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Situation Analysis of Sundergarh

Secondary Steel Cluster

Situational Analysis of Sundergarh Secondary Steel Cluster

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ABBREVIATIONS

CO_2	Carbon dioxide
CR	Cold rolled
CTD	Cold-twisted deformed
DIC	District industry centre
DRI	Direct reduced iron
EAF	Electric arc furnace
EBT	Eccentric bottom tapping
FO	Furnace oil
GCV	Gross calorific value
GJ	Gigajoule
HB	Hard bright
hp	Horsepower
HR	Hot rolled
IE3	Premium efficiency
IFAPA	Indian Ferro Alloys Producers Association
IGBT	Insulated gate bipolar Transistor
JPC	Joint Plant Committee
kcal	Kilocalorie
kW	Kilowatt
kWh	Kilowatt hour
MSME	Micro, small, and medium enterprises
mt	Million tonne
mtoe	Million tonne of oil equivalent
MW	Megawatt
NIC	National Industrial Classification
PAT	Perform, achieve and trade
SA	Stand-alone
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
SS	Stainless steel
TMT	Thermo mechanically treated
toe	Tonne of oil equivalent
tpd	Tonne per day
TPH	Tonne per hour
tpy	Tonne per year
VFD	Variable frequency drives
WHR	Waste heat recovery

1

IRON AND STEEL INDUSTRIES IN ODISHA

1.1 Introduction

The state of Odisha has vast ore and mineral reserves with abundant mining potential. It has a large number of iron and steel industries including public sector undertakings (PSUs), for example, Steel Authority of India Limited (SAIL), Rourkela, an integrated steel plant. The steel production during 2021/22 stood at 23.72[i] million tonne (mt), witnessing about 7.5% growth during 2017 to 2022 (Figure 1).

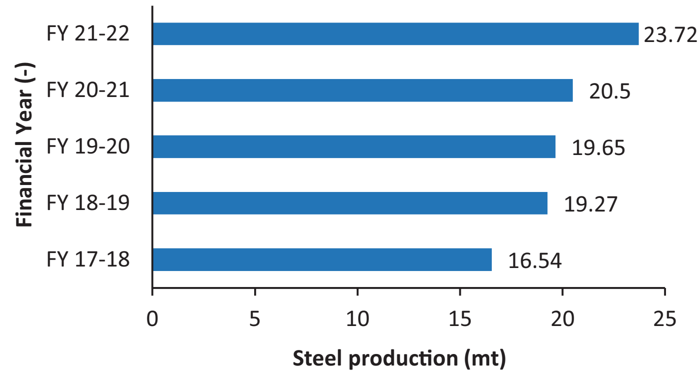

Figure 1: Growth of steel production in Odisha

The concentration of steel manufacturing industries in Odisha is largely influenced by the local availability of iron ores. The Keonjhar district is the primary source of iron ore mining contributing to about 31% share of the total mining in Odisha; it is followed by Sundergarh district, which is 20% of the total (Figure 2).

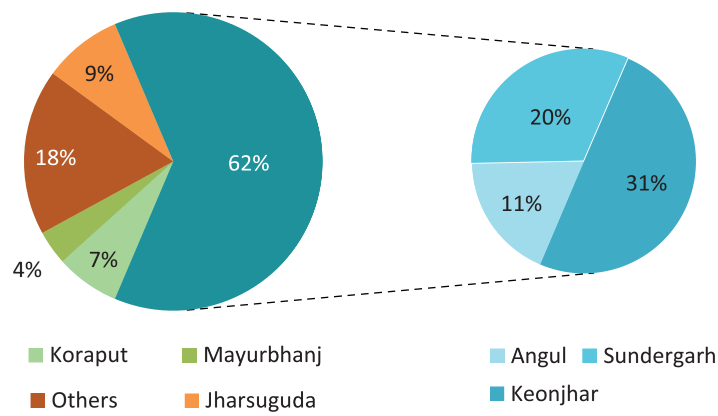

Figure 2: Iron ore mining distribution in Odisha

There are 67 large iron and steel industries[ii] in Odisha, which fall under designated consumer (DC) category. Sundergarh district has 26 DCs, including SIAL Rourkela and Keonjhar district has 13 DCs (Figure 3).

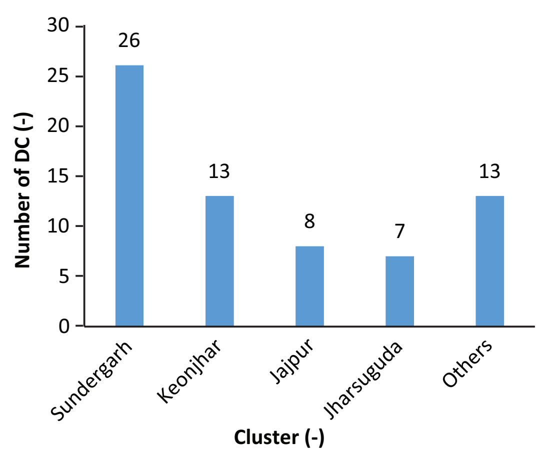

Figure 3: Primary iron and steel clusters with number of DCs in Odisha

The raw material flow chain from mines to finished products (e.g. sponge iron, rolled sheet, alloys, ingots, billets, etc.) in secondary steel industries of Odisha is depicted in Figure 4.

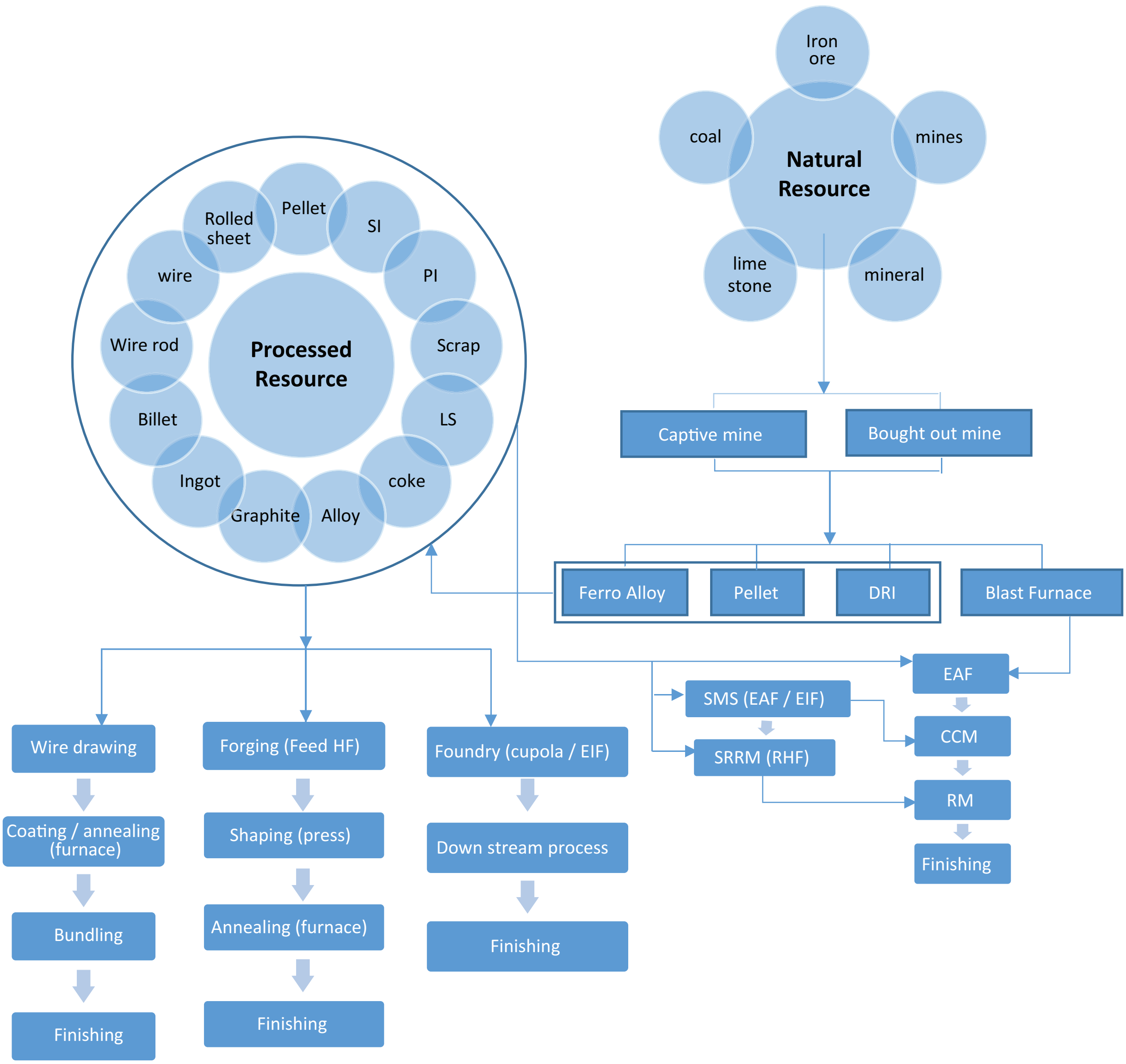

Figure 4: Material flow chain within Odisha steel industries

1.2 Overview of Sundergarh Cluster

Sundergarh is one of the major iron and steel clusters in Odisha with abundant resources like iron ore, limestone, manganese, dolomite, etc. The primary iron and steel industries in Sundergarh include pellet, direct reduced iron (DRI), electric induction furnace (EIF), blast furnace (BF), and BF-basic oxygen furnace (BOF). The downstream processing industries include steel rerolling mill (SRRM), wire drawing, foundry, and forging (Figure 5).

