The Energy and Resources Institute
Creating Innovative Solutions for a Sustainable Future

Promoting Energy Efficiency in SMEs
SAMEEEKSHA

# Situational Analysis of Durgapur

## Secondary Steel Cluster

# Situational Analysis of Durgapur Secondary Steel Cluster

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# ABBREVIATIONS

| | |
|---|---|
| BEE | Bureau of Energy Efficiency |
| BOF | Basic Oxygen Furnace |
| CCM | Continuous Casting Machine |
| CO | Carbon Monoxide |
| $CO_2$ | Carbon Dioxide |
| DCCI | Durgapur Chamber of Commerce and Industries |
| DC | Designated Consumer |
| DCMSME | Development Commissioner Ministry of Micro, Small and Medium Enterprises |
| DIC | District Industry Centre |
| DI | Ductile Iron |
| DPL | Durgapur Projects Limited |
| DRI | Direct Reduced Iron |
| DSP | Durgapur Steel Plant |
| DSTPS | Durgapur Steel Thermal Power Station |
| DVC | Damodar Valley Corporation |
| EAF | Electric Arc Furnace |
| EIF | Electric Induction Furnace |
| FO | Furnace Oil |
| GCV | Gross Calorific Value |
| GHG | Greenhouse Gases |
| Gcal | Giga Calorie |
| hp | Horsepower |
| HB | Hard Bright |
| IE3 | Premium Efficiency |
| IE4 | Super Premium Efficiency |
| IGBT | Insulated Grate Bipolar Transistor |
| kCal | Kilo Calorie |
| kWh | Kilowatt hour |

| | |
|---|---|
| kV | Kilovolt |
| MSME | Micro, Small, and Medium Enterprises |
| Mt | Million Tonne |
| $MtCO_2$ | Million Tonnes of Carbondioxide |
| MU | Million Unit |
| Mtoe | Million Tonne of Oil Equivalent |
| Mtpa | Million Tonne Per Annum |
| MVA | Mega Volt Ampere |
| MW | Mega Watt |
| MWh | Megawatt hour |
| PAT | Perform, Achieve and Trade |
| RHF | Reheating Furnace |
| SAF | Submerged Arc Furnace |
| SAIL | Steel Authority of India Limited |
| SAMEEEKSHA | Small and Medium Enterprises Energy Efficiency Knowledge Sharing |
| SCR | Silicon Controlled Rectifier |
| SDA | State Designated Agency |
| SEC | Specific Energy Consumption |
| SMS | Steel Melting Shop |
| SRRM | Steel Re-rolling Mill |
| TERI | The Energy and Resources Institute |
| TMT | Thermo Mechanically Treated |
| toe | Tonne of Oil Equivalent |
| tpd | Tonne Per Day |
| TPH | Tonne Per Hour |
| UHP | Ultra High power |
| UNEP | United Nations Environment Programme |
| VFD | Variable Frequency Drives |
| VSD | Variable Speed Drives |
| WBSIMA | West Bengal Sponge Iron Manufacturers Association |
| WHR | Waste Heat Recovery |
| WI | Wire Industries |

# INTRODUCTION


*Source: google maps*

## Background

Durgapur is located in Paschim Bardhaman district in the state of West Bengal, in eastern India. A major industrial hub, Durgapur is adjacent to Damodar River. The city developed post the establishment of the Durgapur steel plant in 1959. Some of the industrial areas like Angadpur, Andal, Barjora, Bamunara, Jamuria, and Raniganj are located nearby.

Durgapur Steel Plant (DSP), an integrated steel plant of Steel Authority of India Limited (SAIL) is in the cluster. Durgapur Steel Thermal Power Station (DSTPS) is one of the largest power plants in the cluster. The coal based thermal power plant is operated by Damodar Valley Corporation (DVC). Durgapur Projects Limited (DPL) is another thermal power station in Durgapur that started its operations in 1960 and is now owned by West Bengal Power Development Corporation. The coal mining belt of Raniganj coalfields is adjacent to Durgapur.

Durgapur has one of the largest concentrations of micro, small, and medium enterprises (MSMEs) in West Bengal. The major secondary steel industry segments in Durgapur include direct reduced iron (DRI)/sponge iron, ferro alloys, steel melting, steel re-rolling mills (SRRMs), wire industries (WI), and foundry (Figure 1).

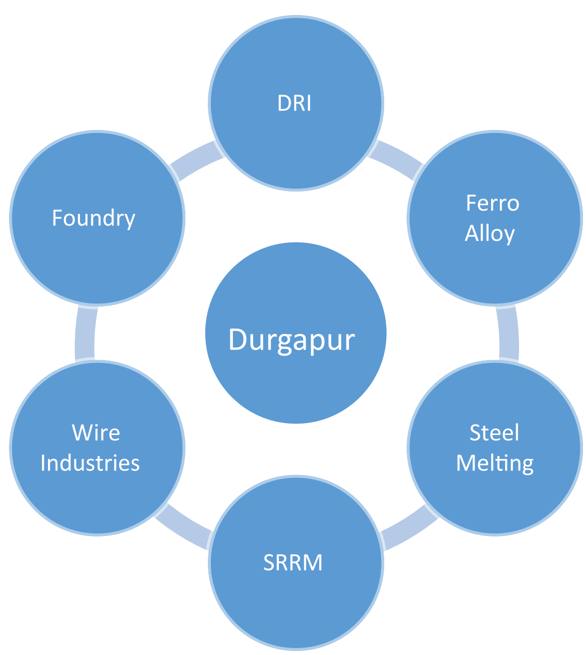


**Figure 1:** Type of industries in Durgapur cluster

## Industry and Technology Details

The industrial base of the region is primarily supported by iron and steel industries. There are at least 136 registered iron and steel industries in the cluster. The category-wise break-up of these industries is shown in Figure 2.

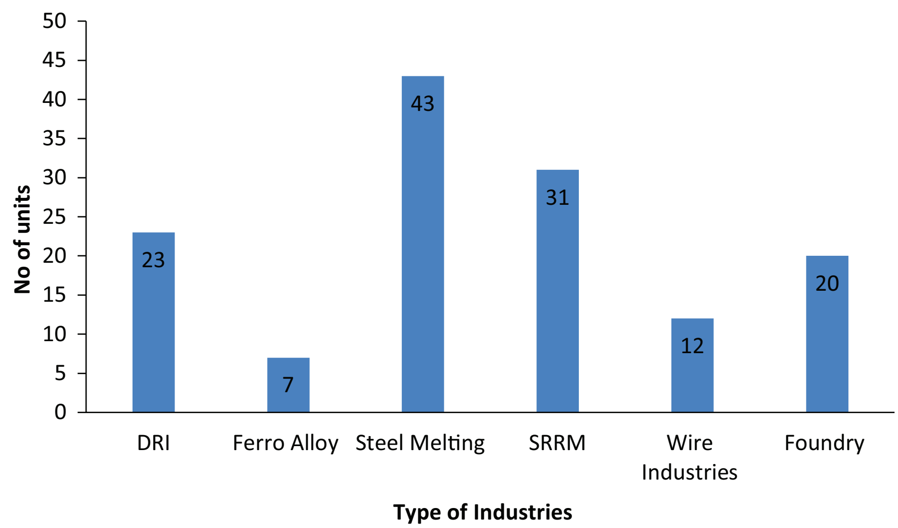


**Figure 2:** Category-wise break-up of industries in Durgapur cluster

Different technologies, raw materials, energy, and processes are used by the industries in the cluster as mentioned in Table 1.

**Table 1:** Technology and other details of secondary steel industries in Durgapur cluster

| Technology | User Industry | Raw material | Process steps | Energy used | End product |
|---|---|---|---|---|---|
| Rotary kiln | DRI | Iron ore | Heating and reduction | Coal, electricity | Sponge iron |
| Submerged arc furnace | Ferro Alloys | Mineral ore | Heating and reduction | Electricity, coke | Alloys |
| Electric induc-tion furnace | SMS | Sponge iron, scrap | Steel melting | Electricity | Ingots, billets |
| Re-heating furnace | SRRM | Ingots, billets | Heating | Coal | Heated feed stock for re-rolling |
| Continuous casting machine | SRRM | Liquid metal | Casting | Electricity | Hot billets |
| Rolling mill | SRRM | Hot ingots, billets | Rolling | Electricity | TMT bars |
| Wire drawing machine | Wire industry | Coiled wire | Drawing | Electricity | Bundled wire |

## Major Products

Some of the products manufactured by the secondary steel industries in the cluster include TMT bars, alloys, ingots, billets, angles, channels, wires, coils, sheets, and pipes (Figure 3). The products manufactured by the industries in the cluster are used in a wide range of end-use sectors, including building and construction, infrastructure, engineering, and so on. The products are transported by road and rail to different parts of the country. Some products are shipped to Haldia port in West Bengal for export.

