SITUATION ANALYSIS

RAIPUR SECONDARY STEEL CLUSTER

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

Promoting Energy Efficiency in SMEs
SAMEEEKSHA

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ABBREVIATIONS

BEE	Bureau of Energy Efficiency
BF	Blast Furnace
BOF	Basic Oxygen Furnace
CCCI	Chhattisgarh Chamber of Commerce and Industries
CCM	Continuous Casting Machine
CF	Cupola Furnace
CFAPA	Chhattisgarh Ferro Alloy Plant Association
CGMSP	Chhattisgarh Mini Steel Plant Association
CGSIMA	Chhattisgarh Sponge Iron Manufacturers Association
CGSRA	Chhattisgarh Steel Re-rollers Association
CI	Cast Iron
CISAA	Chhattisgarh Iron and Steel Agent Association
CO	Carbon Monoxide
CO2	Carbon Dioxide
CR	Cold Rolled
CREDA	Chhattisgarh State Renewable Energy Development Agency
CSIDC	Chhattisgarh State Industrial Development Corporation
CSIDC	Chhattisgarh State Industry Development Centre
CTD	Cold Twisted Deformed
CV	Calorific Value
CWIA	Chhattisgarh Wire Industries Association
DC	Designated Consumer
DCMSME	Development Commissioner Ministry of Micro, Small and Medium Enterprises
DIC	District Industry Centre
DIPM	District Investment Promotion Committees
DRI	Direct Reduced Iron

DTIC	District Trade and Industries Centre
EAF	Electric Arc Furnace
EBT	Eccentric Bottom Tapping
EC	Energy Conservation
EIF	Electric Induction Furnace
ESP	Electrostatic Precipitator
Fe	Iron
FO	Furnace Oil
GCV	Gross Calorific Value
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GJ	Giga Joule
HB	Hard Bright
HF	Heating Furnace
hp	Horsepower
HR	Hot Rolled
ID	Induced Draft
IE3	Premium Efficiency
IF	Induction Furnace
IFAPA	Indian Ferro Alloys Producers Association
IGBT	Insulated Gate Bipolar Transistor
JPC	Joint Plant Committee
kCal	Kilocalorie
kW	Kilowatt
kWh	Kilowatt -hour
MoSPI	Ministry of Statistics and Programme Implementation
MS	Mild Steel
MSME	Micro, Small and Medium Enterprises
MSMEDI	'Micro Small and Medium Enterprises Development Institute

Mtoe	Million Tonne of Oil Equivalent
MW	Megawatt
MWH	Megawatt-hour
NIC	National Industrial Classification
PAT	Perform, Achieve and Trade
PI	Pig Iron
PLC	Programmable Logic Controller
RHF	Re-heating Furnace
RM	Rolling Mill
SA	Standalone
SAF	Submerged Arc Furnace
SAMEEEKSHA	Small and Medium Enterprises Energy Efficiency Knowledge Sharing
SCR	Silicon Controlled Rectifier
SDA	State Designated Agencies
SEC	Specific Energy Consumption
SI	Sponge Iron
SMS	Steel Melting Shop
SRRM	Steel Re-rolling Mill
SS	Stainless Steel
TERI	The Energy and Resources Institute
TMT	Thermo Mechanically Treated
toe	Tonne of Oil Equivalent
TPD	Tonne Per Day
TPH	Tonne Per Hour
UIA	Urla Industries Association
UNEP	United Nations Environment Programme
VFD	Variable Frequency Drive
WHR	Waste Heat Recovery
WI	Wire Industry

1 BACKGROUND

Raipur, the capital city of Chhattisgarh state is a major commercial hub for trade and commerce in eastern region of India. The neighbouring districts of Raipur include Bilaspur, Bastar, Raigarh and Durg. The area is abundantly rich with large deposit of natural resources like coal, iron ore, limestone and other mineral ores. It is one of the largest clusters of MSMEs (micro, small and medium enterprises) and one of the biggest markets of iron and secondary steel products in the country. The main secondary steel industries of the district include DRI, Pellet and Ferro alloys that uses ores and minerals to produce end products, steel melting shop using pre-processed and recycled solid feed stock to produce steel castings and processing of casted steel in steel re-rolling and wire industries. (Figure 1). Most of these industries[1] are located in the well-established industrial estate of Urla and Siltara including its surrounding localities of Rawabhatha, Tatibandh, Sarola, Bagoli, Bhanpuri, Gaugaon and Tendua (Figure 2).

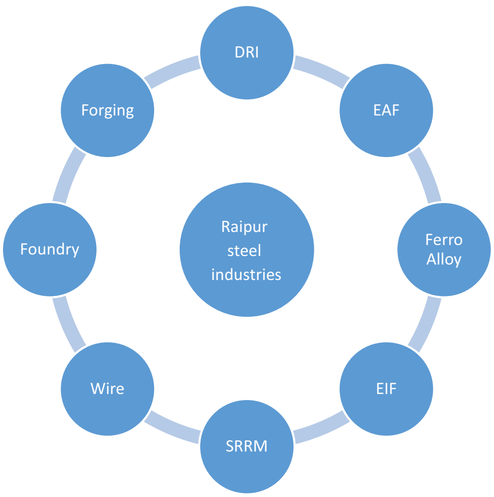

Figure 1: Types of steel industries in Raipur

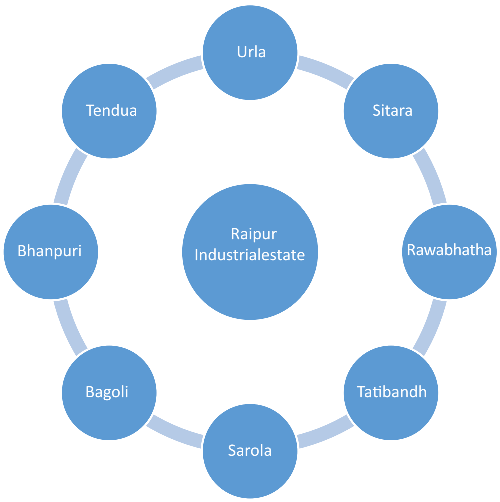

Figure 2: Industrial estate of Raipur cluster

Industry and technology details

There are more than 1200 mineral and metal based registered MSME industries[2] in Raipur and its surrounding areas; of these, about 140 industries belong to medium and large categories. The details of different types of industries in the Raipur cluster are provided in Table 1.

1 Source:- Website of CSIDC, Raipur.

2 Source: DIC and DCMSME , Raipur

Table 1: Details of steel industries & in Raipur cluster

Type	Mixed@ total	DC$	No details	Non DC	Composite#	Stand alone	Actual number
DRI	69	25	24	20	27	18	69
EAF	1	1	0	0	1	0	1
EIF	102	19	27	56	55	20	75
SRRM	128	13	0	115	55	73	73
FERRO	21	3	0	18	0	21	21
WI	111	0	0	111	6	105	105
Other	35	0	0	35	0	35	35
Total	467	61	51	355	144	272	379

DC Designated consumer

& Raipur has 19 integrated secondary steel plants

@ represents the sum of absolute industries that falls under the row of specific type of industry

$ total DC industries in Raipur cluster is 25 as per JPC report. All DCs are from DRI industries but there are another DCs which are not listed in JPC report.

 # industry type under the row has also integrated backward and forward process steps within the same premises

The composite steel industries are associated with multiple industry association bodies. Based on the directory published by cluster level stakeholders including government departments indicate that the total number of actual secondary steel industries in the Raipur cluster is close to 380. The details of a category-wise industries are shown in Figure 3.

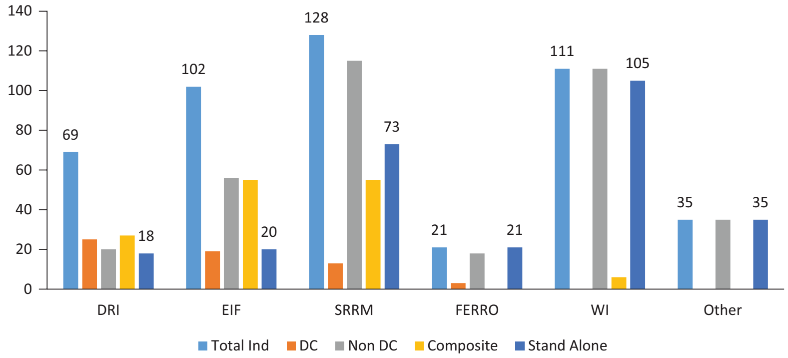

Figure 3: Details of Raipur steel industries

The share of energy intensive secondary steel industries in Raipur cluster is estimated to be 85% mainly accounted by EIF, SRRM and DRI industries (total: 78%) as shown in Figure 4.

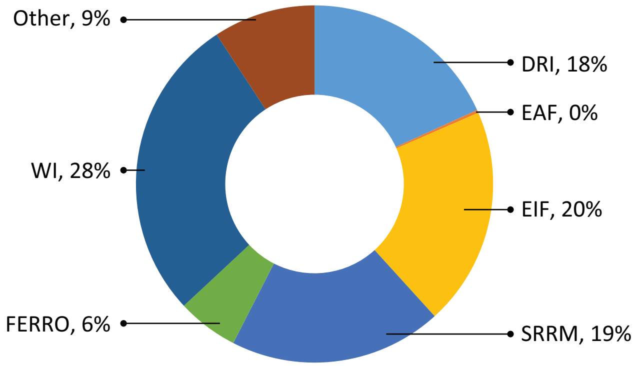

Figure 4: Share of primary steel industries

Most of the secondary steel industries in Raipur cluster use technologies which are inefficient; however, a few large DCs use state of the art technologies (Table 2).

Table 2: Technology, energy and raw material use in Raipur secondary steel industries

Technology	User industry	Raw material	Process step	Energy used	End product
Rotary kiln	DRI	Iron ore	Heating and reduction	Coal,electricity	Sponge iron
Submerged arch Furnace	Ferro alloy	Mineral ore	Heating and reduction	Coal, electricity	Alloys
Electric induction Furnace	SMS	Sponge iron, scrap	Steel melting	Electricity	Ingots and billets
Re-heating furnace	SRRM	Ingots and billets	Heating	Coal	Heated feed stock for milling
Continuous casting machine	SRRM	Liquid metal	Casting	Electricity	Hot billets for milling
Rolling mill	SRRM	Hot ingots and billets	Rolling	Electricity	Rolled products

Technology	User industry	Raw material	Process step	Energy used	End product
Wire drawing machine	Wire Industry	Coiled wire	Drawing	Electricity	Drawn wire
Annealing furnace	Wire industry	Drawn wire	Annealing	Furnace oil, electricity	Annealed wire
Coating bath	Galvanizing industry	Drawn wire	Galvanizing	Furnace oil, electricity	Galvanized wire

The raw material flow chain from mines to finished products within the steel industries in Raipur cluster is depicted in Figure 5.

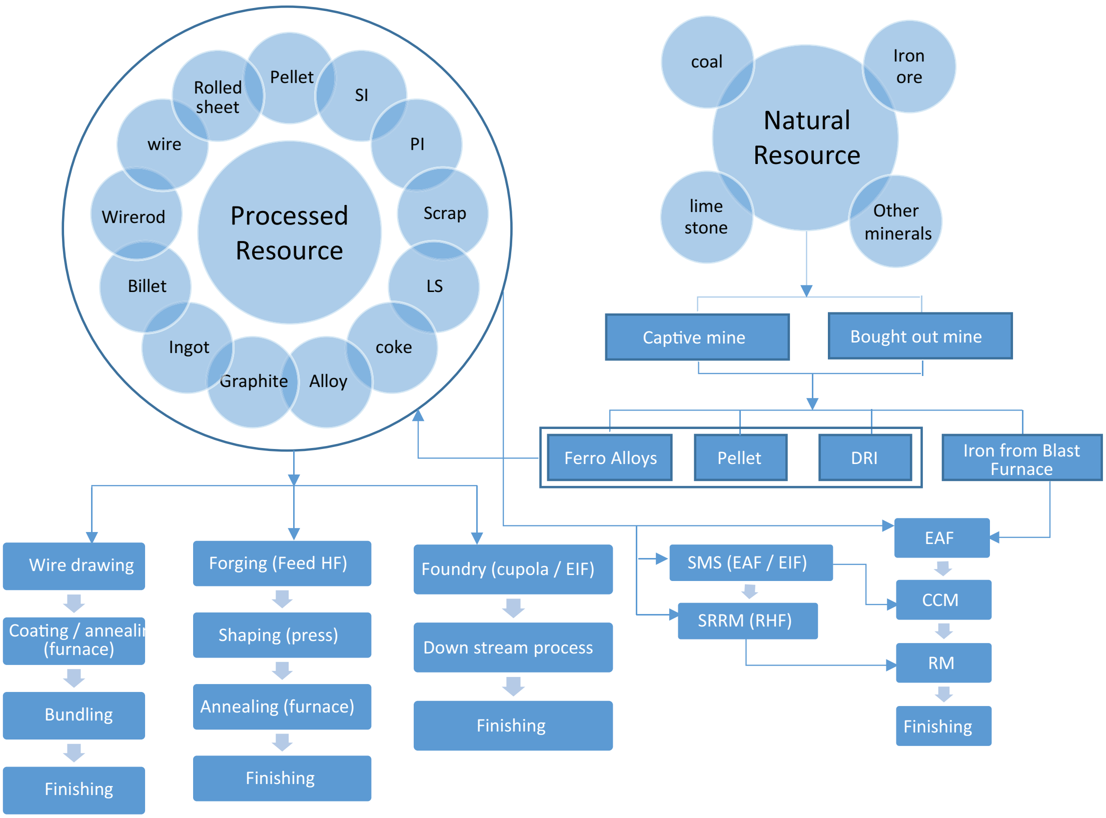

Figure 5: Material flow chain in Raipur steel industries

Major products from Raipur cluster

The products manufactured in secondary steel industries in the Raipur cluster cover a wide range of end-use sectors such as industries, domestic, construction sectors, municipality, medical and academic institutions (Figure 6).