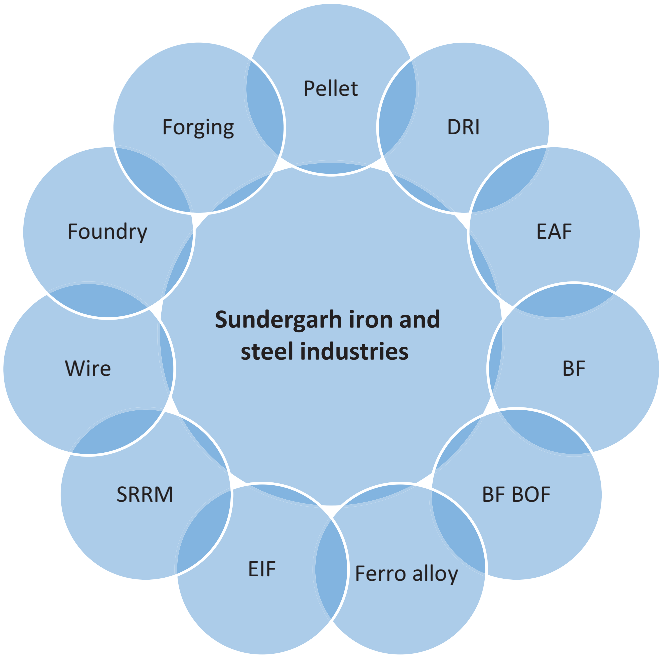

Figure 5: Iron and steel industries in Sundergarh district

Most of these industries are situated in the well-established[iii] six (6) primary industrial estates, namely Rourkela, Kalunga, Mandiakudar, Rajganjpur, and Sundergarh (Figure 6).

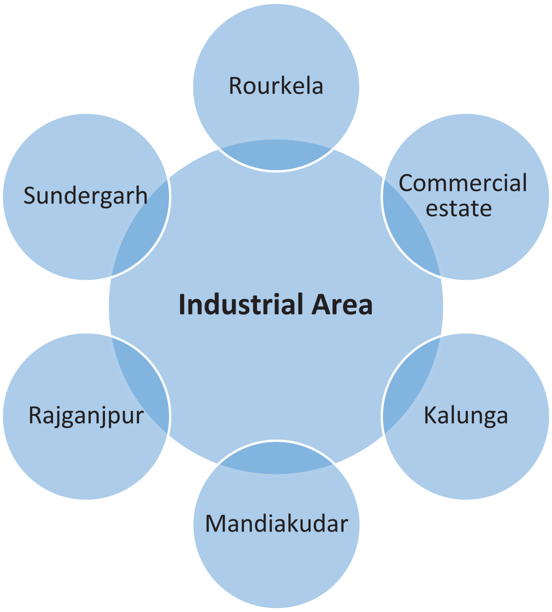

Figure 6: Primary industrial areas of Sundergarh district

1.3 Industry and Technology Details

There are about 87 iron and steel-based registered micro, small, and medium enterprises (MSME)[iv] in Sundergarh. Industries with multiple process steps are termed composite; stand-alone (SA) industries have single process step. Iron and steel industries with an annual energy consumption of at least 20,000 tonne of oil equivalent (toe) fall under DC category of the perform, achieve, and trade (PAT) scheme of the Bureau of Energy Efficiency (BEE). About 60 % of the total 87 secondary steel industries in Sundergarh cluster are DCs; in this 25 (48%) DCs have at least DRI process, followed by 16 DCs (30%) with EIF process (Table 1).

Table 1: Details of iron and steel secondary industries in Sundergarh cluster

Sector	Operating	Stand-alone	Composite	DCs	Non-DCs
Sponge iron	41	29	12	25	16
Pellets	1	–	1	1	–
EIF	25	9	16	16	9
SRRM	16	9	7	7	9
BF	2	–	2	1	1
Ferro alloys	2	–	2	2	–
Total	87	47	40	52	35

These industries have one or more process steps such as pellet, DRI, BF, EIF, SRRM, ferro alloys, etc. (Figure 7). Industries with steel melting shops (SMS) mostly use the EIF process. About 41 industries (47%) in the cluster have DRI manufacturing process.

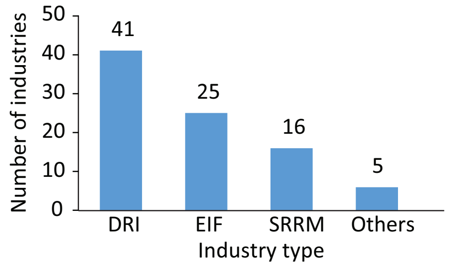

Figure 7: Distribution of industries in Sundergarh cluster

There are 63 independent industries, of which 41 industries (65%) are involved in DRI manufacturing (Figure 8).

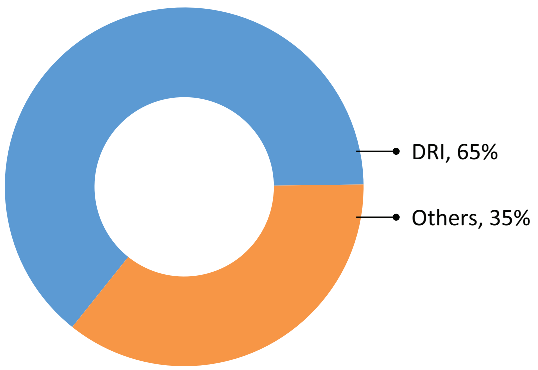

Figure 8: Share of DRI industries in Sundergarh cluster

Majority of these industries in the cluster (about 47 industries) are stand-alone, while the balance 16 industries are composite (Figure 9). Further, analysis indicates that there are 25 DCs (40%) and 38 industries (60%) are non-DCs (Figure 10).

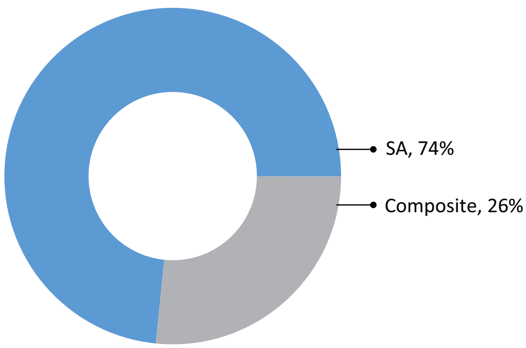

Figure 9: Share of DC and non-DC steel industries in Sundergarh cluster

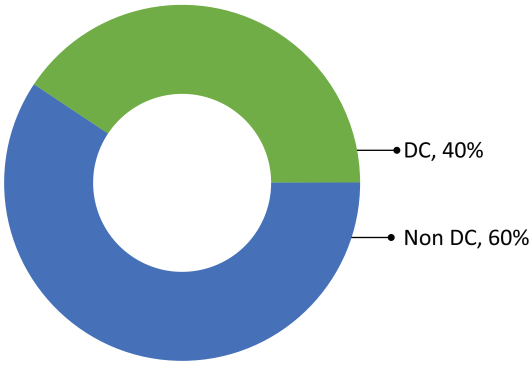

Figure 10: Share of composite and stand-alone steel industries

An in-depth study of the cluster shows that the end products from a process step within a plant are either input raw material in subsequent process steps or final products for marketing (Table 2). Further, most of these units use age-old and inefficient technologies except a few large DCs which have adopted state-of-the-art technologies.

Table 2: Technology, energy, and raw material use in Sundergarh steel cluster

Technology	Industry	Raw material	Process step	Energy type	End-product
Induration furnace	Pellet	Iron ore	Heating	FO, coke, coal, electricity	Pellet
Rotary kiln	DRI	Iron ore/pellet	Heating and reduction	Coal, electricity	Sponge iron
Blast furnace	Iron and steel	Iron ore/ sinter/pellet	Heating and reduction	Coal, electricity	Liquid iron/pig iron
Submerged arc furnace	Ferro alloy	Mineral ore	Heating and reduction	Coal, electricity	Steel alloys
Electric induction furnace	SMS	Sponge iron, scrap	Steel melting	Electricity	Ingots and billets
Reheating 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
Coating bath	Galvanizing industry	Drawn wire	Galvanizing	Furnace oil, electricity	Galvanized wire

1.4 Major Products from Sundergarh Cluster

Sundergarh cluster produces a wide range of products (Figure 11), which find applications across different end-use sectors like industries, domestic, construction sectors, medical, and academic institutions.