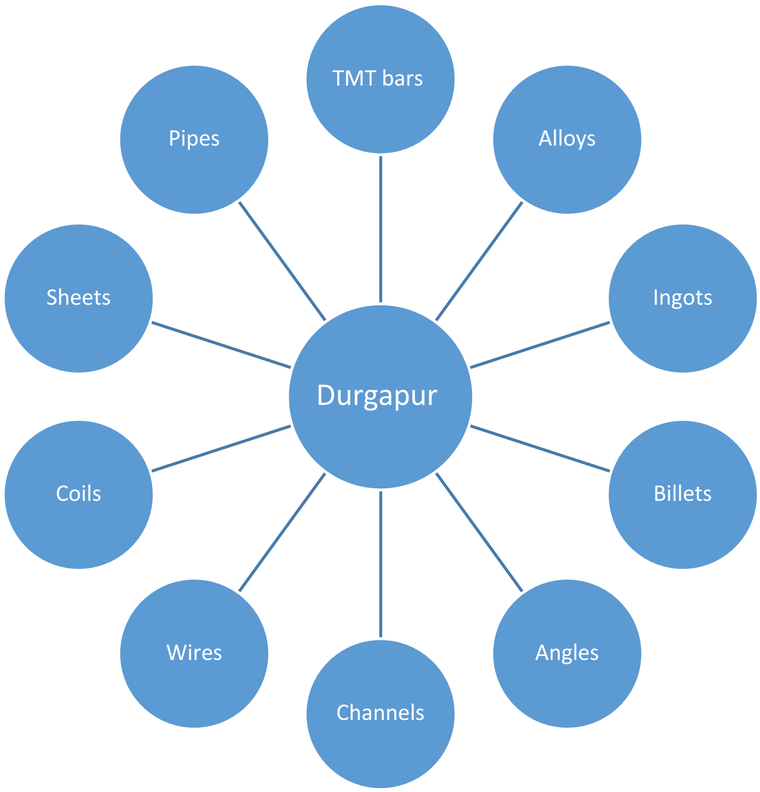


**Figure 3:** End-products of Durgapur cluster

The Durgapur cluster plays a vital role in integrating backward and downstream processes of the secondary steel sector. About 60,000 people are directly or indirectly employed by the steel industries. There is a substantial potential to reduce the energy consumption, with consequent reduction in greenhouse gas (GHG) emissions, among the steel industries in the cluster. Thus, the cluster is poised to play a pivotal role in decarbonization of the steel sector in India.

## Energy Consumption and GHG Emissions

Specific energy consumption (SEC), i.e., the amount of energy consumed per tonne product, varies widely in the cluster depending upon the scale of operation, products manufactured, technology used, and operating practices used by individual industries. Table 2 gives typical SEC ranges for different steel industries in the cluster.

**Table 2:** SECs for different industries in the cluster

| Industry | Thermal (Gcal/t) | Electricity (kWh/t) |
|---|---|---|
| DRI | 4.5 | 70-80 |
| Ferro alloys | 3 | 4750-10000 |
| Electric induction furnace | - | 750-950 |
| Reheating furnace | 0.5 | 4-6 |
| Rolling mill | - | 50-80 |
| Galvanizing | 0.3 | 10-15 |
| Wire drawing | 0.08 | 200-240 |

The annual energy consumption of steel industries in the cluster is estimated to be about 2.18 Mtoe. The equivalent GHG emissions are 9.63 $MtCO_2$. (Table 3).

**Table 3:** Overview of energy consumption and GHG emissions of different industries in the cluster

| Industry type | Annual energy consumption (Mtoe) | | | Annual Emissions ($MtCO_2$) |
|---|---|---|---|---|
| | Thermal | Electricity | Total | |
| DRI | 1.66 | 0.02 | 1.68 | 5.82 |
| Ferro alloys | 0.065 | 0.126 | 0.19 | 1.38 |
| Steel melting | - | 0.20 | 0.20 | 1.80 |
| SRRM | 0.037 | 0.040 | 0.08 | 0.49 |
| Wire drawing | 0.013 | 0.002 | 0.02 | 0.06 |
| Foundry | 0.011 | 0.006 | 0.02 | 0.08 |
| Total | 1.79 | 0.39 | 2.18 | 9.63 |

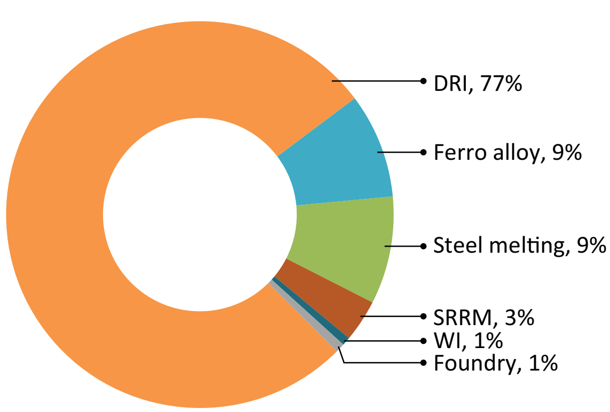


**Figure 4:** : Category-wise share of energy consumption

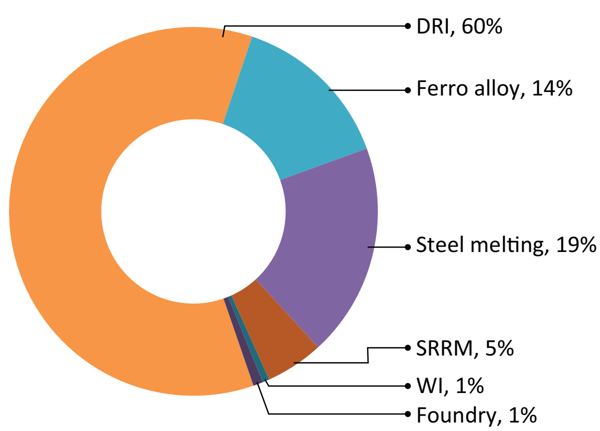


**Figure 5:** Industry-wise emissions in cluster

DRI alone accounts for about 77% of the total energy consumption (Figure 4) and 60% of GHG emissions (Figure 5). Overall, thermal energy (primarily coal) accounts for about 82% of the energy consumption, while the share of electric energy is 18% (Figure 6).

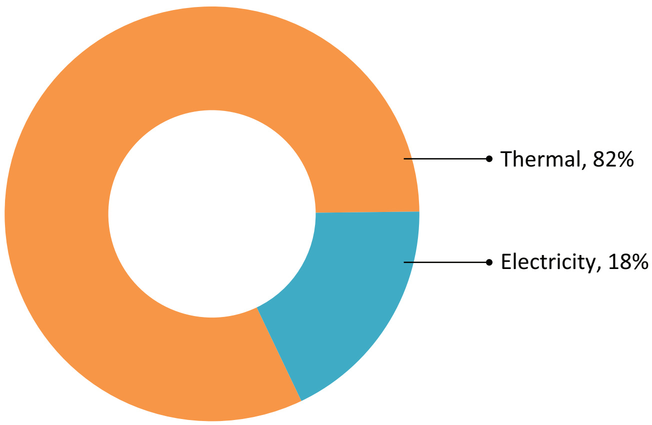


**Figure 6:** Share of energy consumption in the cluster

There is substantial scope for energy efficiency improvement and greenhouse gas (GHG) emissions reduction in the cluster. The technology-use and energy consumption pattern across various secondary steel industry sub-sectors within the cluster are presented in subsequent sections.

# DRI Industry

## Background

India is the largest global producer of sponge iron through the DRI route. In this process, the iron ore is reduced directly to produce metallic iron. Coal, natural gas, and hydrogen can be used as reducing agents for the reduction of iron ore. Most sponge iron production in India comes from coal-based rotary kilns.

The DRI/sponge iron industry in Durgapur cluster is spread across Angadpur, Raturia, Mangalpur, and Jamuria. There are 23 DRI industries in the cluster, out of which 14 are designated consumers (DCs) under the Perform, Achieve and Trade (PAT) scheme. .Bureau of Energy Efficiency (BEE). Eight of these industries are composite in nature and have downstream integration like steel melting shop and re-rolling facilities.

## Production

The total DRI production in the cluster is estimated to be around 2.19 Mtpa (Table 4). Around 61% of the DRI industries are categorized as DCs under the PAT scheme of BEE, as their gate-to-gate total energy consumption exceeds the threshold limit of iron and steel[1] sector; more than 20,000 toe/year (Figure 7).

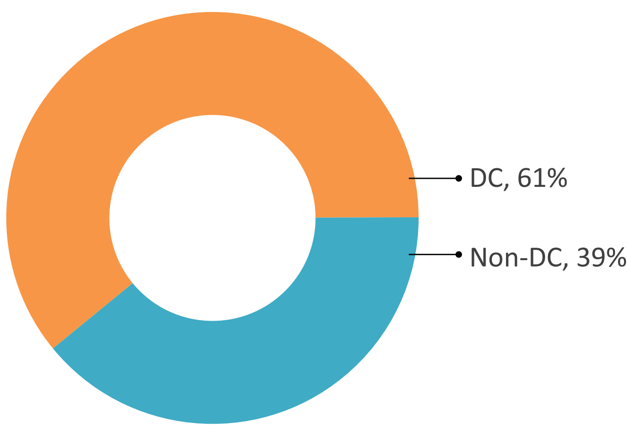


**Figure 7:** Share of units under PAT scheme

## Manufacturing Process

DRI is made through the reduction of iron ore to metallic iron. The main technology used in the Durgapur cluster pertaining to DRI manufacturing process is coal-based rotary kiln. Non-coking coal is used

**Table 4:** Categorization of DRI industries and estimated production

| Capacity (tpd) | Number of industries | Production (Mtpa) |
|---|---|---|
| < 200 | 12 | 0.46 |
| 200-400 | 8 | 1.19 |
| > 400 | 3 | 0.54 |
| Total | 23 | 2.19 |

1 Source: https://beeindia.gov.in/en/programmesperform-achieve-tradepatpat-notifications/pat-sectors-threshold

as a source of heat and as a reducing agent. The reduced iron ore is known as direct reduced iron (DRI). Due to its spongy, honeycomb like texture, it is also known as sponge iron. The main manufacturing processes includes: (i) reduction of iron ore, (ii) cooling of hot sponge iron, and (iii) separation and screening. The generic process flow-chart for DRI manufacturing is shown in Figure 8.