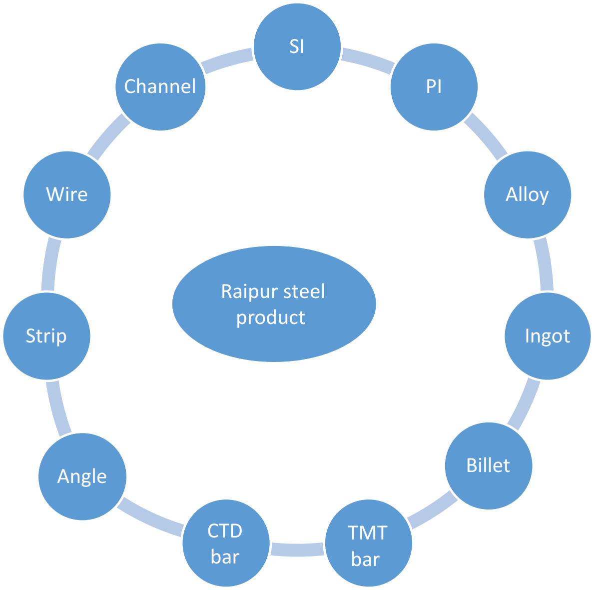

Figure 6: Primary products from Raipur secondary steel cluster

The National Informatics Codes (NIC codes) [3] for basic iron and steel products are mentioned in Division 24 (NIC-2008) and Division 27 (NIC-2004) of National Industrial Classification. The NIC - 2008 is the revised version of NIC-2004. Some of the primary products of steel industries and their NIC code is provided in Table 3.

Table 3: NIC codes of primary steel products

Product	NIC code
Pig iron	24101/27130
DRI / sponge iron	24102/27102
Re-Rolled Products & MS ingot	24103/27104

3 Source: National Industrial Classification - 2008 (NIC-2008), published on 17 April 2009 https://www.ncs.gov.in/Documents/NIC_Sector.pdf

Product	NIC code
Ferro Alloy	24104/27101
HR and CR Steel products	24105
Tube and tube fittings of basic iron and steel	24106
Railway track materials (unassembled rails) of steel	24107
Wire of steel by cold drawing or stretching	24108
Pipes and Tubes Steel	27105
MS Round Bars, TMT Bars	27106
MS Ingot and finished products	27141
Ingots Molds	27310
Forged Rolls, Softs	28910
CI casting	29249
Processing of scrap	37100
SS wires	28999
MS HB Wire	27181
MS wire	27182
Wire coated With Zinc	4126399/4126306
4294601	
Iron Granules powder	269343
U Bolt, nuts & bolts	28991

Criteria for selection of industries

The major criteria considered for selection of secondary steel industries in Raipur cluster include the following.

(i) The steel industries in the cluster belong to both backward and downstream processes of secondary steel sector

(ii) The cumulative number of industries under each category is high, which will have significant effect on cumulative energy consumption and corresponding GHG emissions from the sector

(iii) Studies conducted in similar type of industries in the country suggest that there is a significant energy saving potential in these industries

(iv) The technology options which will be identified will have high replication effects not only within the cluster but across similar secondary steel industries in India.

2
DRI INDUSTRY

Background

There are about 69 DRI [1] industries in Raipur secondary steel cluster, out of these 45 industries are reported to be in operation. Around 27 DRI manufacturing plants are composite in nature with integrated secondary steel manufacturing facilities. Some of the DRI plants in Raipur cluster are stand alone with or without captive power plant (CPP). As per the JPC report 2019, 25 large capacity DRI industries are designated consumers (DCs) under BEE's perform, achieve and trade (PAT) schemes. Figure 7 shows distribution of DRI industries in Raipur cluster.

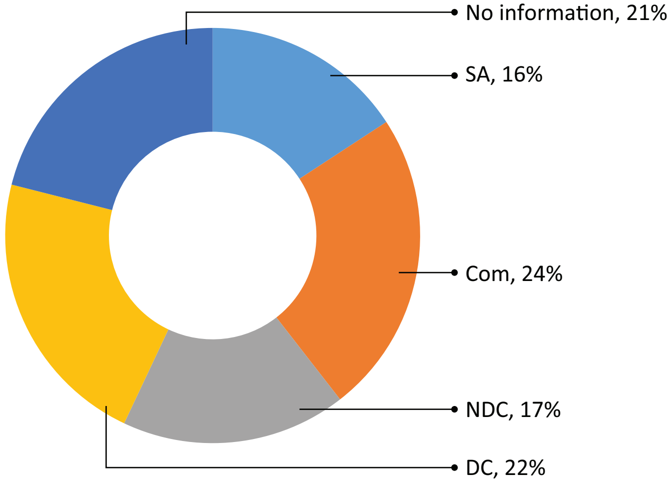

Figure 7: Distribution of units (status)

About 47% of the units are large category, while 31% of the units are of medium size (Figure 8). The primary products manufactured in the cluster are sponge iron, finished steel products such as angle, channel and bars (TMT, CMD and wire rod, etc.). DRI industries in Raipur cluster provide direct or indirect employment for more than 15,000 people.

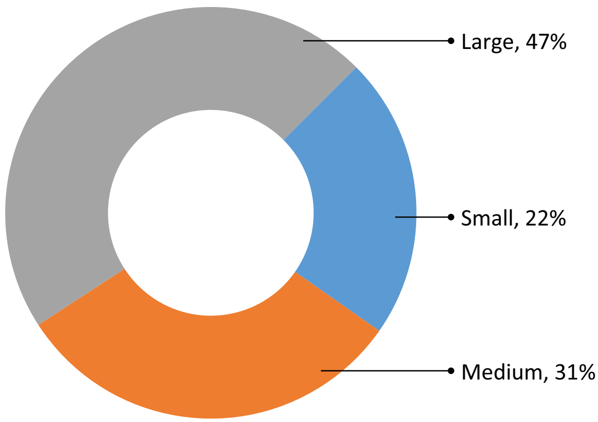

Figure 8: Distribution of units (capacity)

1 JPC report, GIZ report, SIMA-Chhattisgarh chapter, 3rd edition of member directory 2018 of Chhattisgarh Iron and Steel Agent Association

Production

Based on type of products, the DRI manufacturing units can be grouped into (i) standalone that manufactures sponge iron, and (ii) composite or integrated plant, which produces not only DRI but it has extended forward stream of process to manufacture finished steel products. Integrated manufacturing units account for about 60% of total operating DRI units (Figure 9). Around 56% DRI industries are categorised as designated consumers under the PAT scheme of BEE, as their gate-to-gate total energy consumption exceeds the threshold limit of steei[2] sector (more than 20,000 toe/year). A category-wise distribution of DRI industries is shown in Figure 10.

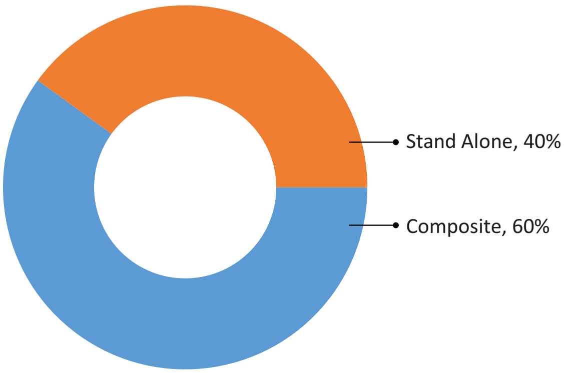

Figure 9: Distribution of units (Plant-wise)

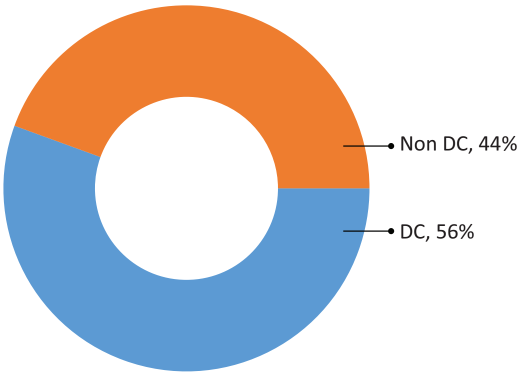

Figure 10: Distribution of units (Category-wise)

The total sponge iron (SI) production in Raipur cluster is estimated to be around 4.82 million tonne per year (Table 4).

Table 4: Annual production of Raipur DRI industries

Industry category	Number of plants	Capacity (tonne/day)	Production (million tonne per year)
Small	10	50-150	0.23
Medium	14	200-250	0.74
Large	21	300-2000	3.85
Total	45		4.82

2 Source PAT-cycle, revised threshold limit for DC under steel sector 2019

Large DRI plants mainly DCs account for about 80% share of the total sponge iron production in Raipur cluster (Figure 11).

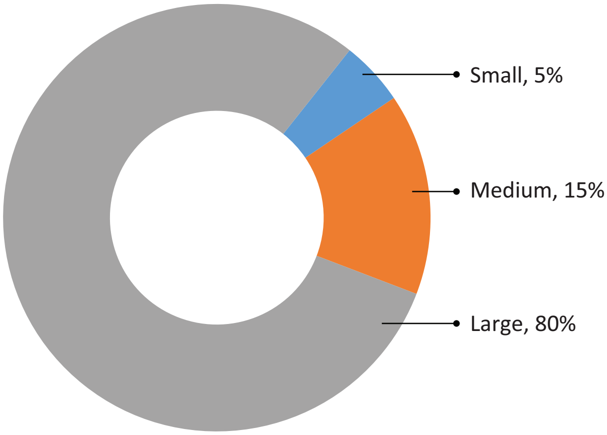

Figure 11: Share of DRI production in Raipur cluster

Manufacturing process

The production of sponge iron is a reduction of iron ore in solid state at temperature below the melting point of iron. The carbon-bearing non-coking coal is used as a source of heat for preheating the iron ore and reducing agent carbon monoxide to complete reduction process. The reduced iron ore in liquid form is cooled to solid state, which is known as 'direct reduced iron (DRI)'. The DRI is also termed 'sponge iron' due to its spongy honeycomb like texture while viewed in microscope. The DRI manufacturing primarily includes (i) reduction of iron ore, (ii) cooling of hot sponge iron, and (iii) separation and screening.

Reduction of iron ore

The raw materials comprising iron ore and part of sized coal is supplied from feed end of the inclined rotary kiln. The feed input is gradually heated up while moving from pre-heating zone to reduction zone by the counter flow hot gases. In the pre-heating zone, initially the moisture is removed before temperature reaches to reducing reaction point. In the reduction zone of the kiln, the oxygen in iron ore is removed, forming carbon monoxide (CO) leaving the metallic iron. The part of coal is pulverized and injected through the exit end of the rotary kiln. The injected coal completes the reaction process. A temperature of about 900-1050 °C is maintained in the kiln. Higher the temperature, faster would be the oxygen removal. The critical factor in the reduction of iron is formation of carbon monoxide through controlled combustion of fuel. The optimum batch cycle for the process is 8 -10 hours.

Cooling of sponge iron

On completion of metallization through reduction process, the mixture of sponge iron and residual charge are transferred to a rotary cooler through a belt conveyor at about 250 °C before the hot product comes in contact with ambient air. The sponge iron at more than 250 °C would tend to oxidise using oxygen of ambient air. The sponge iron is further cooled down to about 100 °C through indirect cooling in rotary cooler.

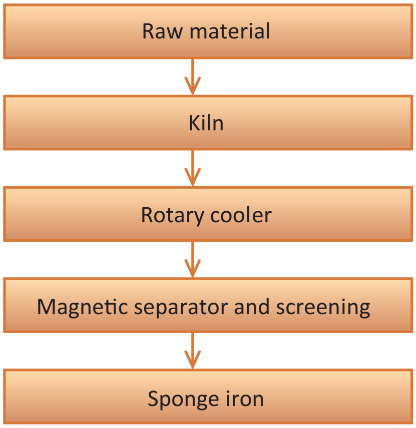

Figure 12: Sponge iron production process

Separation and screening

The solid discharge from the rotary cooler is the mixture of sponge iron and dola char. It is passed through an electromagnetic separator to separate sponge iron from char and other impurities. The separated sponge iron grains are screened in series to different size fraction to separate lumps and fines for storage and dispatch. The generic process flow chart for DRI manufacturing is shown in Figure 12.

Technology use

The broad schematic layout [3] of technologies used in DRI manufacturing process are shown in Figure 13.

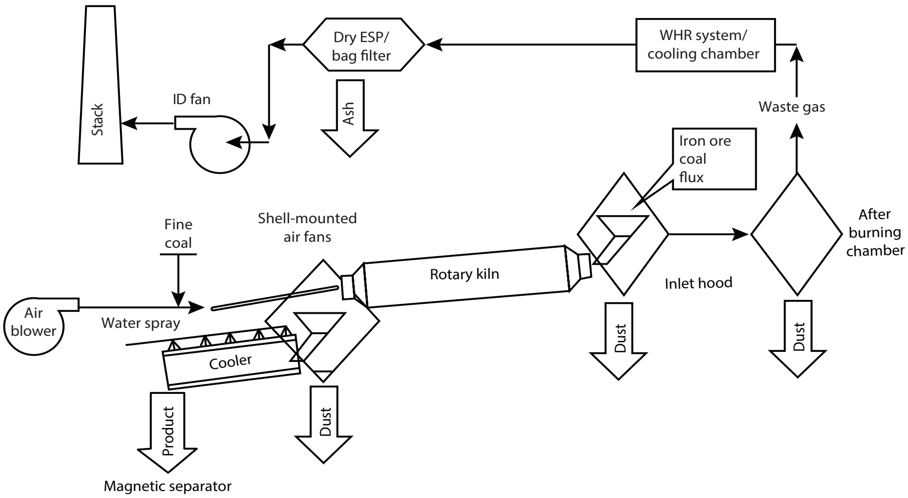

Figure 13: Schematic layout of technologies in DRI process

3 Source: http://www.iipinetwork.org/wp-content/letd/content/direct-reduced-iron.html

The technology description pertaining to DRI manufacturing process is limited to coal based rotary kiln, which is the main technology used in Raipur cluster.

Rotary kiln

Raipur cluster uses horizontal rotary kiln in the production process (Figure 14). The kiln is provided with an inside refractory lining of 150–200 mm to protect the shell and has a slope of 2.5% to 3.0% towards the discharge end. The combustion air requirement for the feed is provided by air blowers along the length of the heating zone. The major raw materials used in sponge iron production include iron ore (Hematite - Fe_2O_3), non-coking coal and limestone/ dolomite. Hematite, rich in iron content of 65% or more is preferred in sponge iron plants. Iron ore can be used in the form of lumps and pellets.

Figure 14: Pictorial view of rotary kiln in DRI plant

The iron ore and non-coking coal are reduced to the required size in crushers. Iron ore, coal, and dolomite of required proportion are fed into the kiln continuously from feed end using weigh feeders. The raw materials move along the length of the kiln with the pre-set rotation. The secondary air is blown into the kiln through air pipes located along the kiln length. The temperatures of different heating zones are measured and controlled using thermocouples mounted across the length of the kiln. Fine coal is injected at the discharge end of the kiln to meet additional carbon requirements for the reactions.