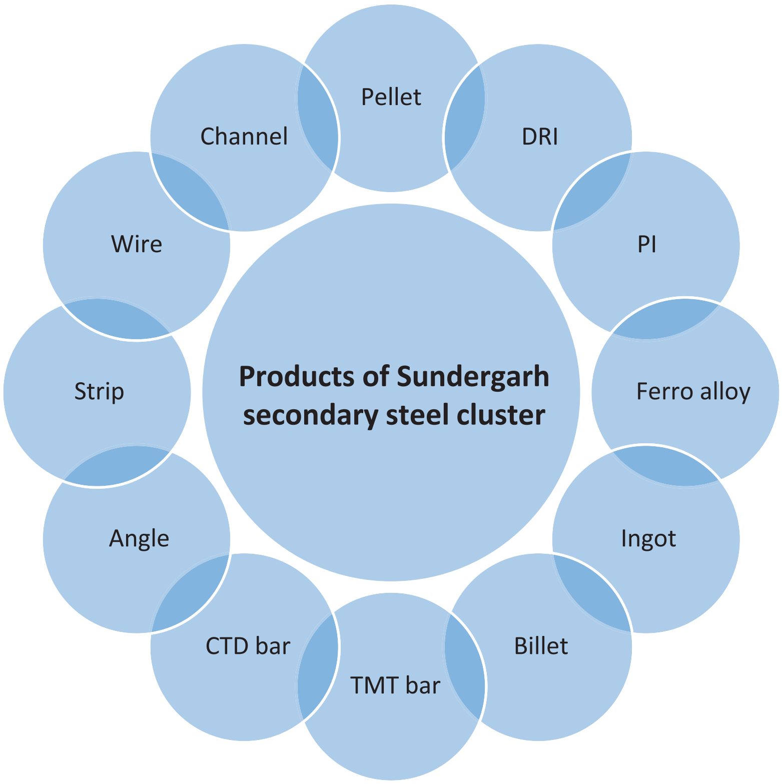

Figure 11: Products of Sundergarh secondary steel cluster

Some of the primary steel products and their National Industrial Classification (NIC) codes[v] applicable to the secondary steel industries in the cluster are listed in Table 3.

Table 3: NIC codes of primary steel products

Product	NIC code
Pig iron	24101/27130
DRI/sponge iron	24102/27102
Rerolled products and MS ingot	24103/27104
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

Product	NIC code
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
SS wires	28999
MS HB wire	27181
MS wire	27182
Wire coated with zinc	4126399/4126306/4294601
Iron granules powder	269343

1.5 Energy Consumption and Carbon Dioxide Emissions

The iron and steel industries in Sundergarh cluster use coal, coke, furnace oil, and electricity to meet their gate-to-gate energy requirements. The total energy consumption of Sundergarh secondary steel cluster is estimated to be 1.85 million tonne of oil equivalent (mtoe) per year with the corresponding emissions[vi] of 8.46 million tonne of carbon dioxide ($mtCO_2$) per year (Table 4).

Table 4: Energy consumption and CO_2 emissions in Sundergarh secondary steel industries

Industry	Energy consumption (mtoe)			CO_2 emissions ($mtCO_2$)
	Thermal	Electricity	Total	
Pellet	0.02	0.01	0.03	0.13
DRI	1.25	0.02	1.27	5.41
BF	0.44	0.01	0.45	1.88
EIF	0.00	0.09	0.09	0.79
SRRM	0.003	0.005	0.007	0.15
Ferro	0.003	0.01	0.012	0.10
Total	1.72	0.13	1.85	8.46

Thermal energy accounts for about 93% of the total energy consumption of 1.85 mtoe in the cluster, while the share of electricity is only about 7% (Figure 12). The corresponding CO_2 emissions from thermal energy and electricity are 86% and 14%, respectively (Figure 13).

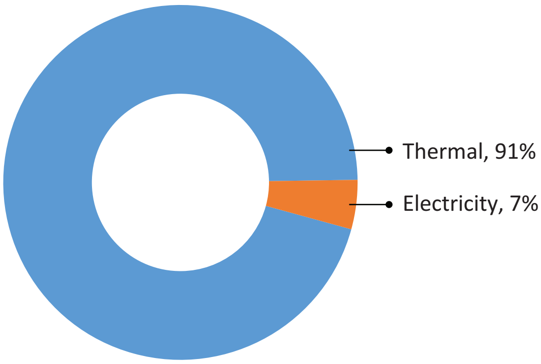

Figure 12: Share of energy consumption

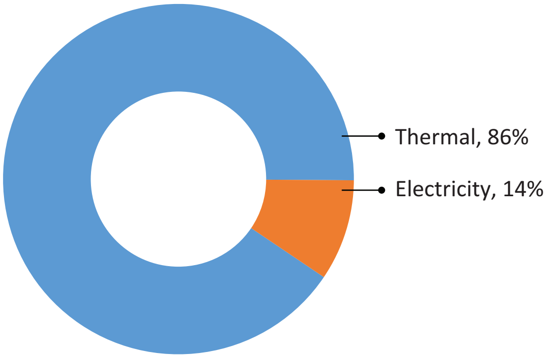

Figure 13: Share of CO_2 emission

DRI industries account for 69% of energy consumption in the cluster (1.27 mtoe) (Figure 14). The share of CO_2 emissions from the cluster is 64% (Figure 15).

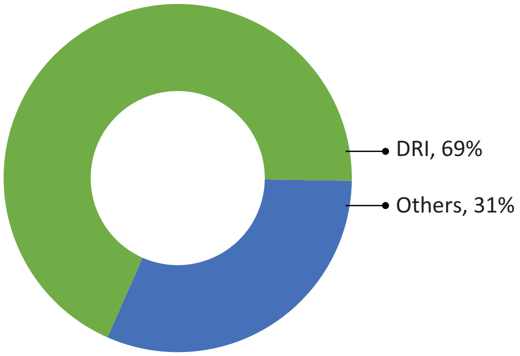

Figure 14: Energy consumption by Sundergarh industry sub-sector

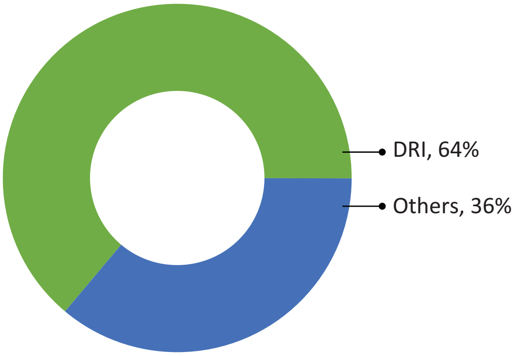

Figure 15: Emission share of industry sub-sector

The overall coal consumption of the cluster is estimated to be 3.19 mt. This is equivalent to 1.72 mtoe per year with corresponding emissions of 7.29 $mtCO_2$ (Table 5).

Table 5: Coal consumption in Sundergarh cluster

Industry sub-sector	Coal* consumption		Emission
	(Mt/year)	(mtoe/year)	($mtCO_2$/year)
DRI	2.50	1.25	5.25
Others	0.69	0.47	2.04
Total	3.19	1.72	7.29

** Average GCV of 5000 kcal/kg considered*

DRI industries account for 78% of coal consumption whereas the share of other industries in the cluster is about 22% (Figure 16).

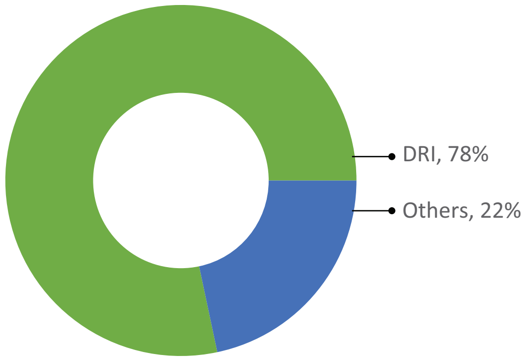

Figure 16: Share of coal consumption in Sundergarh cluster

A summary of share of energy consumption and CO_2 emissions by major industries in the cluster is shown in Figure 17.

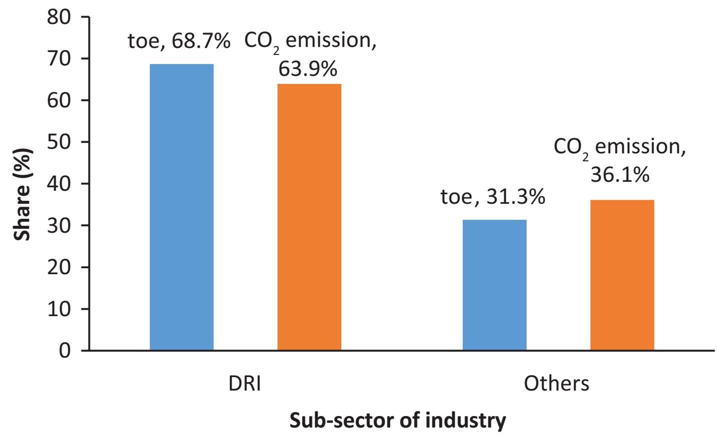

Figure 17: Share of energy consumption and CO_2 emissions by sub-sector

2

PELLET INDUSTRY

2.1 Background

Iron ore lumps and/or fines are used to make iron ore pellets having different mineralogical and chemical compositions into small balls or spherical sizes. This process would help in improving both physical and chemical properties compared to the iron ore material, resulting in higher productivity and lower specific energy consumption (SEC) in the production process.

