units in the Agra, Howrah and Batala clusters have also adopted this advanced technology.*

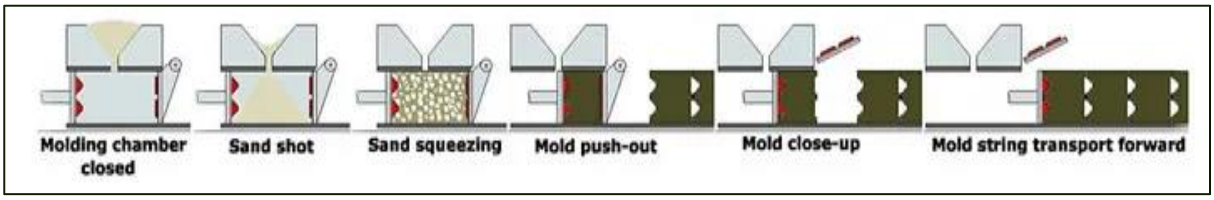



*Figure 24: High pressure moulding lines*

*Four common types of sand moulds are as follows:*

**Greensand mould** is the most common moulding process used in the foundry industry. Typical green sand for moulding contains about 80–85 per cent silica sand, 8–10 per cent clay, 3.5–6 per cent additives / binders , and 3–4 per cent water. The mould sand is pressed manually or with help of pneumatic machines on the pattern to prepare the mould.

*Green sand moulding is most widely adopted form of sand moulding across all foundry clusters.*

*Howrah has the highest % share of green moulding units across different foundry clusters.*

**Dry sand mould**: In a dry sand mould, sometimes called a cold box mould, the sand is mixed only with an organic binder. The mould is strengthened by baking it in an oven. The resulting mould has high dimensional accuracy but is expensive and results in a lower production rate.

*Dry sand mould is being adopted by few units across the Agra, Batala, Kolhapur, Rajkot, Shimoga foundry clusters for preparing the higher finished quality castings.*

**Chemical bonded sand moulding**: In this process chemical binder to impart the required chemical strength to the mould. Specific chemical/ additives are mixed with sand during the mould preparation, to provide the strength to the mould. These moulds are used to cast the products with higher surface finish and good dimensional tolerance can be achieved.

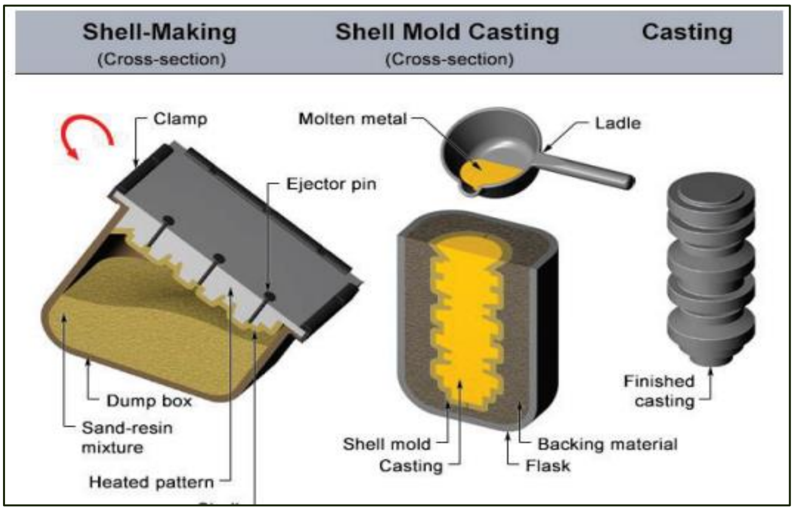
*Chemical bonded sand moulding is being adopted by few units across Batala, Kolhapur, Rajkot, Shimoga foundry clusters for preparing the higher finished quality castings.*

**No-bake mould**: The sand in a no-bake mould is mixed with a liquid resin and hardens at room temperature.

*No bake moulding is being adopted by few units across the Shimoga, Batala, Rajkot foundry clusters.*

### *Shell Moulding*

Shell moulding is generally used by the foundries to prepare the complex and heavy castings. The shell moulding is a casting process in which the mould is a thin shell of 5-10 mm thick, depending on the forming time of the resin. This is made of sand held together by thermosetting resin binder. Set-up and production of shell mould patterns takes weeks, after which an output of 5 - 50 pieces / hr. - mould is attainable.




- **Pattern preparation**– Generally two-pieces of metal with engravings in the form of the desired part, *typically made from iron or steel*, are used for pattern creation.
- Next step includes the heating of the mould, generally done with the help of electrical heaters with required temperature of 150-300 degree C
- **Hot pattern** is clamped and inverted into the mixture of the sand, additives, resin, and binders etc. This process is used for coating of sand-resin mixture over the pattern.
- The box is positioned to the previous stage, so that loose, uncured particles drop away
- Heated pattern partially cures the mixture, after curing the shell is formed around the pattern.
- Then shell is ejected from the pattern and two halves of the shell mould are assembled, supported by sand or metal shot in a box, and pouring is completed

### Investment casting mould

Investment casting (lost-wax process) yields a finely detailed and accurate product, with excellent metallurgical properties. In this casting process, a pattern made of wax is coated with a refractory material to make the mould surface, after which the wax is melted away while pouring the molten metal.

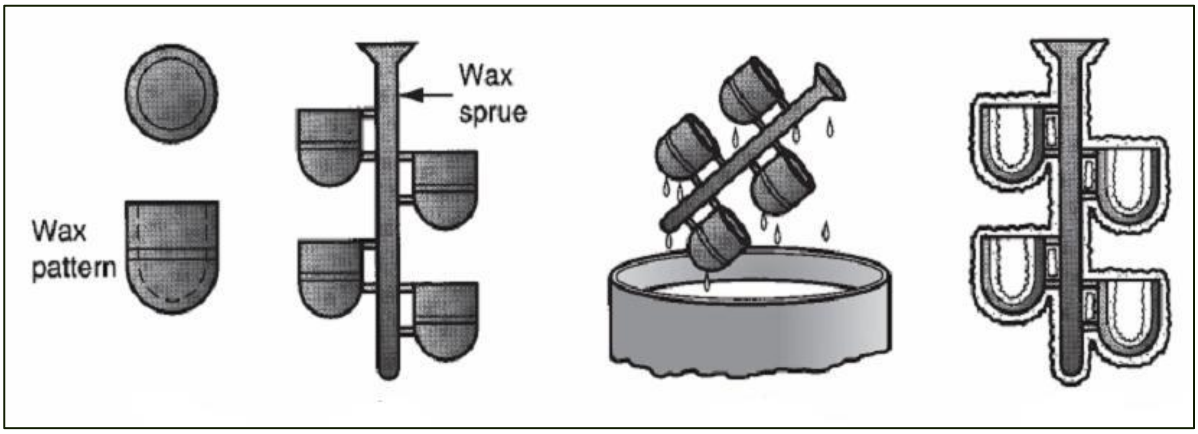



*Figure 25: Investment casting process flow*

The process starts by creating an injection die to the desired specifications. This die will be used to inject wax to create the patterns needed for investment casting. (Polystyrene foam is also used in investment casting)

- Wax patterns are first made, several patterns can be attached to a sprue to form a pattern tree.
- Pattern tree is coated with a thin layer of refractory material and later covered with thick coating to make the rigid full mould
- Heating of mould in inverted position to melt the wax and permit it to drip out of the cavity
- Mould is preheated to a high temperature so that contaminants are eliminated
- Molten metal is poured, and it solidifies, then the mould is removed from the finished casting

*Majority of the units performing operations are presented in the Rajkot and Shimoga clusters. These units typically have higher SEC as additional heating is required in the de-waxing operations.*

***Advantages of wax casting are -***

- Using this casting of high accuracy with intricate details can be made
- Good surface finish is possible
- Applications: - High temperature alloys can be cast - Examples: machine parts, blades, components for turbine engines, dental fixtures

## Core preparation

Cores are forms that are placed into the mould to create the interior contours of the casting. They are typically made of clay-free silica sand mixture. The sand is thoroughly mixed with suitable binders, water, and other ingredients in Muller-type mixers. A range of binders from vegetable oils to synthetic resins like phenol formaldehyde is used. Green sand core and Oil sand cores are most widely used in the foundries.

*Gas is being used as fuel for the core baking in all the units in the Agra, Shimoga, Rajkot, Howrah clusters. Oil is also used as fuel for thermal heating by few units across the clusters of Rajkot, Kolhapur, Batala etc.*

## *Metal preparation and charging*

Raw material for the melting process is received by the industries in the form of iron bars, scrap, metal bar, rods etc., depending upon the type of the product different these are used. Pig iron (majorly used), different grade of metal alloys, foundry return, and other alloys are charged into the furnace for melting. The ratio of different charge materials depends on properties required for the final castings.

Scrap is being cut into the appropriate size and additive metal are weight and prepared the mixture for the melting process. Additives such as Si, Mn and other alloying metals are also added along with charge in the melting furnaces, these additives help in imparting the casted product with desired characteristics such as good machinability & improved microscopic characteristic.

Table 28 presents the melting temperature for different alloys. Temperature depends upon the % of the carbon and % alloying metal in the iron. Electricity, Gas (Graphite is used for bed preparation) are the main form of energy used for heating the metal.

*Table 28: Melting temperature (degree centigrade) for different materials*

| Sr. No. | Metal Alloys | Metal temperature required for melting (ºC) |
|---|---|---|
| 1. | Grey Cast Iron | 1300-1350 |
| 2. | Cast Iron | 1350-1400 |
| 3. | Ductile Iron | 1250-1300 |
| 4. | SG Iron | 1480-1540 |
| 5. | Steel alloys | 1525-1640 |
| 6. | Stainless steel | 1600-1650 |

*CI casting is produced across all foundry clusters, Steel castings are predominantly produced in the foundry clusters in Rajkot, Shimoga, Kolhapur region. Rajkot is the leading cluster to produce the high end investment castings.*

*CI castings contribute to over 78% of the total castings (ferrous) produced in India, SGI and DI contribute to around 10% of the casting, while share of steel and precision casting is around 1% of the total casting produced in the country.*[29]

*Most of the units (Induction melting furnace) in the progressive clusters like Shimoga, Kolhapur, Agra, Rajkot etc. use the pyrometer to closely monitor and maintain the temperature of motel metal.*

## *Metal melting*

The charged material is then melted in various type of melting furnaces. Cupola and Induction melting furnaces are mainly used to melt the metal. Electricity, Gas, and coke are the main forms of energy used for melting the metal.

Coke fired cupola is the predominant technology used for metal melting in Batala, Jalandhar, Ludhiana foundry cluster; Divided blast cupola is predominantly used Howrah, Kolhapur, Belgaum, Rajkot foundry clusters.

Induction furnaces are also used across different foundry clusters; all foundry units in Shimoga cluster have installed induction melting furnaces. Agra cluster have mix of the Gas fired cupola and state of art induction melting furnaces.

[29] http://foundryinfo-india.org/profile_of_indian.aspx - accessed on 20 May 2021

Once the melting is completed, the molten metal is transferred and poured into the sand moulds, *using a ladle operated either manually, automatically or by monorail or using overhead cranes*, that were prepared in the first stage and allowed to cool down and harden.

## Knock out, fettling and Shot blasting

Once the liquid metal has taken the shape of mould, then moulds are left to cool for certain time after which the castings are knocked-out, shot blasted, and cleaned. Fettling and knock-out are the major operations, followed by the casting process in any foundry unit. Knock out operation is done to remove the casting from the mould, vibrators are being used to break the sand from the mould. Fettling followed by knock-out is used for removing the excess metal from the casted product. Runner, risers, and excess metal are removed during this process.

Shot Blasting is a surface treatment operation that uses high velocity steel abrasive. Shot blasting is method through which it is possible to obtain excellent cleaning and surface preparation for secondary finishing operations. This is followed by fettling and machining. Meanwhile, the sand from the moulds is either disposed or treated in a sand reclamation plant for reuse.

## Heat Treatment

Heat treatment (HT) is the process of the heating the metal at specific rate, holding the metal at a temperature for a period of time and gradually cooling the metal at a specific rate to obtain a desired microstructure. HT process helps in removal of residual stress, improving the machinability of the casted product, improving the structural properties of the casted component.

During the process the metal is heated below the lower critical temperature and allowed to cool gradually. Depending upon the type of the product and application of the product, different heat treatment processes are carried out. Electricity, Gas, Oil, HSD are the main forms of energy used for heating the metal. Type of heat treatment processes are presented next.

### Annealing

In this process the casted product is heated above critical temperature[30] and allowing to cool in the furnace itself after switching off the furnace is called annealing. This process increases the ductility and toughness but reduces the hardness in the casted component.

### Normalizing

In this process the casted product is heated above critical temperature, soaking it at that temperature and cooling it in air is called normalizing. This process increases the strength and harden ss. This process is performed on casted components that are to be machined as normalizing improves the machinability of components.

### Case Hardening

Some components require higher hardness at surfaces than at cores. For such casted components surface hardening is done which hardens only the surface/ case. This is done to improve the wear and tear resistance of the component.

[30] Steel undergoes a phase change - recrystallizing as austenite at the critical temperature (~ 700 ºC)

### Tempering

Tempering is performed by elevating the steel to a set point below its lower critical temperature, typically following a hardening operation. Once this temperature is reached, it is held there for a specified amount of time. Material is gradually cooled, tempering also improves the machinability and formability of a hardened steel, and can reduce the risk of the steel cracking or failing due to internal stresses.

## Finishing and Machining

Preparation of the final product might require additional machining operations to produce the final product within the precise dimensions. Casted products are finally machined to deliver the final product in the specified shape, dimensions, and tolerances. Several machining operations such as drilling, shaping, truing, boring, threading, grinding, stamping etc. are carried out with help of the special machines during the finishing process.

# Technologies used in foundry

Different equipment's and machines and processes are adopted to process the different products, depending upon the type of metal being processed, type of product to be formed etc. Details of the different technologies and their applications in different processes are being illustrated in the section.

## Induction melting furnace

Induction furnaces are used by over 40% MSME foundry units for metal melting across different foundry clusters. Induction melting furnaces are operated in batch mode, with cycle time of generally 50-70 minutes. Induction furnaces are available in wide capacities ranging from few kg/cycle to few tonnes /cycle. Induction furnace is made up of nonconductive crucible which is used to hold the metal to be melted, crucible is generally surrounded by multiple coils.

High frequency alternating current is passed through the coils which creates a rapidly reversing magnetic field, this magnetic field penetrates the metal changed in crucible. Alternating high flux magnetic field induces eddy currents (in charged metal), by process of electromagnetic induction. The eddy currents, flowing through the electrical resistance of the bulk metal produces the heating effect. Ferromagnetic materials like iron, the material is  also heated by magnetic hysteresis, the reversal of the molecular magnetic dipoles in the metal. These eddy currents and magnetic hysteresis led to vigorous stirring of the melt, assuring good mixing of the het flux cross the metal, this helps in the heating and melting of the metal.

There are two types of induction melting furnaces widely used across foundry clusters in India. *Silicon controlled rectifier (SCR) induction melting furnaces* and *Insulated gate bipolar transistor (IGBT) based induction melting furnaces*. These two categories are based on the electronic switching of the furnace.

During audit across multiple units in different foundry clusters- the capacity of the induction furnace was observed in the range of 500 kg – 5000 kg per batch, with a connected load of 200–2000 kW. *The specific energy consumption (SEC) of induction furnaces varies in the range of 580 kWh–850 kWh per tonne*.

*IGBT based system are ideal for the high voltage high current operations. IGBT based system is capable of operating at higher frequency (up to 10 kHz)range as compared with SCR based system (up to few hundred Hz). These added benefits of IGBT help in better and precise control of the melting operations in IGBT based melting furnaces.*

*SEC of IGBT based induction furnace varies in range of 584-700 kWh/ tonne for CI casting across the different foundry clusters. SEC for the Steel and alloy varies in range of 650-850 kWh/tonne deepening upon the composition and melting temperature of the ferrous alloy.*

*Less than 40% of the induction furnaces installed across the different foundry clusters have adopted the modern stat of art IGBT*

*IGBT based furnaces are generally 5-15% more efficient than SCR[31] based melting furnaces.*

*Shimoga cluster has highest penetration of the IGBT based induction furnaces across the different foundry clusters.*

Efficiency of the melting in an induction furnace is the function of multiple parameters such as - scrap charging system, scrap density, frequency of operation, metal charging time, metal holding time, furnace top cover, harmonics control, temperature of molten metal, and grade of refractory/ insulating material used. IGBT based induction melting furnaces which have heat transfer efficiencies as high as 75%.

*Table 29: Comparison of metal heating furnace technologies*

| Sr. No. | Technology / Process | Applications / Advantages | Energy consumption |
|---|---|---|---|
| 1. | Induction melting furnace | • Precise metal temperature can be controlled<br>• Advanced skill sets are required to operate the furnace<br>• High installation cost, higher productivity & high-quality casting | 509-650 kWh per tonne |

## Cupola furnace

Cupola is most widely adopted metal meting technology since ages in the foundry sector. Present day foundries use different types of the cupola furnace for metal melting. Some clusters have adopted the coke less (Gas fuel based) cupola, other clusters have adopted the modern designed DBC cupola which operates more efficiently as compared with conventional cupolas. Details of the melting technology are presented in this section.

### Conventional coke based cupola

Cupola is most widely used metal melting technology across different foundry clusters. Size of the cupola used across different cluster varies in range of 20-48 inches with metal melting capacities in the range of 2 tonnes/ hr to 7 tonnes/per hour. Coke to metal ratio for the cupola operating across the clusters varies in the range of 1:4 to 1:13 depending upon the type of operations and practices adopted.

Efficiency of Cupola is the function of air distribution and draft of the air in the cupola. Metal and fuel are charged from the top of the furnace and air is feed using tuyeres at combustion and reduction

[31] Also depends upon the operations and degree to automation and control of the operations.

zone in the furnace. Molten metal is taken out from the tapping at the bottom of the Cupola.

Adoption of the DBC with optimal blast[32] will also help units to improve the coke to metal ratio to 1:10 to 1:14.

### *Divided Blast Cupola (DBC)*

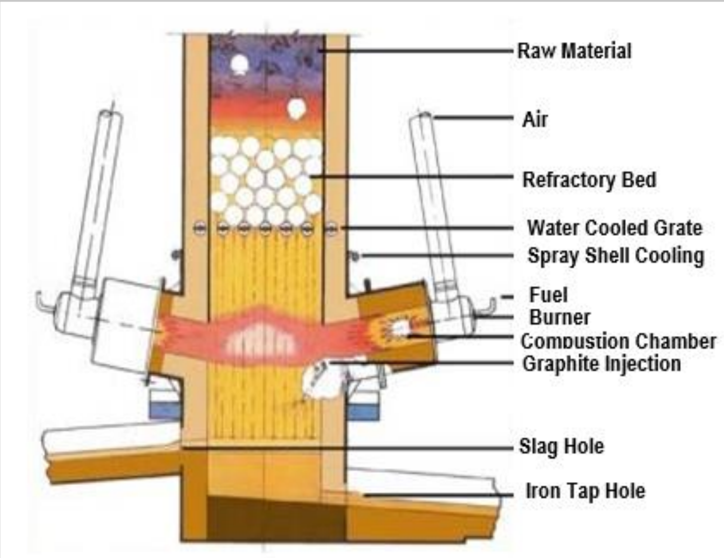
Divided blast cupola (DBC) technology is used by the units in the Rajkot, Howrah, Kolhapur, Belgaum foundry cluster for metal melting. Metal and fuel are charged from the top of the furnace and air is feed using tuyeres at combustion and reduction zones in the furnace. Molten metal is taken out from the tapping at the bottom of the cupola.

Divided air blast help in better combustion of the fuel in cupola and helps in lowering the un-burnt (Carbon monoxide level) in the flue gas. 10-25% of the energy saving can be achieved over the conventional cupola. The average size of the DBC is in the range of 18-46 inch with metal melting capacities of 2.5 - 7 tonne per hour.

*The specific energy consumption (SEC) of furnaces varies in the range of 58-120 kgoe/tonne.* Efficiency of the cupola is function of the air distribution in the cupola and draft of the air in the cupola. *The specific energy consumption (SEC) of furnaces varies in the range of 58-120 kgoe/tonne.* Efficiency of the cupola is function of the air distribution in the cupola and draft of the air in the cupola. *Adoption of the DBC with optimal blast will help unit to improve the coke to metal ratio[33] to 1:12 to 1:14*

*DBC finds the highest pentation in the Howrah and Rajkot foundry clusters, Batala and other foundry clusters in north still use the conventional Cupola for metal melting.*

### *Gas fired Cupola*




*Gas fired cupola technology is used by more than 50% of the units in Agra cluster only for metal melting*. A very few units in the other clusters are now exploring the option of gas fired cupola over the coke based cupola to reduce the emissions. Size of the gas cupola generally varies in the range of 24-30 inch with metal melting capacities in range of 2-3 tonnes per hour. *The specific energy consumption (SEC) of furnaces varies in the range of 60-70 SCM/tonne.*

Metal and fuel are charged from the top of the furnace and air is fed using tuyers at combustion and reduction zones in the furnace. Molten metal is taken out from the tapping at the bottom of the cupola. Efficiency of cupola is the function of –

- Air distribution in the cupola
- Draft of the air in the cupola.

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32 This is function of the operating practices and efficiency of combustion of the fuel in the cupola chamber
33 This is function of the operating practices and efficiency of combustion of the fuel in the cupola chamber

*Table 30: Comparison of metal heating furnace technologies*

| Sr. No. | Technology / Process | Applications / Advantages | Energy consumption[34] |
|---|---|---|---|
| 1. | Divided Blast cupola | • Better temperature control<br>• Higher melting rate higher production<br>• Lower SEC and fuel saving, reduction in $SO_x$, $NO_x$ | 55-80 kgoe/tonne |
| 2. | Adequate draft of cupola (Gas Cupola) | • Better temperature control<br>• Higher melting rate higher production<br>• Lower SEC and fuel saving, reduction in $SO_x$, $NO_x$ | 65-70 SCM/tonne |
| 3. | Using Cupola with adequate draft | • Better temperature control<br>• Higher melting rate higher production<br>• Lower SEC and fuel saving, reduction in $SO_x$, $NO_x$ | 60-100 kgoe/tonne |

*Some major observations for the cupola those were observed during the various energy audit studies across various foundry clusters are-*

- *Most of the foundry units have installed inadequate draft fan for the cupolas – which in turn decreases the optimal combustion efficiency of the cupola*
- *Adoption of the optimal size blowers with best SOPs will also help foundries to improve the melting rate which will help them to improve the bottom line.*
- *Foundries using appropriate sizing of EE blowers (adequate draft and flow) with SOPs are having the coke to metal ratio as high as 1:12-1:13. Gas bases cupolas are having the best SECs of 70 SCM/tonne of molten metal.*

## Sand Mixers

These are used for green sand preparation. Fresh sand is mixed with bentonite and other additives and mixed in muller to make green sand. These usually come in small size of around 250-1000 kg per batch, with typical cycle time come about 5–10 minutes. Sand mixer have connected load in the range of 5-25 kW.

Sand mixers are used in preparation of the sand and mixing it with required additives to ensure the adequate characteristics of the prepared moulding sand remain within a constant range. Automatic and continuous sand mixers provide the added advantage by in-mixer analysis of the sand during mixing. Analyses are based on accurate measurements of compatibility and sand strength. A fewer units in each cluster have adopted for the modern state of art integrated sand plant.

### Sand Mullers

Sand Mullers are widely used in the green sand foundries. These are used for green sand preparation. Fresh sand is mixed with bentonite and other additives and mixed in muller to make green sand. Typical size of the sand mullers varies in range of 200-1000 kg per batch.