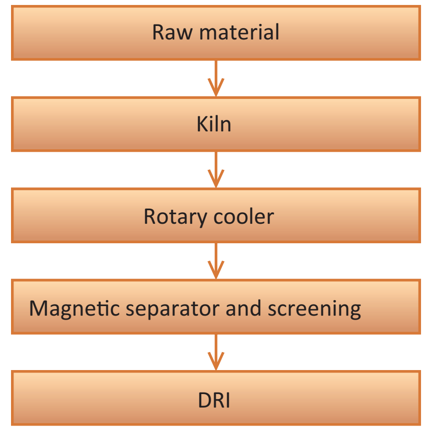


**Figure 8:** DRI production process

## Reduction of iron ore

In the operation of the kiln, a proportionate mixture of iron ore, coal, and dolomite is continuously fed into the kiln from the feed end using weigh feeders. This carefully curated blend moves along the length of the kiln, following its preset rotation. Simultaneously, secondary air is introduced into the kiln through strategically placed air pipes along its length. Initial heating of kiln refractory surpasses the ignition temperature of coal and is accomplished using an oil-fired system located at the discharge end.

**Reactions in coal based DRI process**

$$C + O_2 = CO_2$$
$$CO_2 + C = 2CO$$
$$3Fe_2O_3 + CO = 2Fe_3O_4 + CO_2$$
$$Fe_3O_4 + CO = 3FeO + CO_2$$
$$FeO + CO = Fe\ (\text{product}) + CO_2$$

The additional carbon requirement for the reaction is met by fine coal, which is injected at the kiln's discharge end. As the charge progresses along the kiln's length, it gradually absorbs heat from the hot gases flowing counter to the charge's direction. The preheating zone, constituting approximately 30% of the kiln's length, plays a crucial role in eliminating both moisture and volatile matter present in the feed mixture. The necessary heat in the preheating zone is generated through the combustion of a portion of the coal. Following the preheating zone, the subsequent section of the rotary kiln is designated as the 'reduction zone'. In this zone, oxygen within the iron ore dissociates and oxidizes leading to the reduction of the carbon element in non-coking coal, forming carbon monoxide and leaving behind metallic iron. The kiln's rotation and inclination ensure effective mixing and movement of the charge towards the discharge end at the required rate. Maintaining a temperature range of about 900–1050°C in the reduction zone is critical. The residence time for iron ore inside the kiln is approximately 8 to 9 hours, facilitating the transformation into metallic iron. This intricate process is pivotal in the production of sponge iron for various metallurgical applications[2].

## Cooling of sponge iron

After the metallization process through the reduction process, the amalgamation of sponge iron and residual charge undergoes a seamless transition to a rotary cooler via a belt conveyor, maintaining a

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2 Ghosh, A.M., Vasudevan, N. and Kumar, S. 2021. Compendium: Energy-efficient Technology Options for Direct Reduction of Iron Process (Sponge Iron Plants), TERI

temperature of approximately 250°C. This precautionary step ensures that the hot product encounters ambient air only after reaching this designated temperature, mitigating the risk of oxidation. Sponge iron, when exceeding 250°C, is susceptible to oxidation by the oxygen present in the ambient air. Subsequently it undergoes through an additional cooling phase, further reducing its temperature to approximately 100°C. This cooling process is meticulously executed through an indirect cooling mechanism within the rotary cooler. The controlled cooling not only enhances the stability of the product, but also ensures optimal handling and downstream processing. This strategic approach safeguards the integrity of the product and aligns with best practices in metallurgical production.

### Separation and screening

The material discharged from the rotary cooler is transferred through conveyors for screening of fines and coarse materials. Material of grain size less than 3 mm is separated out and passed through an electromagnetic separator, wherein sponge iron is separated from char and other impurities. The screening process effectively separates the material into distinct categories, distinguishing between lumps and fines.

## Technology Used

A schematic layout of the manufacturing process used in DRI production is shown in Figure 9.

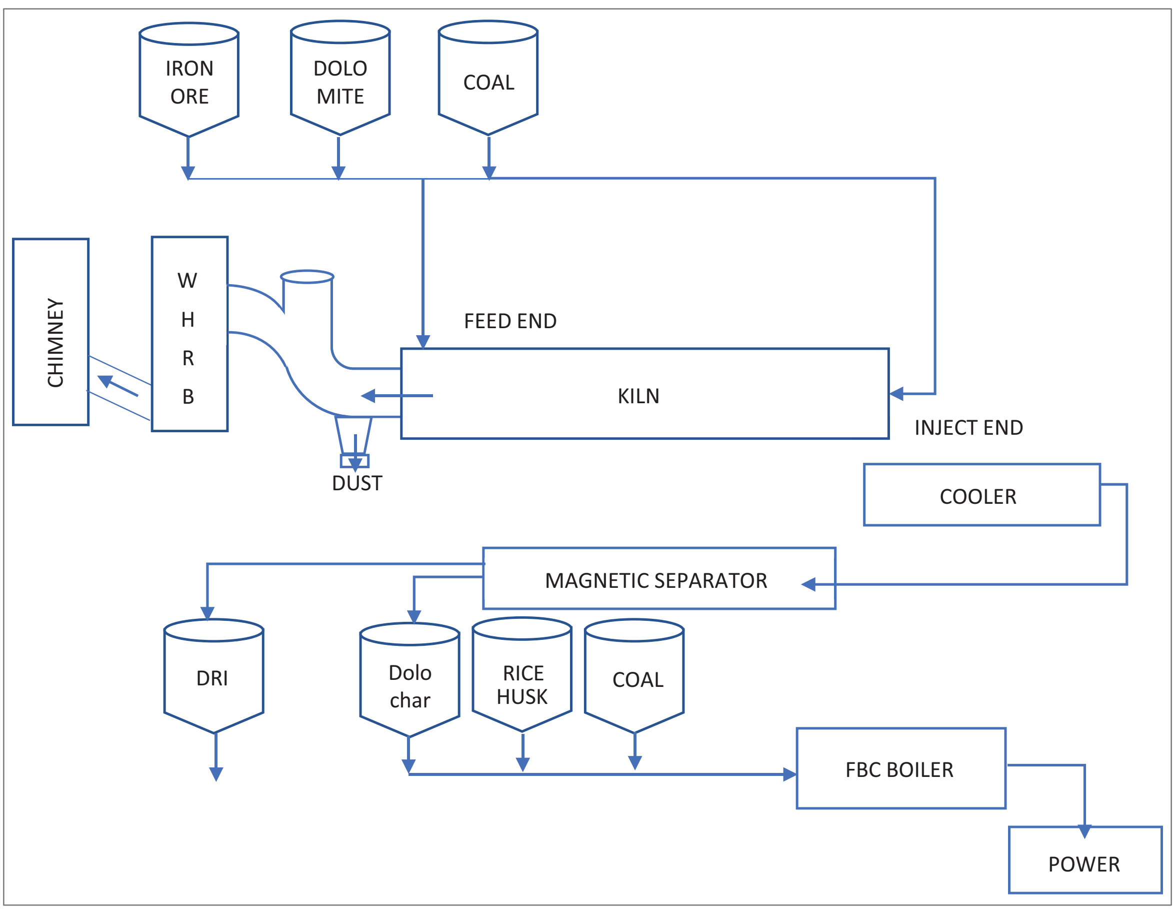


**Figure 9:** Schematic layout of DRI production process

## Rotary kiln


**Figure 10:** Rotary kiln

Horizontal rotary kiln is used in the production of sponge iron (Figure 10). Most of the industries have 100 or 200 tpd kilns. To protect shell, the kiln is protected with an inside refractory lining of 150–200 mm and has a slope of 2.5° towards the discharge end. Combustion air requirement for the feed is provided by air blowers along the length of the heating zone.

Major constituents include iron ore, with a preference for high-content hematite ($Fe_2O_3$) exceeding 65%, coal, and limestone/dolomite (fluxing material). The versatility of iron ore, available in both lumps and pellets, adds flexibility to production dynamics. Iron ore, coal, and dolomite reduced to the required size in crushers are fed into the kiln continuously from the feeder end. The continuous movement of raw materials along the kiln's length adheres to a pre-set rotation for optimal processing.