Pellet industries are generally located close to iron ore mining areas of Odisha, Chhattisgarh, Karnataka, West Bengal, amongst others. There are about 48 pellet industries, with Odisha having the maximum share of 29% (Figure 18). The annual pellet production in India was estimated to be 131 million tonne (mt)[vii] in 2021/22 (Table 6).

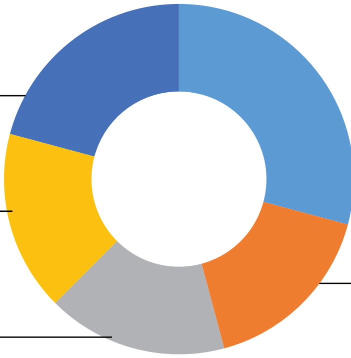

Figure 18: Distribution of pellet industries

Table 6: Pellet production share of different states of India

State	Production (mt)		
	Total	Captive	Merchant
Odisha	47.6	24.7	22.9
Karnataka	27.5	18.7	8.8
West Bengal	14.4	6.7	7.7
Chhattisgarh	9.9	5.5	4.4
Others	32.1	22.1	10
Total	131.5	77.7	53.8

Odisha produces around 47.6 mt of pellets per year (Figure 19). It includes both captive use (52%) and merchant share (48%) covering both domestic and exports (Figure 20).

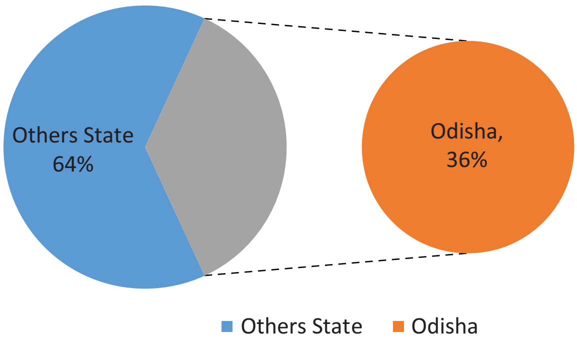

Figure 19: Pellet production share of Odisha

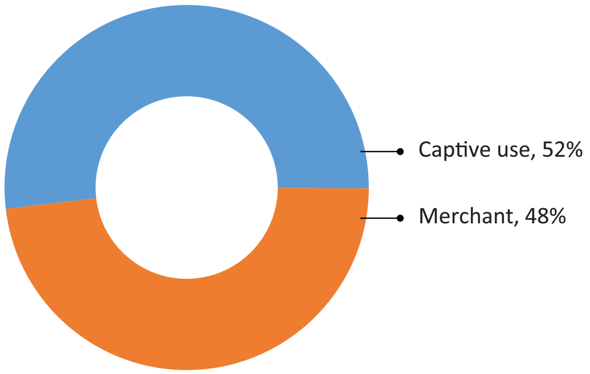

Figure 20: Pellet use in Odisha

2.2 Manufacturing Process

The production of pellets involves shaping a batch mixture of iron ore, coal, coke, dolomite, and binding chemical (bentonite) into green balls, followed by heating green balls in an induration furnace. The steps involved in pellet manufacturing include (i) beneficiation of iron ore, (ii) batch preparation, (ii) forming of green pellets, (iii) separation and screening of green pellets, (iv) preheating, and (v) hardening. The generic process flow chart of pellet manufacturing without beneficiation is shown in Figure 21.

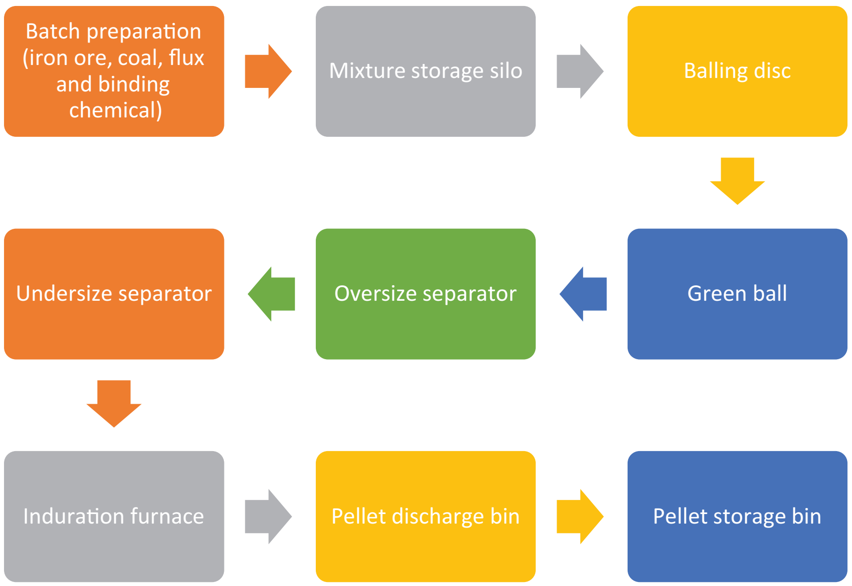

Figure 21: Pellet manufacturing process

A brief description of the primary process steps, such as ore beneficiation, pellet formation, and sintering is provided in the ensuing section.

2.2.1 Beneficiation

Beneficiation is the process to enrich the content of base ore material by removing impurities and gangue material from mined natural ore. It improves overall productivity and yield of the downstream process. The process steps largely depend on the quality of input ore material and the desired percentage of enrichment. The steps in beneficiation cover washing, screening, grinding, slurry concentration, and dewatering. The beneficiation of –8 mm ore size is undertaken in two different lines of process. One of the streams beneficiate ore size of – 8 mm to + 5 mm and other stream processes ore size of – 5 mm. Figure 22 provides the beneficiation process steps for the ore size of – 8 mm.

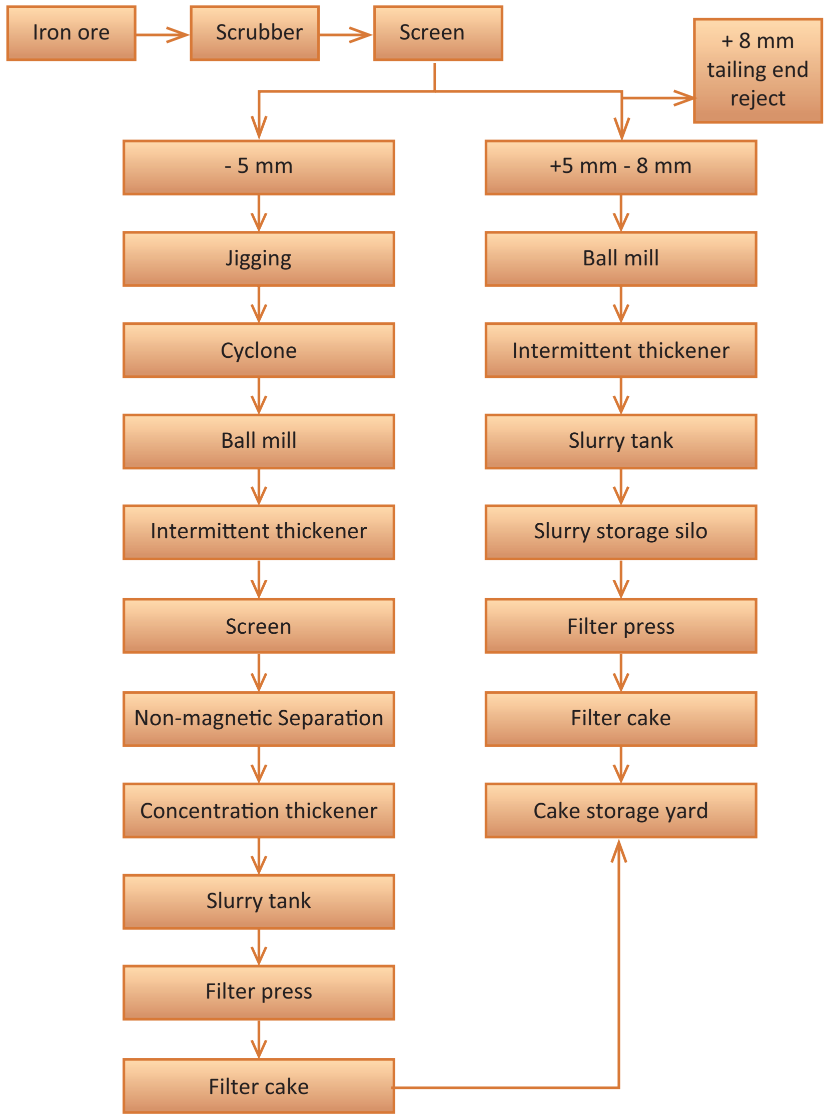

Figure 22: Beneficiation process steps

2.2.2 Formation of pellets

The raw materials comprising iron ore, pulverized coal, coke, and fluxing material are mixed with the binding chemical of bentonite at the required proportion and transferred to the storage silos. The batch mixture is supplied from the storage bin to the rotating balling disc, where the mixture is turned into various sizes of balls. These balls are passed through double-deck roller feeder to remove both oversized and undersized shapes and recycled back to the process for reuse. The pellets of desired sizes, generally 6–18 mm roll off the roller feeder, are deposited in a uniform layer onto a supporting hearth layer of the traveling grate for heating in the induration furnace.