*Sand Mullers are widely used in the Rajkot, Howrah, Belgaum, Batala, Kolhapur and Shimoga foundry clusters*.

[34] SEC also depends upon the metal, technology and SOPs adopted by the specific unit and level of automation and allied processes.

### *Intensive mixers*

Cores are forms that are placed into the mould to create the interior contours of the casting. They are typically made of clay-free silica sand mixture. The sand is thoroughly mixed with suitable binders, water, and other ingredients in intensive mixers. This equipment basically has two motor drives, used to rotate the blades, and perform mixing.

*Intensive sand mixers are widely used in the Rajkot, Howrah, Agra, Kolhapur and Shimoga foundry clusters.*

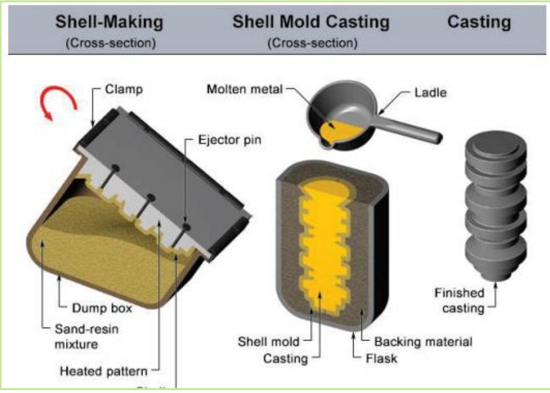
### *Integrated Sand Plant*

Integrated sand plant is one of the most advanced solutions for the foundries. Most of the foundries in India use of small size multiple sand plants which have several inbuilt challenges such as lower efficiency of motors, higher energy cost, higher cost of operations, labour intensive, layout constrains loss of fines in the atmosphere (better air quality) etc.

Integrated sand plant is a one-step solution to meet the higher quality of sand mixture, optimizing the processes and allied operations. Use of the technology in the foundries help not only help in improving the process efficiency but also provide the better productivity and better air quality control.

*A few progressive foundries in the **Agra, Shimoga, Rajkot, Kolhapur** have already adopted the modern state of the art technology for sand preparation and core making.*

## *Shell-moulding*




The shell-mould casting process includes preparation of the patterns that are joined together (two parts) to form the shell.

The two shell halves are joined together to form shell mould. In case of the complex shape of the pattern cores are added as required, they are inserted prior to closing the mould. This is usually located below the sand mixer.

Sand from a hopper falls into the moulding box and then pneumatically or hydraulically pressed to make the final mould. High pressure moulding machines can use moulding sand having lower moisture contents and hence higher mould densities can be achieved. The castings have better dimensional accuracy and better surface finish.

## *Shell Baking furnaces (Investment casting)*

After wax moulding, coating, drying and other processes, the next step is to perform dewaxing and shell baking. Dewaxing is to heat the wax in the mould shell by means of hot gas/ steam to make the wax flow out of the mould shell.

After dewaxing, baking needs to be carried out by heating in NG /oil-fired in shell baking furnaces. The refractory shells are heated to a high temperature (1000 ºC). After manually removing the shells in red hot condition from the furnace, molten metal is poured into them to get the final shape of casting.

*Shell baking furnaces are widely used by the investment casting units across the Rajkot, Shimoga clusters.*

## *Finishing and Machining*

Casted metals generally have the excess metal at the edges runner and rises, which need to be chipped and in order to produce the final product with required dimension and tolerances. Serval machining and finishing operations are carried out depending upon the type and application of the final product.


**Knock out Fettling** : Casted products knocked out from the mould; vibrators are being used to remove the casting from moulds. Casted product has the runner and risers that need to be removed along with the flash (excess metal), which is removed either manually or with trimming dies. Knock out and fettling is done manually in most of the units.

*Fewer of the medium and large units have adopted the pneumatic / robotic fettling operation for the heavy castings and this technology helps units to increase the quality and productivity*

**Shot Blasting**: Shot Blasting is a surface treatment process, using high velocity steel abrasive. Shot blasting is used to obtain excellent cleaning and surface preparation for secondary finishing operations, this process removes the sand particles embedded on the surface of the casted product.

*Centrifugal wheel-based shot blasting is the most common blast cleaning technique used in the foundry industries.*

Rotary turbine delivers abrasive shot by centrifugal force in a specific and controlled direction, speed, and quantity to help the cleaning operations. Turbine in the machine performs the operation similar to that of a fan or centrifugal pump. Shot blasting machines may use one or a multitude of turbines positioned in such a way that the abrasive blast pattern covers the entire surface of the material to be cleaned, material after shot blast provides the cleaner surface and higher surf finish.

Operating time of the shot blast depends upon the type of the casting and surface finish required, precision and high surface finish castings require the lesser shot blast operations.

**Machining Centres:** Serval operations are carried out on the forged parts to get the final product, main machining operations are :Turning, Boring, Drilling , Threading, Grinding etc.  These operations are carried out on Automated Lathe machines or Special purpose machines. Modern 3/4/5 axis machine centre provides the user with multiple programmable options to carry out the multiple operations with ease using the computer based programmable control.

*State of art CNC and VMC provides higher productivity as compared with conventional machines, these machines don't have multi-directional tool movement. Multi axis CNC machines (5 axis, 6 Axis) provide the flexibility for the tools (multiple tools) movement, which reduces the production time (clamping and de-clamping the workpiece again and again) and improves the product quality*

**Grinders:** Machined forged products are finished with the help of the grinders and finishing rollers to give the product desired surface finish and help in achieving the required tolerances. Generally, two types of the grinders are used in the foundries – hand grinder and belt grinders. Different types of the grinding wheels are used to obtain the desired degree of surface finish to the final product.

## Heat treatment

Heat treatment is an important step after casting is prepared, this helps in improving the mechanical properties of ferrous castings. During multiple operations - moulding, pouring, shakeout, and cleaning, castings take their final shape stresses are in-creeped in the metallic grain structures. Heat treatment processes help the removing these creeped form the casted products, to make them strong enough or elastic enough for their final application. Use of the gradual heating and cooling of the castings based on the metallurgy help in relieving the stress, a foundry can change its mechanical properties.

Different types of heat treatment furnaces are being used across different foundries in the different clusters, main type of HT furnaces is presented next-

### Oil fired heat treatment furnaces

Oil fired heat treatment furnace is most conventional from the furnaces used to heating of the casted products. These furnaces used different forms of the oils (LDO, LSHS, FO, Diesel) to generate the thermal heat requirement for the operations. These furnaces can be classified as two types based on the operations – box type or continuous (moving belt).

Fuel is fired in the furnace with the help of the specially designed oil burners which atomise the fuel and mixes it with adequate quality of air for the complete combustion. Heat generated by the combustion is used to heat the furnace and metal. Hot flue gas after the waste heat recovery is sent to the atmosphere.

Optimized control of the air fuel ratio; use of the modern EE burners; proper thermal insulation; WHR (limited the sulphur content in the fuel) from flue gas - helps in optimization of the SEC of the oil furnace.

### Gas fired heat treatment furnaces

Gas fired heat treatment furnace is modern from the furnaces used to heating of the casted products, with lower emissions (Cleaner fuel). These furnaces used different forms of the fuel (NG, PNG, LPG etc.) to generate the thermal heat requirement for the operations. These furnaces can be classified as two types based on the operations – box type or continuous (moving belt).

Gas is fired in the furnace with the help of the specially designed EE gas burners which help in blending the gas and air in the designed proportion for the complete and efficient combustion. Heat generated by the combustion is used to heat the furnace and metal. Hot flue gas after the waste heat recovery is sent to the atmosphere.

Optimized control of the air to gas ratio; use of the modern EE gas burners; proper surface thermal insulation; WHR from flue gas - helps in optimization of the SEC of the gas furnace.
Generally used the clusters where the Gas pipe is available, fewer units in the Norther region and Southern regions also use the LPG cylinders as gas source to operate the Gas fired HT furnaces.

### *Electrically heated heat treatment furnaces*

Electrically operated HT furnaces are more efficient than the conventional heat treatment furnaces operated with oil or gas. Mostly gas / oil fired furnaces have higher SEC and lower efficiency due to inherent losses (dry flue gas loss, unburnt losses etc.). Operation of these furnaces require the complex air / fuel ratio control which is often not easily maintained without automation. They also require specially designed burners for precise temperature control in the furnace. Precise control of temperature across different zones or section of the furnace is also not easy to achieve with fuel fired burners.

Electrically operated heat treatment furnaces use multiple resistive heating coils spread across different furnace sections or zones, and hot air circulation fans for uniform heating. These furnaces provide precise temperature control, by use of PID control or advanced PLC controls for switching the electrical heating coils. Since electrical resistive heating inherently offers less variables and therefore less avenues for losses as compared to fuel firing, they are usually able to achieve better SEC than conventional fuel fired furnaces

*Table 31: Comparison of metal heating furnace technologies*

| Sr. No. | Technology / Process | Applications / Advantages [35] |
|---|---|---|
| 1 | Oil fired | • Large number of LSP are providing the solutions,<br>• Can be used where gas pipeline is not available<br>• Use of the advanced EE burners and Automation can help in reduction of the losses |
| 2 | Gas fired | • Better air to fuel control can be achieved, regulation of the gas flow / air flow can be automated<br>• Lower losses as compared with oil fired furnaces thus resulting in lower emissions |
| 3. | Electrically operated Heat treatment furnaces | • Reduction in cold start time of furnace<br>• Lower losses as compared with oil / gas fired furnaces thus resulting in lower emissions<br>• Use of multiple coils across the furnace (walls), help in controlling the heating more precisely- resulting in higher quality |

[35] Energy consumption of the oil / gas fired furnaces varies in range of 50-120 kgoe/ tonne, this varies with the type of the processes involved during the HT operations. SEC of the fully automated electrical furnace can vary in range of 30-80 kgoe/tonne and if also function of the operations (HT) and level of automation used in furnace.

## Utilities

Utilities like compressed air, cooling water, oil, etc. are being used to support the foundry processes. Compressed air is mainly used in the core preparation, knock out and in machining section. Cooling water is used to cool the machines, induction coils and machines etc.

Several utilities are required to support the foundry operation in the industry. Most commonly used utility along with applications are presented in below : -

### Cooling Tower

Cooling tower helps in rejecting the heat from the induction furnace and maintaining the required temperature of the induction coils and panel cooling of induction heater. Cooling towers are also used along with centralized cooling units. Cooling water from cooling tower helps in removal of the heat from Induction melting furnaces, air compressors and other utilities.

*Most of the units use the FRP based cooling towers for the cooling applications. Fewer units ( <5%) also use the fan less FRP based cooling tower to the processing cooling requirement.*

### Air Compressor

Compressed air in the foundries is used mainly in pneumatic grinders, shot blast, pneumatic rammers, and cleaning. Few units have semi-automated pneumatic line for moulding. Foundry utilizes compressed air in number of process applications which includes mould preparation, pneumatic fettling, and application of cleaning of mould, core, and general cleaning.

Reciprocating screw compressors are generally used by micro and small foundry units to meet the compressed air requirement of the unit. Screw compressors are mostly used by the medium scale foundry units having extensive sand preparation system.

*A few units in the Rajkot and Shimoga have also adopted the modern state of art Permanent magnet screw compressor to meet the process air requirement. SEC for these compressors are ~ 0.13-0.14 kW/cfm as compared to 0.25-0. kW/cfm for reciprocating compressors.*

### Motors and Pump Sets

Motors are used for power - fettling, grinding, shot blast, CNC, drilling, turning and other machines for the machining and finishing operation. *IE2 is predominantly used across the foundry clusters, progressive clusters like Shimoga, Rajkot and Kolhapur also use the modern EE IE3 motors*. IE4 *motors have 5-10% higher efficiency as compared with conventional IE2 motors.*

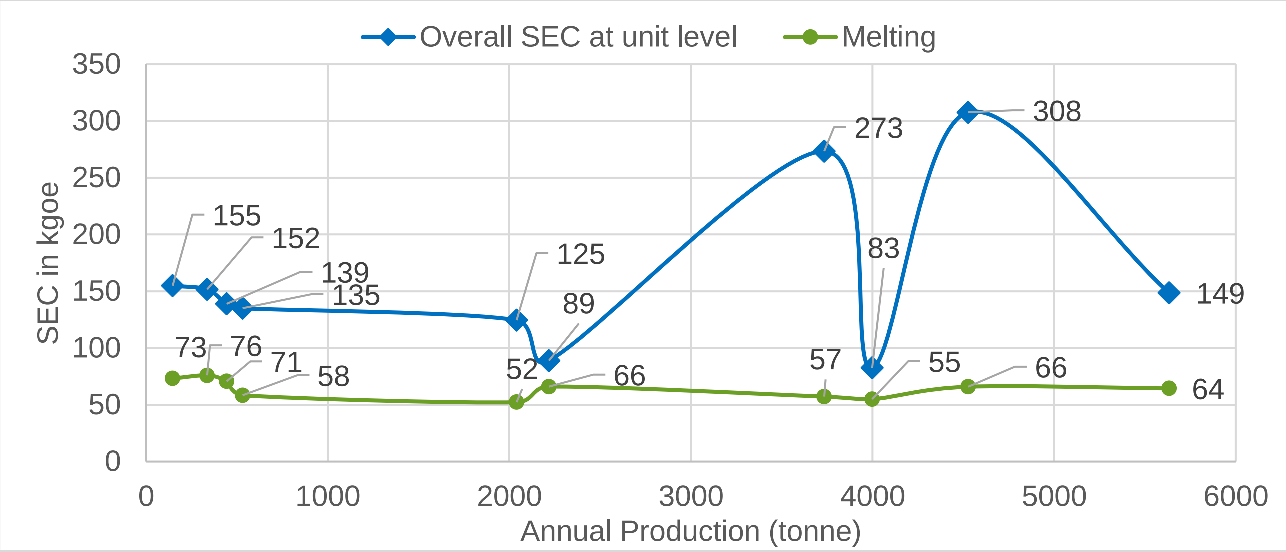
### Pump sets

Pump sets are used to pump the cooling water and other liquid utilizes in the plant. Induction furnace based foundries require cooling of coils in crucible and cooling electronic panel. Pumps running on DM water serve this purpose. Pumps are used along with induction melting furnaces to maintain the panels and coil cooling applications. Foundries in general have end suction mono-block pumps serving the purpose.

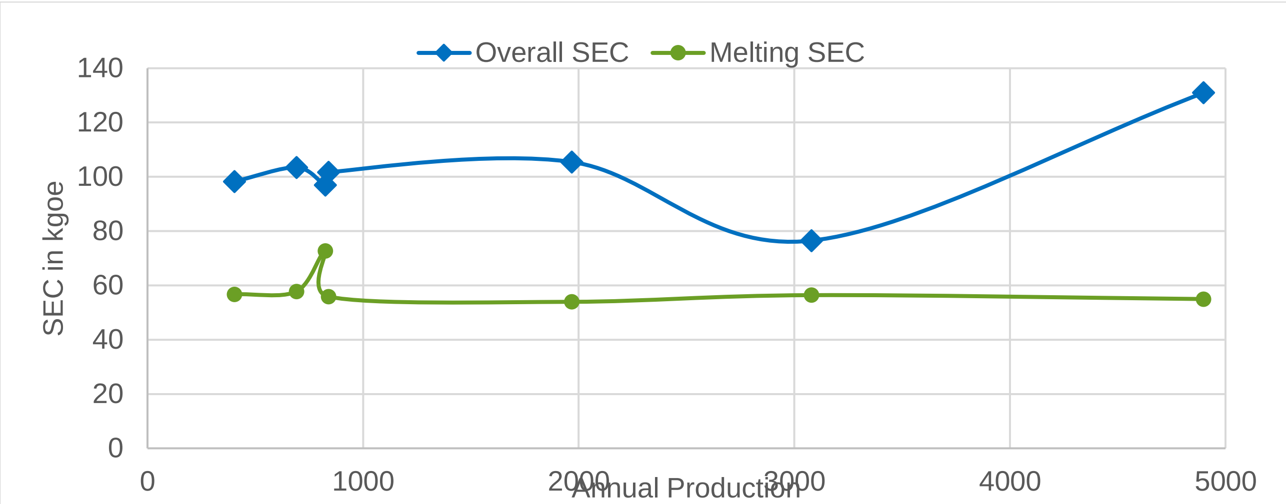
*Most of the pump sets used in the foundry units are of smaller capacities, Pump sets are generally sourced by foundries from local manufacturer. Use of the correct duty pump sets with EE motor and star rated / EE pump will help in the conservation of energy.*

Specific energy consumption across the different foundries based on the production in the different clusters is presented next-

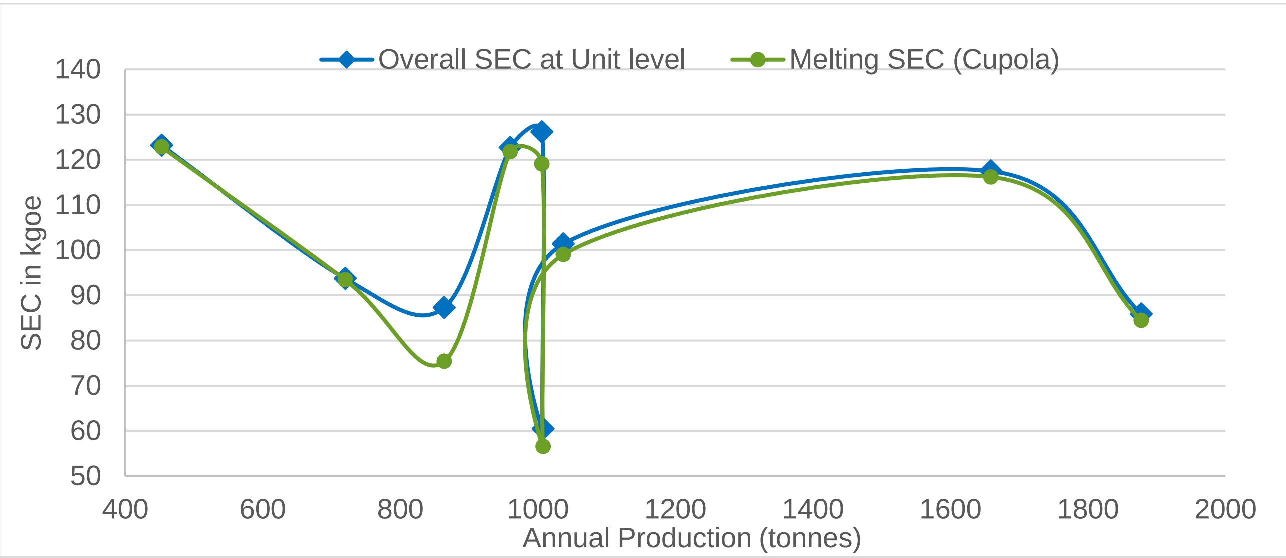
*Shimoga foundry cluster*



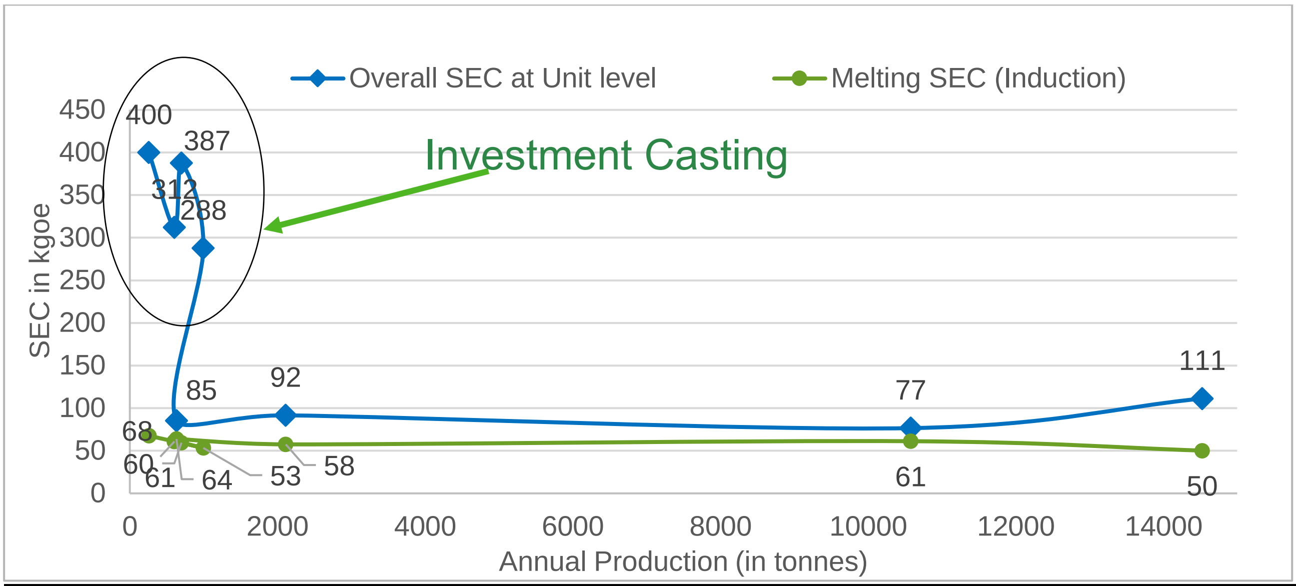

*Agra foundry cluster*




*Batala foundry cluster*



*Rajkot foundry cluster*




*Howrah foundry cluster*

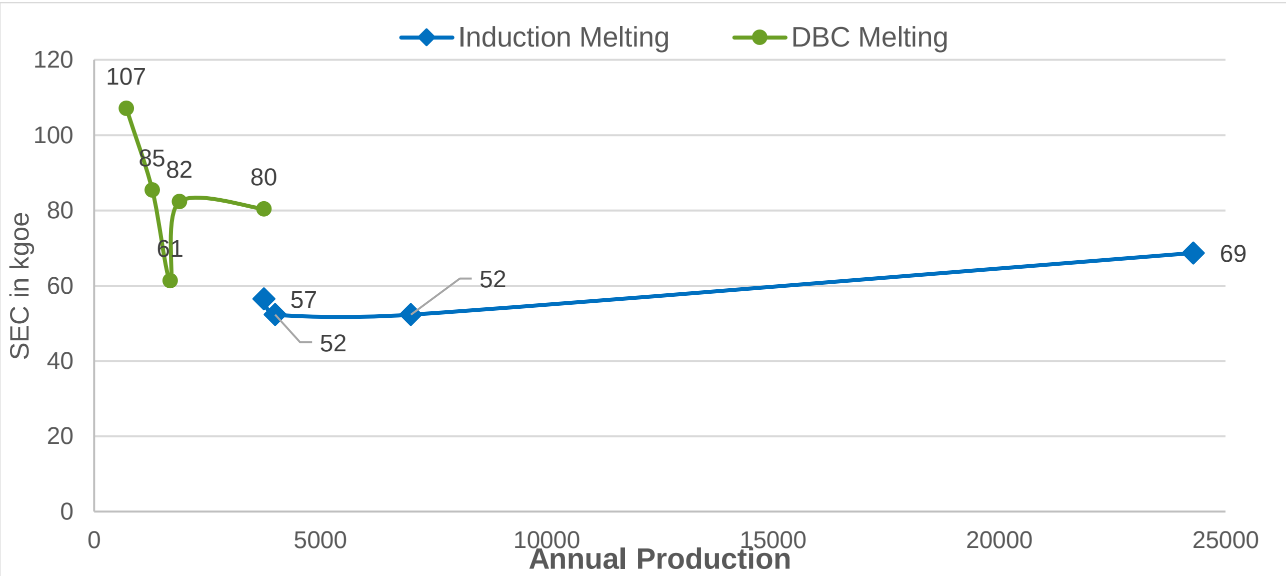



*Figure 26: Variation of SC for different annual production across different foundry clusters*

# B. EE Technology Compendium

# B. EE Technology compendium

Energy efficient technologies are usually sector specific but also governed by type of the products manufactured in the particular cluster, fuel availability along with the awareness, technology availability and level of sophistication etc.