As the charge moves along the kiln length, it gradually picks up heat from the hot gases flowing in the opposite direction of the charge. The preheating zone accounts for about 30% of the kiln length, wherein both moisture and volatile matter presence in feed mixture are removed. The heat required in preheating zone is provided by combustion of part of coal.

The section of rotary kiln after preheating zone is called 'reduction zone'. Here, the oxygen present in the iron ore dissociates and oxidizes reducing carbon element in non-coking coal to form carbon monoxide, leaving the metallic iron. The rotation of the kiln and its slope ensure better mixing and movement of charge towards discharge end of the kiln at the required rate.

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 (product) $+ CO_2$

A temperature of about 900–1050 °C is maintained in the reduction zone. Higher the temperature, faster would be the oxygen removal from hematite. The reduction of iron ore occurs in solid state with the critical factor being 'controlled combustion of coal' towards formation of carbon monoxide. The residence time for iron ore inside the kiln is about 8–10 hours to form metallic iron. The quality of metallization is assessed with the density of sponge iron and the metallic luster.

Energy consumption and GHG emissions

The major energy resources for the DRI industries are non-coking coal. The other energy forms used include either electricity (grid or captive power from WHR system). Specific energy consumption for different process areas of integrated DRI industries are provided covering both thermal and electrical separately in the Table 5.

Table 5: SEC of process areas of integrated DRI industries

Energy cons area	SEC	
(-)	Thermal$ (GCal/tonne)	(kWh/tonne)
Rotary kiln	6	80
Steel melting shop - EIF	-	850
Continuous casting machine (CCM)	-	100
Re-heating furnace (SRF)	0.5	5
Rolling mill (RM)	-	80
Others	-	50

$ - coal heating value considered is 5000 kCal/kg

Cluster level energy consumption and GHG emissions

The total energy consumption of Raipur DRI industry cluster is estimated to be 3.4 million tonne of oil equivalent (mtoe) per year. The equivalent GHG emissions are estimated to be around 16 million tonne of CO_2 (Table 6).

Table 6: Energy consumption and GHG emissions of DRI industries in Raipur cluster

E nergy type	Unit	Annual consumption	Equivalent energy (million toe)	GHG emissions (million t - CO_2)
Coal	million tonne/year	5.9	2.9	11.8
Electricity	million kWh/year	5,314	0.5	4.2
Total			3.4	16

The annual non-coking coal consumption accounts for 85% of total energy consumption in the cluster (Figure 15). About 74% of GHG emissions are accounted by the consumption of non-coking coal (Figure 16).

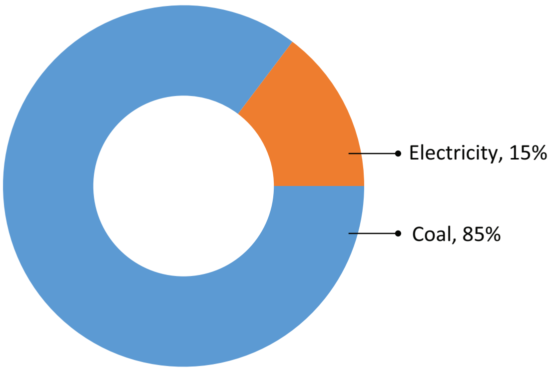

Figure 15: Share of energy consumption

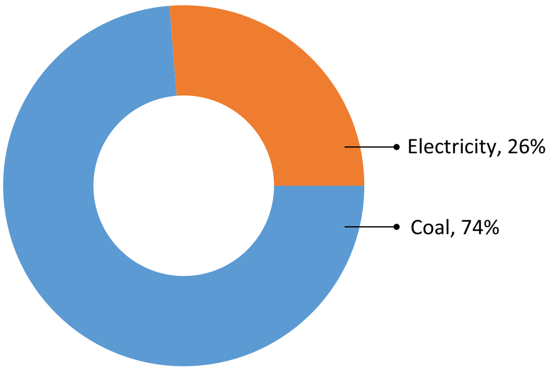

Figure 16: Share of GHG emissions

Energy saving options

Various energy losses occurring in coal-based rotary kilns clearly indicate that there is a significant scope for reducing SEC level and improving energy efficiency. Waste heat in off-gases in rotary kiln forms the major share of heat losses. Thus, waste heat recovery (WHR) has been identified as one of the major options towards maximizing the utilization of heat energy in a DRI plant. Apart from WHR, there are a number of energy-efficiency measures applicable for rotary kiln and associated auxiliaries to improve overall performance of DRI production. The potential energy saving opportunities for Raipur DRI industries are mentioned below.

- Waste heat recovery (WHR) system for (i) captive power generation, and/or (rotary kiln based iron ore preheating)
- Coal gasification for partial substitution in rotary kiln
- Switch over to iron ore pellets
- Mullite based kiln lining
- Decentralized VFDs for shell air fans
- DRI production using gas route e.g. natural gas, hydrogen, etc.

Other important energy saving measures include (i) variable frequency drives for air compressors, (ii) arresting compressed air leakages, (iii) reduction of pressure setting in air compressor, and (iv) Installation of energy efficient motors and multistage centrifugal pumps.

3
FERRO ALLOY INDUSTRY

Background

There are about 21 ferro alloy [1] manufacturing industries in Raipur secondary steel cluster; of these 10 industries are reported to be in operation. A few ferro alloy plants have waste heat recovery based captive power generation system. About 70% of the units are medium category, while the balance 30% are of small size (Figure 17). Some of the ferro alloy products manufactured in the cluster include ferro manganese, silicon manganese, ferro silicon, chrome alloys, etc.

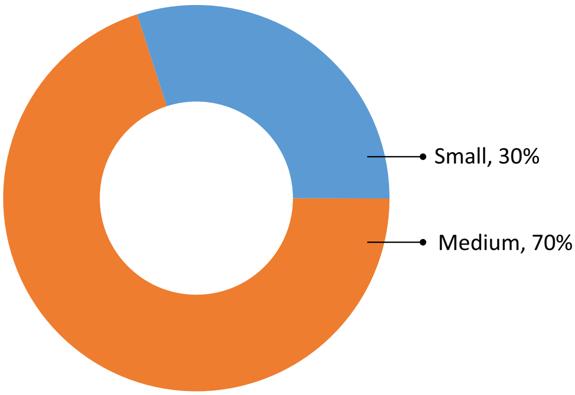

Figure 17 Distribution of units (capacity)

Production

The annual ferro alloy production in Raipur cluster is estimated to be around 185,280 tonne per year. The cluster level product is estimated to be less than 4% in comparison with annual national[2] production of 5.15 million tonne per year (Table 7).

Table 7: Production of Ferro alloy in Raipur cluster

Industry category	Number of plant	Capacity (tonne/year)	Production (tonne per year)
Small	3	3,000-5,000	10,160
Medium	7	12,000 - 60,000	175,120
Total	10		185,280

1 Source: https://uia.org.in/urla-industries-members/directory/ Indian Minerals Yearbook 2019, (Part- II : Metals & Alloys), 58th Edition Indian Ferro Alloys Producers' Association (IFAPA) DIC Raipur

2 Source: http://www.ifapaindia.org/

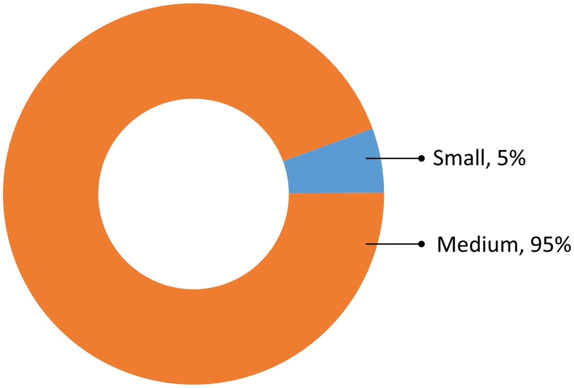

Figure 18: Break-up of Ferro alloy production in Raipur cluster

The medium size plant accounts for 95% share of the total production in Raipur cluster (Figure 18)

Manufacturing of Ferro alloy

The production process of ferro alloys involves reduction of quartz with the help of carboneous reductant in presence of alloy bearing iron ore at a very high temperature. The energy supplied for the reaction comprises electricity from three carbon electrodes and chemical energy released by carbon rich materials. Large electrode shafts are provided for the arcing at the hearth of the furnace generating temperature over 2000 °C. Liquid alloying element is produced at this stage due to reaction with carboneous feed charge material; the reaction produces CO and the mono oxides of alloying element. The liquid alloying element further reacts with iron to produce ferro alloy as shown in the following reactions.

$$XO_2 + C \longrightarrow X + CO + XO$$
$$Fe + X \longrightarrow FeX$$

In the above, ferro alloy (FeX) is an alloy of X and iron. The alloy is mainly used as a deoxidant and an alloying element in the production of steel and cast iron. Use of ferro alloy in steel imparts desired machinability properties while increasing strength, hardness, temperature and corrosion resistance of the base material. The raw materials in ferro alloy process include alloy bearing oxide, iron ore, quartz and carbonaceous reductant. The carbon reductant could be mixed of various grade of coal, charcoal and coke. The shares of different feed raw materials including carbon feed depends on the target product line.

Figure 19: Ferro silicon

Three electrodes in submerged arc furnace (SAF) heat the feed material. Ferro alloy, in liquid state is tapped in ladles and poured in casting beds to produce layer casting (Figure 19). The final alloying metal is cooled and crushed into pieces of variable size.

The submerged arc furnaces are open to the atmosphere; process off-gases are combusted on top of the burden, from where it is cooled and cleaned through a baghouse system before venting to

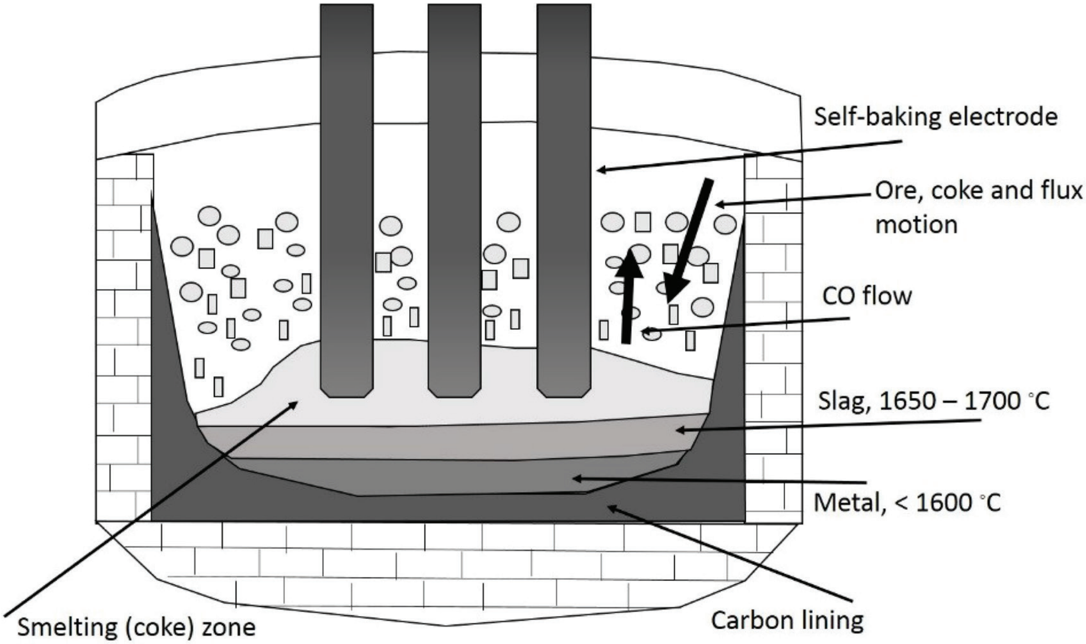

Figure 20: View of submerged arc furnace

atmosphere. A view [3] of submerged electric arc furnace is shown in Figure 20.

Manufacturing process of Ferro alloy industries

The process steps involved in submerged EAF plants include (1) handling and charging of raw materials, (2) stroking, (3) smelting, (4) tapping of liquid metal. The generic process flow of alloy manufacturing process is depicted in Figure 21. The brief descriptions of the process steps are provided below.

Raw material handling

The plant stores sufficient quantity of raw materials in respective storage yards built for different types of raw materials. The raw materials are screened and transported through conveyor belts to respective storage bins wherein they are weighed and samples taken out for analysis of composition.

3 Source: https://www.researchgate.net/

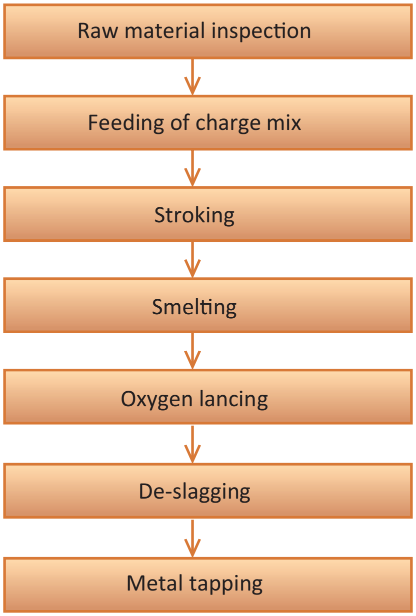

Figure 21: Ferro alloy manufacturing process

The analysis is done for each raw material before feeding into furnace. The raw materials are then mixed and carried through a bucket elevator into circulating feed hopper located at the top of the furnace for feeding inside at stroking floor (Figure 22).

Figure 22: Raw material handling

Stroking

Stroking is mostly carried out in the semi-closed electric 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 ensure no lump is formed (Figure 23).

Figure 23: Stroking in progress

Smelting

Smelting process is heart of the furnace operation. Energy required for smelting includes electrical and chemical. Electricity is fed through graphite electrodes which is the major energy input. Ferro alloy is produced through smelting process that involves high temperature arching of oxide mines in the presence of carbon to produce alloy element in liquid state. The liquid alloy element reacts with iron (Fe) 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 furnace. This arcing required to complete smelting reaction at furnace core. A reaction temperature of about 2000 °C is maintained inside the furnace (Figure 24).

Figure 24: Smelting in progress

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 (Figure 25). The generic production process showing different energy sources, raw materials input and off gases, etc. for a Ferro silicon manufacturing process are shown in Figure 26.