2.2.3 Indurance of pellets

The indurance of green pellets is a heat-treatment process to enhance the mechanical strength to withstand tumbling and falling while transportation and loading inside the furnace. Green pellets are gradually heated up by the counter-flowing hot combustion gases while moving from the inlet to the heating zone to improve mechanical properties like tumbling index, abrasion index, porosity, etc.

2.3 Technology Use

The technology involved in pellet manufacturing process in the Sundergarh cluster involves balling technology to form green pellets and induration furnace for imparting strength to pellets.

2.3.1 Balling technology

The balling technology could be either a balling disc or a balling drum to produce green pellets of variable size distribution. The balling disc is an equipment, which rotates on its axis at a pre-set angle to the horizontal orientation. The main body has a pan with a circular vertical shell at the edge to ensure a closed boundary, creating open space for batch mixture holding. The balling disc is fitted with a scrapper and arrangement for raw material flow onto the pan surface. It has a supplementary water sprayer to feed raw material with less moisture than that required for the formation of the pellets.

Initial pellet formation starts at the nucleation zone of the pan bottom surface areas by rolling action and gradually builds up the size to move in a semi-circular trajectory. Finally, the balls fall on the conveyor surface and are transferred to double-decker roller to screen while rolling over. The pellets smaller than 8 mm or larger than 16 mm are desegregated and the material is recirculated to the balling process. The screened pellets are transferred to induration furnace for heat treatment. A pictorial view[viii] of a generic balling disc is shown in Figure 23.

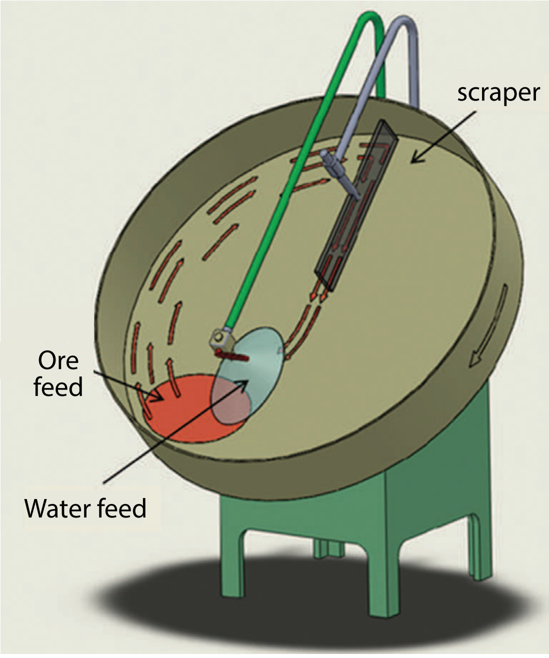

Figure 23: Pictorial view of a balling disc

Apart from balling disc, balling drums are also used in ball-making steps, which is an inclined rotating cylindrical shell with water sprays in its inlet end, where the feed material is introduced to make balls. The formed pellets are discharged, regardless of particle size, which is different compared to the balling disc where only balls larger than a certain size are discharged.

2.3.2 Induration furnace

An induration furnace is a heat-treatment furnace for sintering green pellet to improve both its mechanical and metallurgical properties. The commonly used induration furnaces include (i) straight grate, (ii) rotary kiln grate, and (iii) circular grate. The main sections of the furnace consist of updraft zone, downdraft zone, preheating zone, firing zone, after-firing zone, primary cooling zone, and secondary cooling zone.

The length of each zone is designed on the basis of the ores chemistries to be processed. Similarly, the working temperature range in each section of the furnace is maintained as per the requirement of batch material.

In the updraft zone, initially the moisture in the green pellet is removed using hot gases from downdraft fan followed with drying in downdraft zone and preheating with hot gases from recuperator fan. Air from the cooling air fan enters both primary and secondary cooling zones, where hot air from the primary cooling zone travels to the firing zone for combustion completion, which is transferred to the downdraft zone by the connected recuperator fan in line. Hot air from the secondary cooling zone is transferred to the updraft zone by the connected updraft fan in place. Finally, exhaust gas streams from the wind boxes and hood pass through electrostatic precipitator (ESP) or bag filter being sent to the stack. A schematic[ix] of induration furnace is shown in Figure 24.

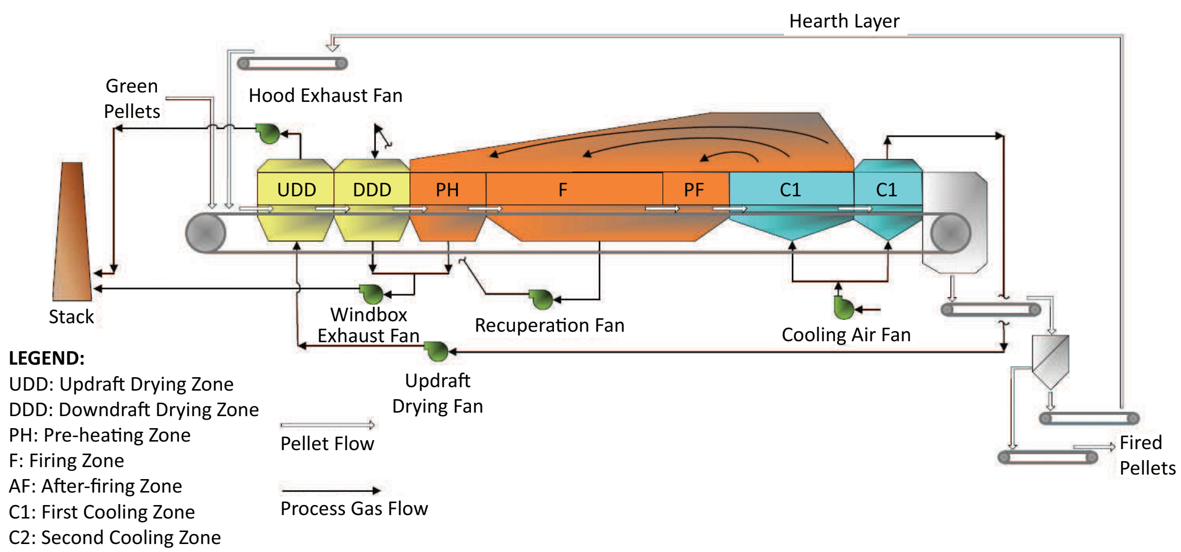

Figure 24: Schematic view of an induration furnace

The flow of hot gases in induration furnace is shown in Figure 25.

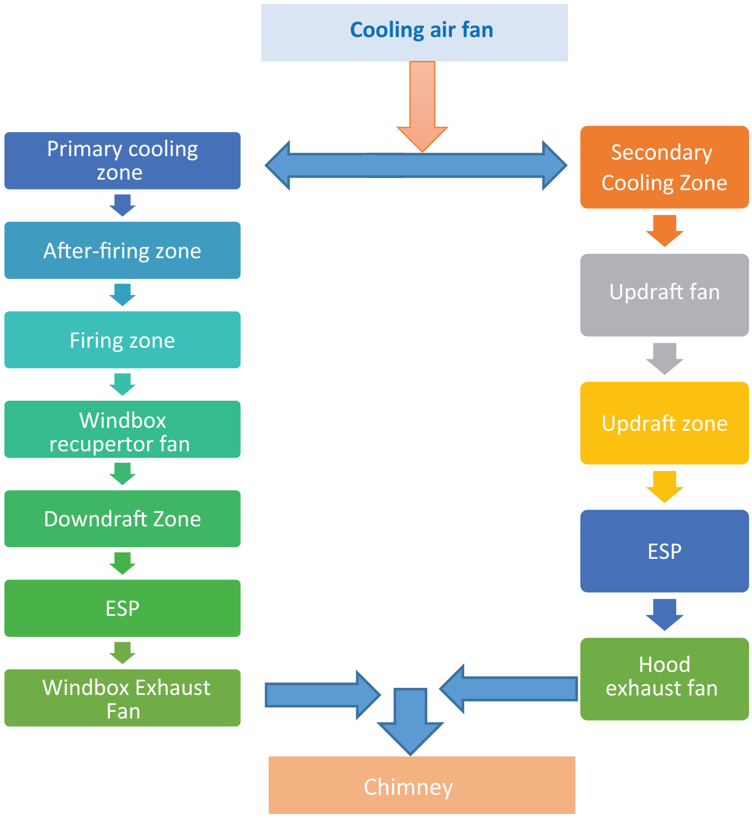

Figure 25: Schematic view of gas flow in an induration furnace

2.4 Energy Consumption and Greenhouse Gas Emissions

2.4.1 Specific energy consumption

Non-coking coal is the major fuel used in pellet manufacturing—both for thermal energy needs and metallurgical requirements. The pellet plants generally use grid electricity for the pellet requirements. The specific coal consumption of pellet production is 0.050–0.055 tonne per tonne of pellet production. The overall SEC of pellet production varies in the range of 0.276–0.305 Gcal per tonne pellet (Table 7).