Different clusters have different requirements depending upon the present level of technologies being used and progressiveness of the specific cluster. We have evaluated and subsequently prioritized EE technologies for Shimoga Foundry cluster based on various parameters such as investment cost, energy savings potential, payback period, replication potential etc

| | | | |
|---|---|---|---|
| Average investment cost | Scalability/ replicability in other similar industries | Technical feasibility (Energy savings potential) | Financial feasibility- IRR, NPV, payback period |

Project team has carried out the in-depth review of the EE technologies based on primary data collection, energy audits carried out in the cluster and in close consultation with IAs and technology providers. EE technologies relevant to the Shimoga cluster are explained in below section:

Team has segregated the EE technologies in two categories based on their applicability in the short-term (next 5 years) and long-term (next 10 years). For all identified EETs replication potential is estimated and segregated into following four categories:

- Low Potential: Less than 10% MSMEs in cluster have replication potential
- Medium Potential: 10%-30% MSMEs in cluster have replication potential
- High Potential: 30%-60% MSMEs in cluster have replication potential
- Saturation: More than 60% MSMEs in the cluster have implemented EET

## Process specific Energy conservation measures

*Table 32: Process specific replication potential of ECM across foundry clusters*[36]

| S. No | Technologies | Energy savings potential | Present level of Implem-entation | Replication Potential in short-term (till 2025) | | | Replication Potential in long-term (till 2030) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Micro | Small | Medium | Micro | Small | Medium |
| 1. | Induction melting Furnace with IGBT control and pyrometer | 10-30% | Low | Low | Low | Medium | Saturation | Saturation | Saturation |
| 2. | Insulation & Lid cover to avoid radiation losses | 5% | Low | Low | Low | Low | Saturation | Saturation | Saturation |
| 3. | DBC with optimized air control | 10-25% | Medium | High | High | Saturation | Saturation | Saturation | Saturation |
| 4. | Auto poring of molten metal for induction furnace | 5% | Low | | | Low | | Low | Medium |
| 5. | Cupola with optimized air control | 10-25% | Low | Low | Medium | High | Saturation | | |
| 6. | Gas based copula with PLC based control | 5-15% | Low | | Low | Low | Low | Saturation | Saturation |
| 7. | Centralised sand plant | 5% | Low | | Low | Low | | Low | Saturation |
| 8. | Auto poring of molten metal for induction furnace | 5% | Low | | Low | Low | | Low | Medium |
| 9. | Automated core and Sand Plant with conveyor system | 5-10% | Low | | | Low | | Low | Medium |
| 10. | Installation of high pressure moulding line in moulding area | 5% | | | | Low | | Low | Medium |
| 11. | Relining of furnaces / Insulation | 5-10% | Low | Low | Medium | High | Saturation | Saturation | Saturation |
| 12. | Electrically operated Heat treatment / Annealing / Normalization furnaces | 20-30% | Low | | Low | Low | Low | Medium | Saturation |
| 13. | Fuel switch in furnace FO- NG for core baking | 10-15% | | | Low | Low | Low | Medium | Saturation |
| 14. | Multi axis Machining centre ( 5 / 6 Axis) | 5-10% | Low | Low | Low | High | Medium | Saturation | Saturation |
| 15. | IoT based EMS | 2-5% | | Low | Low | Medium | Low | Medium | Saturation |

[36] Indicative list not comprehensive, saving envisaged in the table only represents the energy saving, productivity saving from different technologies is not factored in this table

## Utility specific Energy conservation measures[37]

*Table 33: Utility specific replication potential of ECM across foundry clusters*

| S. No | Technologies | Energy savings potential | Present level of Implem-entation | Replication Potential in short-term (till 2025) | | | Replication Potential in long-term (till 2030) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Micro | Small | Medium | Micro | Small | Medium |
| 1 | IE3/IE4 motors | 5-15% | Low | | Low | Low | Low | Medium | High |
| 2 | EE FRP Cooling towers with temperature control / Fan less natural draft cooling tower | 5-10% | Medium | | Low | Low | | Low | High |
| 3 | Appropriate size of air compressor / Arresting air leakage and pressure optimization | 10-30% | Low | | Low | Low | Low | Medium | Saturation |
| 4 | PM Screw Compressor with waste heat recovery | 20-30% | Low | | | Low | Low | Low | High |
| 5 | Use of Hydraulic power pack (VFD) for Clamping application | 20-40% | Low | | | | Low | Medium | High |
| 6 | EE retrofit of low friction metallic pipe for compressed air system | 10-30% | Low | | | Low | Low | Medium | High |
| 7 | Energy Efficient Transformers | 20-50% | Medium | Low | Low | Low | Saturation | Saturation | Saturation |
| 8 | EE Air conditioner / Chillers | 10-25% | Low | | Low | Low | Saturation | Saturation | Saturation |
| 9 | Automatic Power factor Controller | 5-10% | Low | Low | Low | High | Saturation | Saturation | Saturation |
| 10 | Energy Efficient Blower | 20-30% | Low | Low | Low | Low | Saturation | Saturation | Saturation |
| 11 | Energy Efficient Pumps | 20-30% | Low | Low | Low | Low | Saturation | Saturation | Saturation |
| 12 | LED lights | 10-50% | Medium | Low | Medium | Medium | Saturation | Saturation | Saturation |

[37] Indicative list not comprehensive, saving envisaged in the table only represents the energy saving, productivity saving from different technologies is not factored in this table

# EE technologies for melting and core operations

Foundry industry is energy intensive and energy cost accounts for about 20–30 per cent of total production cost. Metal melting and core preparation accounts for 70-80% of the total energy consumption in the foundry industries. Specific Energy Consumption (SEC) for the induction-based melting furnace range between 600-800 kWh per tonne of liquid metal, Furnaces have a huge potential for energy conservation, around 20-35% of the energy can be saved - by selecting right type and size of equipment, automation of processes, and by adopting best operational practices.

## Use of IGBT based induction melting furnaces

*Figure 27 IGBT Induction melting furnace*

IGBT based induction melting furnaces are one of the most advance form the metal melting technology available. IGBT based induction melting furnaces have SEC of 550-600 kWh/ tonne of metal. Induction furnaces provide better control of the molten metal temperature, which is very crucial for casting of the special grade alloys and heavy castings.

**Case Study**[38]
SRC based induction furnace is replaced with IGBT furnace for melting in units with production capacity of 430 MT/year. Intervention resulted in saving of 86,400 kWh/year, with simple payback period of 25 months).

**Case Study:** Use of 12 pulse rectifier instead of 6 pulse rectifier
Induction Furnace 6 Pulse to 12 Pulse Rectifier was implemented in a foundry unit with melting rate of 1000 tonne per month (Furnace rating 1750 kW). Implementation of the ECM has reduced the melting time by 5 minutes per batch. Reduction in current and voltage harmonics were observed after installation of the new rectifier. 22 kW/ tonne of energy saving was observed due to reduced melting time, better power quality and lower harmonics.

| Description | Before implementation of ECM | After Implementation of ECM |
|---|---|---|
| SEC in Melting in kWh/MT | 722 | 700 |
| THD in Current in % | 26.6% | 6.3% |
| Power Factor | 0.94 | 0.955 |

### Features

- **Precision temperature control for molten metal**
- **Lower emissions**
- **Higher productivity and higher alloys can be melted with precision**
- **Average Payback Period: ~ 18-48 months**

[38] Training manual for energy professional in foundry sector (SIDBI) Accessed on 20 May 2021

## Lid mechanism for induction furnace and Ladle

Figure 28 Lid mechanism for induction furnace

Induction furnaces have opening at the top for the charging of metal; once the metal is charged it takes 30-40 minutes for metal to change the state (solid to liquid) and attain the required casting temperature. Temperature of hot surface of metal is in range of 1400-1500°C, which leads to higher loss of energy in form of radiation. Similarly, when metal is poured in ladle, open surface at top is major source of loss thermal energy in form of radiation. Losses can range from 5-10%, depending upon the opening size and time for which metal is stored. Use of hydraulic lid mechanism, for induction furnace and ladle will help in reducing these losses.

**Features**

- **Hot metal temperature can be maintained**
- **Lower energy loss**
- **Average Payback Period: ~ 3-12 months**

## Recuperative Burners

Recuperative burners are equipped with heat exchanger to preheat the incoming combustion air with the exhaust gases from combustion (Figure 29)[39]. These systems can lead to energy savings up to 30% and lower fuel consumption and emissions. The burners can be retrofitted to existing heating systems. The recuperative burners are also economical due to their simpler construction among the non-conventional burner systems.

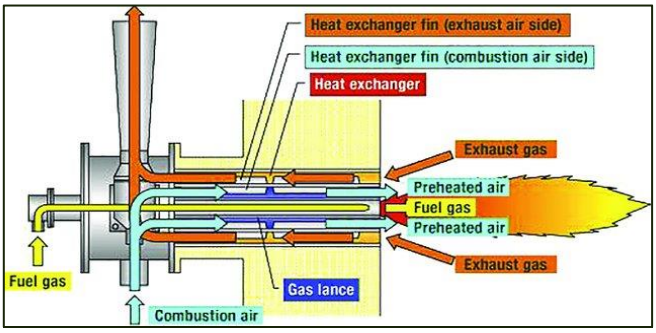



Figure 29 Operation of Recuperative Burners

**Features**

- **Lower fuel consumption**
- **Lower emissions**
- **Simple construction and control**
- **Average payback period: Highly dependent on scale of production**

**Case Study (Retrofitting recuperative burner system to diesel burners)** [40]

EE measure has been carried out in one of the foundry unit with 450 kW burner capacity and annual consumption of 56,160 kg of diesel. The investment cost of the recuperative burner system is estimated to be INR 6.33 lakhs. This intervention in the unit has led to savings of 5% of the annual energy consumption with simple payback of 5.9 years and 14.8% IRR.

[39] Jouhara, H. et al. (2018). Waste Heat Recovery Technologies and Applications. Thermal Science and Engineering Progress. 6. 10.1016/j.tsep.2018.04.017.
[40] *Powermag.com*

## *Multi – Axis CNC machine*

Most of the small and medium foundry units use the CNC, VMC machines, and micro foundry still use the conventional lathe, drilling etc. machines for the machining operations. CNC and VMC provides higher productivity as compared with conventional machines, these machines don't have multi-directional tool movement. Multi axis CNC machines (5 axes, 6 axes) provide flexibility for tools (multiple tools) movement, which reduces the production time (clamping and decamping the workpiece again and again) and improves the product quality (Figure 30)[41].

*Figure 30 Multi Axes CNC Machine*

**Features**

- **Improves the productivity and product quality**
- **Higher efficiency – use of IE4 and higher motors**
- **Average payback period: ~18-36 months**

## *Automation of fuel feeding in core baking furnaces*

Automation for the fuel feeding and combustion air control is widely used to control the appropriate combustion in the furnaces. Excess air control is monitored in the flue gas and fee forward control is being used to control the combustion of the fuel in the furnaces. Precise maintenance of the controlling is not possible with use of the automation via PLC with looped with data signals of the sensors helps in improving the overall efficiency of the furnace. Further resulting in lowering the emissions (SOx, NOx) from furnace.

**Inefficient Furnace**

**Energy efficient Furnace with automated control systems**

*Figure 31 Automated control systems*

[41] *Makino, Vertical 5-Axis,* https://www.makino.com/en-us/machine-technology/machines/vertical-5-axis

### Features

- **Higher efficiency due to lower flue gas loss**
- **Higher combustion efficiency – lower dry flue gas loss**
- **Lower emission**
- **Average payback period: ~18-24 months**
-

### Case Study[42]

EE measure has been carried out in one of the MSME unit with average production of 1,248 tonne per year for FO fired heat treatment furnaces, under **BEE-WB-GEF-SIDBI programme**. This intervention in the unit has led to saving of 29% of the energy consumption of the furnace with simple payback period of less than **6 months**.

## *Electrical Heat treatment / Annealing / Normalization furnaces*

During the heating process the walls of the furnace are also absorb the heat. Hot surface of furnace causes the loss in form of radiation and convection (Furnace Walls) to atmosphere leading to the loss of the energy . Use of the appropriate insulation helps in isolation of the hot furnace environment form the external atmosphere. This thermal helps in reduction of the temperature of the furnace walls, which helps in reduction of the thermal losses and improving the overall efficiency of the furnace. Furthermore, these furnaces can be automated for heat treatment through PLC based control of process parameters such as temperature and variation across surfaces; thus, optimizing the energy consumption.

*Figure 32 Electrical furnace for heat treatment*

### Features

- **Reduction in cold start time of furnace**
- **Lower losses as compared with oil / gas fired furnaces, resulting in lower emissions**
- **Use of multiple coils across the furnace (walls), help in controlling the heating more precisely- resulting in higher quality**
- **Average payback period: ~6-18 months**

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[42] http://www.sameeksha.org/pdf/CS_Forging_Pune-P13.pdf- Accessed on 13th August 2020

## *Optimal Capacity Air Blow for Cupola*

Optimal sizing of the cupola fan is required to meet the best combustion. Flow and pressure are two main characteristics of the cupola blower. Optimal pressure of air is required to meet the proper combustion of the fuel in the cupola, improper combustion of the fuel requests in the higher fuel consumption and irregular heating in the cupola. Localized combustion will lead to higher heating in the section (near the air ducts). Use of the appropriate pressure and air flow will help in proper combustion, this will lead to fuel savings.

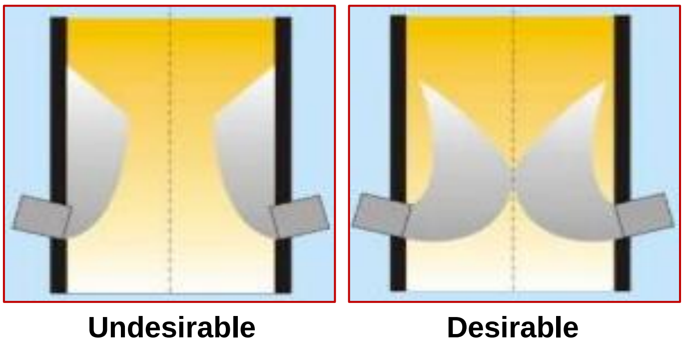


*Figure 33 Optimal Air Flow in Tuyere*

**Features**

- **Higher productivity, improved melting rate**
- **Higher combustion efficiency , Lower unburnt in the fuel**
- **Lower loss due to unburnt carbon**
- **Lower CO in the flue gas**
- **Average Payback Period: ~ 1-6 months**

## *Divided blast cupola furnace for metal melting*

Divided based cupola (DBC) is uses the gas to heat the metal, divided air blast help in better combustion of the fuel in cupola and helps in lowering the un-burnt (Carbon monoxide level) in the flue gas. 10-25% of the energy saving can be achieved over the conventional cupola. Uncontrolled or higher quantity of the excess air will lead to the higher quantity of dry flue gas loss, thus resulting in higher fuel consumption. Coke to metal ratio for perfectly designed and optimally operated DBC varies in range of 1:10-1:14. Average energy consumption of cupola is in range of 60-80 kgoe/tonne of molten metal.

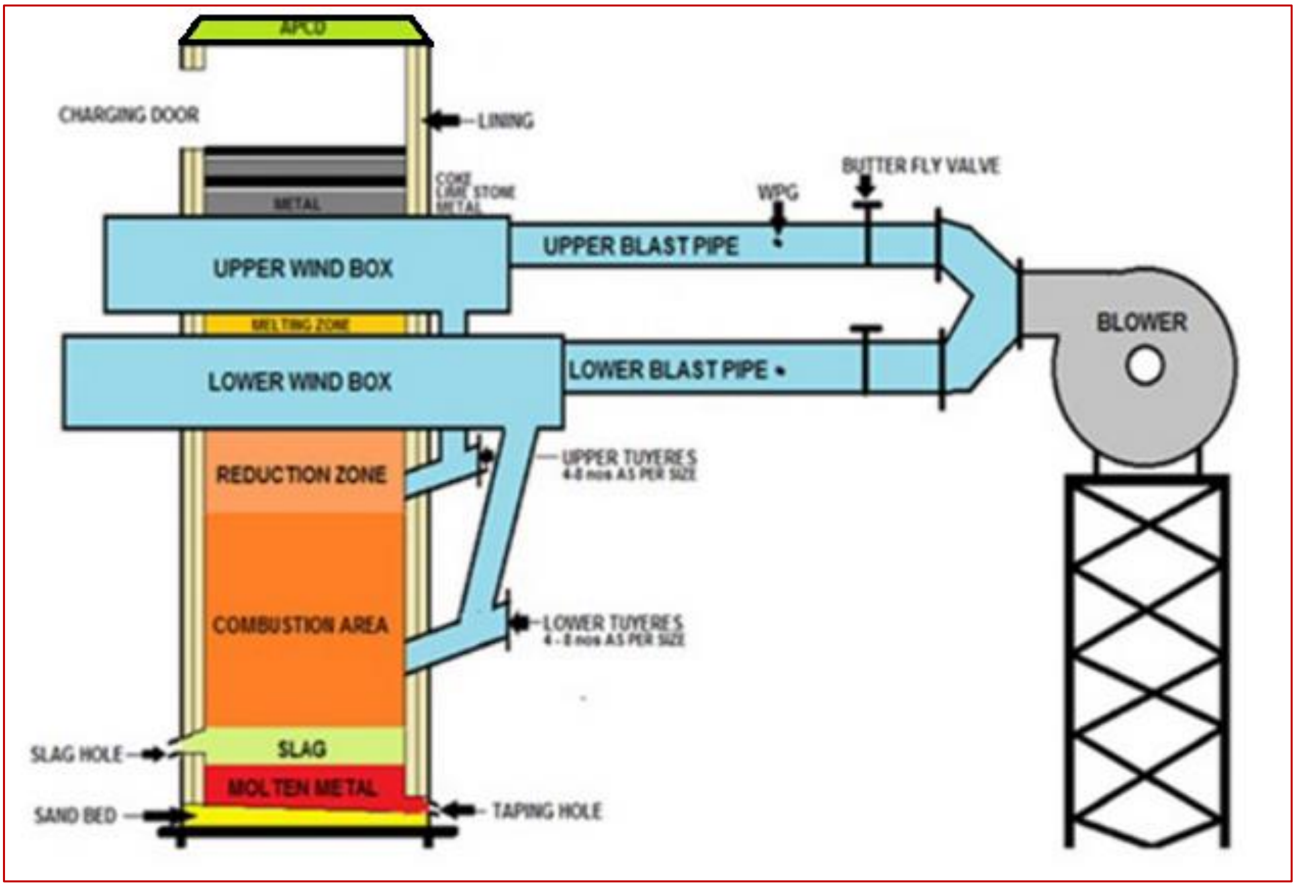


*Figure 34 Divided Blast Cupola Furnace*

**Features**

- **Better combustion lower unburnt in form of carbon dioxide, lower fuel consumption**
- **Lower emissions**
- **Average payback period: ~ 6-18 months**

## *Gas based cupola for metal melting*

Natural gas can be used as form of energy for metal melting. Natural gas fired cupola furnace provides the cleaner combustion and reduces emission levels. Natural gas systems can control the metal temperature effectively. These systems have to be specially designed to meet the required metal flow rates. A schematic arrangement of the gas based melting system is presented in Figure 35. A comparison with coke furnace is presented in Table 34 along with sensitivity analysis of percentage savings in Table 35.

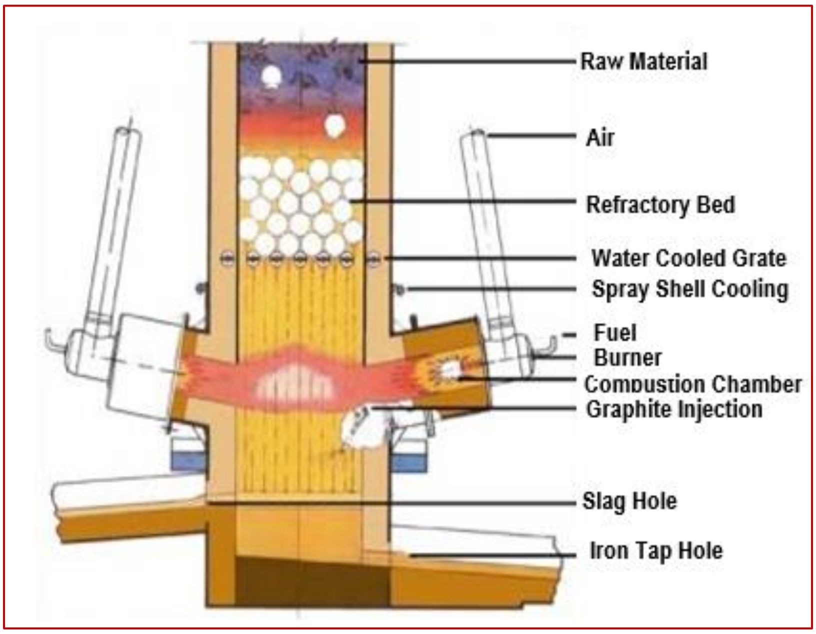


*Figure 35 Gas based melting system*

*Table 34 Comparison of coke and gas based furnaces*

| Parameters | Coke Furnace | Gas Furnace |
|---|---|---|
| Average SEC of Cupola in the cluster (per tonne of metal) | 90 kgoe (0.13 tonne) | 85 SCM |
| Carbon emission for processing one tonne of metal ($tCO_2$) | 0.37 | 0.15 |
| % emission reduction per tonne of molten metal | | **60%** |
| Cost - Coke (INR/kg) ; Gas (INR/SCM) | 12 | 16 |
| % Cost savings | | **12%** |

*Table 35 Sensitivity analysis of savings*

| % Savings | % change in cost of Coal | % change in cost of Gas | % change in SEC of Coke Cupola |
|---|---|---|---|
| -15.0% | -4% | 25% | -4% |
| -7.5% | 5% | 18% | 5% |
| 0.0% | 12% | 12% | 12% |
| 7.5% | 18% | 5% | 18% |
| 15.0% | 23% | -1% | 23% |

**Features**

- **Higher combustion efficiency , Cost savings, Lower emissions**
- **Higher quality casting with lower carbon can be prepared**
- **Better temperature control of the molten metal**
- **Average payback period: Highly dependent on scale of production**

## *Application of thermo ceramic insulation paints (Core baking and Heat treatment furnaces)*


*Figure 36: Application of thermo ceramic insulation paint on hot surface*

Heat treatment furnaces used in the foundry application are used to heat the casted metal to desired temperature. A refractory lining insulates the hot furnace interior surface and retains the generated heat inside the furnace. As the furnace insulation lining weakens with aging, hot spots in the furnace skin or outer surface are created, causing heat loss to the atmosphere in the form of radiation and convection. Use of the appropriate insulation paint applied to the surface will help in reduction of the thermal loss from the furnace. These insulation paints are available in variants suitable for application on cold or hot surfaces. They are generally applied on the cold outer metallic surface and help in sustainable reduction of the surface temperature of the furnace.

This thermo ceramic insulation coating variants that can be applied to hot surfaces additionally help in reducing energy loss due to thermal storage in refectory linings of batch furnaces. Insulation paints can only be applied on the hot face for application where abrasion is not likely during furnace loading and unloading operations. Thus, thermo ceramic coatings act as an additional insulating layer and help in reduction of the thermal losses and improving the overall efficiency of the furnace, resulting in longer refractory life, lower maintenance needs, lower fuel consumption, and lower emissions ($SO_x$, $NO_x$) from furnace

**Features**

- Reduction in cold start time of furnace
- Lower ambient temperature at the shop floor, leading to less fatigue among work force, and higher productivity
- Lower emissions
- Lower surface temperature and lower energy loss from surface of furnace

**Case Study (Thermo ceramic coating on HT furnace )** [43]

EE measure has been carried out in one of the MSME unit with average production of 3,600 tonne per year for 200 kg/hour NG fired forging furnace, under **BEE-WB-GEF-SIDBI**

[43] *Powermag.com*

**programme**. This intervention in the unit has led to saving of Rupees **4.8 lakhs / year** with simple payback period of **less than 6 *months***.