Figure 25: Tapping in progress

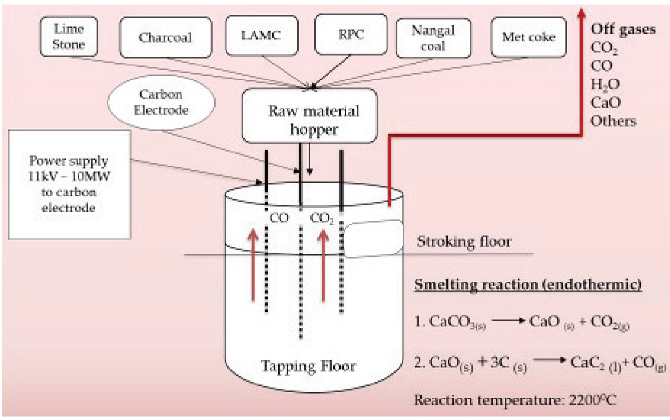

Figure 26: Production process of ferro silicon

Electric arc furnace is cooled through cooling water circulation to maintain work place conditions. The off-gases are cooled with cooling water supplied around the off-gas piping network connecting off-gas hood and later using air to gas heat exchanger prior to the entry into bag filter. The carry over particles i.e. micro silica are recovered in cyclone and bag filters before the off-gases are let off through a chimney (Figure 27).

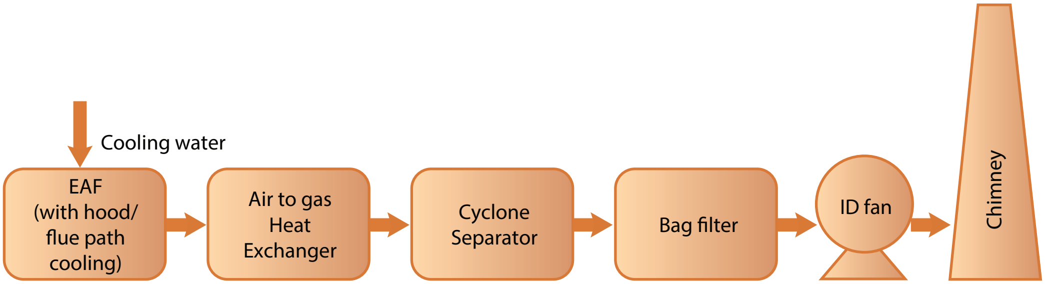

Figure 27: Off-gas cooling and cleaning system

Technology use

The technology description related to ferro alloy manufacturing process is restricted to , submerged electric arc furnace which is the main technology used in the cluster.

The submerged electric arc furnace encompasses an outer cylindrical steel shell internally lined with several layers of designated refractory materials, with the whole system mounted on a motorized tilting mechanism. The three electrodes enter the furnace from the roof through three cylindrical openings at an angle of 120°. The roof is made of refractory brick, usually of high alumina. The vertical

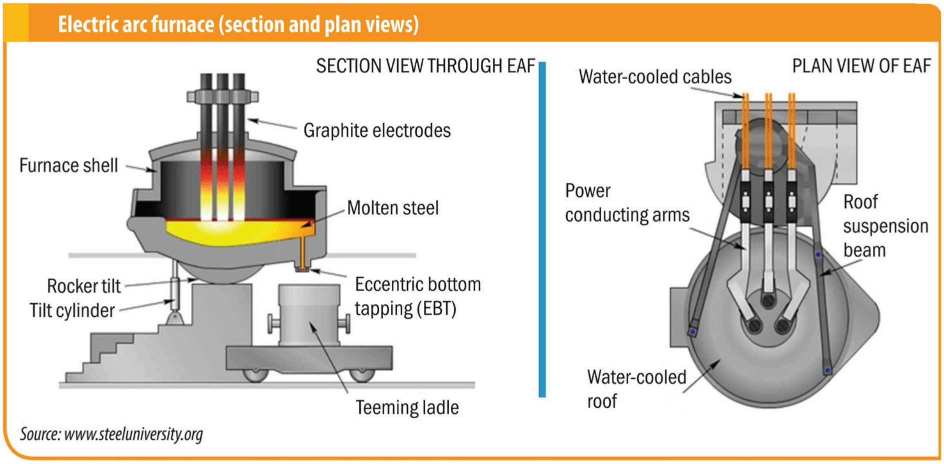

Figure 28: Schematic views of electric arc furnace

movement of electrodes is generally controlled automatically with a thyristor-based system. The crucible, roof, and electrodes are water cooled to maintain the temperature and improve the service life. A pouring spout is present at the front in case of a launder pouring system and an opening is present at the bottom in case of an 'Eccentric Bottom Tapping' (EBT) which leads to slag-free tapping and shorter tap-to-tap times. A generic schematic view of submerged furnace used in ferro alloy manufacturing industries is shown in Figure 28.

Energy consumption and GHG emissions

The main energy resource for the ferro alloy industries is electricity. The other energy forms include carbon rich charcoal and coke. Specific energy consumption for Ferro alloy manufacturing process in the country varied from 3,000 to 12,000 kWh per tonne[4] . The power consumption per tonne of ferroalloys production is provided in the Table 8.

Table 8: SEC[5] of ferro alloy industries

Energy cons area	SEC	
	Thermal[$] (GCal/tonne)	Electrical (MWh/tonne)
SAF	3	8

$ - considered heat value of used fuel is 6000 kCal/kilogramme

Cluster level energy consumption and GHG emissions

The total energy consumption of ferro alloy industries in Raipur cluster is estimated to be 0.18 million toe per year. The equivalent GHG emissions are estimated to be around 1.5 million tonne of CO_2 (Table 9).

Table 9: Energy consumption and GHG emission of Ferro ally industries

Energy type	Unit	Annual consumption	Equivalent energy (million toe)	GHG emissions (million t - CO_2)
Coal	million tonne/year	0.1	0.06	0.3
Electricity	million kWh/year	1,482.24	0.13	1.2
Total			0.19	1.5

The electricity consumption accounts for 70% of total energy consumption in ferro alloy production (Figure 29). Around 81% of GHG emissions are accounted by the consumption of electricity in the process (Figure 30).

4 Source: https://ibm.gov.in/writereaddata/files /08012020124231Ferroalloys2019.pdf
5 Considered 8 MWH/tonne including utilities, source TERI finding under UNEP project for Bhutan Ferro Alloy industry

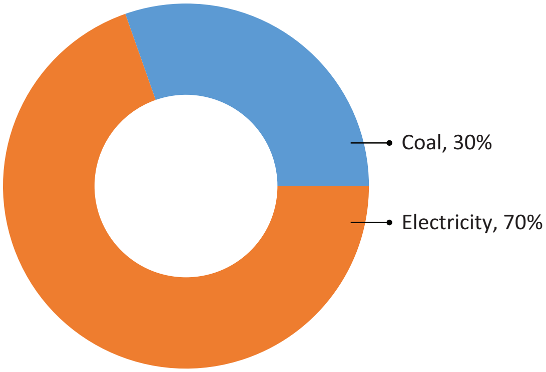

Figure 29: Share of energy consumption

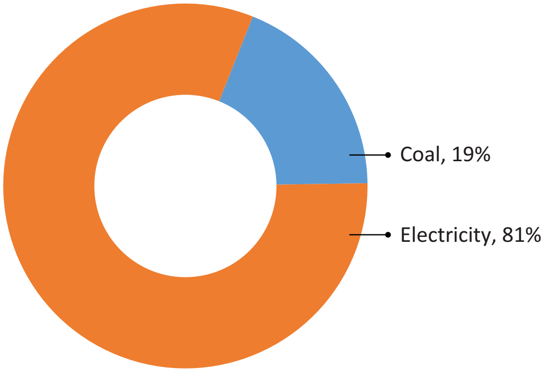

Figure 30: Share of GHG emissions

Energy saving options

It is observed that a significant scope for reducing SEC level and improving energy efficiency exists in ferro alloy manufacturing process. Waste heat in off-gases from arc furnace forms the major share of heat losses. Thus, waste heat recovery (WHR) has been identified as one of the major options to improve energy performance of arc furnaces in the plant. The potential energy saving opportunities for Ferro alloy industries are mentioned below.

- Waste heat recovery for (i) power generation and/or (ii) iron ore preheating
- Decentralized VFDs for shell air fans
- Installation of energy efficient motors
- Adoption of multistage centrifugal pumps for water circulation system

Other important energy saving measures include (i) variable frequency drives for air compressors, (ii) arresting compressed air leakages, (iii) reduction of pressure setting in air compressor.

4

ELECTRIC INDUCTION FURNACE

Background

There are about 102 electric induction furnace[1] industries in Raipur secondary steel cluster, out of these 75 industries are reported to be in operation. Around 55 EIF based plants are composite in nature with integrated secondary steel manufacturing facilities either through hot charging using continuous casting machine (CCM) or cold charging using ingot re-heating furnace. The standalone (SA) EIF plants produce ingots catering to the steel re-rolling mills (SRRM). Distribution of operating EIF based steel melting indicates 36% are installed in DRI plant followed with 28% in steel re-rolling mills (Figure 31.)

About 53% of the units are large category, while 27% of the units are of medium size (Figure 32). The feed raw material primarily consists of sponge iron, bought out scrap, in-house rejects, alloying element and fluxing chemicals. The design rating of the EIF varies in the range of 2.5 MW to 3.5 MW with melting capacity of 6 to 10 tonne per batch. Batch cycle generally takes around 3 hour per heats.

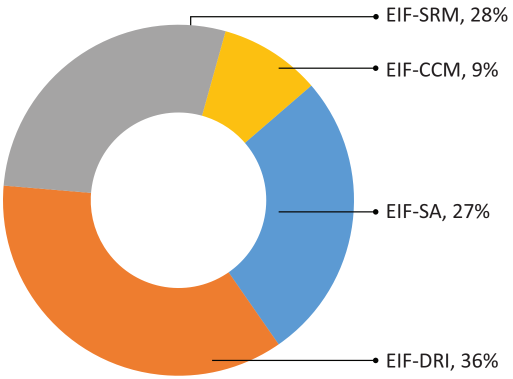

Figure 31: Distribution of operating units

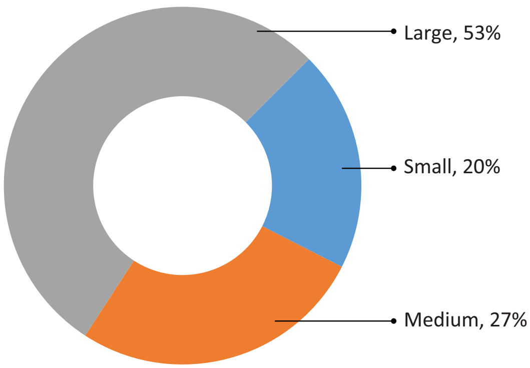

Figure 32: Distribution of units (capacity)

Production

The liquid metal from EIF may be poured with the help of ladle either to CCM or bottom pouring system. The cast products from CCM is directly routed onward as hot charging to rolling mills but casted ingot from bottom pouring is either transferred as cold charge to re-heating furnace for downstream processing within the plant or may be sold as ingot to other industries. Composite EIF units account for about 73% of total operating EIF units (Figure 33). Close to 25% EIF based industries are categorised as 'designated consumers' under the PAT scheme of BEE, as their gate to gate total

1 JPC report, GIZ report, 3rd edition of member directory 2018 of Chhattisgarh Iron and Steel Agent Association, 3rd edition of build profile by CREDA

energy consumption exceeds the threshold limit of steel sector (>= 20,000[2] toe per year). Category-wise distribution of EIF based industries are shown in Figure 34.

The total production from EIF based steel melting shop in Raipur cluster is estimated to be more than 5.9 million tonne per year (Table 10).

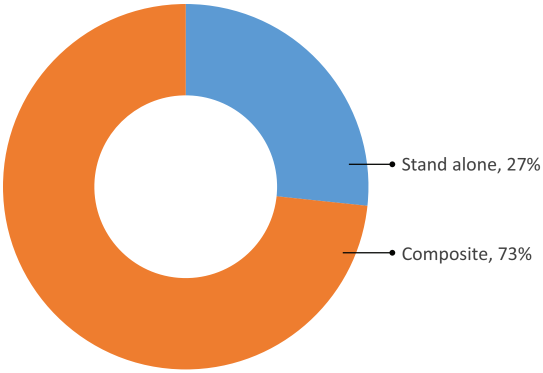

Figure 33: Distribution of units (Plant-wise)

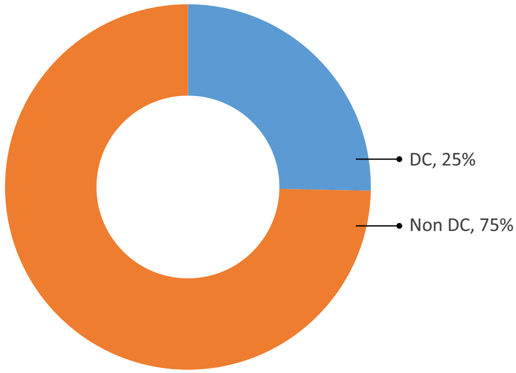

Figure 34: Distribution of units (Category-wise)

Table 10: Annual production of EIF in Raipur cluster

Industry category	Number of plant	Capacity (tonne/year)	Production (million tonne per year)
Small	15	3,000 - <20,000	0.19
Medium	20	20,000 - <50,000	0.58
Large	40	>50,000	5.17
Total	75		5.94

Small and medium size EIF units account for only 13% of steel production, whereas lLarge plants, mainly DCs accounts for 87% share of the total production in Raipur cluster (Figure 35).

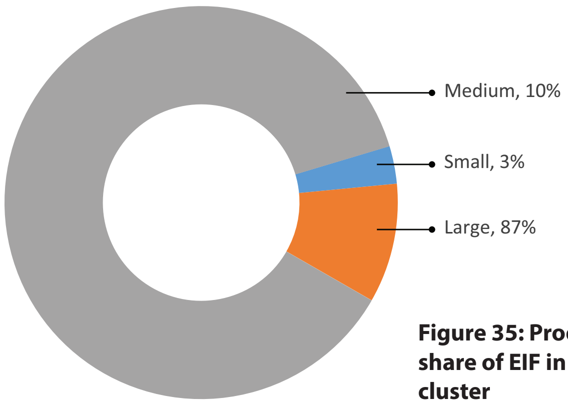

Figure 35: Production share of EIF in Raipur cluster

2 Source PAT cycle, revised threshold limit for DC under steel sector in 2019

Manufacturing process

The raw materials used in electric induction furnaces mainly depend on the product chemistries. The batch materials may include sponge iron, iron pellet, steel scrap and in-house returns. Alloying elements like ferro-silicon, ferro-manganese, silicon carbide, etc., are also dozed to achieve required product quality to improve machinability. De-slagging is done by skimming slag layer manually. The liquid metal from induction furnace is poured into the bottom pouring arrangement to make ingots or transferred to continuous casting machine for billets making, which is further routed to rolling mills directly.