Table 7: SEC of pellet production

Energy source	Unit	Minimum	Maximum
Thermal#	tonne coal/tonne pellet	0.050	0.055
	Gcal/tonne pellet	0.250	0.275
Electricity	kWh/tonne pellet	30	35
	Gcal/tonne pellet	0.026	0.030
Overall SEC	Gcal/tonne pellet	0.276	0.305

 # Considered GCV of used thermal energy source (coal) is 5000 kcal/kg

However, significant variations in SEC level are observed in coal-based pellet production as SEC levels are plant specific, which depends on factors such as iron content in iron ore, fixed carbon and volatile matter in coal, temperature profile of kiln, operating practices, etc.

2.4.2 Energy consumption and greenhouse gas emissions

The total energy consumption of pellet industries in Sundergarh cluster is estimated to be 0.023 million tonne of oil equivalent (mtoe). The corresponding emissions are 0.129 million tonne of carbon dioxide ($mtCO_2$) (Table 8).

Table 8: Energy consumption and CO_2 emissions of pellet industries in Sundergarh cluster

Energy type	Unit	Annual consumption	Equivalent energy (mtoe)	CO_2 emissions ($mtCO_2$)
Coal	mt/year	0.05	0.02	0.104
Electricity	million kWh/year	32	0.003	0.025
Total			0.023	0.129

The non-coking coal accounts for 90% of the total energy consumption of pellet industries in the cluster (Figure 26). About 81% CO_2 emissions is accounted by the use of non-coking coal (Figure 27).

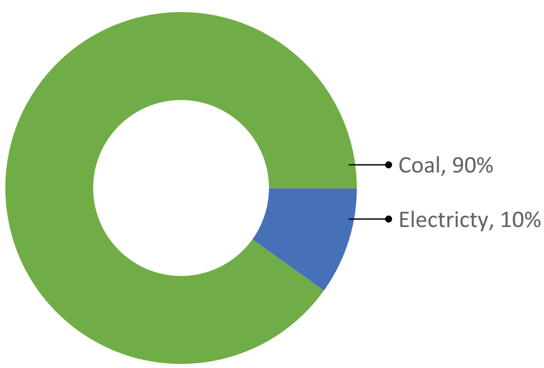

Figure 26: Share of energy consumption in pellet industries

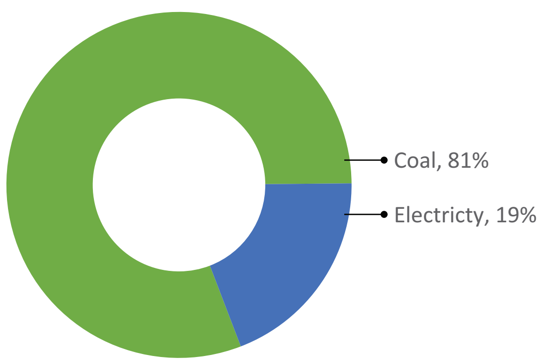

Figure 27: Share of emissions in pellet industries

2.5 Energy-saving Options

Thermal energy consumption has the maximum share in pellet-manufacturing process, which is mainly consumed in induration furnace. The potential energy-saving options applicable for pellet industries include the following:

- Adoption of circular grate technology for heat treatment
- Optimization of hearth layer height
- Oxygen enrichment in combustion air
- Switch over to coal gasification in place of solid coal firing
- Heat treatment using gas route, e.g. natural gas, hydrogen, etc.

Other important energy-saving measures include (i) variable frequency drives (VFD) for air compressors, (ii) arresting compressed air leakages, (iii) reduction of pressure setting in air compressor, and (iv) installation of solar photovoltaic (SPV) system.

3

DIRECT REDUCED IRON INDUSTRY

3.1 Background

Direct reduced iron (DRI) industries are mainly located in five states in India, namely Odisha, Chhattisgarh, West Bengal, Karnataka, and Jharkhand. There are about 318 DRI industries[x] in India, with Odisha having a maximum share of 27% (Figure 28). About 268 DRI industries (~84%) are located in these five states (Table 9).

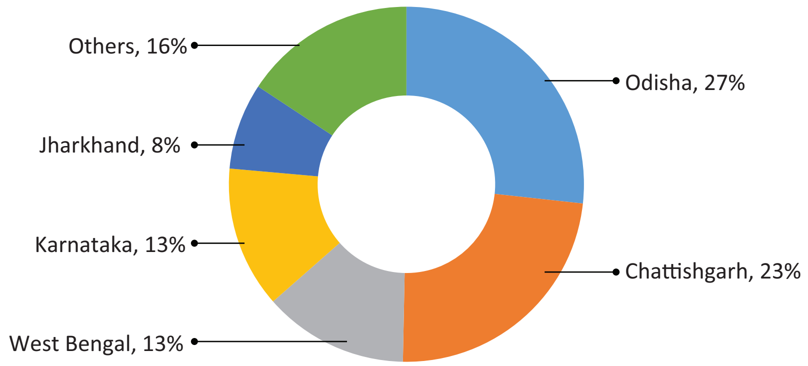

Figure 28: Distribution of DRI industries in India

Table 9: Energy consumption and CO_2 emissions of pellet industries in Sundergarh cluster

State	Number of DRI industries
Odisha	85
Chhattisgarh	75
West Bengal	42
Karnataka	41
Jharkhand	25
Others	50
Total	318

About 44% of DRI industries (179 industries) are located just in four industrial clusters namely, Raipur, Sundergarh, Bellary, and Bardhaman (Table 10 and Figure 29).

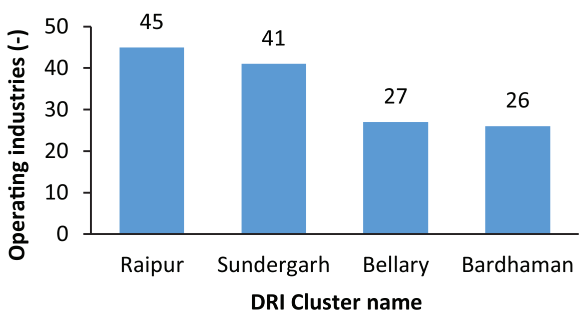

Figure 29: Primary DRI cluster in India

Table 10: Energy consumption and CO_2 emissions of pellet industries in Sundergarh cluster

DRI cluster	Number of industries
Raipur	45
Sundergarh	41
Bellary	27
Bardhaman	26
Others	179

In Odisha, there are 85 DRI industries. Sundergarh is the major DRI cluster in Odisha with 41 industries (48%), followed by Keonjhar with 14 industries (17%) as shown in Figure 30. The DRI industries in Sundergarh cluster provide direct and indirect employment to more than 15,000 people.

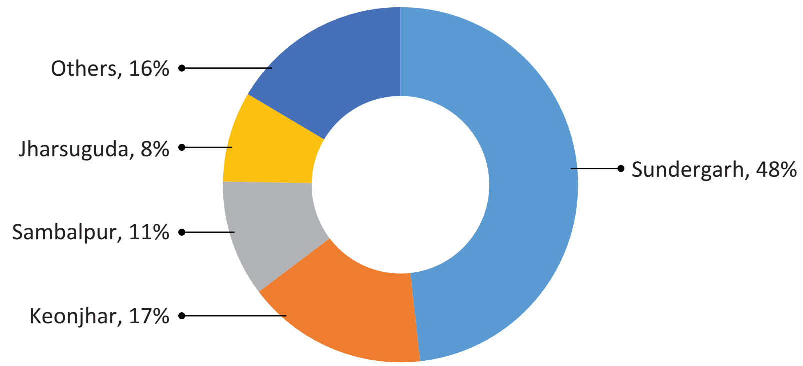

Figure 30 : Primary DRI cluster in Odisha

DRI production in Odisha[xi] increased from 5.88 million tonne (mt) in FY 2017/18 to 9.74 mt in FY 2021/22, registering 10.6% growth in 5 years (Figure 31).