# Energy Consumption and GHG Emissions

The major energy forms used by DRI industries are coal and electricity. About 98% of the energy consumption of coal-based DRI plants comes from thermal sources, while the remaining 2% comes from electricity utilized to power motors and other allied equipment. The average specific energy consumption (SEC) of coal-based DRI plants is 4.51 Giga calories per ton (Gcal/t); varying from 4.10 to 5.26 Gcal/t. About 35% of the coal is charged at the feed end, while the balance 65% of coal is charged at the injection end of the kiln. SEC range for DRI industries is provided in Table 5.

**Table 5:** SEC of DRI industries

| Thermal (Gcal/t) | Electrical (kWh/t) |
|---|---|
| 4.5 | 70-80 |

## Cluster level energy consumption and GHG emissions

The annual energy consumption of DRI industry in the cluster is estimated to be about 1.68 Mtoe. The equivalent GHG emissions is 5.8 $MtCO_2$ per annum (Table 6).

**Table 6:** Energy consumption and GHG emissions of DRI industry in the cluster

| Energy type | Annual consumption | Equivalent energy, (Mtoe) | GHG emission ($MtCO_2$) |
|---|---|---|---|
| Coal | 3.07 Mt | 1.66 | 5.6 |
| Electricity | 285 MU | 0.02 | 0.2 |
| Total | | 1.68 | 5.8 |

## Energy Saving Opportunities

Some of the energy saving opportunities in DRI industry are discussed below.

### Waste heat recovery (WHR) system for power generation

In coal-based DRI production using a rotary kiln, the off-gases exit the kiln at a temperature ranging between 950 to 1000°C, carrying a substantial amount of sensible heat. This heat can be harnessed by employing a waste heat recovery (WHR) boiler to produce high-pressure steam for power generation. A typical 2 x 100 tpd plant has the potential to generate 5 MW of power that can be utilized in the plant for captive consumption, while the excess can be exported to the grid. The capital investment for a WHR power plant of 5 MW is about INR 500 million. The energy saving from a WHR-based power generation system, in a DRI plant of 2 x 100 tpd kiln capacity, is about 39.6 million kWh of electricity per year. The equivalent emission reduction potential is 31,284 tonne $CO_2$ per year.

### Replacement of iron ore lumps with pellets

Coal-based DRI plants commonly utilize iron ore lumps, sized between 5–20 mm. Naturally mined iron ore supplied to DRI plants typically contains low iron content. Processing these lumps often leads to the generation of fines, necessitating agglomeration processes to maintain yield levels. An alternative approach involves using iron ore pellets instead of lumps, which can notably enhance the yield of the DRI process.

### Improved kiln lining to reduce surface heat losses

In a conventional rotary kiln, high-alumina low-cement castable refractories are used as inner lining. The temperatures of external surfaces of the kiln are about 180–250°C. The radiation heat loss of the rotary kiln typically accounts for up to 5% of the total heat input, which can be reduced with the application of low-thermal conductivity material such as mullite-based kiln lining. The energy saving potential for a 100 tpd kiln with improved lining is 580 tonne of coal per year, equivalent to an emission reduction potential of 1050 tonne $CO_2$ per year.

# Ferro Alloys Industry

## Background

Ferro alloys play crucial role in producing alloys and special steel. They act as de-oxidisers and serve as alloy additives in the steel manufacturing process to impart special properties to steel. There are seven ferro alloys manufacturing industries in the cluster. The ferro alloys manufactured in the cluster include ferro-manganese, silicomanganese, and ferro-silicon.

## Production

Total ferro alloys production in the cluster is estimated to be around 1,56,000 tonne per year (Table 7).

**Table 7:** Production of ferro alloys in the Durgapur cluster

| Material loading capacity (tpd) | Transformer Rating (MVA) | Number of plants | Production (tpa) |
|---|---|---|---|
| 18–40 | 4–9 | 3 | 34,600 |
| 40–160 | 9–40 | 4 | 1,21,400 |
| Total | Total | 7 | 1,56,000 |

## Manufacturing of Ferro Alloys

The ferro alloy production process involves reduction of quartz with a carbonaceous reductant in the presence of alloy-bearing iron ore, conducted at an elevated temperature exceeding 2000°C. The energy for this reaction is sourced from three carbon electrodes and the chemical energy released by carbon-rich materials. The large electrode shafts facilitate arcing at the hearth of the furnace, generating the required temperatures.

During this phase, a liquid alloying element is formed through reactions with the carbonaceous feed charge material, producing CO and mono oxides of the alloying element. The subsequent reaction between the liquid alloying element and iron results in the production of ferro alloy, represented by the following reactions:

$$XO_2 + C \rightarrow X + CO + XO$$

$$Fe + X \rightarrow FeX$$

Here, ferro alloy (FeX) is an alloy of X and iron, primarily employed as a deoxidant and alloying element in steel and cast-iron production. The use of ferro alloy enhances machinability properties while boosting strength, hardness, temperature resistance, and corrosion resistance of the base material. The raw materials utilized in the ferro alloy process encompass alloy-bearing oxide, iron ore, quartz, and a carbonaceous reductant, which can be a blend of various coal grades, charcoal, and coke. The proportions of different raw materials including the carbon feed are tailored based on the target product line. Electrodes heat the feed material in the furnace, leading to the production of liquid ferro alloy. This molten alloy is poured into ladles and poured into casting beds, creating layer casting. The final alloying metal undergoes a cooling process and is subsequently crushed into pieces of variable sizes.

The steps involved in ferro alloy production process include (1) handling and charging of raw materials, (2) stroking, (3) smelting, and (4) tapping of liquid metal. The generic process flow of ferro alloy manufacturing process is described below and the process flow chart is shown in Figure 11.

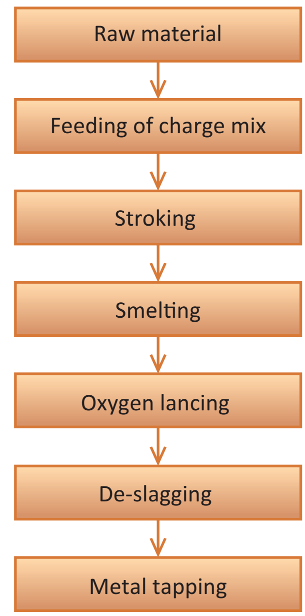


**Figure 11:** Ferro alloys production process

## Raw material handling

The raw materials stored in the storage yard are screened and transported through conveyor belts to respective storage bins where they are weighed, and samples are taken out for composition analysis. This analysis is conducted for each raw material before feeding them into the furnace. It is further mixed and carried through a bucket elevator into a circulating feed hopper, located at the top of the furnace for feeding inside stroking floor.

## Stroking

Stroking is mostly carried out in the semi-closed arc furnace. The raw materials form lumps while feeding and need to be evenly spread out. Strokers are used regularly to spread raw materials uniformly inside the furnace and to ensure that no lump is formed.

## Smelting

Smelting is the heart of the furnace operation. Electrical and chemical energy is used for smelting. Electricity is fed through graphite electrodes, which is the major energy input. Ferro alloy is produced through smelting that involves high temperature arching of oxide mines in the presence of carbon to produce alloy element in the liquid state. The liquid alloy element reacts with iron to form ferro alloy. The electric furnace has three carbon electrodes, which supply high voltage electricity to generate high temperature arcing at the core of the furnace. A reaction temperature of about 2000°C is maintained inside the furnace.

## Tapping

The molten ferro alloy is drawn out from the bottom of the furnace through tapping holes at a holding temperature of 1500–1600°C.

# Technology Used

A submerged arc furnace (SAF) is composed of an external cylindrical steel shell, internally lined with multiple layers of specialized refractory materials with separate holes for slag and metal. The word 'submerged' implies that the electrodes of the furnace are deeply embedded into the material being heated in the furnace. Three electrodes penetrate the furnace from the roof through cylindrical openings, at an angle of 120 degrees. A typical view of the submerged arc furnace[3] is shown in Figure 12.

SAF for the ferro alloys industry typically range from 4.5 to 24 MVA rated power (material loading capacity in the range of 25 to 100 tph). Rated voltage of 11kV power is supplied for typical semi-closed type Indian make furnaces which are used in the cluster. Typical accessories include electrode column,

[3] https://www.researchgate.net/figure/A-sketch-of-submerged-arc-furnace-modified-from-Yang-et-al-2004_fig4_266977143

pressure ring, slipping device, mantle, cooling shield, smoke hood, ducting, charge hoppers, and raw material handling. The roof—typically constructed with high alumina refractory brick ensures durability. The shell bottom is usually cooled by forced air ventilation. The self-baking electrodes with casings, or prebaked electrodes are periodically extended by new pieces. The electrode is semi-automatically slipped into the bath with the furnace, at full electric load and with no interruptions of the furnace operation. The electrode column assemblies contain all facilities to hold, slip, and regulate the penetration into the bath. All electrode operations are performed hydraulically[4].