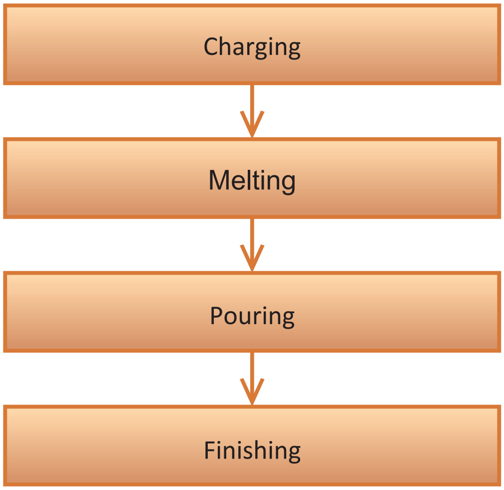

Figure 36: Process flow for EIF furnace unit

Induction furnace is the main technology/ equipment used in induction furnace plants for melting. The major steps involved in induction furnaces include batch preparation and charging, melting, pouring and finishing (Figure 36). The brief descriptions of the process steps are provided below.

Preparation of charge material

This involves preparation of charge (metals and alloys). Measured quantities of metal scrap, pig 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 casting varies between 1,500 to 1,650 °C, depending on grade of steel.

Pouring

Once melt attained required temperature and metallurgy, the liquid melt is poured into either bottom pouring moulds / tundish of CCM for moulding using ladles and shaped into desired product.

Finishing

The casting from CCM goes to desired product line in rolling mill sections for shaping into final products. Casting from bottom pouring may be transferred to re-heating furnace within the same premises or sold as ingots for onward processing to final products.

Technology use

The electric induction furnace (EIF) consists of a non-conductive crucible surrounded by a coil of copper wire with supply of powerful alternating current (Figure 37). The electricity passing through the coil heats the bulk metal by joule heating effect. EIFs use silicon-controlled rectifier (SCR) or insulated gate bipolar transistor (IGBT) for controlling power circuit of which IGBT type is more efficient.

The main parts of coreless IF are crucible, power circuit, cooling system for power panel and furnace coil. A schematic view [3]of coreless IF is shown in Figure 38.

Figure 37: Copper coil in induction furnace

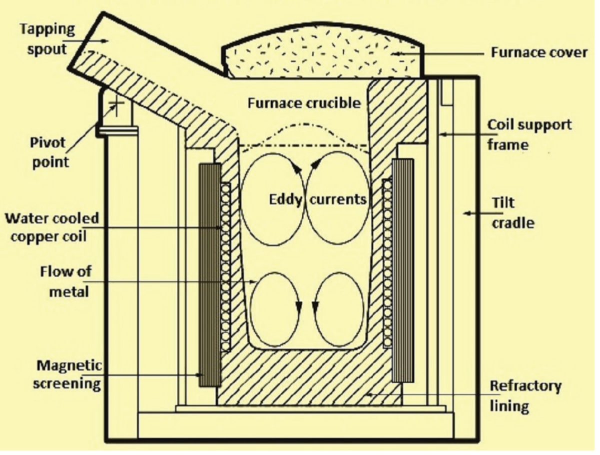

Figure 38: Schematic view of electric induction furnace

Energy consumption and GHG emissions

The designed power rating of the electric induction furnaces in Raipur cluster varies between 2,500 kW – 4,000 kW for capacity of 6 to 12 tonne per batch with cycle time 2 to 3 hours. The EIF based secondary steel melting consumes 100% electricity for melting apart from utility support cooling water and compressed air. Specific energy consumption for EIF based melting including associate downstream process areas of integrated EIF based industries excluding DRI plant are provided in the Table 11. EIF accounts for major energy share in integrated plants.

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

Table 11: SEC of EIF and associate process areas of integrated industries

Energy consumption area	Specific Energy Consumption (kWh/t)
Induction furnace	850
Continuous casting machine	100
Rolling mill	80
Utilities	50

Cluster level energy consumption and GHG emissions

The equivalent total energy consumption by EIF in steel melting and connected associate process areas is estimated to be 0.11 million toe per year. The downstream process includes CCM, rolling mill and utility for liquid metal utilization to produce finish steel products. This excludes energy consumption incurred by EIF and associate process areas in DRI industries. The equivalent GHG emissions are estimated to be around 0.97 million tonne of CO_2 (Table 12).

Table 12: Details of energy consumption and GHG emissions

Energy type	Unit	Annual consumption	Equivalent energy (million toe)	GHG emissions (million t - CO_2)
Electricity	million kWh/year	1,225	0.11	0.97

Energy saving options

The potential energy saving opportunities for Raipur EIF based industries are mentioned below.

- Installation of scrap bundling system
- Adoption of continuous casting and direct rolling in composite EIF system
- Installation of VFDs in (i) cooling pump system of continuous casting machine and (ii) air compressor
- Replacement of the inefficient compressor with energy efficient air compressor
- Installation of multistage centrifugal cooling water pumps

5

STEEL RE-ROLLING MILL INDUSTRIES

Background

There are about 128 steel re-rolling mills (SRRM), out of these 57% industries are reported to be in operating stand alone. Around 43% SRRM based plants are composite in nature with cold ingot charging in reheating furnace (Figure 39.). Distribution of SRRMs, which are in operation indicates 10% are installed within integrated secondary steel industries that are categorised as designated consumers under the PAT scheme of BEE, as their gate-to-gate total energy consumption exceeds the threshold limit of steel sector[1] (more than) 20,000 toe per year as shown in Figure 40.

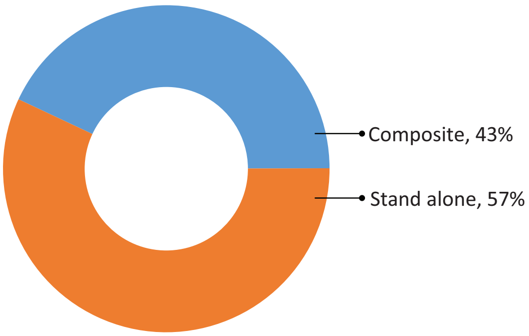

Figure 39: Share of units (operating status)

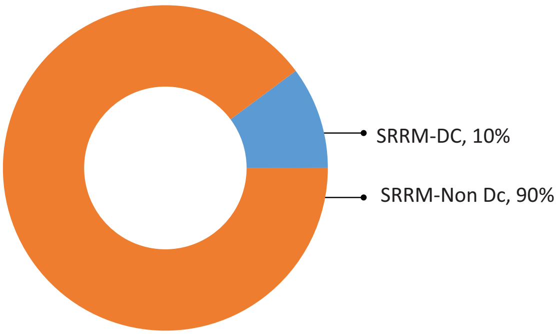

Figure 40: Share of units (category wise)

Production

About 64% of the SRRM units are small category (less than 200 tpd), while 26% of the units are of large size (more than 200 tpd) (Figure 41). Composite SRRMs use in-house ingots whereas stand-alone SRRMs procure ingots/billets from outside. The total production from standalone SRRM in Raipur cluster is estimated to be 2.45 million tonne per year and of composite plants is 6.92 million tonne per year as shown in Table 13.

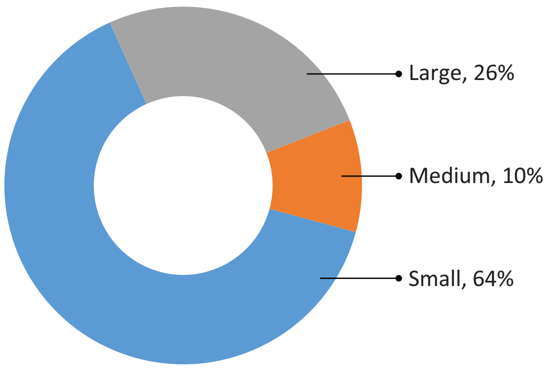

Figure 41: Distribution of units (capacity)

1 Source PAT cycle, revised threshold limit for DC under steel sector in 2019

Table 13: Production from SRRMs in Raipur cluster

Industry category	Number of plant	Capacity (tonne/day)	Production (million tonne per year)
Stand alone	73	80 – 130	2.45
Composite	55	120 - 250	6.92
Total	128		9.37

The composite plant accounts for 69% share of the total production in Raipur cluster (Figure 43).

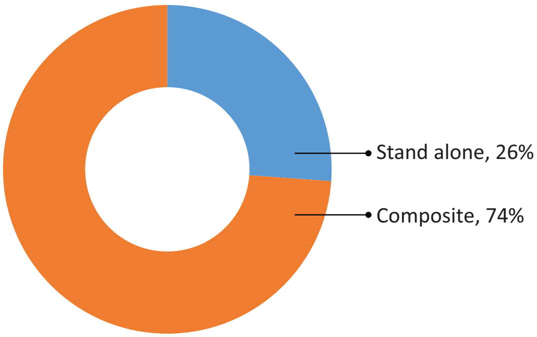

Figure 42: Production share (industries type)

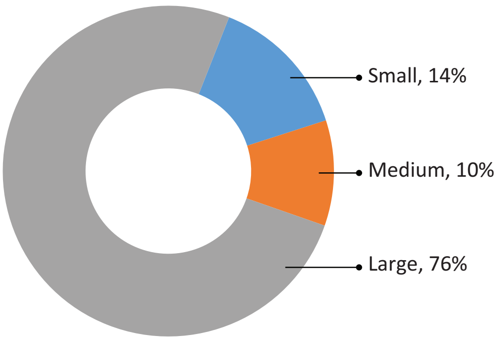

Figure 43: Production share of industries (capacity wise)

Manufacturing process

Steel re-rolling mills are used to roll different kinds of metal objects to give them desired shape, thickness, and curves. The feed raw materials for typical a steel re-rolling mills include bars, billets, ingots and blooms. SRRM industries in Raipur cluster use different quality of coal as energy source for heating. Electricity is used for different motive loads like coal pulveriser, feed pusher, driving motor for rolling stands, etc. The major products manufactured in Raipur by SRRM industries include angles, channels, H-beams, I-beams, TMT bars, flats, HR strips, wire rods, etc.

The broad process steps in a typical SRRM include feed charging, heating, rolling and finishing which are briefed below. Pre-sized ingot /billets in a single or double row are gradually pushed inside the furnace using a pusher motor at a pre-set speed. The feed materials pass through three zones inside the furnace namely preheating (using exhaust gases), heating and soaking (using burners). Coal is the main fuel used in furnaces in re-rolling mills.

Rolling mill receive heated feed at desired temperature for further shaping. In the rolling section, the hot feed passes through rolling stands in series - roughening stand, intermediate stand and finishing stands. Multiple passes within a stands squeeze and stretch the fed feed material into various finished steel products.

On completion of rolling, hot products are allowed to cool down before transferred for sizing to shearing machine and onward straightening and storing yard. The process flow in a steel rerolling mill is shown in the Figure 44.

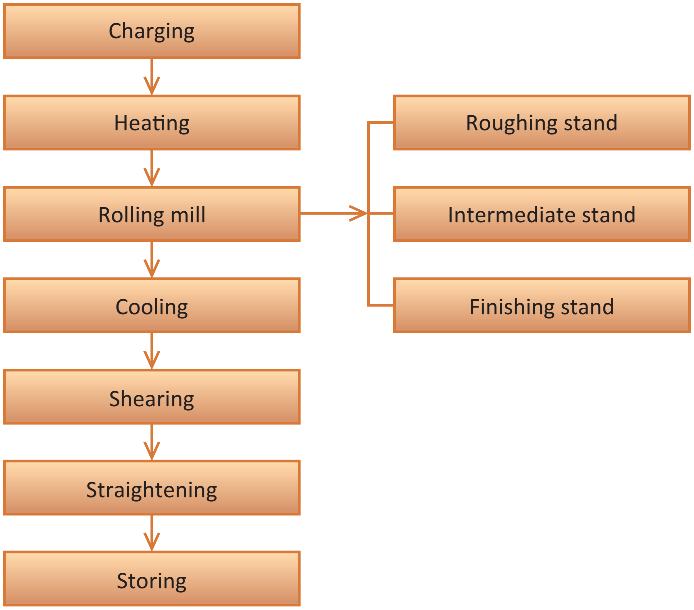

Figure 44: Process flow of SRRM in Raipur cluster

Technology use

Reheating furnace and rolling mill are two important process technology, which are described below.

Reheating furnace

Reheating furnaces are used in hot rolling mills to heat the steel feedstock to temperatures of around 1,050-1,100 °C, which is suitable for plastic deformation of steel and hence for rolling in the mill. The temperature of the feed stock is increased gradually while it moves through pre-heating zone, heating and soaking zone. The rerolling mills in Raipur cluster have installed pusher hearth type of furnaces with pulverised coal fired systems with very low level of automation. Some of the furnaces are equipped with recuperator system to use waste heat for preheating of combustion air. A few units have installed coal gasification and recuparator to optimise furnace performance.

The feed material may be pushed inside either in one row or double row depending on design features. Most of the reheating furnace in Raipur cluster has feed rate capacity of 10 tph. Furnaces are operated either continuously or batch mode wherein batch furnaces operate for 10 to 12 hour per day. Coal consumption varies in the range of 90to 130 kg per tonne of feed stock depending upon the quality of coal and installed add on system like coal gasification, waste heat recovery, etc. to optimize furnace performance. The reheating furnace could be retrofitted with coal gasification, PLC based automation to control air flow and fuel supply based on set temperature and residual oxygen level in flue gases and piped recuperator for waste heat recovery to minimise coal consumption. The reheating furnace, coal gasification and recuperator are shown in Figure 45, Figure 46 and Figure 47 respectively.

Figure 45: View of re-heating furnace

Figure 46: View of coal gasification

Figure 47: View of recuperator

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. The heated slab is rolled in a roughing stand, in which the thickness is partly reduced in various passes, back and forth. Normally, roughening stand has three passes. Similarly, intermediate stand has multiple passes depending on the product and finally desired shape is achieved in finishing stand, which will also has multiple passes.