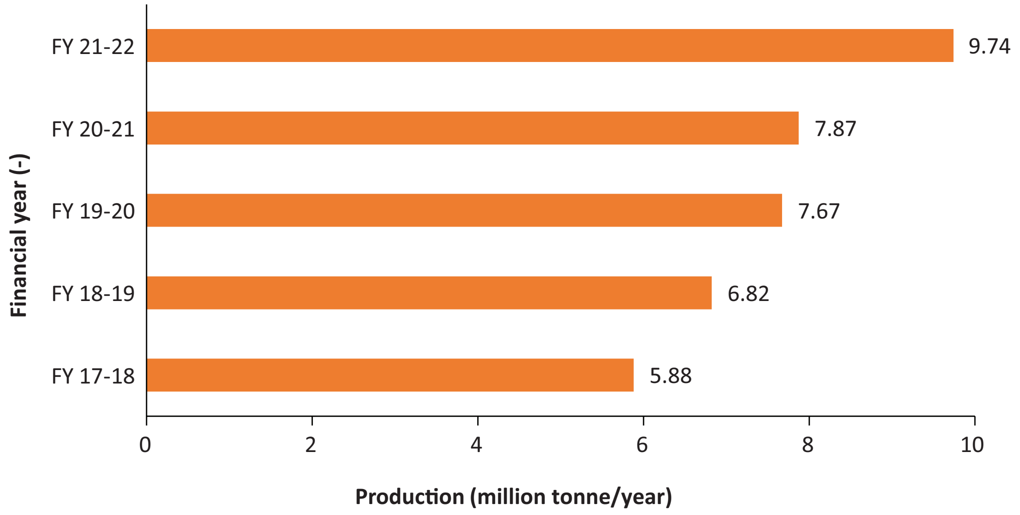

Figure 31 : DRI production in five financial years

There are 25 large DRI industries (61% of total) with 200 tonne per day (tpd) capacity or more and 16 medium DRI industries (less than 200 tpd) in Sundergarh[xii] (Figure 32). All these large industries fall under designated consumer (DC) category of Perform, Achieve, and Trade (PAT) scheme with their gate-to-gate total energy consumption more than the threshold limit for steel sector (≥ 20,000 toe per year).

Within DRI industries, 29 plants are stand-alone (71%) producing sponge iron as final product (Figure 33). The remaining 12 DRI industries are composite in nature having integrated secondary steel manufacturing facilities such as steel melting shops (SMS) having Electric Induction Furnace (EIF) with continuous casting machines (CCM) and Steel Re-rolling mills (SRRM) within the same premise.

3.1.1 Production of sponge iron

The total sponge iron production in Sundergarh cluster is estimated to be 2.5 mt per year (Table 11). About 80% of sponge iron production is accounted by DC industries (Figure 34).

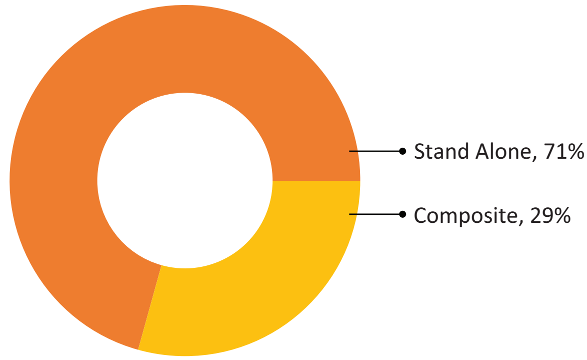

Figure 32: Capacity-wise distribution of DRI industries in Sundergarh

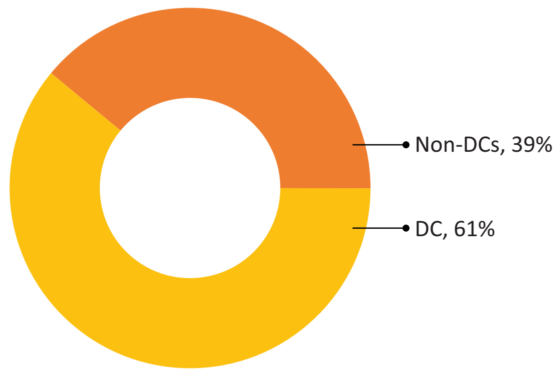

Figure 33: Structure-wise distribution of DRI industries in Sundergarh

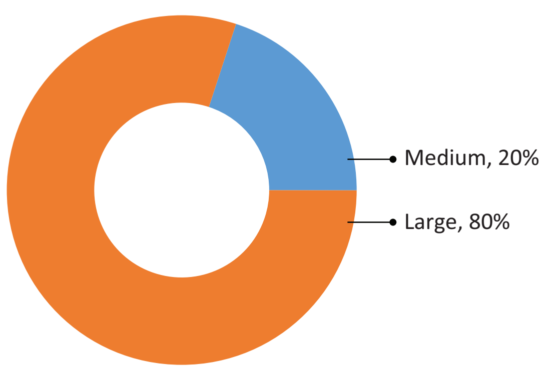

Figure 34: Production share of DRI in Sundergarh cluster

Table 11: Sponge iron production from Sundergarh cluster

Category	Number of DRI industries	Capacity range (tpd)	Production (million tpy)
Medium	16	<200	0.5
Large	25	> = 200	2.0
Total	41		2.5

3.2 Manufacturing Process

The production of sponge iron involves 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 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 (Figure 35).

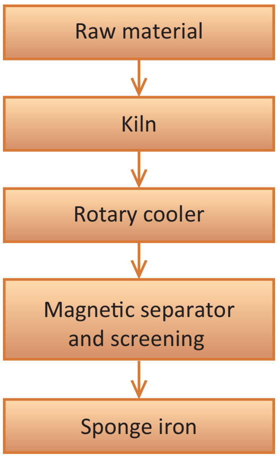

Figure 35: Sponge iron production process

3.2.1 Reduction of iron ore

The raw materials comprising iron ore and part of sized coal is supplied from feed end of an inclined rotary kiln. The feed input is gradually heated up while moving from preheating zone to reduction zone by the counter flow hot gases. In the preheating 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 leaving the metallic iron. Part of coal is pulverized and injected through the exit end of the rotary kiln which helps in completing 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.

3.2.2 Cooling of sponge iron

On completion of metallization through reduction process, the mixture of sponge iron and residual charge is 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 oxidize using oxygen of ambient air. The sponge iron is further cooled down to about 100°C through indirect cooling in rotary cooler.

3.2.3 Separation and screening

The solid discharge from the rotary cooler is a mixture of sponge iron and dolochar. 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 fractions to separate lumps and fines for storage and dispatch.

3.3 Technology Use

The broad schematic layout[xiii] of technologies used in DRI manufacturing process comprising rotary kiln, rotary cooler, waste heat recovery (WHR) system, off-gas cleaning, etc. are shown in Figure 36.

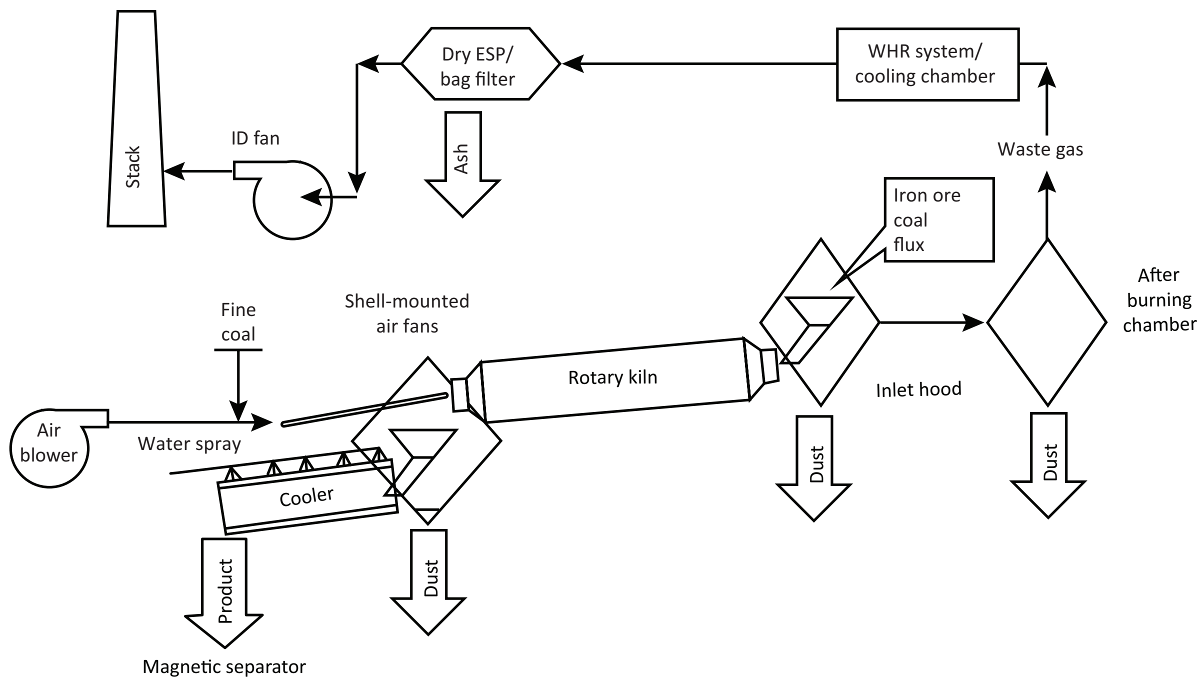

Figure 36: Schematic layout of DRI manufacturing process

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

3.3.1 Rotary kiln

The Sundergarh cluster uses horizontal rotary kilns for production of sponge iron (Figure 37). The kiln is provided with an inside refractory lining of 150–200 mm to protect the shell and has a slope of 2.5–3.0% 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 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 as lumps and/or pellets.