**Case Study Core baking furnaces**

Shell moulding machine was selected, and the heater box covers are applied with thermal paint. After implementation the outer surface skin temperature reduced to around 120 degree C from 145 degree C. Reduction in surface loss temperature has resulted in saving over 10% of energy in shell baking furnace. *SEC per mould before insultation paint was **1.209 kWh/ mould**, which has reduced to **1.08 kWh/mould**, payback for the ECM was less than one quarter.*

## *PLC based automation for Oil/Gas to air ratio for Blower (Heat treatment furnaces)*

For the complete combustion of the fuel, adequate supply of air is required. In a typical furnace, the excess air and CO in flue gas are not monitored. Lower air to fuel ratio leads to incomplete combustion (CO loss) thus leading to energy losses. Conversely, higher quantity of combustion air will result in higher fraction of dry flue gas losses. The PLC based automation system for blower monitors the composition of flue gases and controls the air flow required to enhance complete combustion products and lower the emissions. The system can also control the temperature of the metal.

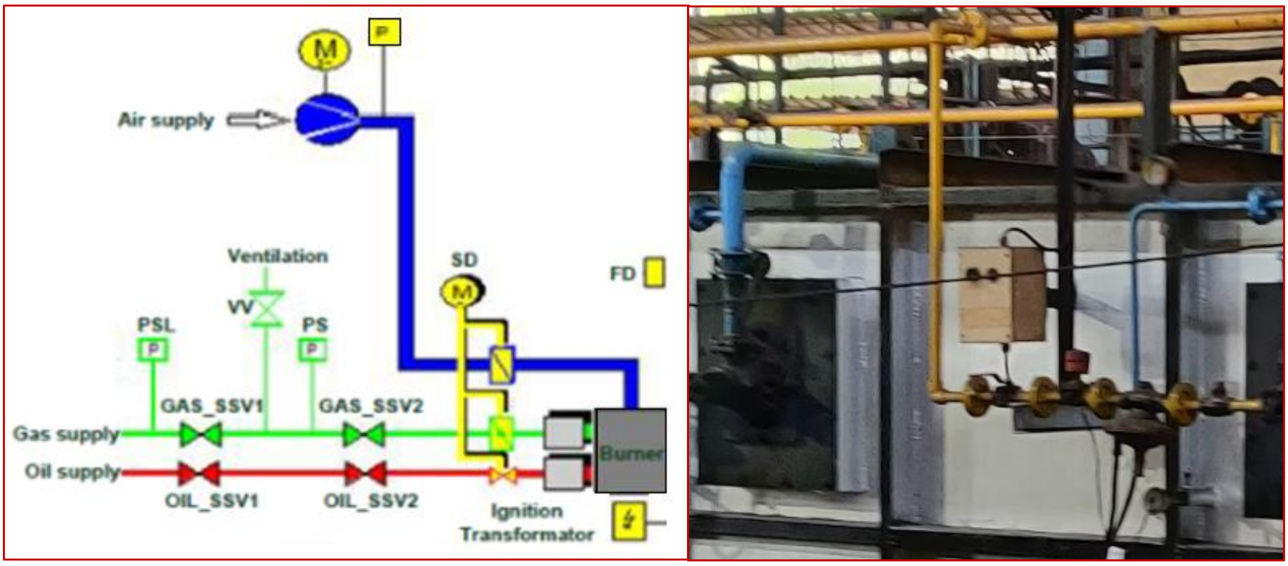


*Figure 37 PLC automation system for Fuel to Air Ratio Control*

**Features**

- **Higher combustion efficiency**
- **Lower Gas/Oil consumption per tonne of molten metal**
- **Lower unburnt in the fuel (lower CO level in flue gas)**
- **Better temperature control of the metal**
- **Average payback period: ~ 6-12 months**

## *Energy monitoring system - IoT Based Platform*[44]

Real time energy data (fuel used in melting furnaces, electricity consumed in Inducting melting furnaces, Compressor, pump sets ) in the MSME foundry units is not monitored. With use of IoT based application enabled with reliable high speed internet data, smart metering systems makes it viable to - record, save and transmit energy data of each equipment and communicate to the energy manager. Use of the data and trends, with auto generated alerts and flags will help operations team to identify opportunities to reduce the energy consumption on real time basis. With use of the IoT based EnMS there is potential of energy saving in range of 2-5%.

### Features

- **Real time monitoring and preventive actions**
- **Reduction in failures and breakdowns**
- **Improve availability and reliability of the process, resulting in lowering SEC of the unit**
- **Average payback period: ~18-36 months**

### Case Study[45]

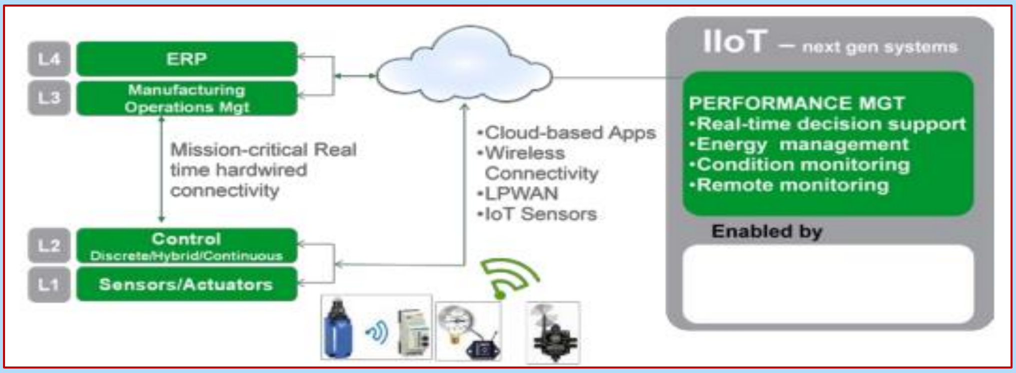


*Figure 38: IoT based real time energy management*

IoT based system has been implemented one unit **in Pune** with production capacity of 300 tonne/ month. IoT based system is used to derive the baseline energy scenario of the unit over the period of 15 days. Use of the ***AI*** along with **real time data monitoring** has helped the unit to identify the losses in the *compressed air system, water pumping system and transformer losses*.

With advanced analytic and feedback received from IoT platform, unit is able to save –

- **~300 kWh/day** in compressed air system
- **~50 kWh/day** in water pumping system
- **~ 25 kWh/day** in transformer network

[44] https://download.schneider-electric.com/files?p_enDocType=White+Paper&p_File_Name=998-2095-10-16-15BR0_EN.pdf&p_Doc_Ref=998-2095-10-16-15BR0_EN

[45] Implemented in one unit in Pune

## EE retrofits (Utilities)

Several low investment EE retrofits are available which helps in reduction of energy consumption in the equipment and utilities, without impacting the process parameters. Details of the EE retrofits relevant to the foundry industries is presented in this section along with the case studies from the past interventions under BEE programs.

### EE motor for Shot blast, machining

Higher efficiency class motors IE3, IE4 are more efficient than with IE2 and IE1 motors. Lower efficiency of the motor leads to the higher energy consumption. Re-wound motors are less efficient than new motors, with every re-winding efficiency of the due to quality of wire, increase in resistance per phase etc.[46].

**Features**

- **Lower energy consumption**
- **Higher efficiency**
- **Average payback period: ~ 18-30 months**

### Use of FRP blades in cooling tower fans

Fibre Reinforced plastic (FRP) blades are now widely used in the forced draft cooling towers, FRP based blades are lighter as compared with the conventional metallic blades (Figure 39), lighter weight of the blades helps in the reduction of the energy consumption. These blades have the better aerodynamic properties as compared with conventional metallic blades. Use of these blades improves the life of the drive system.

**Metallic bladed fan**

**Fibre reinforced blended plastic fan**

*Figure 39: FRP blade cooling tower*

**Features**

- **Lower energy consumption**
- **Higher efficiency**
- **Average payback period: ~ 18-30 months**

[46] https://beeindia.gov.in/sites/default/files/4Ch5.pdf- Accessed on 14th August 2020

## *Permanent Magnet Screw air compressor with waste heat recovery*

Permanent magnet-based screw air compressors are one the premium air compressors available that provides the lowest SEC. Compressor uses the premium IE5 equivalent motors and waste heat generated from the compressor can be used to heat the water via heat exchanger. Hot fluid (water) can be used for process applications. SEC of the compressor varies in range of (12-14 kW/ 100 cfm)[47].

**Features**

- **Lower energy consumption**
- **Efficiency of motor up to 95-96% can be achieved**
- **Hot water/ air from WHR can be used for process heating application**
- **Average payback period: ~ 30-42 months**

## *Use of Heat Pump for waste heat recovery*

Heat pumps can be used to recover the lower temperature (50-100°C) waste heat from different applications. Heat pumps utilize low grade - hot water, exhaust gases, fuel any combination of these heat sources, to pump heat. Heat pumps can be used to recover 10-35% of waste heat from the process. Presently only less than 1% of the units use the heat pump technology.

**Features**

- **Recovery of low temperature WHR recovery**
- **Hot water can be used for heating application of washing, electroplating etc.**
- **Lower emissions**
- **Average payback period: ~ 24-48 months**

## *EE motor for soft water pump set*

Higher efficiency class motors IE3, IE4 are more efficient than with IE2 and IE1 motors. Lower efficiency of the motor leads to the higher energy consumption. Re-wound motors are less efficient than new motors, with every re-winding efficiency of the due to quality of wire, increase in resistance per phase etc.[48].

**Features**

- **Lower energy consumption**
- **Higher efficiency**
- **Average payback period: ~ 6-15 months**

[47] 7 bar pressure for service air
[48] https://beeindia.gov.in/sites/default/files/4Ch5.pdf- *Accessed on 14th August 2020*

## *Use of Metallic low friction piping for compressed air system*

High surface finish aluminium based compressed air piping system helps in the reduction of the pressure drop in the piping network; use of the leakage proof fittings helps in lowering the compressed air leakage from the piping network. Implementing this retrofit will help in reduction of the discharge pressure (due to lower pressure loss) from the compressor; Lower demand of the compressed air quantity (due to lower leakages) (Figure 40) helps in reduction of the total energy consumption of the compressed air system. Reduction of 1 bar generation pressure at compressor alone results in 6-10% reduction in energy consumption at compressor[49].

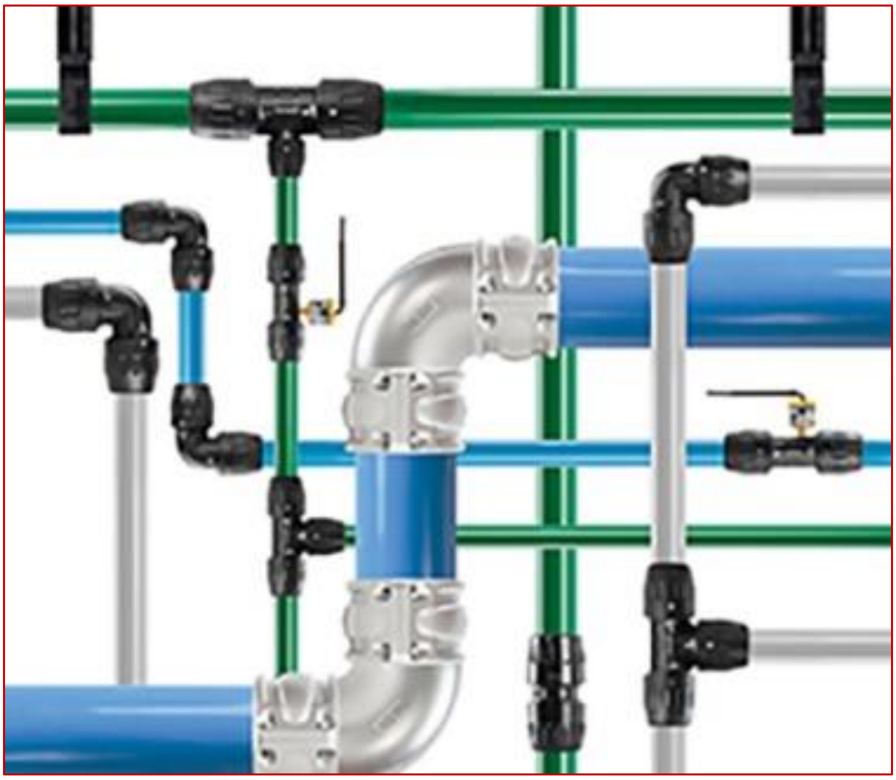

*Figure 40: Low friction compressed air piping and fittings*

**Features**

- **Reduced pressure drop**
- **Reduction in leakages**
- **Reduced energy consumption in compressed air system**
- **Average payback period: ~ 12-24 months**

**Case Study[50]**

EE retrofit has been carried out in one of the MSME unit, under **BEE-UNIDO programme** – *"Promoting Energy Efficiency and Renewable Energy in selected MSME clusters".* This intervention in the unit has led to saving of ***20%*** *of the energy consumption for the compressed air system**.*** with simple payback period of ***15 months***.

[49] https://beeindia.gov.in/sites/default/files/3Ch3.pdf - *Accessed on 13th August 2020*
[50] http://www.sameeeksha.org/pdf/5-cs-Installing-new-pipeline-compressed-air-Belgaum.pdf *Accessed on 13th August 2020*

## *Use of appropriate size motors*

As the loading on the motor decrease the efficiency of the motors decreases, at loading below 60% the efficiency of the motor fall at faster rate as presented[51] in Figure 41. Thus, operating the motors at lower capacity than rated leads to the inefficient operation leading to higher energy consumption in the system.

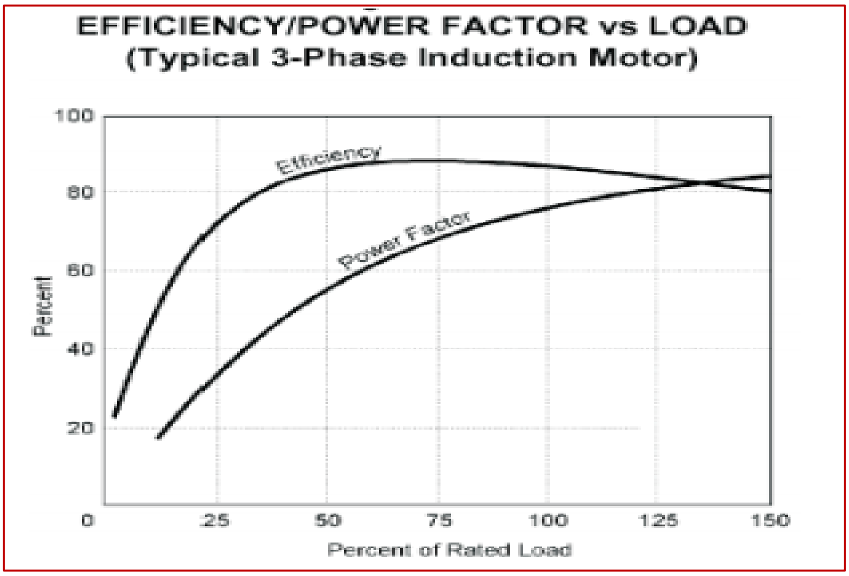


*Figure 41: Efficiency v/s loading of motors*

### Features

- **Lower energy consumption**
- **Higher efficiency**
- **Average payback period: ~ 6-30 months**

### Case Study[52]

EE measure has been carried out in one of the MSME unit with under **BEE-UNIDO programme** – *"Promoting Energy Efficiency and Renewable Energy in selected MSME clusters".* Replacing the one 4 kW, two 2 kW and three 1.5 kW motors in place of 7.5 kW, 4 kW and 2 kW motors in shank grinder, stone grinder, and furnace blower, helps in reduction of the energy consumption. This intervention in the unit has led to reduction in 9 kW of installed capacity, monthly energy saving of 2,684 kWh. This intervention is having simple payback period of less than 10 months for this EE retrofit.

[51] *https://beeindia.gov.in/sites/default/files/3Ch2.pdf- Accessed on 14th August 2020*
[52] *http://www.sameeeksha.org/pdf/2-cs-New-Eff-motor-lower-capacity-Jalandhar.pdf Accessed on 14th August 2020*

## *Automatic Power Factor Controller (APFC)*

The forging units have components running on inductive loads. These loads lead to lagging power factor of the unit overall. The low power factor is responsible for higher power consumption and penalty from utility beyond the particular set range. The Automatic Power Factor Controller (APFC) is a microprocessor based control which maintains the power factor close to unity by providing appropriate capacitive/leading load at the transformer level.

**Features**

- **Lower energy consumption**
- **Lower electricity bills**
- **Reduced losses**
- **Average payback period: ~ 6-15 months**

## *Energy Efficient Lighting System*

Lightings consume 5-10% of the overall energy in the units. Several units are still using the conventional lighting systems such as incandescent bulbs, CFL, metal halide lamps etc. The new energy efficient LED lighting system consume one third to a half of the energy to provide equivalent illumination. Furthermore, automation of these lighting system based on occupants or time of day in certain locations can lead to additional savings. Alternatives such as light pipe can also be used to maximize daylight usage for illumination.

**Features**

- **Lower energy consumption**
- **Longer lifetime**
- **Reduced O&M cost**
- **Average payback period: ~ 12-24 months**

# State of the Art Technologies in Metal Casting

## Oxyfuel ladle preheating

The ladle heating is performed using conventional burner technologies which use air directly in an open environment. Oxyfuel combustion technology uses pure oxygen instead of air for combustion of the fuel. The oxyfuel combustion of hydrocarbon fuels such as natural gas can reduce the flue gases including NOx emissions by 75-80% and 55% lower fuel consumption. Oxyfuel combustion can also reach higher temperatures up to 1500°C[53,54,55]. Some oxyfuel systems optimize combustion to achieve flameless operation which promotes uniform heating and extends useful life of refractory lining. These systems are compact and rugged and can be retrofitted to existing burner systems A schematic representation of oxyfuel burners is shown in figure 42. The comparison of different burner systems is presented in Table 36.

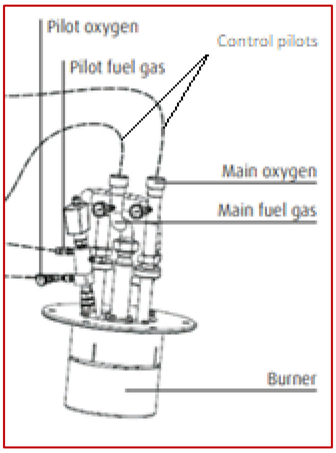


*Figure 42: Low friction compressed air piping and fittings*

*Table 36 Comparison of performance parameters and costs across burners*

| System Considerations | Cold Air | Hot Air (Recuperative) | Regenerative | Oxy-Fuel |
|---|---|---|---|---|
| Thermal Efficiency | Low | Medium | High | High |
| Fuel Usage | High | Medium | Low | Low |
| $CO_2$ Emissions | High | Medium | Low | Low |
| Maintenance Required | Low | High | High | High |
| Initial Cost | Low | Medium | High | Medium |
| Operating Cost | High | Medium | Low | High |

### Features

- **Lower fuel consumption**
- **Higher temperature possible**
- **~40-70% energy savings**
- **Uniform heating**
- **Lower emissions**
- **Longer refractory lining life**
- **Average payback period: ~ 3-5 years**

### Case Study (Retrofitting Oxyfuel system to diesel burners)[56]

EE measure has been carried out in one of the foundry unit with annual consumption of 2,284 MWhe of diesel with 1600 kW capacity. The investment cost of the oxyfuel burner system is estimated to be INR 1.27 crore. This intervention in the unit has led to savings of 40% of the annual energy consumption with simple payback of 3.9 years and 24.8% IRR[57].

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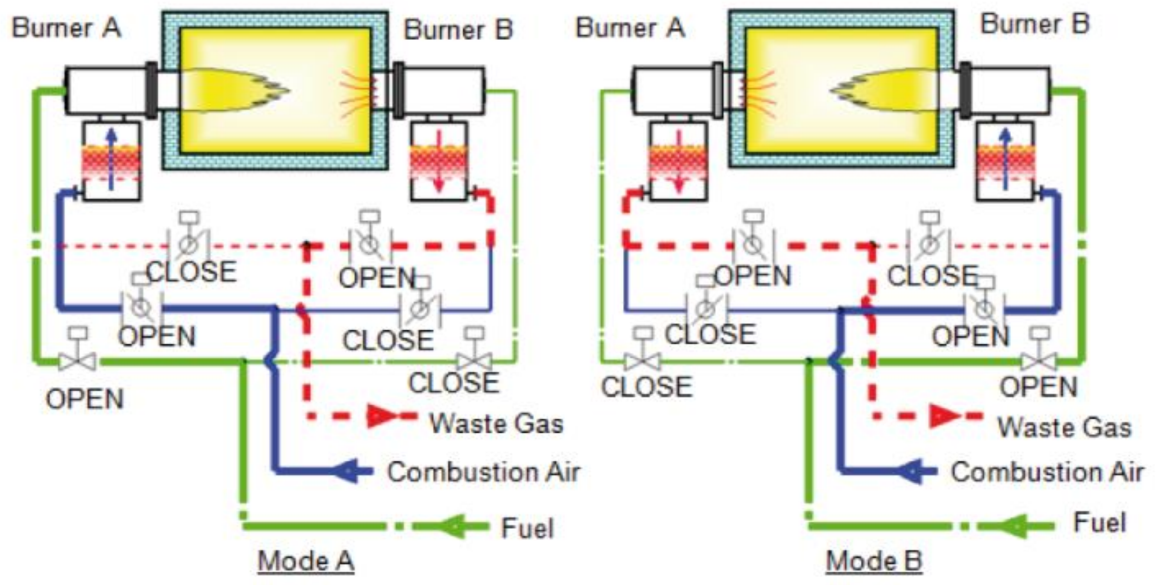
[53] *von Scheele, J., Mahoney, W., Ritzén, O., Linde, Hydrogen Steelmaking Solutions for Melting, Reheating, and Gasification, 2020, https://www.researchgate.net/publication/349215137*
[54] *Air Products, APCOS™ Technology—Air Products Cupola Oxy-fuel System for Iron Production, https://www.airproducts.com/equipment/oxy-fuel-systems-cupolas*
[55] *Messer group, OXIPYR™ for Ladle Preheating, https://specialtygases.messergroup.com/oxipyr*
[56] *Linde Gas, Maximize efficiency in ladle preheating with OXYGON®, https://www.linde-gas.com/en/industries/steel_metal/steel/oxyfuel-solution-for-ladle-preheating/index.html*
[57] *Linde Gas*

## Regenerative Burner System

Regenerative burner system is an energy efficient alternative to conventional burners for metal reheating purposes. Regenerative burner system has two burners which operate alternatively in regenerative and combustion modes respectively. In regenerative mode, the incoming combustion air to the burner is preheated by the flue gas from the combustion mode of the other burner (Figure 43) [58]. Thus, these systems offer continuous high thermal efficiency operations. The regenerative systems can reduce the energy consumption by 30-70%[59] along with emissions. These systems can achieve preheating temperatures over 1000 °C. A comparison of different burner systems is presented in Figure 43.




| | Mode A | Mode B |
|---|---|---|
| Burner A | Combustion | Regeneration |
| Burner B | Regeneration | Combustion |

*Figure 43 Operation of Regenerative Burners*

**Features**

- **Lower fuel consumption**
- **Higher preheating temperature**
- **~30-70% energy savings**
- **Lower emissions**

[58] Nippon Steel Engineering, Regenerative Burner-type Reheating Furnace, https://www.eng.nipponsteel.com/english/whatwedo/steelplants/rolling/regenerative_burner_type_reheating_furnace/

[59] *Nutec Bickley, Regenerative Burner Retrofits, https://www.nutecbickley.com/what-we-do/metal-furnaces-and-ovens/products-for-metals/regenerative-burner-retrofits*

## Hydrogen as a fuel

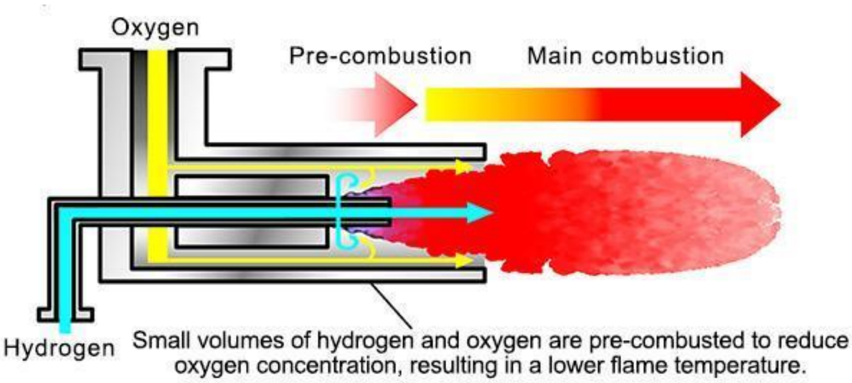



*Figure 44: Hydrogen fired oxyfuel burner*

Use of hydrogen as a fuel can reduce the $CO_2$ emissions by 100%. Hydrogen can be used in various stages of melting casting processes. In ladle preheating, hydrogen can be used in oxyfuel burners for a flameless operation as a standalone fuel or in mixture with other fuels. Hydrogen and oxyfuel combination can also be used for steel reheating. State-of-the-art oxyfuel hydrogen reheating solution such as Linde REBOX can achieve uniform temperatures within a margin of 5 °C[60]. A hydrogen fired oxyfuel burner under operation is shown in Figure 44. Hydrogen can also be used to provide protective atmosphere in heat treatment furnaces for processes such as annealing, hardening and brazing[61]. The hydrogen atmosphere can reduce iron oxide to iron and control carbon percentage steel. Also, with oxygen, hydrogen can provide thermal energy for heat treatment.