In Raipur cluster, rolling mills that produces structural steel products like angle, channel, beams, TMT bar, wire rod, etc., have a total of 11 passes from three stages of milling stands. All rolling stands are driven by a common drive shaft, which is connected through belt to a rolling motor. The designed rating of the rolling motor may vary in the range of 1,200 to 1,500 hp. The rolling motor and rolling stands are shown in Figure 48 and 49 respectively.

Figure 48: Rolling motor

Figure 49: Rolling stands

Energy consumption and GHG emissions

The standalone SRRM based finished secondary steel making industry in Raipur cluster consumes coal for heating feed stock and 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 including associate process areas

Energy consumption area[$]	Coal (kg/tonne)	Specific Energy Consumption	
		Thermal (million kCal/tonne)	(kWh/tonne)
Reheating furnace	100	0.5	5
Rolling mill	-	-	80
Utility	-	-	50

$ - Coal gasification is ignored as not very common

Cluster level energy consumption and GHG emissions

The equivalent total energy consumption by standalone SRRM and connected associate process areas is estimated to be 0.2 million toe per year. The downstream process includes rolling mill and utility to produce finish steel products. This excludes energy consumption incurred by composite SRRM, which is calculated alone with EIF and DRI based composite industries. The equivalent GHG emissions are estimated to be around 0.87 million tonne of CO_2 (Table 15).

Table 15: Details of energy consumption and GHG emission

Energy type	Unit	Annual consumption	Equivalent energy (million toe/year)	GHG emissions (million t-CO_2/year)
Coal	million tonne/ year	0.32	0.16	0.64
Electricity	million kWh/ year	427.1	0.04	0.34
Total			0.20	0.97

Thermal energy accounts for 81% (Figure 50) with contribution of GHG emission around 61% (Figure 51).

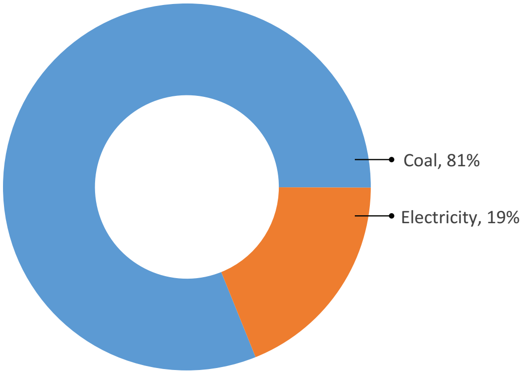

Figure 50: Energy consumption share

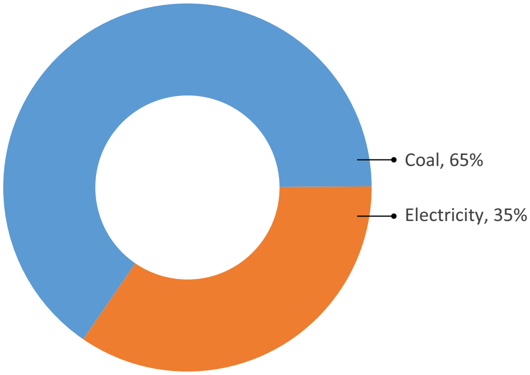

Figure 51: GHG emission share

Energy saving options

The potential energy saving opportunities for Raipur standalone SRRM based industries are mentioned below.

- Installation of PLC based automatic fuel firing system
- Installation of regenerative burners
- Renovation of furnace lining and surface insulation
- Application of heat resistance coating in the internal surface of batch type furnace
- Regular maintenance and overhauling of the recuperator for optimum performance
- Installation of multistage centrifugal cooling water pumps
- Implementation of continuous casting and direct rolling

6

WIRE INDUSTRIES

Background

There are about 111 wire industries[1] in Raipur cluster. Most of the industries use wire rod manufactured by local secondary steel industries. A few large integrated secondary steel industries in Raipur also produce wire of various size and grade. Most of these industries[2] are located in the well-established industrial estate of Urla and Siltara including its surrounding localities of Rawabhatha, Tatibandh, Sarola, Bagoli, Bhanpuri, Gaugaon and Tendua. The common NIC code of wire drawing industries products are provided in Table 16.

Table 16: NIC code of primary products of wire industries

Product	NIC code
Wire of iron or non-alloy steel	4126399
Barbed wire of iron and steel	28999
Barbed wire and nails	271300
Cold drawing SS wire	24108
Binding wire	27104
Wire coated with zinc	4126304,4126306
Hard bright MS and SS wire	27181,27182, 27184

Wires produced in the cluster are either coated with zinc (Zn) or lead (Pb) or simply drawn to smaller size through die. The share of wire drawing industries is more than 90% (Figure 52). Most of the wire industries in Raipur cluster is smaller in capacity and accounts for 95%, while 5% of the units are of medium size (Figure 53).

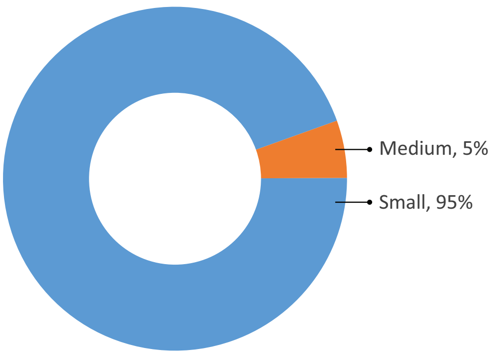

Figure 52: Distribution of units (product-wise)

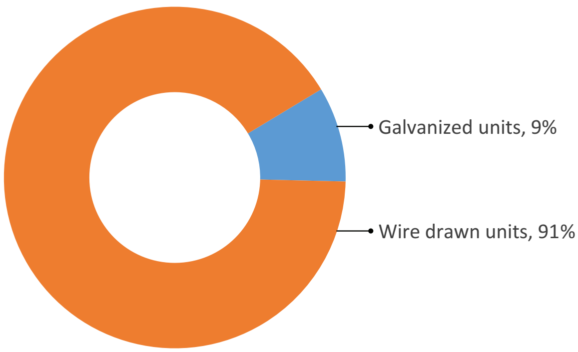

Figure 53: Distribution of units (capacity-wise)

1 Industry list of DIC, Raipur and directory of Raipur wire industries, published by CREDA, Raipur.
2 Source:- Website of CSIDC, Raipur. List of DIC, Raipur

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 product of the wire drawing units includes hard bright wire (HB wire), barbed wire, binding wires, barbed wire with nails, etc. to serve specific application. The galvanizing wire industries use either lead bath or zinc bath for applying anti-corrosive coating on MS wire. The production capacities among small plants vary in the range of 3,000 to 5,000 tonnes per annum but same is in the range of 12,000 to 60,000 tonne per year for a few medium scale industries. The estimated production of the cluster is around 653,371 tonne per year (Table 17).

Table 17: Production of wire industries in Raipur cluster

Industry type	Production capacity (tonne/year)	Annual production (tonne/year)
Small	3,000 - 5,000	395,371
Medium	12,000 - 60,000	258,000
Total		653,371

The smaller plants account for 61% share of the total production in Raipur cluster (Figure 54).

Manufacturing process

The manufacturing process of wire drawing and wire galvanizing is described below.

Wire drawing

Wire drawing is a cold working process wherein the cross section of the wire is uniformly reduce to smaller sizes by pulling through a single or a series of drawing dies. The base material in rolled coil is uncoiled, cleaned and descaled and subjected to annealing before being drawn through the dies. Base rod is passed through hot water bath to make it soft before drawn through dies for size reduction. Generally, water is heated around 70–80 °C using electric heating coil but without any

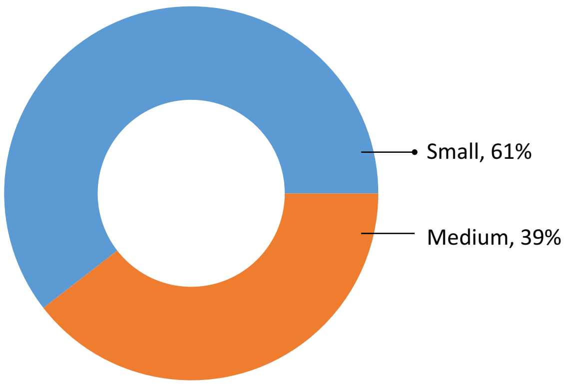

Figure 54: Production share of wire industries in Raipur cluster

online temperature measuring instrument in place. The temperature of the bath is generally controlled based on eye judgement and is subjective.

The heated wire is put through dies of various sizes that are placed in series and drawn wire is guided to the following dies with the help of pulley or pay-off spool and sets of coiler drums driven by electric motors. The pay-off spool feeds the wire into the drawing die with lubricant in dry or liquid form. A tensiometer installed in the system measures the tensile load of wire emerging after size reduction. The pick-up spool assembly mounted directly on the shaft of a step or induction motor provides the required force to pull the wire drawn after size reduction. A jockey mechanism is used to maintain tension of the wire drawn from one coil to the other. The drawn wire is dipped in a chromate protective solution from weathering action before coiling of the drawn wire. A typical wire drawing process is shown in Figure 55.

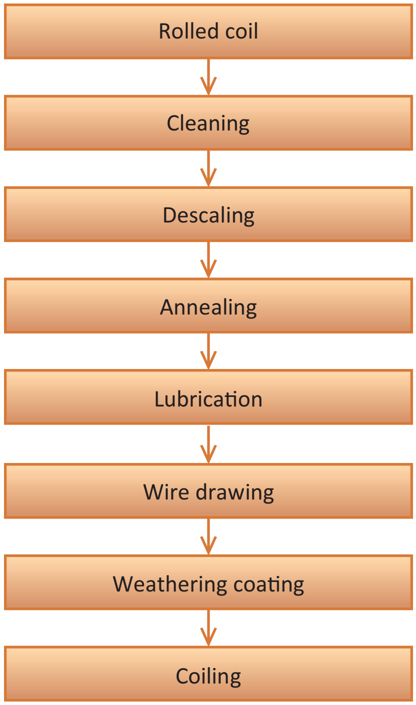

Figure 55: Wire drawing process

Galvanizing

Galvanizing is the process of providing anticorrosive zinc coating on the metallic surface. Galvanizing is a short batch process for structural article but wire galvanizing is a longer and continuous process till the connected wire of coil drum is completely coated. The primary steps of galvanizing process includes De-greasing, Pickling, Fluxing, Drying, and Dipping in zinc bath apart from rinsing prior to some of the steps and final quenching. The galvanizing process of wire article is briefly described below.

The received wire article is uncoiled to clean surface contaminants like rust, oil, paint, etc. by mechanical cleaning if needed followed with de-greasing by dipping in caustic solution. De-greased article is rinsed in water to remove left over any traces of caustic solution from the surface before it passes through hydrochloric acid solution for further neutralization of left over traces of caustic solution. This is known as pickling of the article to be coated. Once again, article is rinsed before it is passed through zinc ammonium chloride solution of 65 °C for fluxing. The flux solution removes the oxide film which forms on the highly reactive steel surface after acid cleaning, and prevents further oxidation by provides pre-coat before galvanizing. The wire is then dried ready for passing through galvanizing bath.

On immersion in the galvanizing bath the article surface is wetted by the molten zinc and reacts to form a series of zinc-iron alloy layers. To allow formation of the coating the work remains in the bath until its temperature reaches that of the molten zinc, in the range 450-465 °C. The wire is then withdrawn at a controlled rate to allow solidification of the outer layer of molten zinc to relatively pure outer zinc coating. The period of immersion in the galvanizing bath depends on the article size. The coated article cooled and quenched in a mild sodium dichromate solution to prevent the onset of wet storage staining during the early life of galvanizing. The process steps of wire galvanizing is shown in Figure 56.

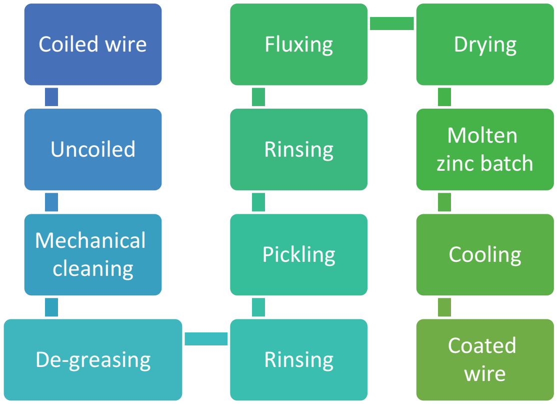

Figure 56: Process flow of wire galvanizing unit

Technology use

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

Annealing furnace

Annealing furnace is a stress relieving system to remove the induce stresses in drawn wire and improve its mechanical strength. These stresses are mainly induced during pulling of the wire article through different dies. These are either furnace oil (FO) fired or induction heating lead bath through which drawn wire passes. The temperature of the lead bath is maintained in the range of 380-400 °C (Figure 57).

Figure 57: FO based Lead bath

Zinc bath

The 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 450 °C. Although the exhaust gas temperatures are high (about 600 °C) but there is no waste heat recovery system in place to pre-heating combustion air.

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 the Table 18.

Table 18: SEC of galvanizing and wire drawing industries

Industry type	SEC		
	FO consumption (kg/tonne)	Thermal$ (million kCal/tonne)	(kWh/t)
Galvanizing	30	0.3	10
Wire-drawing	8	0.08	200

$ - considered heat value of used FO is 10050 kCal/kilogramme of FO

Cluster level energy consumption and GHG emissions

The total energy consumption of wire industry in Raipur cluster is estimated to be 17,815 toe per year. The equivalent GHG emissions are estimated to be around 106,944 tonne of CO_2 per year (Table 19).

Table 19: Energy consumption of wire industries of Raipur cluster

Energy type	Unit	Annual consumption	Equivalent energy (toe/year)	GHG emissions (t - CO_2/year)
Furnace Oil	million tonne/year	0.01	9,295	28,679
Electricity	million kWh/year	96.36	8,287	76,125
Total			17,582	1,04,804

The annual FO consumption accounts for 53% of total energy consumption in the cluster (Figure 58). Around 73% of GHG emissions are accounted by the consumption of electricity in the process (Figure 59).