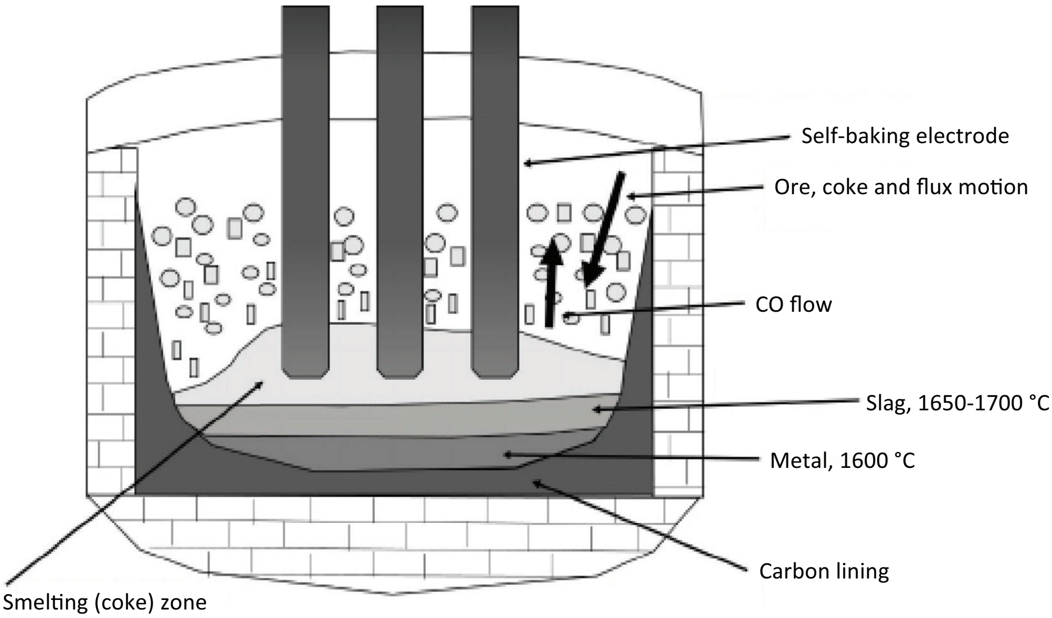


**Figure 12:** View of a submerged arc furnace

## Energy Consumption and GHG Emissions

The main energy forms in the ferro alloys industry are electricity and coke. About 68% of the energy consumption of SAF plants comes from electrical sources, while the remaining 32% comes from coke and other carbonaceous materials. The SEC for ferro alloys manufacturing process in the country varies from 4,750 to 10,000 kWh per tonne. A very high consumption of power (i.e., 9,000 to 10,000 kWh) is required to produce one tonne of ferrosilicon. Around 4,750 to 5,250 kWh power is consumed to produce one tonne of silicomanganese. Power consumption of 4,500 kWh is required to produce one tonne of ferrochrome[5]. Table 8 provides power consumption per tonne of ferro alloys production.

**Table 8:** SEC of ferro alloys industries

| Thermal (Gcal/t) | Electrical (kWh/t) |
| --- | --- |
| 3 | 4.75–10 |

4 https://www.ispatguru.com/submerged-arc-furnaces/

5 https://ibm.gov.in/writereaddata/files/11292021123407Ferro%20Alloys_%202020.pdf

## Cluster level energy consumption and GHG emissions

The total energy consumption of ferro alloy industries in Durgapur cluster is estimated to be 0.19 Mtoe. The equivalent GHG emissions are estimated to be around 1.38 million tonne of $CO_2$ (Table 9).

**Table 9:** Energy consumption and GHG emissions of ferro alloy industries in the cluster

| Energy type | Annual consumption | Equivalent energy (Mtoe) | GHG emissions ($MtCO_2$) |
|---|---|---|---|
| Coke | 0.12 Mt | 0.06 | 0.22 |
| Electricity | 1466 MU | 0.13 | 1.16 |
| Total | | 0.19 | 1.38 |

## Energy saving opportunities

Some of the energy saving opportunities in the ferro alloys industry are discussed below.

### Use of efficient transformers

The submerged arc furnace uses a specialized arc transformer. Inefficient transformers can be replaced with efficient ones. The major benefits of efficient transformers include increase in productivity, reduction in electrode consumption, and energy saving.

### WHR for power generation

The waste heat available in off-gases in the ferro alloys plant can be utilized to generate captive power. Reduction in electrical load with the adoption of WHR-based power generation systems in ferro alloys industry would help in bringing down energy cost to a significant extent. Capital investment in the waste heat recovery-based boiler and power plant system would have an attractive payback of 3–4 years.

### Feed material drying and preheating

The off-gases from the furnace leave at about 900–1200°C, carrying about 20% of input energy. This waste heat available in off-gases can be effectively recovered and reused. Waste heat recovery from off-gases can be used in preheating of input scrap material. A ferro alloys plant can also utilize the waste heat for drying and preheating of feed material. Apart from having an attractive payback on investment, the dryer will help in reducing GHG emissions as well.

# Steel Melting Industry

# Background

There are about 43 steel melting units in the Durgapur cluster that use electric induction furnace (EIF). Around 14 of these plants are composite in nature using hot metal in a continuous casting machine (CCM). Others produce ingots/billets catering to the steel re-rolling mill (SRRM).

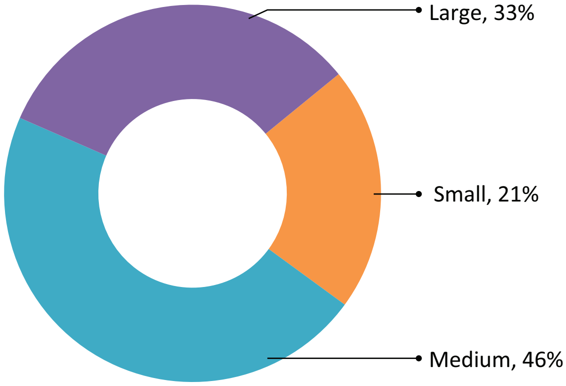


**Figure 13:** Capacity-wise distribution of units

About 33% of the units are in the large category, majority of the units (46%) are of medium size, and 21% of them are categorised as small (Figure 13). The feed raw material primarily consists of sponge iron, iron scrap, pig iron, in-house rejects, alloying element, and fluxing chemicals. The rating of the induction furnaces varies in the range of 2.5 MW to 3.5 MW, with a melting capacity of 4 to 20 tonnes per batch. The cycle time of each batch is 3 to 4 hours per heat.

# Production

Liquid metal from the induction furnace is poured with the help of a ladle, either to CCM or a bottom pouring system. The cast products from CCM are directly routed further as hot charge to rolling mills, while the cold charge (ingots/billet) from bottom pouring is sold to reheating furnace units or other allied industries.

The total production from electric induction furnace -based steel melting shops in the Durgapur cluster is estimated to be around 1.76 million tonne per year (Table 10).

**Table 10:** Categorization of EIF industries and estimated production

| Capacity (tpa) | Number of plants | Production (Mtpa) |
|---|---|---|
| 2,000 – 20,000 | 9 | 0.07 |
| 20,000 – 75,000 | 20 | 0.85 |
| 75,000 and above | 14 | 0.83 |
| Total | 43 | 1.76 |

# Manufacturing Process

Use of raw materials in electric induction furnaces depends on the product chemistry. The batch materials include sponge iron, pig iron, steel scrap and in-house returns. Alloying elements like ferro-silicon, ferro-manganese, silicon carbide, etc., are also dozed to achieve required product chemistry. Slag is removed from the top layer of molten metal manually. The liquid metal from induction furnace is poured into the bottom pouring system finally to make ingots/billets.

Induction furnace is the main equipment used in these units for melting. Major steps of the steel melting process include batch preparation, charging, melting, pouring, and finishing (Figure 14). Brief descriptions of these process steps are provided below.

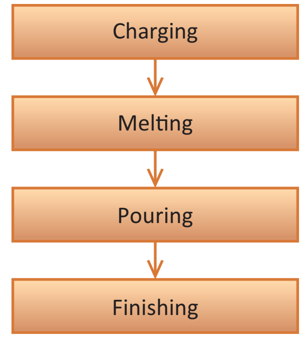

**Figure 14:** Steel melting process flow

## Preparation of charge material

This involves preparation of raw materials for charging. Measured quantities of metal scrap, pig iron, sponge iron, and other alloys are loaded into the furnace for melting. The ratio between raw materials depends on final casting properties.

## Melting

The charge is melted in the induction furnace. The temperature requirement for the melting varies between 1,500 to 1,650°C, depending on the grade of the steel.

## Pouring

Once the required temperature and metallurgy is achieved, the liquid melt is poured into a ladle to transfer it to the continuous caster machine (Figure 15).

**Figure 15:** Induction furnace pouring

## Finishing

The molten metal is poured into caster to convert it shape to billet/ingots. These billets are further transferred to rolling mill sections for shaping them into the final product in integrated plants or are sold as ingots to other industries to make final steel products.

# Technology Used

The furnace consists of a non-conductive crucible surrounded by a coil of copper wire with supply of powerful alternating current. The electricity passing through the coil heats the bulk metal by joule heating effect. Furnaces use silicon-controlled rectifier (SCR) or insulated gate bipolar transistor (IGBT) for controlling power circuit of which the IGBT type is more efficient.

The main parts of the coreless induction furnace are crucible, power circuit, cooling system for power panel, and furnace coil. A schematic view[6] the of coreless induction furnace is shown in Figure 16.