New production processes are exploring the use of hydrogen gas instead of coke. Hydrogen reacts with iron oxide in a similar fashion to carbon monoxide, but instead of producing carbon dioxide, the only by-product is water vapor.  sources itself, the steel making process can become completely emission-free, creating 'green steel.'

Case Study - A HYBRIT Development AB pilot plant[62] was constructed during 2018 at the SSAB site in Luleå, Sweden, with SEK 500 million ($51.88 million) in funding assistance from the Swedish Energy Agency. HYBRIT was awarded the Environmental Goals Prize by the Swedish Environmental Protection Agency for "boldness and momentum".

**Features**

- **Lower fuel consumption**
- **Higher temperature possible**
- **Lower NOx and CO2 emissions**
- **Possible production from renewable energy sources**
- **Decreased scaling losses**

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[60] *von Scheele, J., Mahoney, W., Ritzén, O., Linde, Hydrogen Steelmaking Solutions for Melting, Reheating, and Gasification, 2020, https://www.researchgate.net/publication/349215137*
[61] *L&L Furnace, Heat Treatment Furnace Atmospheres: Inert Gas and Hydrogen, 2019, https://llfurnace.com/blog/heat-treatment-furnace-atmospheres-inert-gas-and-hydrogen/*
[62] https://www.fchea.org/in-transition/2019/11/25/hydrogen-in-the-iron-and-steel-industry

## *Vacuum Process for Sand Mixing*

The sand or other moulding materials require degassing and moisture removal to produce consistent quality of products. Vacuum mixers enable sufficient cooling of the moulding material to 40 °C[63]. The deaeration and evaporation leads to low fluctuations in the quality of moulding sand which reduces the rejection rates. The viscosity of moulding sand increases exponentially in conventional batch type mixers as the dwell time increases between batches. State-of-the-art technologies for vacuum mixing can ensure that the viscosity of the moulding sand remains constant[64]. The sand mixing technology is compact and can be retrofitted in existing foundries.

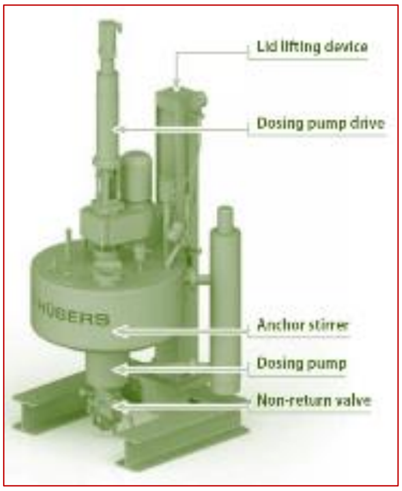


*Figure 45 Vacuum mixer*

**Features**

- **Consistent quality and viscosity of moulding material**
- **Deaeration and evaporation of moisture**
- **Compact and retrofitting possible**

## *Hydraulic high pressure automated moulding lines*

High pressure, hydraulic squeeze moulding technique are used to produce the high quality using green sand moulding. Use of the hydraulic compacting improves pressure bearing characteristics of the mould, imparting the better surface finish and casting can be produced in near to net shape with close tolerances. This process improves the quality and simultaneously help is reduction of the molten metal : final product ratio, which in turn improves the SEC of overall casting process.

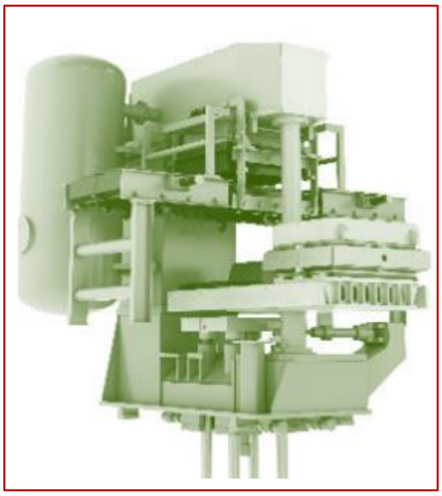

*Figure 46 Hydraulic high pressure automated moulding lines*

**Features**

- **Lower fuel consumption**
- **Optimum casting quality due to high pressure, uniform mould compaction**
- **Constant and lower casting weight - Near net shape castings for less cleaning**
- **Average payback period: Varies from operation to operation**

## *Automated Casting Lines*

Synchronization of pouring and moulding lines is an advanced solution for the foundry industry. Development of IoT and Industry 4.0 is key enabler for this technology. Automation of moulding lines and interfaced will pouring lines, makes the casting process becomes faster while producing higher quality components more consistently. Automated pouring of molten metal at optimal casting temperature will increase the quality, which in turn reduces the defects in castings.

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[63] *Modern Casting, Small Foundry Installs Vacuum Mixing Technology, 2020* *https://www.moderncasting.com/index.php/articles/2020/04/14/small-foundry-installs-vacuum-mixing-technology*

[64] *HUEBERS, Process technology for processing of casting and impregnating materials, 2021,* *https://www.huebers.de/dls/HUEBERS_KnowHow_GB.pdf*

*Figure 47 Automated Casting Lines*

**Features**

- **Higher productivity, higher level of automation**
- **Better quality**
- **Lower defects and higher pass rate for casted products**
- **Average Payback Period: Highly dependent on the scale of production and degree of automation**

## *Robotic Fettling*

The grinding and de-flashing processes after metal casting are currently carried out manually. These processes require longer process times and also pose health hazards to workers from dust and noise. Another, industry 4.0 technology is automation of the grinding and deflashing process. Robotic fettling in a foundry can increase the productivity by 3 to 8 times with reduced processing time for each casting. These robotic fettling systems can handle casting weight from 1 kg to 4 tons. For fettling, the desired model part is input to the robotic system along with required tolerances. The robotic machine has wide variety of tooling selection which also improves the final product quality. Automation can also eliminate health hazards to workers from dust and noise. The robotic system can give payback within 3 years given high volume of production. The improved surface finish in robotic fettling is presented in Figure 48[65].

**Manual Fettling** **Robotic Fettling**


*Figure 48 Surface finish in manual and robotic fettling*

[65] *Grind Master Machines Pvt. Ltd., http://robofinish.net/*

*Figure 49 Robotic grinding machine*

**Features**

- **Improved surface finish**
- **Higher productivity**
- **Reduced rejection rates**
- **Low tolerance requirements**

## *Robotic Casting*

One of the most advance solution in foundry is full automation of the gravity die casting process through robots. These robots are capable of metal pouring, mould spraying as well as machining process such as trimming and deburring. These robots can operate in an islanding mode with remote supervision of humans. State of the art systems offer end-to-end integrated systems capable of casting products from 3 kg to 1300 kg[66]. These robots have high dexterity and heat resistance which enables casting of complex shapes and high productivity with high amount of safety.

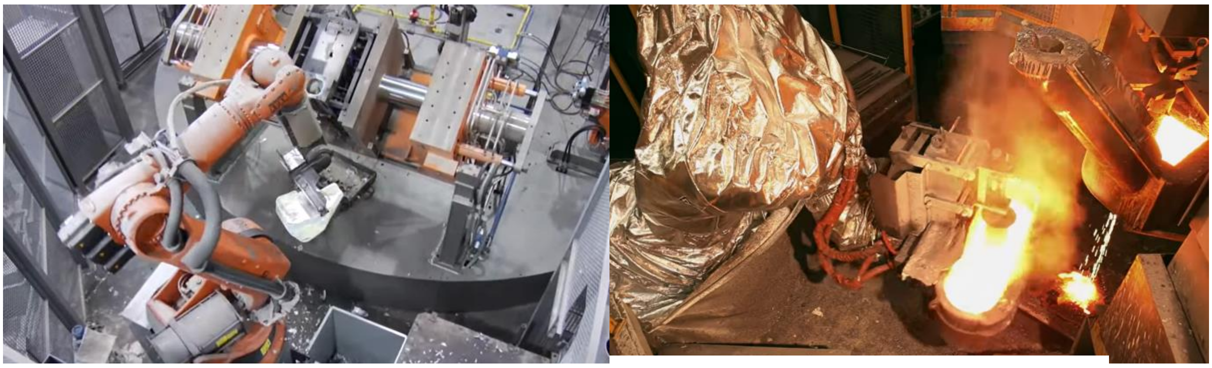

*Figure 50 Fully automated casting process*

**Features**

- **High productivity**
- **Improved accuracy and reduced rejection rates**
- **Limited human intervention required**
- **Compact system, High pouring rate**

[66] KUKA, Robots in the foundry, https://www.kuka.com/en-in/products/robotics-systems/industrial-robots/foundryrobots

## *Integrated Sand Plant with Automation*

Integrated sand plant with complete automation is one of the most advanced solutions for the foundries. Most of the foundries in India use of small size multiple sand plants which *have several inbuilt challenges such as lower efficiency, higher energy cost, higher cost of operations, loss of fines in the atmosphere (better air quality) etc.*

Integrated sand plant with complete automation providers the highest level of green sand quality and better quality of mould/core etc. There are other allied benefits of Integrated green sand plant for the foundry - *compact layout*, which help in minimising and optimization of the distance between all the different foundry process stages, which further help the units to optimally utilize the manpower and machinery requirements, shorter distances for materials to move – and no need for forklifts in the plant area etc. The integrated sand plant also has the timer in-built in the system and is inherently energy efficient.

*Progressive foundries in the Agra, Shimoga, Rajkot have already adopted the modern state of the art technology for sand preparation and core making.*

The modern technology provides the flexibility for the production line runs automatically and continuously, from sand preparation and iron melting through to moulding, pouring, shake-out and blasting. Every work area and piece of equipment is seamlessly and automatically coordinated with its neighbouring process and the moulding line.

*Figure 51: Integrated Sand plant with automation [67]*

**Features**

- **Lower energy consumption, better efficiency of the electrical motors**
- **Centralized controlling is possible, and higher productivity**
- **Better air quality inside the plant boundary**
- **Highest quality of green sand, better blending of additives along with sand**
- **Better working environment and air quality in the foundry unit**

[67] https://www.foundry-planet.com/d/a-complete-green-sand-solution-disa-and-wheelabrator-fit-out-dianzhans-brand-new-jiujiang-foundry/

## *Computer Aided Design for Casting*

The foundry sector has been slow to adapt emerging technologies and transforming towards industry 4.0. The computer aided design and simulation of casting process can simulate the flow characteristics of the molten metal. The software can predict porosity, air entrapment and misruns in the casting product based on location input of runner and risers. The pouring pressure and temperature of the molten metal can be used to predict the temperature variation of casting. Furthermore, these software packages can also optimize these casting parameters and metal characteristics to eliminate the defects. The use of simulations can reduce energy consumption and scrap by up to 20%[68] as well as improve quality of casting and reduce rejection rates. This type of design also enables collaboration and advisory for improvement across the clients across the globe. Examples of these software include Click2Cast and CastView. presents few cases of CAD simulation of casting processes[69].

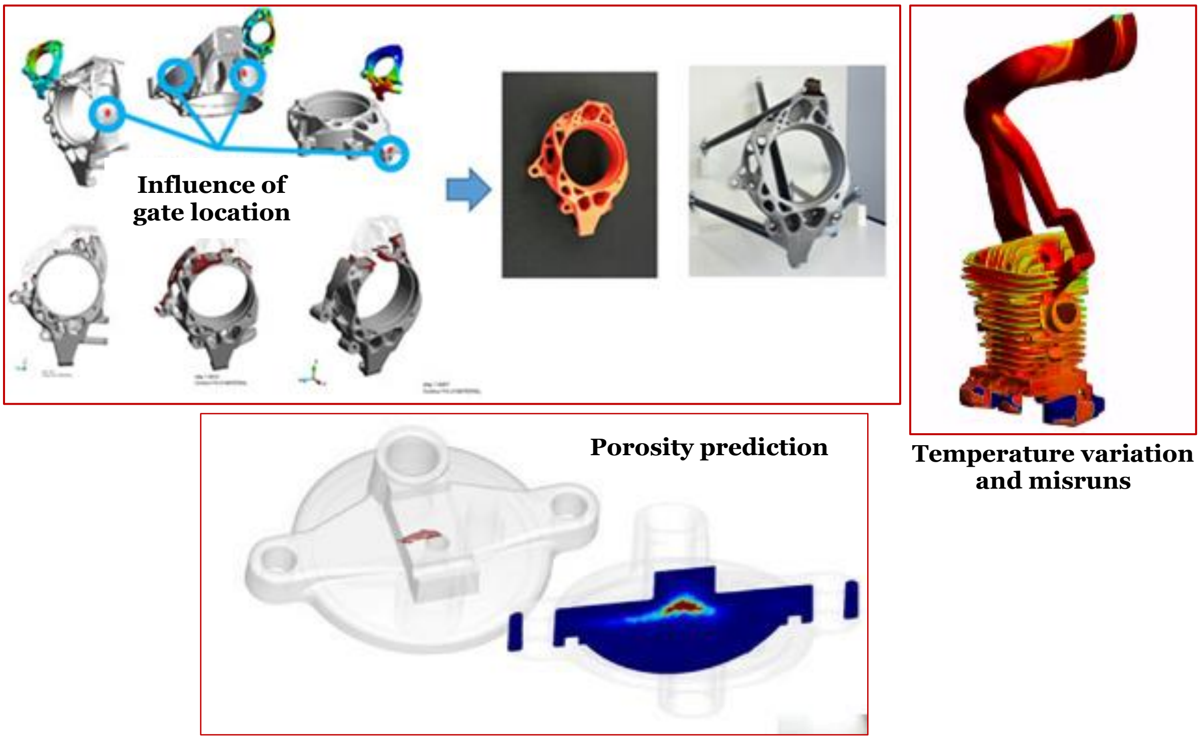


*Figure 52: Simulation of casting process*

**Features**

- **Optimized gate locations**
- **Elimination of casting defects such as air entrapment, misruns, and porosity**
- **Lower energy consumption**
- **~20% scrap reduction**
- **Lower rejection**

[68] *Altair, Emerging Technologies and Design for Manufacturing – The Metal Casting Process, 2016, https://www.altair.com/newsroom/articles/emerging-technologies-and-design-for-manufacturing-the-metal-casting-process/*

[69] *Office of Industrial Technologies, Metal Casting – Industry of the Future, https://www.nrel.gov/docs/fy01osti/29343.pdf*

## *3D Printing – Selective Laser Melting*

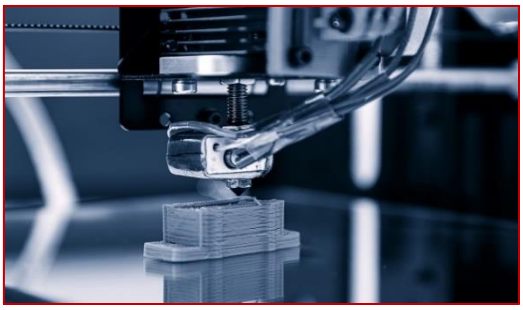

*Figure 54 Metal 3D printing process*

The conventional casting techniques cannot be used to produce complex components as a single part and require machining as well as joints, welding and fastening processes to do so. The 3D printing technology for metals are emerging as technology of choice for manufacturing complex parts in several sectors including aerospace and defence. The 3D printing components eliminate the assembly of parts, thus, eliminating possible points of failures. The selective laser melting (SLM) process is most common metal 3D printing technology. The SLM machine slices the CAD model into layers several micrometres thick. Each layer is deposited as a fine metal powder which is melted by lasers inside an inert atmosphere which effectively welds it to the previous layer. The selective laser melting process can reduce the raw material requirement as compared to casting technologies such as gravity die casting. The energy savings from SLM can be as high as 75% against the gravity die casting process[70]. Figure 54 shows the metal 3D printing process in action[71]. Skyroot Aerospace has fully 3D printed rocket engine Dhawan-1 (Figure 53)[72]. Figure 55[73] shows a complex 3D printed HVAC component called Octovalve which is used in the Tesla Model Y car to effectively manages the flow of cooling fluid to various components.


*Figure 53 Dhawan-1 rocket engine*

*Figure 55 3D printed Tesla Model Y Octovalve*

**Features**

- **Energy savings up to 75%**
- **Manufacturing of complex components and potentially reduced**
- **Reduced machining requirements**
- **Reduced joints and reduced failure points**
- **Lower raw material requirements**

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[70] *US Department of Energy, Chapter 6: Innovating Clean Energy Technologies in Advanced Manufacturing, 2015, https://www.energy.gov/sites/prod/files/2017/03/f34/qtr-2015-chapter6.pdf*
[71] *Belmont, 3D Metal Printing: Alloys and Powder Types and Specshttps://www.belmontmetals.com/alloys-and-powder-specs-for-3d-printing/*
[72] *Sher, D., (2020), Skyroot Aerospace shows off 100% 3D printed Dhawan-1 rocket engine, https://www.3dprintingmedia.network/skyroot-aerospace-shows-off-100-3d-printed-dhawan-1-rocket-engine/*
[73] *Munro Live, Model Y E36: The Octovalve Episode, https://www.youtube.com/watch?v=eGffUODWWSE*

## Lost Foam Process

The conventional sand moulding process requires provision of draft on the pattern for easy removal. Also, such a casting process limits the products to relatively simpler designs. In lost foam metal casting process, the patterns are made of foam materials such as polystyrene. The foam is expanded in casting tool and assembled using glue to form the desired pattern. The foam pattern covered with refractory material is then compacted inside sand. As the molten metal is poured, the thermal energy evaporates the foam and molten metal fills the mould. Unlike sand moulding, the patterns need not be removed, which enables casting of complex components (Figure 56)[74]. The lower to no draft casting can reduce the scrap from machining processes. Although the tooling for the process is expensive, the tool can last 400-750 thousand cycles[75]. Furthermore, lost foam process can lead to energy savings of up to 27%.

**Foam Pattern** **Cast Component**

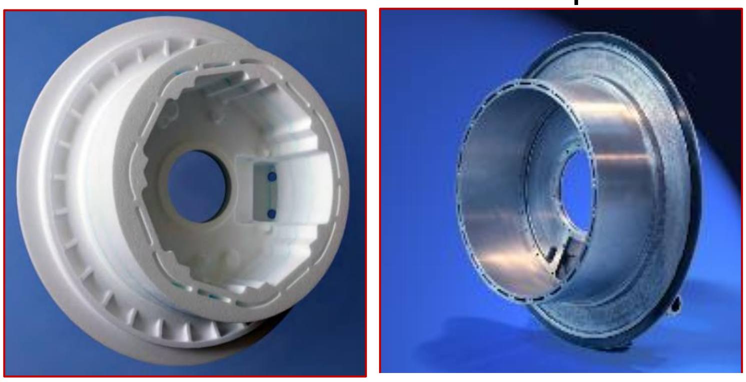


*Figure 56 Hub motor housing with integrated cooling*

**Features**

- **Reduced machining requirements and tool wear**
- **Near-net design and Scrap reduction**
- **Lower energy consumption**
- **Long cycle life**
- **Lightweight patterns**
- **Elimination of welding and joining process**
- **Complex component design**

[74] *Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Casting Technology, https://www.ifam.fraunhofer.de/content/dam/ifam/en/documents/Shaping_Functional_Materials/casting_technology/casting_technology_fraunhofer_ifam.pdf*

[75] *Miller, M., Why Lost Foam? Casting Source, 2020, https://www.castingsource.com/articles/2020/04/07/why-lost-foam*

## *Best Operating Practices*[76]

Metal melting and core preparation accounts for 70-80% of the total energy consumption in the foundry industries. It is very essential to select proper type & size of furnaces and operate & maintain the equipment scientifically with proper measurements. Auxiliaries also have a huge potential for energy conservation, around 10-15% of the energy can be saved - by selecting right type and size of equipment, waste heat recovery, automation of processes, periodical maintenance, and by adopting best operational practices. This section covers the BOP, monitoring parameters and SEC/Efficiencies defined for foundry as per energy conservation guidelines by BEE (Table 37).