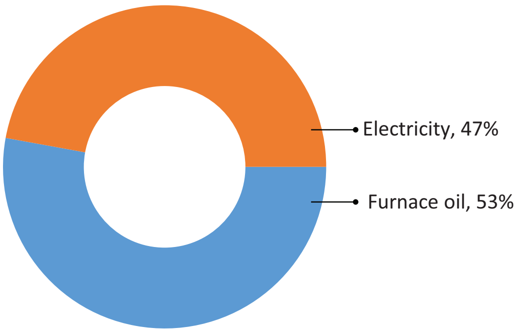

Figure 58: Share of energy consumption

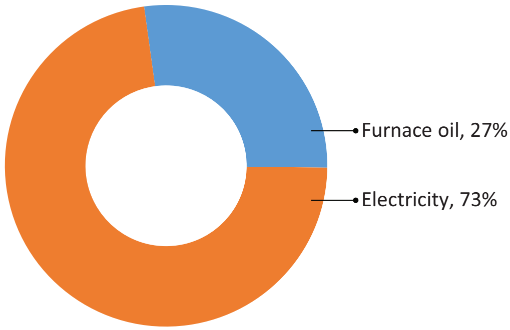

Figure 59: Share of GHG emissions

Energy saving options

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

i) Replace FO fired annealing with induction heating furnace in wire drawing
ii) Replace FO fired zinc bath with induction heating furnace
iii) Use of energy efficient IE3 motors
iv) Auto control of electrical heater used in FO heating

7 OTHER MANUFACTURING UNITS

Background

Raipur secondary steel cluster predominantly known by manufacturing industries like DRI, ferro alloy, finished steel products from composite 'steel melting shops' (SMS) and steel re-rolling mills (SRRM). These industries create regular demands for various casted spare parts, which are manufactured in allied secondary steel industries like foundry and forging. There are about 30 such industries[1] in Raipur cluster. Most of the industries produce and supply casted spares to the local secondary steel industries. These industries[2] are located either in industrial estate or surrounding industrial localities of Raipur. The common NIC code of foundry and forging[3] industries products are provided in Table 20.

Table 20: NIC code of primary products of wire industries

Product	NIC code
Cast iron casting	24319
Forged products	25910 / 28910
U-bolt, nut, bolts	28991
Pipes and Tubes Steel	27105
Tube and tube fittings of basic iron and steel	24106
Railway track materials (unassembled rails) of steel	24107

The share of foundry industries in the grouped allied industry is more than 57% (Figure 60).

Production

The allied foundry and forging industries mostly produces customized castings to meet specific demand and application. The primary products of these units include assorted casting and forged products like bottom pouring system, laddle, mould, machinery parts and maintenance spares, etc. to serve specific application. The estimated production of the cluster is around 76,350 tonne /year, of which foundry accounts more than 65,000 tonne per year (Table 21).

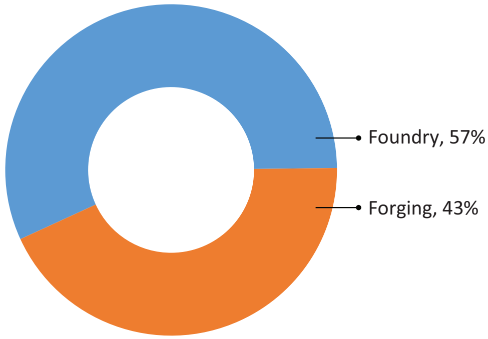

Figure 60: Distribution of units (product-wise)

1 Industry list of DIC, Raipur and local industry directory of Raipur, published by industry Association and CREDA, Raipur.
2 Source:- Website of CSIDC, Raipur. List of DIC, Raipur
3 Source: National Industrial Classification - 2008 (NIC-2008), published on 17 April 2009
https://www.ncs.gov.in/Documents/NIC_Sector.pdf

Table 21 : Production of allied industries in Raipur cluster

Industry type	Number of industry	Annual production (tonne/year)
Foundry	17	65,192
Forging	13	11,158
Total		76,350

The annual product from foundry plants account for 85% share of the total production in Raipur cluster (Figure 61)

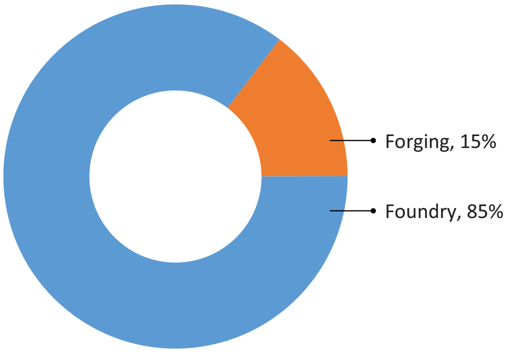

Figure 61: Production share of allied industries in Raipur cluster

Manufacturing process

The description of the broad manufacturing process under this section includes foundry process and forging process. These are explained below.

Manufacturing process of foundry industry

The primary process steps in a foundry industry include mould preparation, melting, pouring, knockout and finishing operations (Figure 62). The melting process accounts for a major energy consumption in the foundry industry mostly in the form of thermal energy, which is met either from coke in cupolas or electricity in induction furnaces.

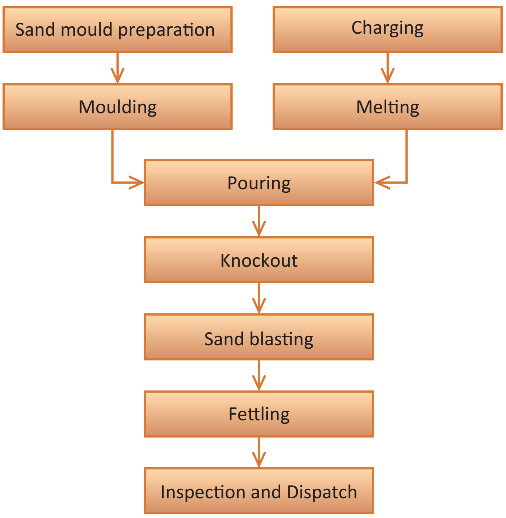

Figure 62: Process flow in foundry

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 flask comprises two halves, that is, cope (upper 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 either in cupola furnace or induction furnace. Depending upon product chemistry, charge batch is prepared comprising pig iron, metal scrap and foundry return, etc., which is charged either manually or mechanically. The typical temperature of molten metal for grey iron is about $1400^{O}C$ and for steel grade is $1650\ ^{O}C$. 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 semi/automatic pouring system.

Casting

The poured molten metal takes the shape of the mould. The cast product is sand blasted after de-moulding and other downstream finishing processes.

Manufacturing process of forging

Forging is a metal deformation process at forging temperature. It is performed either in presses or hammers. The shaping can be done in open die, closed die or impression, and ring forging process. The forging process primarily consists of three main steps namely preparatory work, forging or shape forming and finishing activities. The major process steps involved in forging process include die-making and setting, raw material preparation, heating, forging, trimming and finishing (Figure 63).

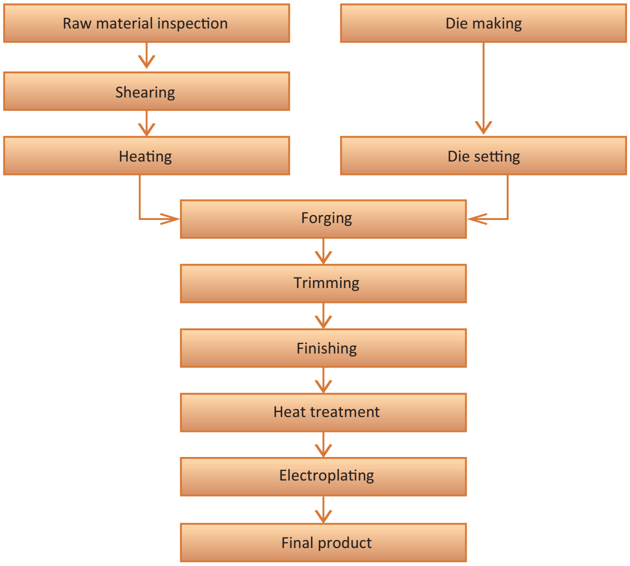

Figure 63: Process flow in forging industry

Die making and setting

Based on the shape and specifications of final product, impressions are created in a steel tool die either in in-house tool room or outsourced. Corresponding die is installed in the hammer or press for shaping.

Raw material preparation

The raw material received in the shape of rod, bar, billet, etc., undergoes physical inspection and chemical testing before routed for shearing operation.

Heating

The sized material is heated to about 1,150-1,250°C using fossil-fuel fired or induction furnace.

Forging

The shaping of heated material is done in a single or multiple stroke using a press or hammer. Impression die forging is used for simple shape and uses a single press stroke. Most of the forging process requires multiple dies of different impressions for sequential forging operation. In sequential forging using hammers, first stroke is edging which increases the cross-section of the work piece. The second stroke is blocking to refine the shape for finish forging. The last stroke completes the shape of the forged product. In finish-forging, bulk of metal is forced into the impression while a thin layer called flash, flowing out between the dies at the parting plane.

Closed die forging

The metal is pressed between two dies containing a pre-cut profile based on product specifications. A temperature of about 1,250 °C is maintained for forging operation. The process can handle materials of a few kilogram to 25 tonne. The process uses hydraulic press, mechanical press, and hammers. Impression die forging can produce products of complex shapes and close tolerances. It can handle carbon and alloy steel, tool steel, and stainless, aluminium, and copper alloys, etc. The closed-die forging is shown in Figure 64.

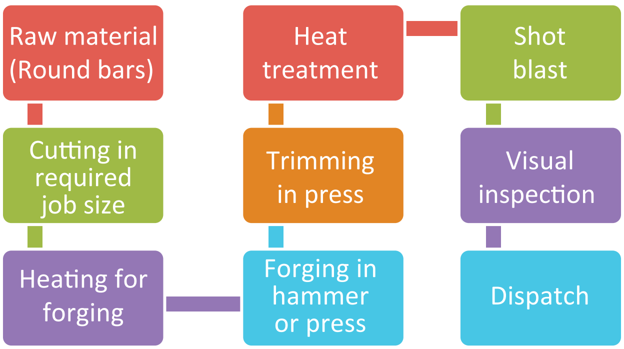

Figure 64: Closed-die forging

Ring rolling forging

Long bars are used as raw material in ring rolling forging. Induction heating furnaces using long bars are operated in line with ring rolling machine or high speed hot forming machine. Heated long bars are cut to required size and pressed into pancake shape. Piercing operation is done and pre-sizing is carried out before ring rolling operation. The components are shifted to annealing furnace for heat treatment. Shot blasting is done to achieve desired surface finish followed by rough and final turning in lathe machines. The ring rolling forging is shown in Figure 65.

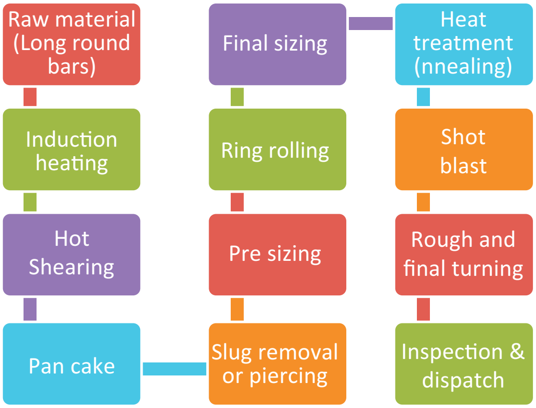

Figure 65: Ring rolling forging

Trimming

The unwanted material in the forged product is removed either manually or with trimming dies.

Finishing

It includes fettling, shot blasting, cleaning, and machining of the forged product. Based on requirements, the forged products are subjected to heat treatment and electroplating.

Technology use

The major equipment used in foundry industries are the melting furnaces, which may be cupola furnace or induction furnace. These are explained following sections.

Cupola furnace

The cupola furnace is a cylindrical metallic shell having refractory lining at the internal surface and is used for melting charge material. The raw material batch is fed into it from the top, and liquid metal is drawn from the bottom either intermittently or continuously, depending on the design feature. Cupola furnaces use for melting the charge materials. The capacity of the cupola furnace depends on the inner diameter after refractory lining (Figure 66).

Figure 66: Cupola furnace

Induction furnace

The induction furnace uses electricity for heating and melting using either silicon controlled rectifier (SCR) or insulated gate bipolar transistor (IGBT) type technology. Heating is done through induction effects, and heating elements are placed in the refractory lining facing charge holding crucible. It is the batch type and the capacity of furnaces depends on the crucible volumetric capacity and designed electric load (Figure 67).

Figure 67: Induction furnace in foundry rolling forging

The major technologies used in the forging industries are provided below.

Oil fired furnace

The types of furnaces used in forging industry include (1) box type, and (2) pusher type for heating of raw material (billets of various grades of steel) to 1150–1,200°C. Furnace oil is predominantly used as fuel in the furnace. The forging furnaces are used for heating of raw material. The capacities of furnaces are 50-400 kg per hour. Billets are heated either in batches or continuously. Heat treatment furnaces are used for normalizing, annealing, hardening, tempering, and carburizing as per requirements. (Figure 68).

Figure 68: FO fired forging furnace

Electrical furnace

Electrical furnaces are either batch (pit type) or continuous (pusher type) with a rating of 15-120 kW. These are used for billet heating (Figure 69) prior to forging operation and annealing of forged products (Figure 70). The production capacity of electrical induction furnaces ranges between 100–500 kg per hour.

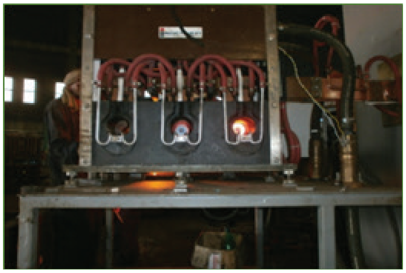

Figure 69: Induction billet heater

Figure 70: Bell type heat treatment furnace

Closed die hammers

The closed die hammers of belt drop type are used for forging of hot billets into various shapes like shafts, flanges, gear blanks, pipe fittings, rollers, hubs, etc. The capacity of the forging hammers typically range between 0.5 to 3 tonne (Figure 71).

Figure 71: close die hammer

Screw press

The capacity of screw presses varies from 100 to 1,500 tonnes. These presses are operated with pneumatic clutch and brake and screw is used for adjusting the height of stroke length. It is used mostly with shaft end heating jobs (Figure 72).

Figure 72: Screw press

Ring rolling machines

Ring rolling machines are equipped to process one job at a time. These machines can be effectively used for large diameter products (Figure 73). Although use of ring rolling machines would help in higher quality of products, the processing rates are quite low.