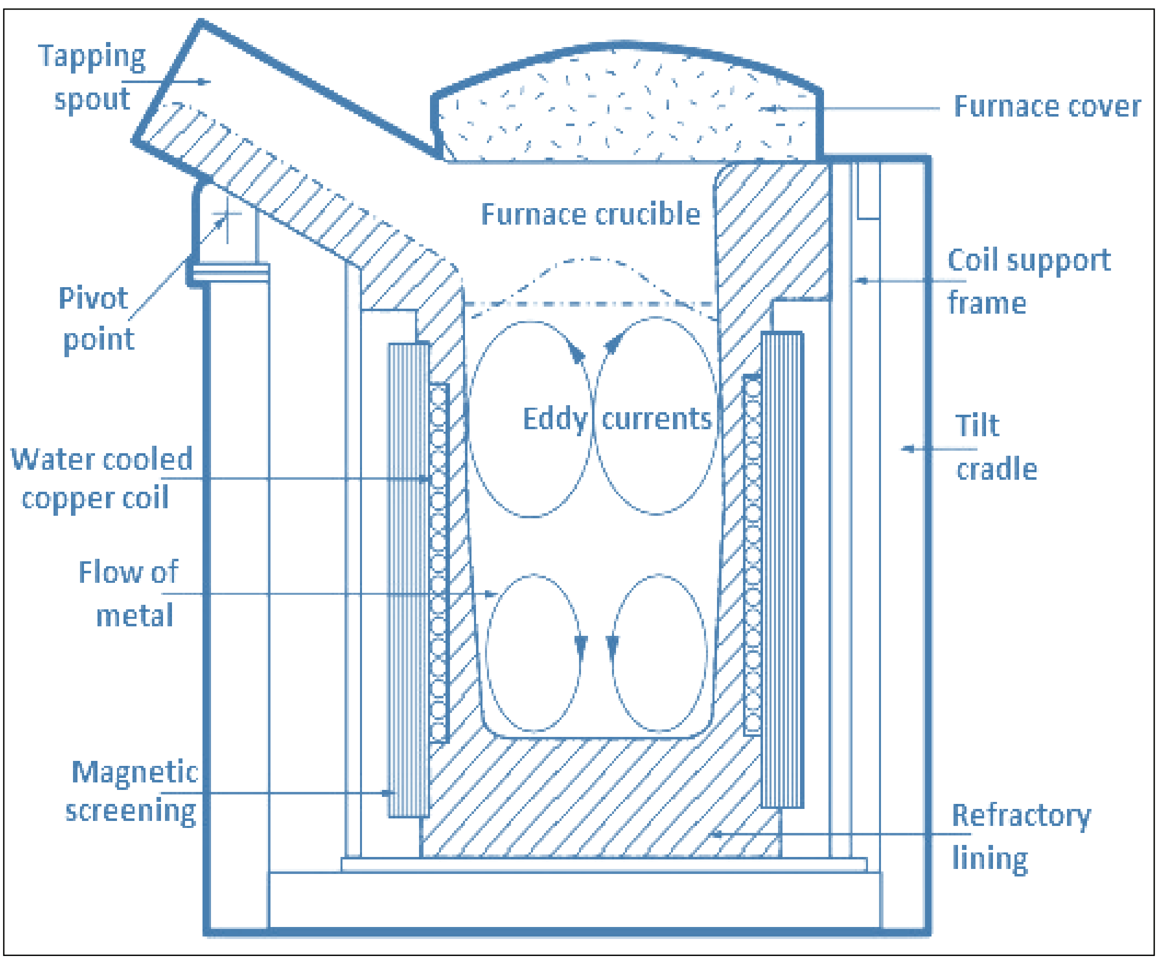


**Figure 16:** Schematic view of an electric induction furnace

6 Source: https://www.ispatguru.com/steelmaking-by-induction-furnace/

# Energy Consumption and GHG Emissions

Induction furnace-based secondary steel melting consumes 100% electricity for melting apart, from utility support from cooling water and compressed air. SEC for the induction furnace-based melting, including associate downstream process areas, is provided in Table 11.

**Table 11:** SEC of EIF industries

| Process | SEC (Electrical, kWh/t) |
|---|---|
| EAF and auxiliaries | 750-950 |

## Cluster level energy consumption and GHG emissions

The equivalent total energy consumption in steel melting and associated process areas is estimated to be 0.20 Mtoe. The equivalent GHG emissions are estimated to be around 1.80 $MtCO_2$ (Table 12).

**Table 12:** : Details of energy consumption and GHG emissions

| Energy type | Annual consumption | Equivalent energy (Mtoe) | GHG emissions ($MtCO_2$) |
|---|---|---|---|
| Electricity | 2282 MU | 0.20 | 1.80 |

# Energy Saving Opportunities

The induction furnace is the major energy consuming equipment in these plants; however, the auxiliary systems involved in the production process also consume a significant amount of energy. There is potential in energy saving by minimizing the losses during the production process. Some of the energy saving measures in the induction furnace-based industries are mentioned below.

## Efficient charge preparation and charging

The raw material must be weighed and arranged on the melt floor near the furnace before starting the melting. Charge must be free from sand, dirt, and oil/grease. Rusty scrap not only takes more time to melt, but also contains less metal per charging. For every 1% slag formed at 1500 °C, energy loss is 10 kWh per tonne. An efficient scrap charging system in the furnace will lead to less electricity consumption. It will save on heating cycle time which consumes less electricity. The potential energy saving is estimated to be 5–10% of the present electricity consumption per heat.

## Efficient furnace operation

The units do not follow standard operating procedures and are operated crudely. There are many tips to ensure efficient furnace operation, such as the following:

- Always run the furnace with full power. This not only reduces batch duration, but also improves energy efficiency.
- Use lid mechanism for furnace crucible; radiation heat loss accounts for 4–6% input energy.
- Reduce interruptions by locating spectro-testing labs near the melt shop to avoid waiting time for chemical analysis.
- Avoid unnecessary super-heating of metal. Superheating by 50°C can increase furnace specific energy consumption by 25 kWh per tonne.

## Replacement by IGBT type induction furnace

Many of the steel melting industries use silicon-controlled rectifier (SCR) type furnace. Replacing SCR-based induction furnace with the insulated gate bipolar transistor (IGBT) type induction furnace would help in reducing SEC level. The potential energy saving is about 15–25%. The investment for IGBT furnace is expected to payback within one year, on account of energy saving alone.

## Retrofit of lid mechanism for furnace crucible

All induction furnaces use crucibles for melting. The mouth of the crucible is kept open during operation, resulting in substantial radiation losses (6–8% of total energy input). Retrofitting induction furnace crucible with a lid mechanism will lead to an energy saving of up to 3%. The saving would depend on size of crucible and operating practices. The investment for lid mechanism is expected to payback within a few months.

# Steel Re-rolling Mills

## Background

Re-rolling operations contribute to a major share of finished steel production. The major products manufactured in steel re-rolling mills (SRRMs) are angles, strips, and bars. The final products of the SRMMs are used in construction, transport, and other infrastructure sectors.

There are around 31 SRRMs in the Durgapur cluster. The distribution of SRRMs within the region consists of standalone as well as composite industries. Composite SRRMs use in-house billets produced through the CCM route, whereas standalone SRRMs procure ingots/billets from outside.

## Production

The total production of the SRRM units is estimated to be around 2.30 Mtpa as shown in Table 13.

**Table 13:** Categorization of SRRM industries and estimated production

| Capacity (tpd) | Number of plants | Production (Mtpa) |
|---|---|---|
| < 300 | 23 | 0.91 |
| >300 | 8 | 1.39 |
| Total | 31 | 2.30 |

## Manufacturing process

The feed raw material for a typical steel re-rolling mill is billet. The smaller SRRM industries use coal as an energy source for heating. Most of the larger rolling mills have electric induction melting furnaces and continuous casting and rolling machines. Electricity is used for different motive loads like coal pulveriser, feed pusher, driving motors for rolling stands, etc.

The broad process steps in a typical coal-based reheating furnace-based SRRM include feed charging, heating, rolling, and finishing which are briefed below. Pre-sized billets in a single or double row are gradually pushed inside the furnace using a pusher motor at a preset speed. The feed materials pass through three zones inside the furnace: namely preheating, heating, and soaking. Rolling mill receives heated feedstock at desired temperature for further shaping. In the re-rolling section, the hot feedstock passes through rolling stands in a series—roughing, intermediate, and finishing stands. Multiple passes within a stand squeeze and stretch the material into various finished steel products. On completion of process, hot products are allowed to cool down before being transferred for sizing to a shearing machine and onward straightening and storing yard. The process flow in a steel re-rolling mill is shown in the Figure 17.