*Table 37: Best Operating practices*

| Equipment | Best Operating Practices | Parameters to be monitored | SEC/Efficiency range[77] |
|---|---|---|---|
| **Induction melting furnaces** | • Operate at full capacity<br>• Maintain appropriate melting temperature<br>• Low holding time<br>• Fast charging and pouring (< 10 minutes)<br>• Less time for Spectro – analysis | • Temperature of the hot metal (using pyrometer)<br>• Power consumption by furnace (kWh/tonne)<br>• Material flow rate (tonne / batch)<br>• Heat loss prevention by covering top surface with insulated lid | • CI: 600-846 kWh/tonne (Median: 656 kWh/tonne)<br>• SGI: 585-907 kWh/tonne (Median: 727 kWh/tonne)<br>• Steel and alloy: 608-847 kWh/tonne (Median: 775 kWh/tonne) |
| **Coke based Cupola (Single and Double Blast)** | • Maintaining proper blast in cupola controlling the draft and air flow<br>• Using low ash coke and shot blasted foundry returns; Use of the adequate size of the metallic scrap<br>• Weighment of the metal and coke during feeding<br>• Use of the adequate size of the metallic scrap<br>• | • Blower discharge pressure<br>• Quantity of bed coke, booster coke, and bed coke returns<br>• Quantity and flow rate of gas used for the process<br>• Ash quantity and GCV of coke<br>• Temperature of molten metal | • CI: Coke to metal ratio Single Blast: 5.9-13.8 (Median: 7.7) DBC: 5.2-11.0 (Median: 8.4) |
| **Gas fired Cupola** | • Maintaining proper blast in cupola controlling the draft and air flow<br>• Use of the adequate size of the metallic scrap | • Blower discharge pressure<br>• Quantity and flow rate of gas used for the process<br>• Temperature of molten metal | • CI: 74-80 SCM/tonne (Median: 77 kWh/tonne)<br>• SGI: ~70 SCM/tonne |

[76] https://beeindia.gov.in/sites/default/files/Annexure%202.pdf- *Accessed on 12th August 2020*
[77] Based on present study

| Equipment | Best Operating Practices | Parameters to be monitored | SEC/Efficiency range[77] |
|---|---|---|---|
| | • Weighment of the metal and gas flow rate during feeding | | |
| **Compressed Air system** | • Operate the compressor at the optimal pressure requirement<br>• Limit the compressed air leakage within 3% to 10%.<br>• Maintain operating SPC within the design range as provided by the OEMs.<br>• Periodic cleaning of the suction filters<br>• Ensure the optimal dryer operation<br>• Maintain specified air temperature after intercooler | • Power consumption<br>• Air flow<br>• Pressure of compressed Air<br>• Loading and Unloading time<br>• Pressure drop in piping system<br>• Pressure drop across the filters | • Reciprocating – 0.20-0.25 kWh/cfm<br>• Screw single stage – 0.14-0.25 kWh/cfm<br>• Screw multistage – 0.18-0.25 kWh/cfm |
| **Pump and Pumping system** | • Operate the pump close to the design values<br>• Replace rewound motors in pumps with IE3 motors or higher efficiency class<br>• Ensure the no leakage in piping system and valves shouldn't be throttled as much as possible<br>• Use star rated pump sets if size is small and available with BEE star label | • Pressure at pump discharge<br>• Pressure drop in the system<br>• Flow at the pump discharge<br>• Power consumption by the pump set | • Efficiency of the pump set 60-85%, depending upon the flow and head of the pump set (Refer the pump curve supplied by the manufacturer) |
| **Fans and blowers** | • Operate the pump close to the design values<br>• Replace rewound motors in pumps with IE3 motors or higher efficiency class<br>• Periodic cleaning of the suction filters | • Energy consumption<br>• Draft across the suction and delivery<br>• Temperature of the air entering the fan | • Backward curve aerofoil shaped blades – 79-83%<br>• Modified radical curve blades -72-79%<br>• Pressure blower – 58-68%<br>• Forward curve blades – 60-65% |
| **Cooling towers** | • Maintain cycle of concentration (COC) of 8 to 10 for optimum performance.<br>• Maintain approach of 4 °C – 5 °C. | • Ambient dry and wet bulb temperature<br>• Cooling water inlet and outlet temperature | • COC – 8-10<br>• Approach 4-5 degree centigrade |

| Equipment | Best Operating Practices | Parameters to be monitored | SEC/Efficiency range[77] |
|---|---|---|---|
| | • Control the drift loss 0.001% – 0.005% of circulating flow rate.<br>• Replace rewound motors in pumps with IE3 motors or higher efficiency class | • Circulating water flow rate<br>• Make up water flow rate<br>• TDS in the make-up water | • Range 8-9 degree centigrade<br>• Drift Loss – 0.002% - 0.005% |
| **Electric Motors** | • Use IE3 or higher rating motors<br>• Use BLDC motors for fans, blowers etc.<br>• Maintain voltage and current imbalance as low as possible as prescribed by IEEE<br>• Replace the motor after rewinding once | • Voltage<br>• Current<br>• Power factor<br>• Harmonics<br>• Electricity energy consumption | • Refer Efficiency of Motor as per catalogue of motor manufacturer<br>• Efficiency varies in rage of 75%-95% for different rating of the motors from 0.3 kW-500 kW |
| **Transformer** | • Maintain winding temperature within 100 °C –120 °C.<br>• Maintain oil temperature within 90 °C.<br>• Maintain unity power factor at the transformer. | • Voltage , Current, Power factor<br>• Oil temperature<br>• Winding temperature<br>• Harmonics (Voltage and Current)<br>• Tap position if available | • Refer Efficiency as per catalogue of manufacturer or refer star label[78], generally efficiencies are in rage of 98-99.5% |
| **Lighting System** | Maintain the appropriate lux levels<br>• Administrative building 50–400<br>• Administrative corridor 100<br>• Shop floor lighting (process) 150–300<br>• Workshop 150–300<br>• Use 3-5 star rated LED lights | • Monitor the lux level<br>• Monitor the power consumption<br>• CRI to be monitored where required | • 90-120 watt/lumen[79] |

Induction melting with best operating practices is adopted by very few units across the clusters of Shimoga Rajkot, Agra and Howrah. A few units in Agra are efficiently with BOPs.

[78] https://www.beestarlabel.com/Content/Files/DTnoti.pdf- Accessed on 13 August 2020
[79] BEE Star rated appliances - https://www.beestarlabel.com/Content/Files/LED_schedule.pdf Accessed on 13 August 2020

Few units in Batala and Rajkot are operating the cupola very efficiently. There are mix of units following BOP partially and not adopting all BOP measures in clusters of Howrah, Batala Rajkot. Fewer units across the different clusters have adopted BOP in utilities but most of the units have adopted EE LED lights. Progressive units in Shimoga, Rajkot are practising BOPs relevant to motors and utilities like compressed air systems,

## *Compressed Air Management*


Use of multiple compressors to achieve different air pressures, can lead to non-optimum operation, and can lead to higher energy consumption (Figure 58). The sequential air management systems can be used to manage the compressed air flow requirements through sequential air compression. The most efficient compressor operates for majority of the time and the other compressors are brought into operation as and when required to cater to the plant air requirement. Thus, the optimized air flow can lead to energy savings of up to 30% (Figure 57).

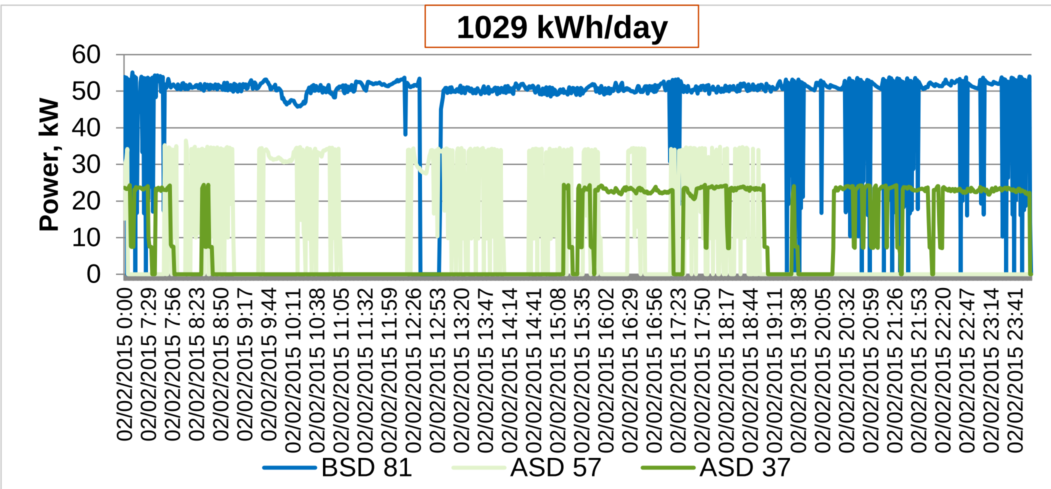



*Figure 58 Sub-optimal operation of compressors*

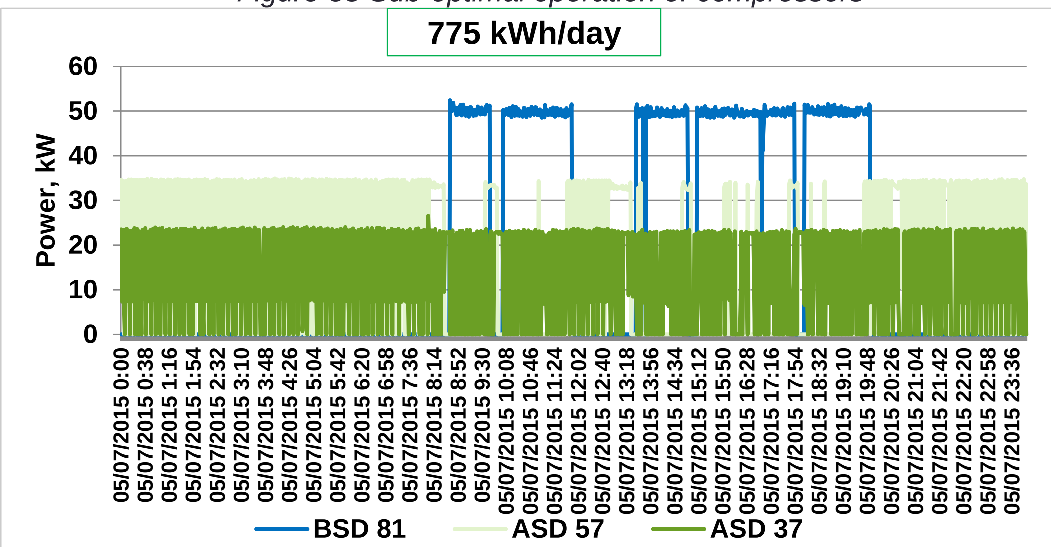



*Figure 57 Compressed Air Management System*

**Key Feature:** Operation of air compressors at peak efficiency

## *Optimizing Operations of Induction Furnace*

In operation of a typical induction furnace, the charging, melting, and pouring process may not be managed properly. As a result, the furnace consumes power during the charging process which is essentially lost as heat. Further, if the pouring process is not continuous or mould is not readily available, then the metal needs to be reheated multiple times which is essentially a loss of useful energy (Figure 59). By proper management of induction furnace operation sequences, the energy consumption can be optimized and is limited only to the melting process (Figure 60).

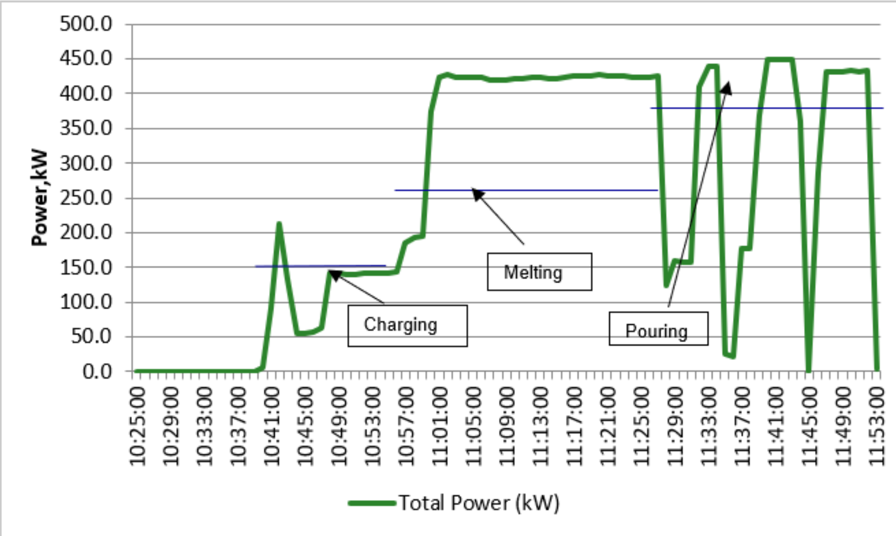



*Figure 59 Sub-optimal Induction Furnace Operations*

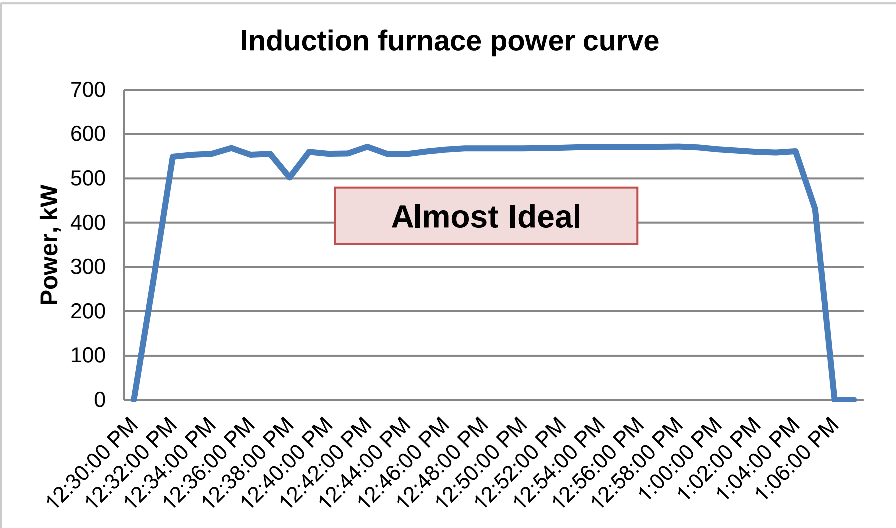



*Figure 60 Ideal Power Curve for Induction Furnace*

**Key Feature:** Induction furnace operation at peak efficiency and energy savings.

## Optimizing use of CI boring in induction melting furnace

It is recommended that the appropriate quality of the loose CI boring in the induction melting furnace. Use of the lower quality of loose CI boring help in reduction of the melting time required for the melting the metal ad also lowers the overall energy requirement. Although there is additional cost for compacting the CI boring / use of the solid metal, however the allied productivity and energy savings are proportionally higher.

**Case Study :**

| Description | Scenario-1 | Scenario-2 | Savings / Improvement |
|---|---|---|---|
| Solid Metal / CI boring | 60:40 | 95:5 | |
| Melting time (min) / batch | 70 | 50 | 2.5 more heat per shift; 15-20% productivity improvement |
| SEC (kWh/tonne) | 723 | 652 | ~9% energy saving |

**Key Feature: Higher Productivity and lower Energy consumption**

## Cogged V-Belt

The Cogged V-Belt are 3-5% more efficient than the normal V-let thus, it is recommended to replace the standard V-belt with cogged V-Belt this will help in reducing the energy consumption as they reduce the slippage between rotating parts. The cogged V-belt also has improved useful life. The cogged V-belt cost between INR 10,000 to 20,000 depending on the load requirements. Replacing with these belts on transmission systems can reduce 1-3% of the electricity consumption of the motors.

**Before:** Flat V-belts used

**After:** Use cogged V-belts

*Figure 61 Use of Cogged V-Belt*

**Key Feature:** Reduction of heat loss from surface

**Case Study**

In a foundry unit, it was estimated that replacement of V-belts with cogged V-belts can improve the transmission efficiency by 3%. This EE intervention led to 183 kWh of savings per year. The monetary investment required was INR 20,000 with a simple payback of 7 years.

## Proper Storage of Raw Materials

Storing raw material in closed or covered space can significantly reduce the effect of the weather and rain or storm on the raw material. The open storage can increase moisture content which directly affects the combustion characteristics for instance in case of coke. It is estimated that for every 1% increase in moisture in coke, the coke consumption increases by 0.1% as its effective heating value is reduced. The operating practice requires only a one-time cost of construction of covered storage space of Rs. 0.25-0.50 lakh with simple payback of 12-24 months.

**Before:** Storage in open space

**After:** Store under shed

*Figure 62 Proper storage of raw materials*

**Key Feature:** Reduction of heat loss from surface

## *Use of Proper Lining of Ladle*

The ladle is used to transport and hold molten metal. The lining of the ladles provides effective insulation to heat losses. However, the damage to ladle with use as well as improper lining leads to higher heat loss. This results in temperature drop which in turn leads to higher coke consumption. Use of refractory and fireclay in 3:1 ratio for preparing lining material can reduce these loses and lower the fuel consumption. The associated costs of proper lining are estimated to be INR 1000-2000 per ladle. A savings of 0.5-1.0% in coke consumption can be achieved with this intervention.


**Before:** Ladle lining was done improperly

**After:** Use ladle with proper lining

*Figure 63 Proper lining of ladle*

**Key Feature: Reduction of heat loss from surface**

## Optimal size of bed coke

The use of larger coke size leads to high quantity of initial chill metal. Chill metal corresponds to higher consumption of coke as much as 13 kg per 100 kg of chill metal. Use of coke size to 3 to 6 inches can improve heat transfer and reduce the coke consumption by 0.2-0.5%. The cost associated with this EE intervention is negligible.


**Before:** Large coke used for bed preparation

**After:** Recommended bed coke size 3-6”

*Figure 64 Optimal size of bed coke*

**Key Feature: Enhanced heat transfer**

## Bulk Density of Coke

By measuring the bulk density of coke in the cupola for bed and charge, combustion and melting process can be made more effective. The quantity of coke added is optimized to the ratio of metal to be melted in the cupola. The operating practice has negligible associated cost but can lead to 3-5% of bed coke savings.


**Before:** Bed coke not estimated

**After:** Coke for bed and charge calculated using bulk density

*Figure 65 Coke Measurement using Bulk Density*

**Key Feature: Appropriate quantity of coke use.**

## Optimal Size of Limestone

The limestone is often used as sourced directly. If the size of limestone is larger, it can lead to higher consumption of refractory as well as affect the de-slagging from the furnace. By maintaining the limestone size to 1-2 inches, can reduce the erosion of refractory lining and enhance reaction rate. Optimizing size of limestone can increase its cost by 30%. However, with 20-40% savings of the refractory, the payback is immediate.

**Before:** Large size ≥ 3”

**After:** Recommended size 1-2”

*Figure 66 Optimal coke size*

**Key Feature: Higher reaction rate and effective de-slagging**

## Scrap and foundry return size

It is recommended that the size of the scrap added to the furnace must be less than 1/3rd of the cupola ID. This ensures proper compacting of the metal inside the cupola and maximizes the amount of melting. Thus, reducing the consumption of coke and fuel and the chances of bridging. Pre-processing the scrap to meet the required dimensions has estimated cost of Rs. 700/heat. However, with 2-3% of coke savings the payback is immediate.


**Before:** Size larger than safe limit

**After:** Restrict metallics size ≤ ⅓ of furnace ID

*Figure 67 Size of scrap metal*

**Key Feature: Maximizes rate of metal melting**

## Limestone quantity

The limestone for slag formation should be used in appropriate proportion to the bed and split coke. This leads to effective slag formation and decreases erosion of the refractory lining. Also, if the fraction of limestone is higher, then the slag maybe carried over into tuyeres. Through appropriate weighing the limestone quantity in the furnace should be decided. This operating practice has no associated costs and can reduce refractory erosion by 10-30%.

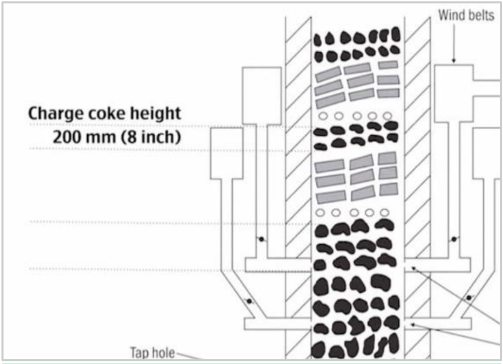
| **Before:** Inadequate bed limestone (<10%) and varied split limestone (15-45%) | **After:** Bed limestone 15-20% of bed coke and Split limestone 30-35% of split coke |
|---|---|

*Figure 68 Optimal quantity of limestone*

**Key Feature: Reduces erosion of refractory.**

## Split coke quantity

The split coke quantity should be fixed with respect to the quantity of metal to be melted. Often the coke quantity is subjectively fixed. This can lead to increased heat loss in flue gases as combustion rate of coke increases but the metal quantity is not sufficient to absorb the heat completely. By optimizing split coke quantity, 2-5% fuel savings can be achieved with essentially negligible cost.




| **Before:** Quantity subjectively fixed | **After:** Quantity for 200 mm height in cupola |
|---|---|

*Figure 69 Optimizing quantity of split coke*

**Key Feature: Reduced coke consumption.**

## *Stack filling*

Non optimal filling of the stack in the furnace can reduce the overall efficiency of the cupola. The pre-heating of the charge is sub-optimal and heat loss is high from flue gases. Also, the refractory lining undergo erosion. Hence, by filling the stack completely maximizes melt rate and output. It also leads to savings of about 1% in coke consumption.

**Before:** Charge height in stack not maintained

**After:** Stack to be always full

*Figure 70 Maintain charge level in stack*

**Key Feature: Optimal use of furnace capacity.**

## *Pressure gauge*

Pressure gauge monitoring is essential to maintain optimum pressure and flow rate. The improper location of pressure gauge can lead to difficulty and resulting error in measurement. By locating the pressure gauges where they can be accessed easily and replacing them, if needed, with the glycerine filled dial pressure gauges calibrated in mmWC can give accurate measurements. These gauges cost between Rs. 3,000-5,000. The proper air distribution can lead to immediate payback.

**Before:** Improper pressure gauge and location

**After:** Install gauge in accessible location

*Figure 71 Easy Access of Pressure Gauge*

**Key Feature: Ensures proper air pressure and easy monitoring**

## *Air leakage in wind box*

Air leakages lead to lower flow and pressure drop. Consequently, additional air needs to be blown by the blower and increases energy consumption. Periodic inspection and timely maintenance enable arresting the air leakages. The associated cost is negligible and can save 1-2 kWh/tonne of


**Before:** Wind box damaged by wear and tear

**After:** Periodic inspection to arrest leakage

*Figure 72 Air leakage in wind box*

**Key Feature: Optimum operation of blowers**

melt.

## *Air leakage from tuyere cover*

The air leakage from tuyere has direct impact on melt rate and the metal temperature inside the furnace, as it affects the blast pressure and volume. By arresting the leakage through proper sealing of the tuyere cover can lead to 1-3% of coke savings at a negligible cost.