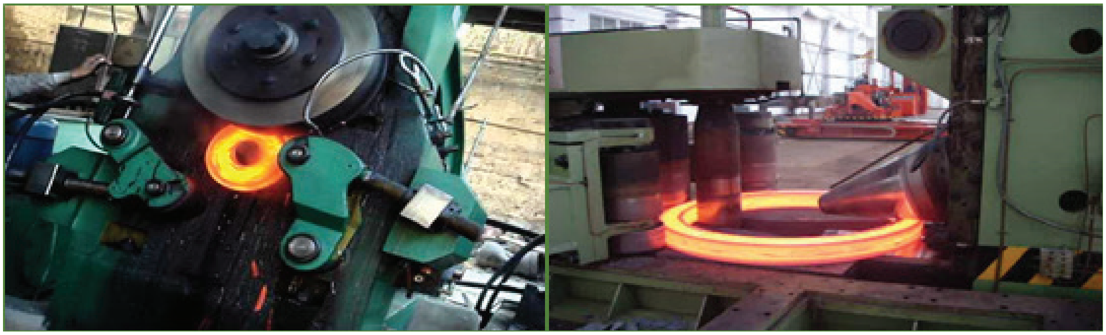

Figure 73; Ring rolling forging

Energy consumption and GHG emissions

Foundry uses mainly coke in cupola furnace to produce liquid metal with coke consumption varies 100 to 110 kg per tonne of raw material processing plus 30 kWh per tonne for motive load operation.

Forging industries use both furnace oil (average 900 kg/tonne) and induction furnace (around 650 kWh/tonne) for heating job article before forging operation. Specific energy consumption for per tonne of production is provided in the Table 22.

Table 22: SEC of foundry and forging industries

Industry type (-)	SEC	
	Thermal$ (Gcal/tonne)	(kWh/t)
Foundry	0.66	30
Forging	9.04	650

$ - considered heat value of used FO is 10050 kCal/kilogramme of FO and 6000 kCal/kg for coke

Cluster level energy consumption and GHG emissions

The total energy consumption of foundry and forging industry in Raipur cluster is estimated to be 15,187 toe per year. The equivalent GHG emissions are estimated to be around 59,298 tonne of CO_2 per year (Table 23).

Table 23: Energy consumption of the Raipur foundry and forging industries

Energy type	Unit	Equivalent energy (toe)	GHG emissions (t- CO_2)
Coke	million tonne/year	4,303	20,882
Electricity	million kWh/year	792	7,275
Furnace oil	million tonne/year	10,092	31,141
Total		15,187	59,298

The annual consumption accounts 67% for FO and 28% for coke out of total energy consumption in the cluster (Figure 74). Around 53% of GHG emissions are accounted by the consumption of furnace oil followed by coke (35%) in the process (Figure 75).

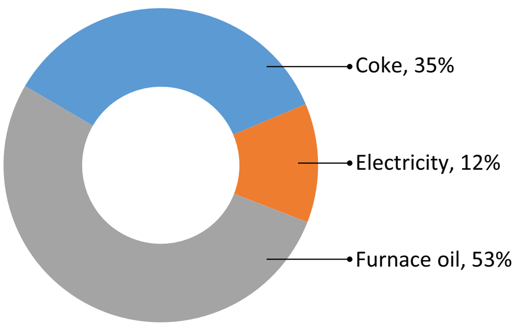

Figure 74: Share of GHG emissions

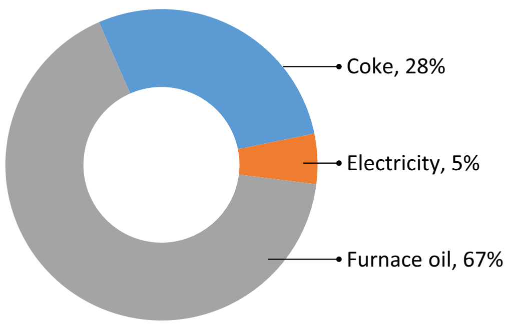

Figure 75: Share of energy consumption

Energy saving options

The major energy saving opportunities in Raipur foundry and forging industries are summarised below.

i) Replace inefficient cupola with energy efficient cupola
ii) Use of energy efficient IE3 motors
iii) Replacing FO fired furnace with induction billet heater
iv) FO fired reheating furnaces:
a) Install recuperator to enable waste heat recovery from hot flue gases
b) Enhancing furnace insulation
v) Thyristor control for electrical heat treatment furnaces
vi) High speed hot former machine for ring rolling

Other important energy saving measures include (i) variable frequency drives for press machines and air compressors, (ii) arresting compressed air leakages, (iii) reduction of pressure setting in air compressor, and (iv) replacement of rewound motors with energy efficient motors.

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8

INDUSTRY ASSOCIATIONS

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Permanent Invite :

Rajkumar Agrawal, Dilip Patel

Sanrakchhak Mandal :

Bimlesh Gupta, Ramanand Agrawal, Jagdish Pd. Agrawal, K.N. Rungta, Subhash Agrawal, K.K. Agrawal, Ashok Ku. Agrawal, Ramesh Agrawal, Vijayraj Bothra, Mahaveer Taleda, Ashok Agrawal

CATEGORY

Rolling Mill

The industry associations are one of the key stakeholders in the cluster, facilitating networking and addressing pertinent issues of the industries. Some of the active industry associations also facilitate technical support to the member industries by organising events such as workshops, training, etc. The primary stakeholders like industry associations, government departments such as state designated agencies (SDAs), DIC, DCMSME pertaining to secondary steel industries in Raipur cluster are shown in Table 24.

Table 24: Primary stakeholders of Raipur secondary steel cluster

Institution/ organization	Contact details
Raipur Iron and Steel Trade Association (RISTA)	RISTA c/o.308,3rd floor, samta shopping arcade, Samta colony, Raipur-492001
Chhattisgarh Ferro Alloy Plant Association (CFAPA)	Samta Colony, Raipur-492001, Chhattisgarh
Chhattisgarh Wire Industries Association (CWIA)	Raipur, Chhattisgarh
Chhattisgarh Steel Re-rollers Association (CGSRA)	1st floor, Sona Tower, Ramsagarpara, Raipur - 492001
Chhattisgarh mini steel plant association (CGMSP)	Shop no: 408, Samta Shopping Arcade, Main Road, Samta Colony, Raipur, Chhattisgarh - 492001
Urla industries association (UIA)	Urla Industrial complex, Raipur - 493221
Chhattisgarh State Renewable Energy Development Agency(CREDA-SDA)	2nd Floor, CSERC Building, Shanti Nagar, Raipur, email: contact.creda@gov.in http://www.creda.in
MSME- Development Institute, Raipur	Near Urkura Railway Station Bhanpuri Industrial area, Post- Birgaon Raipur (Chhattisgarh)- 493221 E-mail: dcdi-raipur@dcmsme.gov.in www.msmediraipur.gov.in
Directorate of Industries	Directorate of Industries, Udyog Bhavan Ring road no. 01, Telibandha, Raipur E-mail : dtic-directorate.cg@gov.in https://industries.cg.gov.in/department_page.aspx

Institution/ organization	Contact details
Chhattisgarh State Industrial Development Corporation (CSIDC)	Chhattisgarh State Industrial Development Corporation (CSIDC), Udyog Bhawan, Ring road no. 01, Telibandha, Raipur - 492001, E-mail : csidc.cg@nic.in , csidc_raipur@yahoo.com , csidc.cg@gov.in https://csidc.in/
District Investment Promotion Committees (DIPC)	Udyog Bhawan, Ring road no. 01, Telibandha, Raipur - 492001
District Trade and Industries Centre(DTIC)	Udyog Bhawan, Ring road no. 01, Telibandha, Raipur - 49200 https://industries.cg.gov.in/contact_us.aspx
Chhattisgarh Chamber of Commerce and Industries (CCCI)	Ch. Devilal Vyapar Udyog Bhawan 2nd Floor, Bombay Market, Raipur, Chhattisgarh phone: +91 (771) 2539275, 4034572 Whats app: +91 9340389971, Email: info.cgchamber@gmail.com Web: www.cgchamber.org

9 CONCLUSIONS

The Raipur is an important MSME cluster of secondary steel where there is a presence of a large number of different categories of secondary steel industries are available. The major secondary steel industries in the Raipur cluster include sponge iron industries, electric induction furnace units, steel re-rolling mills, wire drawing industries (Figure 76).

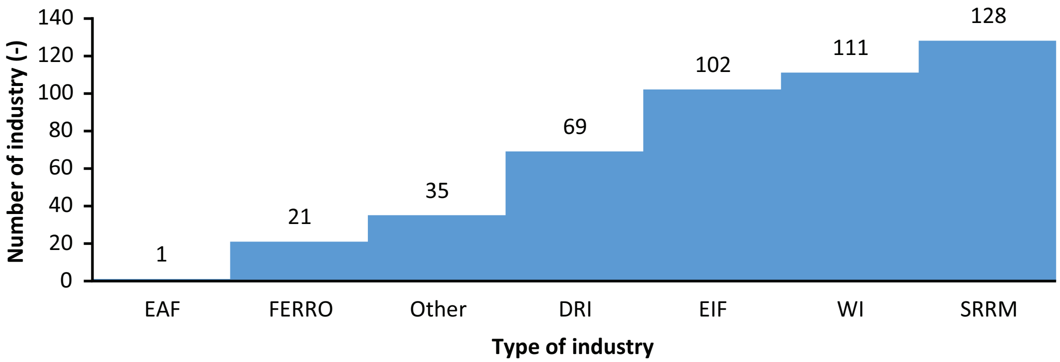

Figure 76: Secondary steel industries in Raipur cluster

The specific energy consumption (SEC) in different secondary steel industries in Raipur cluster widely varies depending upon the product profile, technology in use and operating practices being followed. The range of SECs per tonne basis for different industries in Raipur cluster is furnished in Table 25.

Table 25: SECs per tonne basis for different industries in Raipur cluster

Industry type	Specific consumption (unit/tonne)			
	kWh	Coal (kg)	Coke (kg)	FO (kg)
DRI	70 - 80	1,000 - 1,200	-	-
Ferro alloy	7,000 - 8,500	-	450 - 550	-
Electric induction furnace	800 - 900	-	-	-
Re-heating furnace	4 - 6	100 - 130	-	-
Continuous casting machine	80 - 100	-	-	-
Rolling mill	50 - 80	-	-	-
Forging	600 - 800	-	-	850 - 950
Foundry	25 - 30	-	100 - 110	-

Industry type	Specific consumption (unit/tonne)			
	kWh	Coal (kg)	Coke (kg)	FO (kg)
Galvanizing	6 - 10	-	-	25 - 30
Wire drawing	200 - 300	-	-	5 - 8

The total number of allied-steel industries is estimated to be more than 450 units (Table 26).

Table 26: Overview of secondary steel industries in Raipur cluster

Type	NO	Production (tpy)	Energy consumption			Total	
			Thermal (toe/yr)	Electricity		Energy	GHG emission
			(toe/yr)	(m kWh/yr)	(toe/yr)	(toe/yr)	(m toe/yr)
DRI	69	4,826,000	2,940,027	5,314	457,048	3.39	16.01
EAF	1		0		0		
EIF	102	5,939,900	0	1,225	105,354	0.1	0.97
SRRM	128	9,366,739	158,180	427	36,729	0.19	0.97
FERRO	21	185,280	55,584	1,482	127,472	0.19	1.44
WI	111	653,371	9,294	96	8,287	0.02	0.11
Other	35	76,350	14,395	9	792	0.01	0.06
Total	467	21,047,640	3,177,481	8554	735,684	3.91	19.56

An analysis of energy consumption shows thermal energy accounts for about 81% of total energy consumption, while the share of electricity was 19% (Figure 77). The total energy consumption of

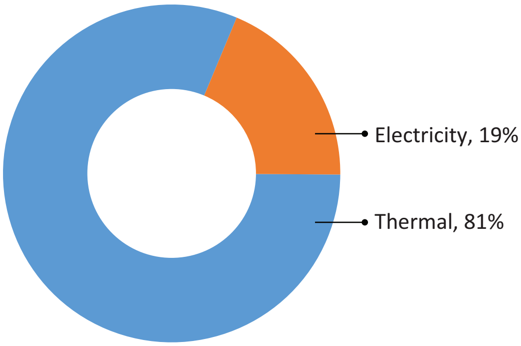

Figure 77: Share of energy consumption

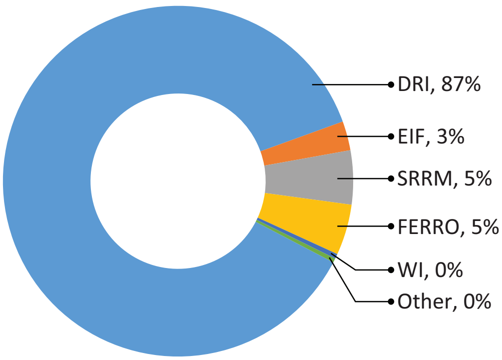

Figure 78: Share of GHG emission by industry sub-sector

secondary steel industries in Raipur cluster comprising DRI, EIF, SRRM, etc. is estimated to be 3.91 mtoe per year; DRI alone accounts for about 87% of the total (Figure 78). The equivalent GHG emissions are estimated to be 19.6 million tonne CO_2 per year with 82% share by DRI industries (Figure 79).

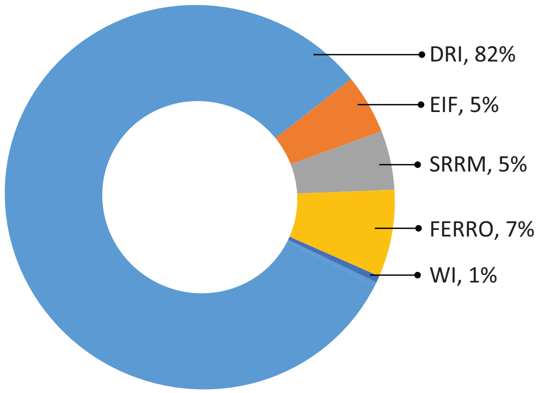

Figure 79: Share of GHG emission by industry sub-sector

The technology use and energy consumption levels of different secondary steel industries in Raipur cluster indicate a significant scope for energy saving and GHG reductions. The energy saving potential at the cluster level may be assessed through energy assessment studies in representative industries in Raipur cluster. A programmatic approach can be initiated at the cluster level to provide technical assistance to identify energy efficiency options and provide technical backup support for their adoption. A large scale dissemination of energy efficiency options across the cluster would involve long-term involvement at project level to extend technical support to industrial units and strengthen local capacities with close cooperation of key stakeholders at both cluster and national level. The assessment studies would further help in identifying appropriate decarbonisation options for potential adoption in the cluster as long-term goal.

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