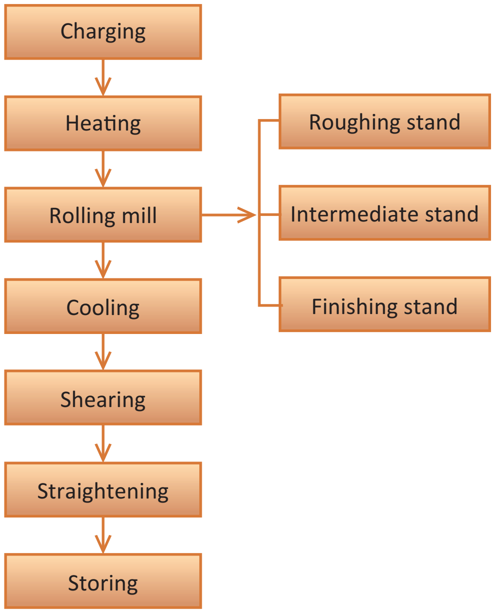


**Figure 17:** Re-rolling process flow

# Technology Used

Continuous casting machine or reheating furnace, along with rolling mill are two important process technology that are described below.

## Continuous casting machine

Continuous casting is a process used in the steel industry to efficiently produce high-end, quality products such as steel billet, blooms, slabs, etc. The technology is a modern method of casting molten metal without interruption allowing continuous production of uniform and defect-free metal products. The continuous casting machine is the central component in the process of re-rolling. The molten metal from the induction furnace is poured in the continuous caster machine and the output comes out in a uniform shape as shown in Figure 18.

**Figure 18:** Continuous casting process

## Reheating furnace

Reheating furnace is a crucial equipment in the process of re-rolling mills. Its primary function is to raise the temperature of the incoming raw material (typically steel billet or slab) to an optimal level for the subsequent rolling process. The reheating furnace plays a significant role in achieving the desired metallurgical properties, reducing material brittleness, and facilitating the plastic deformation required for shaping and forming. The temperature of the soaking zone is around 1,250°C, which is suitable for plastic deformation of steel. A typical reheating furnace is shown in Figure 19.

**Figure 19:** Reheating furnace

## Rolling mill

The primary function of the rolling mill is to shape the hot ingot into thinner and longer products through successive rolling mill stands. A typical rolling mill stand is shown in Figure 20. The heated slab is rolled in a roughing stand, where the thickness is partly reduced in various passes, back and forth. Normally, a roughening stand has three passes. Similarly, an intermediate stand has multiple passes depending on the product, and finally the desired shape is achieved in a finishing stand, which also has multiple passes.

**Figure 20:** Rolling mill

In the Durgapur cluster, re-rolling mills that produce structural steel products like angles, channels, beams, TMT bars, etc. have a total of 11 to 14 passes from three stages of milling stands. All rolling stands are driven by a common drive shaft, which is connected through a belt to a rolling motor. The designed rating of the rolling motor may vary in the range of 1200 to 1500 hp.

# Energy Consumption and GHG Emissions

The standalone SRRM-based industry in the Durgapur cluster consumes coal for heating feedstock, along with electricity for connected rolling mill and other motive load in utilities. Specific energy consumption for standalone SRRM-based finished steel making (including associate downstream process areas, except coal gasification system) are provided in the Table 14.

**Table 14:** SEC of standalone SRRM and utility areas

| Energy consumption area | SEC | | |
|---|---|---|---|
| | Coal (kg/t) | Thermal (Gcal/t) | Electrical (kWh/t) |
| Reheating furnace | 100 | 0.5 | 4-6 |
| Rolling mill | - | - | 50-80 |
| Utility | - | - | 50 |

## Cluster level energy consumption and GHG emissions

The equivalent total energy consumption by standalone SRRM and utility areas is estimated to 0.077 Mtoe/annum. The annual equivalent GHG emissions are estimated to be around 0.49 $MtCO_2$ (Table 15).

**Table 15:** Details of energy consumption and GHG emission

| Energy type | Annual consumption | Equivalent energy (Mtoe) | GHG emissions ($MtCO_2$) |
|---|---|---|---|
| Coal | 0.07 Mt | 0.037 | 0.13 |
| Electricity | 460 MU | 0.04 | 0.36 |
| Total | | 0.077 | 0.49 |

# Energy Saving Opportunities

Re-rolling industries have significant opportunities to reduce operational costs and environmental impact. Some energy savings opportunities in re-rolling industries are given below.

## Installing high efficiency recuperator

Waste heat from high-temperature flue gases (650–800°C) in reheating furnaces can be recovered to reduce fuel consumption. The conventional, economical, and convenient method is using a recuperator system to preheat combustion air. A recuperator facilitates heat exchange between flue gases and combustion air through metallic or ceramic walls. Ducts or tubes carry combustion air for preheating, while waste heat (flue gas) flows to the other side. Recovering heat from flue gas and transferring it to combustion air can reduce fuel consumption by up to 25%.

## Excess air optimization and VSDs on combustion fans

Waste heat generation correlates with the amount of air used for combustion. Slightly excess air beyond the stoichiometric ratio, ensures complete fuel combustion, depending on fuel type. Excess air reduces combustion efficiency, generating excessive hot waste gases. Controlling oxygen levels and using variable speed drives (VSDs) on combustion air fans optimizes furnace combustion. VSDs aid in controlling oxygen levels, especially during varying production rates. Savings in fuel and electricity in reheating furnaces through excess air level optimization, depends on furnace load factor and applied control strategies. Estimated energy savings range from 4–9% of thermal energy.

## Improved insulation and refractories of reheating furnace

The heat loss from furnace walls and material discharge doors is about 3–5%, which is significant. These heat losses include radiation loss through openings and furnace surface, as well heat loss due to damaged/poor internal insulation. Reduction in radiation heat loss from furnace surface can be achieved by improving the insulation. This includes covering of internal wall surface with ceramic fibre insulation and external wall surface with ceramic fibre or rock wool insulation. The potential energy savings for insulating a reheating furnace were estimated to range from 2–5% of thermal energy savings.

# Wire Industries

# Background

There are about 12 wire industries in the Durgapur cluster. These industries use wire rod manufactured by the local secondary steel industries to draw wires of various sizes/grades. The end product of wire industries is used as binding wires in construction and to make mesh, nails, and similar products.

# Production

Wire drawing is a metal working process to reduce the cross section of a wire to smaller sizes by pulling through a single or a series of drawing dies. The products are mostly market driven in terms of size, but some products are also customized to meet specific demand. The products of the wire drawing units include hard bright wire[7] (HB wire), barbed wire[8], binding wires, etc., to serve specific applications. The production capacity of the units varies widely, from 2,000 to 15,000 tpa. The estimated production of the cluster is around 110,250 tpa (Table 16).

**Table 16:** Categorization of SRRM industries and estimated production

| Capacity (tpa) | Number of plants | Annual production (tpa) |
|---|---|---|
| 2,000–8,000 | 9 | 67,500 |
| 8,000–15,000 | 3 | 42,750 |
| Total | 12 | 110,250 |

# Manufacturing Process

Wire drawing is a cold working process, wherein the cross section of the wire is uniformly reduced to smaller sizes by pulling through a single or a series of drawing dies. The base material is uncoiled, cleaned, and descaled before further processing. The wire is put through dies of various sizes that are placed in a series; the drawn wire is guided to the following dies with the help of a pulley or spools. The sets of coiler drums are driven by electric motors. The spool feeds the wire into the drawing die with the help of a lubricant in dry or liquid form. The spool assembly is mounted directly on the shaft of an induction motor, which provides the required force to pull the wire drawn after size reduction. The drawn wire is dipped in a protective solution (from weathering) before coiling of the wire. The manufacturing process of wire drawing and wire galvanizing is described in Figure 21.

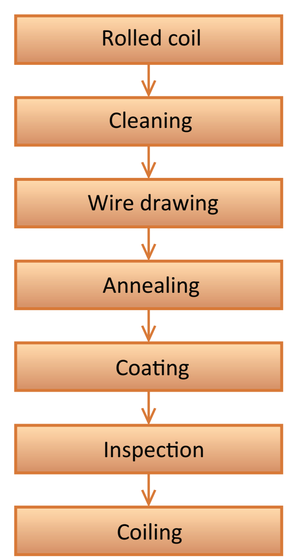


**Figure 21:** Process flow of wire drawing

## Galvanizing

Galvanizing is a process commonly used in wire industries to protect steel wires from corrosion. The process involves applying a protective zinc coating

7 Hard bright wire (HB wire) is a high-quality alloy steel wire. It is used in many industries to make fasteners, bearings, and other components that need to be strong and durable.

8 Barbed wire is a type of steel fencing wire constructed with sharp edges or points arranged at intervals along the stands.

to the surface of the steel wire, creating a barrier that helps prevent rust and corrosion. The wire is dipped in the solution bath. The process typically consist of degreasing, pickling, fluxing, and dipping in zinc bath apart from rinsing prior to some of the steps and final quenching.

# Technology Used

Mainly, annealing furnace for wire drawing and zinc bath for galvanizing are used in the process.

## Annealing furnace

Annealing furnace is a stress relieving system to remove the induced stresses in the drawn wire and improve its mechanical strength. These are either furnace oil (FO) fired or electrically heated, where the drawn wire is kept for some duration. The temperature inside the furnace is maintained in the range of 700–900°C, depending on the type of wire. A typical annealing furnace is shown in Figure 22.

**Figure 22:** : Annealing Furnace

## Zinc bath

The furnace oil (FO) fired zinc bath is commonly used by galvanizing units. The FO is heated by electrical heaters to improve its fluidity, before pumping to burning. The temperature of the zinc bath is maintained around 440–470°C.