**Before:** Lack of sealing in tuyeres

**After:** Ensure proper seal of tuyere covers

*Figure 73 Prevent Air Leakage from Tuyeres*

**Key Feature: Adequate melt rate and metal temperature.**

# *List of Vendors / Suppliers of Energy Efficient Technology Solutions*

*Table 38: List of prominent technology vendors*

| Technologies | Vendors / Suppliers | Contact details | Email ID |
|---|---|---|---|
| **IGBT based Induction melting furnaces** | Plasma Induction | Mr. Mayur Suhagiya | ms@plasmainduction.com |
| **IGBT based Induction melting furnaces** | Inductotherm | Mr. RD Mehta | rmehta@inductothermindia.com |
| **IGBT based Induction melting furnaces** | Megatherm | Mr. Suchintya Paul | suchintya.paul@megatherm.com |
| **Automated Sand plants** | Ganesh Quality Machine | Mr. Milind Bindar | response@ganeshfoundryequipment.com |
| **Automated Sand plants** | JK Foundry engineers | Mr. Krupal Patel | kpatel@jkfoundryequipments.com |
| **Screw Air compressor with VFD and WHR** | Atlas Copco | Ms. Divya Purohit | Divya.Purohit@in.atlascopco.com |
| **Screw Air compressor with VFD and WHR** | Kaeser compressors | Mr. Amit Rajpal | kpatel@jkfoundryequipments.com |
| **Screw Air compressor with VFD and WHR** | Elgi | Mr. Gopal Krishna | gopikrishna@elgi.com |
| **Energy Efficient Blowers** | Generally locally fabricated | | |
| **Energy Efficient Blowers** | Alfa blowers | Ms. B Sarita | sales@alphablowers.com |
| **Energy Efficient Blowers** | Srilaxmi Air control | Mr. Raju | raju@srilaxmiair.com |
| **IE3 / IE4 motors** | Siemens | Mr. Anshul Luthra | anshul.luthra@siemens.com |
| **IE3 / IE4 motors** | Crompton Greaves | Mr. Sukhraj Singh | sukhraj.singh@cgglobal.com |
| **Aluminum compressed air piping** | Parker Legris | Mr. Joy Dewan | joy.dewan@parker.com |
| **Aluminum compressed air piping** | Samarthair Pneumatics Pvt. Ltd | Mr. Chetan Damle | sales@samarthair.in |
| **Aluminum compressed air piping** | Luthra PNEUMSYS | Mr. A Appare | rl@pneumsysenergy.com |
| **EE pump sets** | Grundfos | Mr. Laxesh Sharma | laxesh@grundfos.com |
| **EE pump sets** | Shakti pumps | Mr. L Joshi | Laxmikant.Joshi@kirloskar.com> |
| **IoT based EnMS** | Schneider Electric | Mr. Rohit Chashta | Rohit.Chashta@schneider-electric.com |
| **IoT based EnMS** | Enerlly | Mr. Nilesh Shedge | nil.shedge@gmail.com |
| **IoT based EnMS** | Sensegrow | Mr. Krishanu Sudi | krishanu.sudi@sensegrow.com |
| **BLDC fans** | Sinox | Mr. Himanshu Ajudia | sinoxpower@gmail.com |
| **BLDC fans** | Atomberg | Mr. Rohit Vohra | rohitvohra@atomberg.com |
| **VFD drives** | Schneider Electric | Mr. Rohit Chashta | Rohit.Chashta@schneider-electric.com |
| **VFD drives** | Siemens | Mr. Anshul Luthra | anshul.luthra@siemens.com |
| **VFD drives** | ABB | Mr. Vinay Tiwari | vinay.tiwari@in.abb.com |
| **Thermo-ceramic / Insulation coating** | ISCT | Mr. Nikhilesh | isct.nikhilesh@gmail.com |

| Technologies | Vendors / Suppliers | Contact details | Email ID |
|---|---|---|---|
| **Thermo-ceramic / Insulation coating** | A-ONE INSULATIONS | Mr. Parth | contactinsulation@gmail.com |
| **Automated casting system** | KÜNKEL WAGNER India Pvt. Ltd | | INFO@KUENKEL-WAGNER.COM |
| **Automated Sand plants** | KÜNKEL WAGNER India Pvt. Ltd | | INFO@KUENKEL-WAGNER.COM |
| **Automated casting system** | Concast India Limited | | cil.sales.ccm@primetals.com |
| **Divided Blast Cupola** | Cupola designed from TERI - locally fabricated | | |
| **Divided Blast Cupola** | Foundry Friends, Pune | Mrs. S. S. Karkhanis | ananz@vsnl.com |
| **Cupola** | Cupola designed from TERI - locally fabricated | | |
| **Cupola** | Foundry Friends, Pune | Mrs. S. S. Karkhanis | ananz@vsnl.com |

# C. Strategies for Decarbonization and Circular Economy

# C. Strategies for Decarbonization and Circular Economy

Foundry sector is one of the energy intensive sectors. As a result, the sector also has a considerable impact on the GHG emissions. The total estimated emissions related to the MSME foundry sector in India is ~12 Million tonnes annually. The electricity is a major source of energy for foundries in India. However, as the Indian electricity grid is highly dependent on the coal for power generation, the foundry units are responsible for GHG emissions indirectly. Whereas the natural gas, coke and oil used in foundry units lead to direct emissions on-site.

The industries have a significant role to play in mitigating the effects of climate change and meet the climate commitments made by India. Hence, it is necessary to explore strategies for decarbonization of the foundry sector. Apart from energy efficiency measures, the technologies such as use of renewable energy sources such as solar, wind and biomass can play a vital role in decarbonizing the energy demand of the foundries in India. Furthermore, hydrogen is an emerging energy source which also has an important role to play in a long-term low carbon future of the sector and the economy as a whole. These technologies are discussed in subsequent sections.

## Biomass Gasifier

Biomass is a net carbon-neutral alternative to fossil fuels when procured from sustainable sources such as groundnut shells and saw dust. Biomass gasifier can be used to generate producer gas from the biomass source through a sequence of thermo-chemical reactions. The producer gas mainly consists of carbon monoxide (~20%), hydrogen (~17%), $CO_2$ (~10%) and nitrogen (~50%) apart from methane, water vapor and hydrocarbons in trace amounts. The producer gas can replace the fossil fuels used in foundries such as coke, natural gas, FO and LDO. The construction and working of two types of biomass gasifiers, updraft and downdraft, is shown in the following figure.

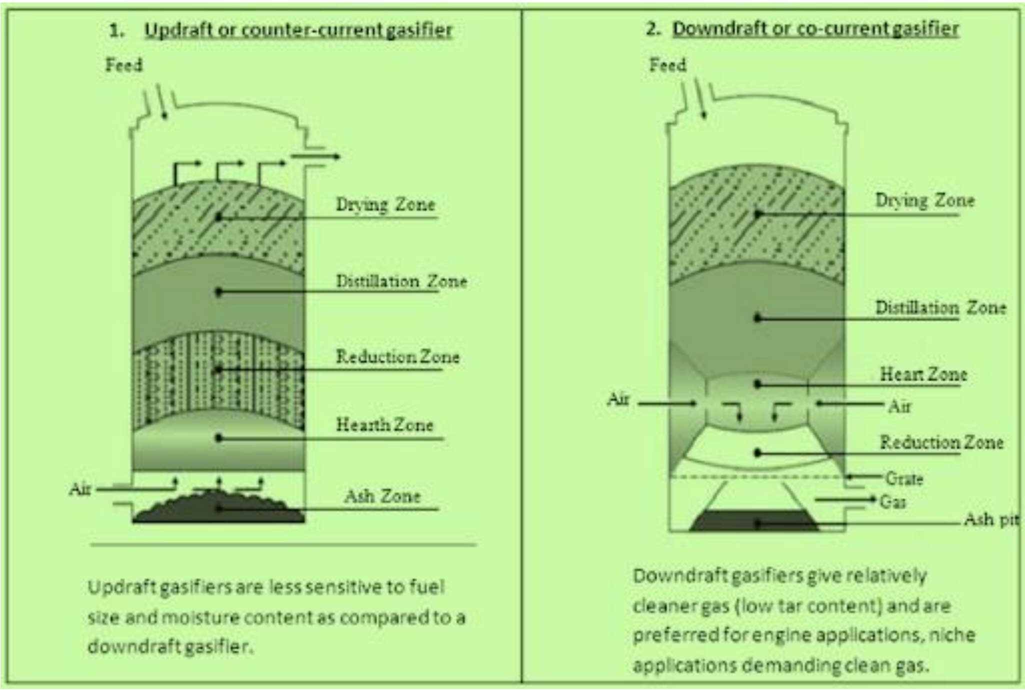



*Figure 74 Working principle of Biomass gasifier*

The biomass gasifier has several areas of applications relevant to foundry units such as:

- Core drying
- Sand drying
- Preheating furnace, and
- Heat treatment furnace

*Figure 75 Biomass Gasifier installation*

The producer gas has lower calorific value (~2500 kCal/kg) as compared to the fossil fuels. However, substitution with biomass gasifier can be cost effective and decarbonizing measure for a foundry unit. The payback of less than one year has been achieved in one of the foundry units at Kolhapur using LDO for heat treatment furnace.

Other strategies for decarbonization of the foundry sector include fuel switching such as from furnace oil to natural gas which have been discussed in the previous sections in detail.

## Hydrogen

Hydrogen has high gravimetric energy density as compared to other fossil fuels typically used presently. However, hydrogen production currently is not economically viable but several countries as well as private players have committed to provide technological and policy environment to accelerate the development of 'green hydrogen'. These measures are projected to reduce the cost of hydrogen production drastically in the coming decade. Green hydrogen is the hydrogen produced from electrolyzers using renewable energy sources. The use of green hydrogen as a fuel will effectively reduce 100% reduction in CO2 emissions.

In the metal casting, hydrogen can be used in various stages of the processes. Hydrogen when used as fuel can be used to replace the existing sources completely or in combination of the fuel such as natural gas co-firing. Some of the major applications are presented next.

### Hydrogen for Ladle Preheating

In ladle preheating, hydrogen can be used in oxyfuel burners for a flameless operation as either a standalone fuel or in mixture with other fuels. Hydrogen and oxyfuel combination can also be used for steel reheating. State-of-the-art oxyfuel hydrogen reheating solution such as Linde REBOX can achieve uniform temperatures within a margin of 5 °C[80]. A hydrogen fired oxyfuel burner under operation is shown in Figure 44.

### Hydrogen for heat treatment

Hydrogen can also be used to provide protective atmosphere in heat treatment furnaces for processes such as annealing, hardening and brazing81. The hydrogen atmosphere can reduce iron oxide to iron and control carbon percentage steel. Also, with oxygen, hydrogen can provide thermal energy for heat treatment.

[80] *von Scheele, J., Mahoney, W., Ritzén, O., Linde, Hydrogen Steelmaking Solutions for Melting, Reheating, and Gasification, 2020, https://www.researchgate.net/publication/349215137*

[81] *L&L Furnace, Heat Treatment Furnace Atmospheres: Inert Gas and Hydrogen, 2019, https://llfurnace.com/blog/heat-treatment-furnace-atmospheres-inert-gas-and-hydrogen/*

### *Hydrogen as reducing agent*

New production processes are exploring the use of hydrogen gas instead of coke. Hydrogen reacts with iron oxide in a similar fashion to carbon monoxide, but instead of producing carbon dioxide, the only by-product is water vapor. When hydrogen used in this process is derived from renewable or decarbonized sources itself, the steel making process can become completely emission-free, creating 'green steel.'

Case Study - A HYBRIT Development AB pilot plant82 was constructed during 2018 at the SSAB site in Luleå, Sweden, with SEK 500 million ($51.88 million) in funding assistance from the Swedish Energy Agency. HYBRIT was awarded the Environmental Goals Prize by the Swedish Environmental Protection Agency for "boldness and momentum".

**Features**

- **Lower fuel consumption**
- **Higher temperature possible**
- **Lower $NO_x$ and $CO_2$ emissions**
- **Possible production from renewable energy sources**
- **Decreased scaling losses**

## *Rooftop Solar*

Installation of solar PV on the rooftops is being taken up by industrial and commercial consumers in the past few years due to reducing cost of solar panels. The rooftop solar PV can reduce the electricity cost of the consumer and also help them in decarbonizing their energy demand. Rooftop solar also offers flexibility to sell the excess power to the grid for additional revenue for the units. However, there are several challenges associated with installation of rooftop solar:

- Space availability: For installation of solar panels, the MSME should have sufficient rooftop space available. Furthermore, the installation should be on a strong and stable structure which requires roof to have sufficient load bearing capacity. The efficiency of solar PV ranges between 15-22% depending upon the type of PV module. A list of average solar irradiance across different foundry clusters in India along with estimated annual power generation is provided in the table below.

*Table 39: Solar energy generation potential across different foundry clusters*

| Cluster | Solar Irradiance (kWh/m$^2$/day) | Estimated Annual Generation (kWh/year) |
|---|---|---|
| **Agra** | 4.73 | 24,123 |
| **Batala** | 4.45 | 22,695 |
| **Howrah** | 4.22 | 21,522 |
| **Rajkot** | 5.09 | 25,959 |
| **Shimoga** | 5.01 | 25,551 |

- Regular Cleaning: Due to various processes in the foundry units and dust environment, the solar panels are susceptible to acquiring dust which can reduce their performance significantly. The degradation of output with dust is shown in the figure[83]. Hence, regular cleaning and maintenance of solar panels is required which may lead to additional cost.
- Policy challenges: The net metering policies are not favorable in many states and the sale of power to distribution company may not lead to significant revenue for the unit.

[82] https://www.fchea.org/in-transition/2019/11/25/hydrogen-in-the-iron-and-steel-industry
[83] Maghami, M., *et al.,* Power loss due to soiling on solar panel: A review, Renewable and Sustainable Energy Reviews, Volume 59, 2016, Pages 1307-1316, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2016.01.044.

## *Renewable Power Procurement*

The rooftop solar offers power generation only to limited extent due to space constraints. Hence, the direct procurement of renewable power through power purchase agreements is becoming a viable option for industrial consumers for satisfying their power demand and thereby decarbonizing the production. The PPA tariff is for renewable energy has been falling in the past few years between the industrial consumers and renewable energy developers is also possible.

The hybrid wind-solar projects are also capable of supplying round the clock clean electricity to their consumers. The effective electricity tariff lower than the grid electricity has been achieved in various consumer segments whereas with falling cost of generation from renewables will also lead to increasing viability for other consumer segments as well. For open access procurement of renewable energy (wind and solar), the MSME units can opt for group captive as well as power purchase agreement (PPA) with third-party RE developers.

A comparison of industrial tariff with the open access modes for major states having foundry/forging cluster is provided in the Table below. The open access tariff for solar as well as wind can be observed to be competitive or even lower than the existing industrial tariff set by the utilities. Thus, in addition to reducing the environmental impact of the MSME units, these RE solutions also have potential to reduce the financial expenditure on energy. The group captive open access can be driven by the regional industrial associations. These measures can significantly improve the global competitiveness of the Indian foundry/forging units.

MSME can save on the landed cost of energy (kWh) in range of Rupee 0.44 – 4.28 / kWh (captive cost vis- a – vis the cost of power procured from DISCOM) though captive power plant (solar / wind) installed in the same state where MSME is operating.

While drawing power from third party the MSME units need to pay the additional taxes and duties levied by the state. MSME units can also explore the options for withdrawing power through open access / long term PPA though group captives across the state borders.

Wheeling power though central transmission network (across different states), MSMEs may incur additional charges and different states levy different taxes and duties. Wheeling of RE power especially through the third party route can be more expensive in certain scenarios considering the taxes duties and additional changes levied by the state where power is produced and state where the power is drawn. Hence MSME units can explore suitable RE partners and evaluate the viability of landed cost of RE power at their unit in case of third party procurement. Detailed ranges of the tariffs based on multiple combinations discussed above, are presented next.

*Table 40: Comparison of electricity tariff DISCOM / Open access* [84]

| Withdrawal State | Industrial Tariff (Rs./kWh) | Injection State | Solar (Rs./kWh) | | Wind (Rs./kWh) | |
|---|---|---|---|---|---|---|
| | | | Captive | Third Party | Captive | Third Party |
| **Karnataka** | 7.08 | Karnataka | 4.08 | 6.18 | 4.04 | 6.14 |
| | | Rest of India | 4.84 – 5.91 | 6.94 – 8.02 | 4.80 – 5.75 | 6.90 – 7.85 |
| **Punjab** | 6.60 | Punjab | 4.59 | 6.07 | 4.48 | 5.96 |

[84] https://cef.ceew.in/intelligence/tool/open-access accessed on 31st January 2022

| Withdrawal State | Industrial Tariff (Rs./kWh) | Injection State | Solar (Rs./kWh) | | Wind (Rs./kWh) | |
|---|---|---|---|---|---|---|
| | | | Captive | Third Party | Captive | Third Party |
| | | Rest of India | 5.37 – 6.44 | 6.85 – 7.92 | 5.25 – 6.20 | 6.73 – 7.68 |
| **Gujarat** | 4.58 | Gujarat | 5.04 | 7.21 | 4.64 | 5.80 |
| | | Rest of India | 5.81 – 6.85 | 7.98 – 9.02 | 5.39 – 6.31 | 5.56 – 7.47 |
| **Maharashtra** | 7.30 | Maharashtra | 6.80 | 8.51 | 6.63 | 8.34 |
| | | Rest of India | 7.61 – 8.73 | 7.86 – 10.44 | 7.44 – 8.36 | 9.15 – 10.07 |
| **Tamil Nadu** | 8.40 | Tamil Nadu | 4.12 | 4.62 | 3.88 | 4.55 |
| | | Rest of India | 4.89 – 5.92 | 5.39 – 6.42 | 4.63 – 5.55 | 5.30 – 6.22 |
| **West Bengal** | 7.15 | West Bengal | 5.50 | 9.04 | 5.50 | 9.04 |
| | | Rest of India | 6.38 – 7.51 | 9.92 – 11.05 | 6.38 – 7.39 | 9.92 – 10.93 |
| **Uttar Pradesh** | 7.10 | Uttar Pradesh | 3.99 | 3.99 | 4.53 | 5.46 |
| | | Rest of India | 4.79 – 5.91 | 4.79 – 5.91 | 5.34 - 6.33 | 6.27 – 7.26 |

Summary of the power cost for the different forging clusters are presented next-

*Table 41: Comparative analysis of the GRID power and RE power cost for different clusters*

| Cluster Name | Cost of Electricity (per unit)# INR / kWh | Cost of RE from Grid (per unit) ## INR / kWh | Total Electricity Consumption (MWh) | Total cost of electricity (INR Crore) | Cost of power if RE component is: (INR/kWh) 30% | 50% | 80% |
|---|---|---|---|---|---|---|---|
| | A | B | C | B x C | (Wt. Average of A, B) | | |
| **Howrah** | 7.2 | 5.5 | 331 | 182 | 6.7 | 6.3 | 5.8 |
| **Rajkot** | 4.6 | 4.8 | 1189 | 575 | 4.7 | 4.7 | 4.8 |
| **Agra** | 7.1 | 4.3 | 123 | 52 | 6.2 | 5.7 | 4.8 |
| **Batala** | 6.6 | 4.5 | 9 | 4 | 6.0 | 5.6 | 4.9 |
| **Shimoga** | 7.1 | 4.1 | 146 | 59 | 6.2 | 5.6 | 4.7 |

*#Only cost of energy INR /kWh is considered – demand charges and other specific changes will be levied as per SERC guidelines.*

*## Only average cost of captive generation is considered and presented in the column*

## *Circular resource utilization*

Foundries is a best example of circular economy, the majority of the raw material used by the industry is the scrap that is being re-melted to form the new castings. The percentage of recycled materials used to replace the raw materials has increased over the years. Foundry waste is also reused by the foundries, ~ 95% of the waste earth (green sand) produced in the foundry is reused by adding appropriate additives and binders. Development of the cluster level sand reclamation facility in Belgaum is the best facility to boost the use of the re-cycling in the foundry sector. Thus, foundries play a pivotal role in the circular economy. Major components of the circular economy 3R:-


- Reduce
- Reuse
- Recycle

Production processes with the typical losses in the foundry sector are presented in the Figure 76.

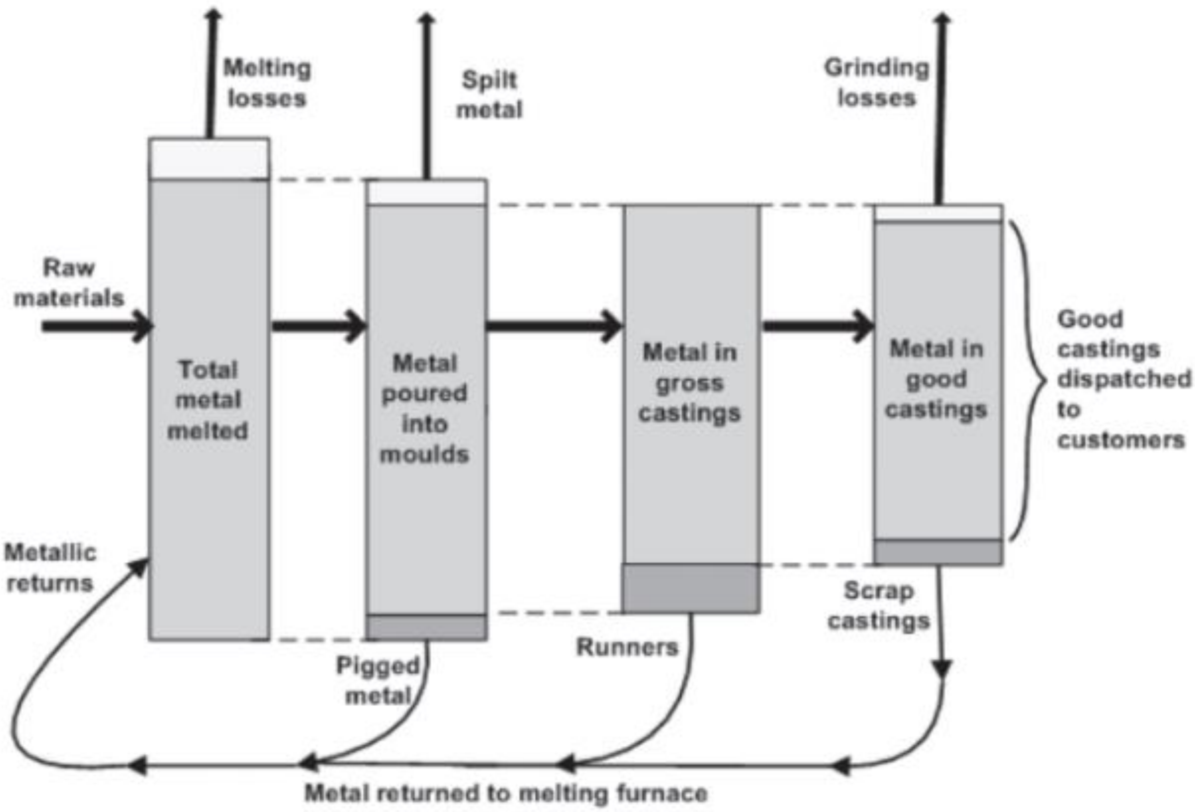



*Figure 76: Metal loss and rejection in the foundry processes*

**Reduce –** Most of the progressive foundries in India have adopted the state of art technologies and management system to control the production processes, these implementations help foundry units to optimize the use of the resources. Key Performance Indicators (KPI) which drive the optimal utilization of the resources in the foundry, are identified as – process yield, production efficiency, capacity utilization, energy consumption, fresh sand consumption etc. Melting losses are the biggest source of the losses in the foundry which can be reduced by improving raw material quality and shot blast of foundry return and adding the appropriate additives to control the oxidation of the molten metal. Use of the simulation in the foundries help in the reduction of the split metal losses (runner and riser). Use of state of art technologies help in reduction of the machining and trimming losses form the casted products. Adoption of the new and state of technologies described in technology compendium will help foundries to reduce the energy, water, metal and other resources while maintaining the quality of the casted products.

**Reuse –** Foundry processes use the sand for the preparation of the mould and molten metal for the castings. Mould are broken after the casting is cooled down and the green sand is used by most the foundries, by adding the appropriate additives and binder to regain the desired strength for the mould only 5-10% of the burnt out sand is rejected by the foundries.

To promote the sustainable solutions - Belgaum Foundry Cluster has set up Reclamation Plant for reclaiming Thermal Sand, Green Sand & Silicate Sand & No-Bake Sand.[85]

**Recycle -** Foundries represent the sector which not only recycle 100% of their rejects produced by the industries in the sector, but also support the ecosystem that also support the re-cycling of the metallic waste by melting the metallic scrap by remelting the rejected metal parts in the melting furnace / cupola to form the new components and products.

Recycling of the waste and rejects should be processed to remove the foreign particles, dust and other inert particles before metallic rejects are melted in the furnaces, these processes will help in the further reduction of the slag loss during the melting. These added processes will further strengthen the circular resource utilization in the foundries to best possible levels.

[85] https://bfcindia.co.in/sand-reclamation-plant/#

# D. Existing EE policy initiatives and programmes for the sector

# D. Existing EE Policy initiatives and programs for the sector

Realizing the importance of creating enabling environment for MSMEs- BEE, MoMSME and various international development agencies have been devising key programmatic interventions and policies for the MSME sector.

MoMSME has developed special subsidies schemes and funds to support Energy efficiency in MSME sectors. BEE had initiated an SME program during the year 2009 with an objective to improve the energy performance of MSME sector. EE in the MSME sector has also remained on the programme agenda of several institutes and development agencies, including GIZ, World Bank, UNIDO, UNDP, IFC and JICA for a significant time now.