# Energy Consumption and GHG Emissions

The major energy resources for the units are electricity and furnace oil. Specific energy consumption both electrical and thermal energy per ton of product for galvanizing and wire drawing units are provided in Table 17.

**Table 17:** SEC of galvanizing and wire drawing industries

| Industry type | SEC | | |
|---|---|---|---|
| | FO consumption (kg/t) | Thermal (Gcal/t) | Electrical (kWh/t) |
| Galvanizing | 30 | 0.3 | 10–15 |
| Wiredrawing | 8 | 0.08 | 200–240 |

## Cluster level energy consumption and GHG emissions

The total energy consumption of the wire industry in the cluster is estimated to be 15,382 toe/annum. The equivalent annual GHG emissions are estimated to be around 57,468 $tCO_2$. (Table 18).

**Table 18:** Energy consumption of wire industries of the Durgapur cluster

| Energy type | Annual consumption | Equivalent energy (toe) | GHG emissions ($tCO_2$) |
|---|---|---|---|
| FO | 0.01 Mt | 13,296 | 38,306 |
| Electricity | 24.26 MU | 2,086 | 19,161 |
| Total | | 15,382 | 57,468 |

# Energy Saving Opportunities

The potential energy saving measures for wire industries are mentioned below.

## Replace FO fired annealing with electric heating in wire drawing

Annealing furnace is used to improve the strength of the wire and consumes a significant amount of fuel. Replacing an FO fired furnace with electrical heating will reduce the carbon emissions and provide uniform heating, along with a clean working environment.

## Use of energy efficient motors

Most of the motors used in wire drawing machines are of old standard and rewound more than two times. These motors consume more power than energy efficient (EE) motors. There is significant potential for energy savings by replacing the standard efficiency motors with energy efficient IE3/IE4 motors. Depending on the operating period of the machine, payback period for the EE motors can vary between 1 to 3 years. Energy savings of 3–5% can be achieved by replacing the existing standard efficiency motors.

# Iron Melting Industries (Foundries)

## Background

There are around 20 iron melting industries (foundries) in the cluster. Products manufactured by these industries include grey iron castings for railways, engineering, and other construction sectors, as well as ductile iron (DI) castings and pipes.

## Production

The estimated production of the foundry units in the cluster is around 141,600 tpa (Table 19).

**Table 19:** Production of foundry industries in the cluster

| Industry type | Number of industries | Annual production (tpa) |
|---|---|---|
| Foundry | 20 | 141,600 |
| Total | | 141,600 |

## Manufacturing Process

The primary process steps include mould preparation, melting, pouring, knockout, and finishing operations (Figure 23). The melting process accounts for major energy consumption in the foundry, mostly in the form of electrical energy used in induction furnaces.

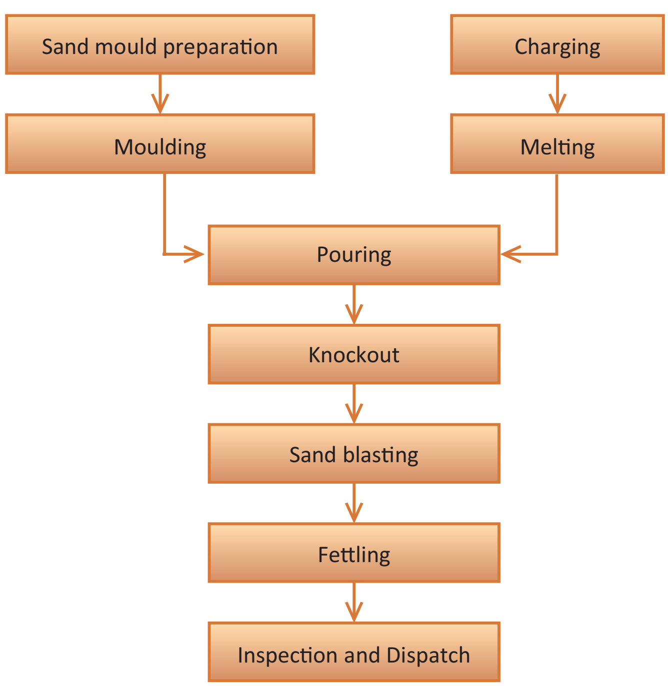


**Figure 23:** Foundry production process

### Sand preparation

Green sand is prepared by mixing fresh sand and binders, such as bentonite, coal dust, water, and other additives in mixers.

## Mould preparation

The mould comprises of two halves, i.e., cope (top half) and drag (bottom half). The mould cavity is formed by packing sand around the pattern, which is a replica of the external shape of the desired casting. Moulds are prepared either manually or using moulding machines.

## Melting

The charged material is melted in an induction furnace. Depending upon product chemistry, a batch is prepared comprising of pig iron, metal scrap and foundry return, alloys etc., which is charged manually. The typical temperature of molten metal for grey iron is about 1400°C. Depending on the melting system employed, the molten metal is poured either intermittently or continuously into sand moulds. Pouring may be done either manually or using a semi/automatic pouring system.

## Casting

The poured molten metal takes the shape of the mould. The cast product is shot blasted after demoulding and carried forward to other downstream finishing processes.

# Energy Consumption and GHG Emissions

Foundry mainly uses induction furnace for melting. Coal or natural gas is used in heat treatment furnaces in some units. The specific energy consumption of the foundry is in range between 550–650 kWh/tonne.

## Cluster level energy consumption and GHG emissions

The total energy consumption of the foundry industry in the Durgapur cluster is estimated to be 16,254 toe/annum. The equivalent annual GHG emissions are estimated to be around 81,891 $tCO_2$ (Table 20).

**Table 20:** Energy consumption of the cluster

| Energy type | Annual Consumption | Equivalent energy (toe) | GHG emissions ($tCO_2$) |
|---|---|---|---|
| Coal | 0.012 Mt | 6,000 | 21,792 |
| Electricity | 64.294 MU | 5,529 | 50,792 |
| Natural Gas | 5.4 million SCM | 4,725 | 9,307 |
| Total | | 16,254 | 81,891 |

# Energy Saving Opportunities

The major energy saving opportunities among foundry units in the cluster are summarized below.

## Replacing inefficient induction furnaces with IGBT induction furnace

Older induction furnaces operating in the cluster have an SEC level of 750 kWh or more per tonne of molten metal. These inefficient furnaces can be replaced with IGBT (Insulated Gate Bipolar Transistor) furnaces. With IGBT furnaces, an SEC level of about 550 kWh per tonne of molten metal can be achieved. The other advantages of an energy efficient 24-pulse IGBT furnace include higher power factor (~0.97) and lower total harmonic distortion in current.

## Lid mechanism for induction furnace

Most of the induction furnaces operating in the cluster do not have any lid mechanism, resulting in higher heat losses due to radiation and convection. About 6–8% of energy input is lost through radiation and convection losses due to absence of a lid mechanism. A lid mechanism helps in reducing these losses and the payback period for investment on a lid mechanism is less than a year.

## Replacement of rewound motors

Motor burn-out is not a rare phenomenon in foundries; this is a result of number of factors including power quality, overloading, etc. Rewinding of motors is the cheapest solution followed by foundrymen, but it results in a drop in the efficiency of the motor by 3–5%. It is better to replace old motors that have undergone rewinding two or more times. The old rewound motors may be replaced with energy efficient motors (IE3/IE4 efficiency class). This would result into significant energy savings, with simple payback period of 2–3 years.

## Replacing old inefficient compressors with energy efficient compressors

Plants use old inefficient compressors (more than 15 years old) which consume high power for delivering compressed air, i.e., the specific power consumption of these compressors (kW/cfm) is high. Old compressors should be replaced with new energy efficient permanent magnet synchronous motor (PMSM) compressors that deliver a high performance and run on a low specific power consumption.


# Industry Associations

Industry associations are one of the key stakeholders in the cluster, facilitating networking and addressing pertinent issues of the industries. These associations facilitate knowledge sharing among the member industries by organizing events such as workshops, training programs, and so on. Some of the major industry associations and government departments, such as District Industries Centre, in the cluster are given in Table 21.

**Table 21:** Key stakeholders in the cluster

| Institution/organization | Contact address |
|---|---|
| Durgapur Chamber of Commerce and Industries | Nachan Road, Benachity, Durgapur, West Bengal 713213 |
| West Bengal Sponge Iron Manufacturers Association | Industrial Area, Durgapur, West Bengal 713215 |
| District Industries Centre, Durgapur | 3rd Administrative Building, City Centre, Durgapur, West Bengal 713216 |
| Durgapur Small Industries Association | Dr Zakir Hussain Avenue, Durgapur 713205 |
| Bamunara Steel Association | Bamunara, Durgapur |
| Raniganj Chamber of Commerce and Industries | Govind Ram, BP Khaitan Rd, Burns Plot, Raniganj, West Bengal 713347 |
| Asansol Chamber of Commerce | 54, Chamber Bhawan, GT Road East, Murgasol, Asansol, West Bengal 713303 |
| Jamuria Industries Association | Ikra, Jamuria Industrial Estate, West Bengal |

# NOTES

# NOTES