The activities undertaken under these interventions include ranging from direct financial and technical support to capacity building and knowledge dissemination activities

- **Financial support**- Capital subsidies, soft loans, interest subventions, risk guarantee mechanism
- **Technical support**- Energy audits, preparing IGDPRs and hand-holding support for EE implementations
- **Knowledge and capacity building**- Preparation of cluster manuals, technology compendium, energy benchmarks and awareness creation through workshops, exhibitions, and technology demonstration

MSME specific EE policies, schemes, and programmatic interventions are categorized into mainly following:

**Govt. (MoMSME) supported subsidies scheme**

- Credit Linked Capital Subsidy Scheme
- Technology and Quality Upgradation (TEQUP)
- Financial Support to MSMEs in ZED Certification Scheme

**IDA led programmatic interventions**

- GEF UNIDO BEE Program- Promoting EE and RE in Selected MSME Clusters
- GEF-World Bank BEE SIDBI Project- Financing Energy Efficiency at MSMEs

**BEE Supported schemes**

- BEE SME Programme- including Energy mapping studiy for MSME clusters
- Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE)

Although these interventions have demonstrated the effectiveness of the energy efficient technologies however, the need of enabling eco-system for large-scale deployment of EE technologies in MSMEs has been extremely limited.

## MoMSME supported schemes

The Government launched National Competitiveness Programme in 2005 with an objective to support the Small and Medium Enterprises (SMEs) to become competitive and adjust the competitive pressure caused by liberalization and moderation. MSME Ministry employs the programme under the guidance of the National Manufacturing Competitiveness Council. Main components of the programme were aimed to address MSME competitiveness issues. 10 components of the programme are illustrated below-

- Support related to entrepreneurial and managerial development of SMEs by means of incubation
- Improving quality through Quality Management Standards in addition to technology Tools
- Technology up-gradation and quality certification assistance to SMEs
- Marketing assistance to MSMEs
- Marketing assistance for SMEs and technology up-gradation activities
- Design clinic scheme to convey design or innovation expertise
- Promotion of ICT
- Setting up the Mini Tool Room in addition to Training Centers
- Building awareness on Intellectual Property Rights
- National Programme related to the function of Lean Manufacturing

Few of these initiatives help in improvement in the efficiency of the MSMEs, adoption of the new energy efficient technologies and developing the ecosystem for energy efficiency, lean manufacturing, ZED leading to lowering the emission.

### Credit Linked Capital Subsidy Scheme (CLCSS) for Technology Upgradation of the Small-Scale Industries[86]

The Credit Linked Capital Subsidy Scheme (CLCSS) facilitates subsidy to 51 sub-sectors/products. The main objective of the scheme is to facilitate technology up-gradation in MSMEs by providing an upfront capital subsidy for installation of well-established and improved technology in the specified sub-sectors/products approved. This scheme provides capital subsidy of 15% on actual term loan sanctioned and disbursed, with maximum limit of eligible loan of 1 Cr (maximum 15 lakhs of subsidy)

At present the Scheme is under revision and will be launched soon after obtaining the necessary approvals. Capital Subsidy disbursed under the scheme reaches to Rs. 2360 crore. The fund expenditure incurred for FY 20 was Rs. 438.59 Crore with 87.15% of allocated funding was disbursed for FY 2020-21.

*Table 42: Key features of the CLCSS scheme*

| Feature | Description |
|---|---|
| Objective | Facilitate technology up-gradation in MSEs by providing an upfront capital subsidy |
| Eligibility Criteria | Installation of appropriate eligible and proven technology approved under scheme (list based)<br>(Covers technologies from 51 sectors/ sub-sectors) |
| Type of support | 15% Capital Subsidy, with maximum limit of eligible loan of 1 Cr (15 lakhs of subsidy) |
| Nodal agencies | Supported by MoMSME. 11 nodal agencies including SIDBI and 10 other PSU banks |

[86] http://dcmsme.gov.in/CLCS-TUS%20Guidelines-14-8-2019.pdf - Assessed on 29 August 2020

| Feature | Description |
|---|---|
| Budget Allocation and disbursed till date | All allocated funds were disbursed. 65,000 beneficiaries and 4000 Cr. Funds disbursed |
| Current Status (along with Year of inception) | Inception 2000, At present the scheme is under revision and running under sunset clause |

## *Technology and Quality Upgradation (TEQUP)*

Main objective of this scheme was to sensitize MSME Sector by conducting Awareness workshops to adopt Energy Efficient Technologies and acquire Product Certification/ Licenses from National/ International Bodies.

This scheme also supported the MSME with financial assistance in the form of subsidy to the extent of 25% of the project cost for implementation of Energy Efficient Technology (EET). The maximum amount of subsidy will be Rs. 10 Lakh for project cost of Rs. 40 Lakhs.

This activity is implemented through various nodal banks. The scheme was in operation87 till 30.09.2017 and over 4500 MSMEs have been reached through workshops conducted under this scheme; total of 202 awareness workshops were conducted in different MSME clusters. 300 MSMEs were assisted for energy efficient technologies, and 1100 units were assisted for production certification under the programme. Financial outlay of 90 crore has been supported government for this scheme since inception.

*Table 43: Key features of the TEQUP scheme*

| Feature | Description |
|---|---|
| Objective | 1. Sensitize and encourage the manufacturing MSMEs to the use of EE Technologies and Manufacturing Processes<br>2. Encourage the MSMEs to acquire Product Certification/ Licenses from National/ International Bodies |
| Type of support | Technical Assistance along with capital subsidy based on eligibility based on technical studies |
| Benefits under the scheme | 1. Provide Financial Assistance in the form of subsidy to the extent of 25% of the project cost for implementation of Energy Efficient Technology (EET). The maximum amount of subsidy will be Rs. 10 Lakh.<br>2. Provide subsidy to MSME units to the extent of 75% of the actual expenditure incurred by them for obtaining Product Certification Licenses, maximum subsidy of 2 lakh |
| Eligibility Criteria | The Detailed Project Report (DPR) to be prepared by a Qualified Energy Manager/Auditor.<br>The EET machinery installed should have minimum of 15% energy saving, and EA audit report also to be submitted |
| Nodal agencies | Supported by MoMSME. SIDBI is the nodal agency and 6 FIs are empanelled including SIDBI |
| Disbursement and status | Total no. of beneficiaries 1188, total disbursement 89.94 Cr. (only 40% of allocated funds were disbursed)<br>i. MSME assisted for EET ~ 300, |

87 http://www.dcmsme.gov.in/schemes/TEQUPDetail.htm Assessed on 19 August 2020

| Feature | Description |
|---|---|
| | ii. Units assisted for product certification ~ 1100 |
| Current Status | Launched in FY 2010-11, The scheme is not fully operation since 2017, very few disbursements in recent years |

### *Financial Support to MSMEs in ZED Certification Scheme*[88,89]

Main objectives of the scheme include inculcating Zero Defect & Zero Effect practices in manufacturing processes, ensure continuous improvement and supporting the Make in India initiative. This scheme was launched to provide support the MSMEs for:

- Development of an ecosystem for Zero Defect Manufacturing in MSMEs
- Promote adaptation of Quality tools/systems and Energy Efficient manufacturing.
- Enable MSMEs for manufacturing of quality products.
- Encourage MSMEs to constantly upgrade their quality standards in products and processes.
- Drive manufacturing with adoption of Zero Defect production processes and without impacting the environment.

Financial outlay of 100 Crores was contributed by Government of India[90] during 2019-20 under the ZED programme for MSME sector.

### *Lean Manufacturing Competitiveness Scheme (LMCS)*[91]

The Pilot Phase of Lean Manufacturing Competitiveness Scheme was approved for 100 MSME Clusters. Main objective of the Scheme was to enhance the manufacturing competitiveness of MSMEs through the application of various Lean Manufacturing (LM) techniques by:

- Reducing waste
- Increasing productivity
- Introducing innovative practices for improving overall competitiveness
- Inculcating good management systems
- Imbibing a culture of continuous improvement

This scheme has supported over 4500 MSMEs since the inception of the programme in 2007, financial support of over INR 58 crore has been provided by the government for this program since inception till 2017.

## *Programmatic interventions supported by Multilateral and Bilateral Development Agencies*

Public funding plays crucial role in the field of energy efficiency for MSMEs and one of the key sources of public funding for EE interventions is multilateral / bi-lateral development banks, which help developing economies like India where the EE potential is maximum. Energy Efficiency in the MSME sector has also remained on the programme agenda of development agencies, including IFC, World Bank, UNIDO, UNDP, JICA and GiZ etc. for a significant time now.

88 https://msme.gov.in/3-technology-upgradation-and-quality-certification Assessed on 19 August 2020
89 https://msme.gov.in/technology-and-quality-upgradation Assessed on 19 August 2020
90 http://www.dcmsme.gov.in/schemes/FAQ_ZED_11619.pdf - Assessed on 29 August 2020
91 http://www.dcmsme.gov.in/Guidelines%20Lean.pdf Assessed on 19 August 2020

## *"Financing Energy Efficiency at MSMEs" – BEE-WB-SIDBI-GEF programme*

Financing Energy Efficiency at MSMEs was a GEF funded projected aimed at increasing the demand for energy efficiency investments in target micro, small and medium enterprise clusters and to build their capacity to access commercial finance. The GEF implementing agency was the World Bank and it was jointly executed by BEE and SIDBI. The project budget was USD 63.61 million.

The project is focused on 4 components:

- Activities to Build Capacity and Awareness
- Activities to Increase Investment in Energy Efficiency
- Knowledge Management
- Project Management Support

FEEM was conceived to complement the World Bank's engagement with GoI on the $520 million IBRD-funded SME Finance and Development Project. The GEF-funded FEEMP was designed to increase the flow of capital for EE measures and address institutional weaknesses and capacity constraints of FIs that restricted them from supporting MSMEs.

- Increase demand for EE investments in target MSME clusters.
- Build capacity of MSMEs to access commercial finance.

A few important achievements of FEEMP are:

- Project was carried out in three phases, Phase -I interventions were carried out in five clusters, later this programme was extended to twenty-five MSME clusters across India
- Programme covered 13 states and union territories including foundry clusters in Kolhapur, Belgaum, Pune, Faridabad, Coimbatore, Rajkot etc.
- A total of 1,120 experts from 75 FIs and 750 energy audit professionals were trained to develop energy audit reports on the basis of which commercial finance could be sought.
- 1,257 IGDPRs were prepared exceeding the initial target of 730
- INR 3,322 million direct EE investments from project.
- Performance linked grant was given to 67 early adopters.
- The project supported SIDBI's "End-to-End Energy Efficiency (4E) scheme, the WB supported revolving fund provided a maximum interest subsidy of 2.5 percent (increased to 3.58%)

## *Promoting Energy Efficiency and Renewable Energy in selected MSME clusters of India" BEE -GEF - UNIDO Project*

**Scheme Duration**: April 2011 – Ongoing

Promoting EE & RE in MSME in India is a GEF funded project aimed at introducing energy efficient technologies and enhancing the use of renewable energy technologies in process applications in energy intensive MSMEs in 5 sectors (brass, ceramics, dairy, foundry, and hand tools). The GEF executing partner is UNIDO and other executing partners are BEE, MoMSME, MNRE.

The project has 4 main components as detailed below:

- Increased capacity of suppliers of EE/RE product suppliers/service providers/finance providers to support the expansion of EE/RE in the clusters.
- Increasing the level of end-use demand and implementation of EE and RE technologies and practices by MSMEs.
- Scaling up of the project to a national level.
- Strengthening policy, institutional and decision-making frameworks.

A few important achievements from the scheme are:

| | |
|---|---|
| 22 Pilot projects implemented, 212 DPRs developed | 7894 toe annual energy savings |
| 478 EE & RE measures implemented | 6.62 million US$ monetary savings |
| 78 Workshops organized with 2250 participants | 7.19 million US$ co-financing |
| 220 case studies prepared | 49896 tonnes of co2 emissions avoided |

Programme supported the foundry cluster in Belgaum, Coimbatore, and Indore, 144 projects were supported under this programme in Jalandhar and 43 projects in Nagaur, leading to saving of over 768 tonne of oil equivalent and reduction of over 5400 tonne of carbon dioxide annually.

## BEE -SME programme [92]

Considering the urgent need to develop, demonstrate and disseminate energy efficient technologies at the cluster level, "National Programme on Energy Efficiency and Technology Upgradation in SMEs" was evolved by BEE to address the various challenges faced by SMEs in India, subsequently BEE initiated the BEE-SME programme in 2009.

Over 375 Bankable DPR's for energy efficiency projects were prepared in 35 clusters across India. Under the programme several initiatives were taken for capacity building of Local Service Providers/Technology Providers. BEE facilitated implementation of Energy Efficiency Measures through development of DPRs in 29 out of the 35 clusters for which baseline studies were undertaken.

In recent years, under BEE SME programme various initiatives are being carried out as described below, to boost energy conservation in the SME clusters.

### Energy and Resource mapping of SME sector

BEE is presently conducting an energy and resource mapping study in the most energy intensive MSME sectors in the country. Study is presently being carried out in nine energy intensive sectors (Forging, Foundry, Bricks, Chemicals, Dairy, Glass and refractory, Pharma, Steel) in 45 MSME clusters across the country. Main objectives of the study are

- Evaluate the present specific energy consumption of the different MSME clusters for nine sectors
- Evaluate the extent of EE improvement potential across these sectors
- Estimation of energy efficiency improvement, energy saving potential for each sector.

Key expected outcome of the study will include – preparing of roadmap for these sectors to make them energy & resource efficient. Study will also prepare list of policy level recommendations required for faster adoption of the energy efficiency measures in these sectors.

### Development and Launch of knowledge portal for SMEs

A knowledge management portal - *Simplified Digital Hands-on Information on Energy Efficiency in MSMEs (SIDHIEE)* has been developed by Bureau of Energy Efficiency which hosts variety of knowledge resources like case studies, best operating practices, details of latest energy efficient technologies etc. Dissemination of Recognizing the importance and effectiveness of well-presented success stories to ensure widespread replication of efficient technologies and practices, BEE has developed around 50 multimedia presentations showcasing successful case studies of implemented EE interventions for different MSME sectors. These are now being widely disseminated and are hosted in the Knowledge Management Portal "SIDHIEE" created under the BEE-SME Programme.

### Promoting Energy Efficiency and Technology Upgradation in SMEs through ESCO

[92] https://beeindia.gov.in/sites/default/files/Situation%20analysis.pdf- Assessed on 20 September 2020

BEE has institutionalized Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE), which provides a partial coverage of risk involved in extending loans for Energy Efficiency projects. PRGFEE guarantees up to 50% of loan amount or Rs. 10 crore per project, whichever is less. PRGFEE support has been provided to government buildings, private buildings, municipalities, SMEs, and industries. This guarantee is extended to participating financial institutions which will extend loans to ESCOs for implementing EE projects.

Under the IFC Eco-cities programme supported by BEE, investment grade DPRs are presently being prepared for energy efficiency investments at MSMEs in 4 ECO-Cities across India, wherein a pipeline for loans benefitting from PRGFEE is expected to be created.

***Dissemination of EE technologies and Awareness:***

a. More than 60 Capacity building cum Knowledge dissemination programme were organised in SME clusters for dissemination of available energy efficient technologies in SME sectors. National Summit on Energy Efficiency in SMEs was also organized in consultation with leading stakeholders for further scaling up the project for transformational results.
b. Identification of Local Service Providers and Suppliers: About 70 local service providers were identified for offering services and supplies of various technologies in 5 clusters for ensuring the replication of the identified technologies in the clusters.

# GiZ Initiative for secondary steel sector including (Foundry)

## Baseline energy audit and benchmarking study for secondary steel sector in India

GIZ is fully owned by the German Federal Government that supports developing the multiple programs with partner countries on behalf of the German Government with ultimate goal of sustainable development. The Federal Republic of Germany and the Government of the Republic of India have, under the Indo-German Technical Cooperation, agreed to jointly promote the *"Indo-German Energy Programme" (IGEN)* with the aim to promote energy efficiency/conservation, renewable energy, access to energy, etc. and in turn improve the environment/climate protection. GiZ India team works in collaboration with the Bureau of Energy Efficiency (BEE), for the implementation of the Energy Conservation Act (EC Act, 2001), focusing on energy efficiency and conservation.

GiZ is undertaking "*Energy Efficiency in Industry and Data"* for secondary steel sector in India with boarder objectives –

- Building the capacity of State Designated Agencies (SDAs) to promote energy efficiency in plants under the secondary steel sector, that are not covered in the PAT scheme
- Developing tools and knowledge products for Non-PAT secondary steel and pulp and paper plants with access to information on key energy efficiency processes and technologies
- Promote peer-to-peer learning among SDAs and Non-PAT secondary steel industrial clusters
- National Energy Efficiency dialogue for secondary steel and pulp and paper sector between policy makers, research institutions and business associations.
- Developing the energy consumption baseline for Non-PAT industries in secondary steel sector
- Promoting the adoption of energy efficiency measurers
- Empowering the stakeholders with necessary information for energy efficiency related decision making
- Preparing the long-term energy efficiency scenarios of the sector for policy makers

## *Uptake of existing and past EE interventions and schemes*

Indian govt. has undertaken several policies, schemes and programs targeted at promoting energy efficiency in the MSME sector. Energy Efficiency in the MSME sector has also remained on the programme agenda of development agencies such as WB, JICA, IFC, GIZ, UNIDO, UNDP etc.

As single scheme/ interventions cannot eliminate all technical. financial and capacity building barriers faced by MSMEs while adopting energy efficiency enhancing projects. Accordingly, various schemes/ interventions have been introduced to promote MSMEs and energy efficiency or with a focus of promoting energy efficiency centric activities in MSMEs.

While these programmatic interventions have made an impact, there is a long way to go before majority of MSMEs voluntarily increase their uptake of energy efficiency interventions. The observations on the current and past EE schemes & interventions are presented below

*Table 44: Major features and key takeaways from different schemes*

| Major Feature | Key Schemes | Observations/Takeaway |
|---|---|---|
| **Capital Subsidy schemes** | Credit Linked Capital Subsidy Scheme (CLCSS)<br>**High uptake** | • High uptake of the scheme due to direct financial benefits such as capital subsidies<br>• Widely disseminated through comprehensive list of lending institutes<br>• List-based approach simplifies the process |
| **Subsidy linked to Energy audits** | Technology Up-gradation Scheme for MSMEs (TEQUP)<br>**Low uptake** | • Scheme requirements such as Energy DPR increases the transaction cost and lead time<br>• Lack of promotion and awareness of the scheme among MSMEs |
| **Risk guarantee mechanism** | PRSF, PRGFEE-<br>**Low uptake** | • ESCO eco-system, required for scalability, is not yet developed,<br>• Need of energy study & M&V process increases the project cost at MSME level |
| | CGTSME- **High uptake** | • Simple procedural norms, less documents<br>• No need of project report for availing guarantee under the scheme |
| **Long term Technical Assistance** | WB-GEF FEEMP<br>**High Uptake**<br>BEE SME Programme<br>**High Uptake**<br>UNIDO-GEF EE & RE Adoption- **High Uptake** | • TA programs create awareness on EE amongst different MSME stakeholders<br>• Create culture for EE in clusters due to long term support, but not market driven<br>• Able to cater to part of the MSME sector, as outreach to limited number of clusters |
| **List based scheme** | JICA SIDBI – **High uptake** | • Long list of EETs helped in faster loan appraisal, hence higher uptake<br>• SPEED Plus scheme promotes collaboration with OEMs/ vendors |
| **Revolving funds for EE** | SIDBI 4E Scheme- **Medium uptake** | • Requires pipeline generation at cluster/ sector level for faster up-taking |

# State of art technology research institutes

## The National Institute of Foundry and Forge Technology, Ranchi[93]

National Institute of Foundry and Forge Technology (NIFFT) is a public engineering and research institution in Ranchi. It was established in 1966 by the GoI in collaboration with UNDP to provide qualified engineers and specialists for running foundry and forge industries.

Since its inception, institute has been supporting the Foundry and Forging sector to meet the technology advancement and demand of trained skilled manpower. Institute is the front runner in supporting the foundry and forging sectors by development and research in the area of Metallurgy and Materials Engineering and other in Manufacturing Engineering. Institute host the world class publications[94] and research papers for the continuous improvement in the sectors with aim of developing the new technologies to meet the future requirement of the forging, foundry, and manufacturing sector.

There is need felt across the IIF to leverage this premium institution for preparing the new skillset for the work force in the foundry sector. This premium institution can play the leading role in developing the new age of the skillset required by the foundry industry to meet next generation of technological advancement.

# State level initiatives

## Promotion of Energy Audit and Conservation of Energy (PEACE)[95]

Government of Tamil Nadu has launched the PACE scheme with broader objective to foster the EE culture across the MSME sector. Main objectives of the scheme are –

a. Creating awareness and promoting the advantages of new EE technologies.
b. Identification of the gaps and barriers hindering the uptake of the for-energy conservation and promoting adoption of suitable techniques for energy efficiency and energy conservation.
c. Promoting the culture for conducting the energy audits to improve energy efficiency and implementing the fuel substitution and monitoring the implementation of recommendations suggested by energy auditors.
d. Subsidy offered to MSMEs - 50% of the Energy Audit cost subject to a maximum of 75,000 thousand Rupees per energy audit per unit.

## Financial Incentives for MSMEs in state of Punjab[96]

Energy department in state of Punjab supports the MSMEs in the region with multiple financial incentives to promote the adoption of the new EE technologies and promote the uptake of the energy audit in the MSME units. Broader objective of the incentives offered by the state government is to promote the sustainable cluster of conserving energy in the MSME units. Some of the key financial incentives offered by the government are –

a. In addition to the 15% up front capital subsidy offered by GoI under CLCSS scheme, state Government is supporting MSMEs with additional interest subsidy @ 5% up to a maximum of 5 lakhs per year for a period of 3 years.

[93] http://www.nifft.ac.in/Home.aspx - Assessed on 25 august 2020
[94] http://www.nifft.ac.in/UserView/PublicationUserView.aspx?TypeID=3 - Assessed on 25 august 2020
[95] https://www.msmeonline.tn.gov.in/incentives/html_cye_peace1.php
[96] https://investpunjab.gov.in/assets/docs/Detailed_Schemes_and_Operational_Guidelines2018.pdf

b. Assistance for technology acquisition for MSME, state government is offering the subsidy up to 50% on the cost for adopting technology from recognized National Institutes subject to maximum of 25 lakh Rupees.
c. State government is supporting MSMEs with 100% reimbursement of guarantee fee charged by the financial institution from the MSME up to one lakh Rupees under CGTSME scheme offered by the GoI.
d. Reimbursement of expenses incurred on Energy Audit to MSMEs, up to 75% of the cost of energy audit (pre-audit and post energy audit) is reimbursed to MSMEs with maximum value up to Rupees two lakh.
e. Reimbursement of expenses incurred on Water Audit to MSMEs, up to 75% of the cost of energy audit (pre-audit and post water audit) is reimbursed to MSMEs with maximum value up to Rupees one lakh.

## *Financial Incentives for MSMEs in state of Gujarat*[97]

Government of Gujrat (GoG) is frosting the culture of energy efficiency and energy conservation for the MSMEs. GoG with multiple schemes and polices supports MSMEs financially to uptake the new EE technologies. Key incentives offered by the state government are –

a. Reimbursement of expenses incurred on Water Audit to MSMEs, up to 75% of the cost of energy and water audit is reimbursed to MSMEs with maximum value up to Rupees fifty thousand and 25% of cost of equipment recommended by the auditing authority subject to maximum INR 20 lakhs.
b. To encourage innovation and adoption of new EE, cleaner production, and sophisticated technologies by MSME, GoG provide fiscal support to MSMEs for purchase of new technologies as well as in acquisition of patented technologies from foreign companies. MSMEs are entitled by the GoG for financial assistance up to 65% of the cost payable with upper limit of Rupees 50 lakhs for acquisition of technology

[97] https://eoibrasilia.gov.in/?pdf11603