Figure 37:View of rotary kiln in DRI industry

The iron ore and non-coking coal are reduced to the required size in crushers. Raw materials of the 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 speed of 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 volatile matter in coal and moisture present 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. Oxygen present in 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.

3.3.2 Waste heat recovery-based power generation

About 60% of DRI plants in Sundergarh secondary steel cluster have installed WHR-based power generation system (steam based) to recover high-temperature heat available in off-gases leaving rotary kilns. It may be pertinent to mention that the sensible heat in off-gases accounts for around 40% of the total heat input to the rotary kiln. The sensible heat of exhausted off-gases from the rotary kiln can be suitably pre-treated and passed through a WHR system like WHR boiler to generate steam at high pressure and temperature and can be utilized for power generation.

The power generation potential using off-gases from the rotary kiln in DRI manufacturing depends on the average production capacity of the kiln in operation. WHR systems are financially viable for production capacities of more than 200 tpd. Table 12 provides power generation potential[xiv] from different capacities of rotary kilns.

Table 12: Power generation potential in coal based DRI industries in Sundergarh

Kiln capacity (tpd)	Power generation potential (MW)
100	1.5–2
200	3.5–4.0
350	7.5–8.0
500	10–12.0

Source: Compendium on 'Energy efficient technology options for direct reduction of iron process (sponge iron plants)', TERI 2021

3.4 Energy Consumption and Greenhouse Gas emissions

3.4.1 Specific energy consumption

Non-coking coal is the major fuel used in DRI plants—both for thermal energy needs and chemical reactions. The specific coal consumption of sponge iron production is in the range of 0.95–1.05 tonne per tonne of sponge iron production. Coal accounts for about 95–98% of the total energy consumption, while electricity consumption is about 2–5%. The DRI plants, which do not have WHR-based power generation system use grid electricity to meet electricity demands.

Significant variations in SEC level can be observed in coal-based DRI production as SEC levels are plant specific, which depends on various factors such as iron content in iron ore, fixed carbon and volatile matter in coal, temperature profile of kiln, operating practices, etc. The SEC level of sponge iron production considering both thermal and electricity input in DRI manufacturing varies in the range of 4.81–5.32 Gcal per tonne sponge iron (Table 13).

Table 13: Specific energy consumption of DRI production

Energy source	Unit	Minimum	Maximum
Thermal#	tonne/tonne DRI	0.95	1.05
	Gcal/tonne DRI	4.75	5.25
Electricity	kWh/tonne DRI	70	80
	Gcal/tonne DRI	0.06	0.07
SEC	Gcal/tonne DRI	4.81	5.32

 # Considered GCV of used thermal energy source (coal) is 5000 kcal/kg

3.4.2 Energy consumption and greenhouse gas emissions

The total energy consumption of Sundergarh DRI industries is estimated to be 1.27 mtoe; the corresponding emissions are 5.41 mtCO_2 (Table 14).

Table 14: Energy consumption and CO_2 emissions of DRI industries in Sundergarh cluster

Energy type	Annual consumption	Equivalent energy (mtoe)	CO_2 emissions (mtCO_2)
Coal	2.50 mt	1.25	5.25
Electricity	200 million kWh	0.02	0.16
Total		1.27	5.41

The annual non-coking coal consumption accounts for more than 99% of the total energy consumption of DRI industries in the cluster (Figure 38). The CO_2 emissions are about 97%, mainly accounted by coal (Figure 39).

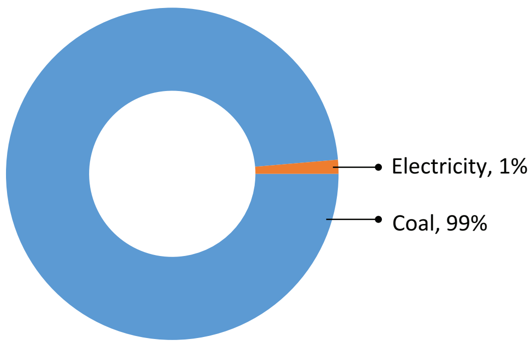

Figure 38: Share of energy consumption in DRI units

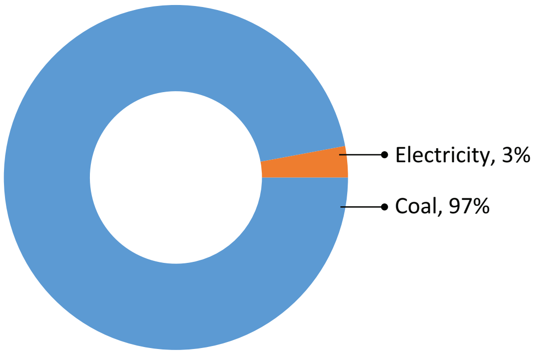

Figure 39: Share of CO_2 emissions in DRI units

3.5 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 WHR system has been identified as one of the major options towards maximizing the utilization of heat energy in DRI industries. The major energy-saving options in DRI plants include the following:

- WHR system for captive power generation, and/or iron ore preheating
- Coal gasification for partial substitution in kiln
- DRI production using gas route, e.g. natural gas, hydrogen, etc.

Other important energy-saving measures include (i) improved insulation and better material in refractory lining in rotary kiln (ii) variable frequency drives (VFDs) for variable motive loads (blowers, air compressors, etc.) (iii) arresting compressed air leakages, (iv) reduction of pressure setting in air compressor, and (v) installation of energy-efficient motors and multi-stage centrifugal pumps.

4

BLAST FURNACE INDUSTRY

4.1 Background

There are two (2) more mini-blast furnace (BF) industries in Rourkela under Sundergarh cluster producing merchant cast pig iron. All these industries[xv] are composite in nature, having multiple process steps apart from the crude molten iron production process. Only one mini BF industry qualifies as designated consumer (DC).

4.2 Production

The pig iron production from Sundergarh cluster is estimated to be 0.9 million tonne (mt) per year.

4.3 Manufacturing Process

The BF uses three types of material to prepare charge mixture, namely (i) iron mineral directly or processed form, (ii) source of heat and reducing agent, (iii) fluxing chemical. The charge mixture is transferred using a mechanized system to the charging chute, placed at the top of the BF stack. The elements that are generally used in the charge mixture are shown in Figure 40.

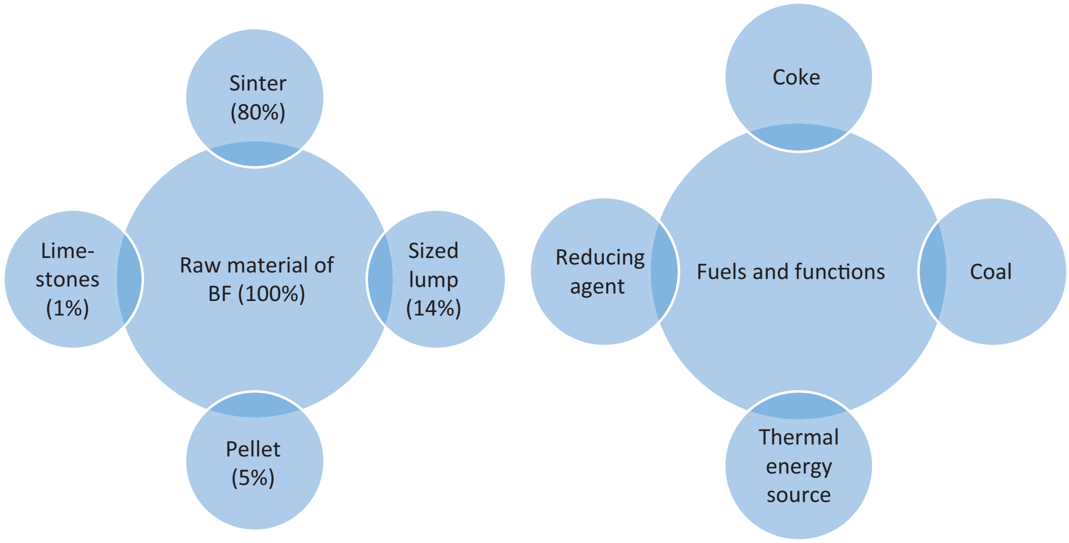

Figure 40: Constituents of charge material

While descending, the charged burden materials (coke, iron ore, and fluxes/additives) react with the ascending hot gases and produce liquid iron and slag, which are tapped from the bottom of the furnace at specific intervals. Ascending hot gases are generated from the oxidation of fuel at the raceway area with the help of injected hot blasts from tuyeres. The cycle time for the materials to transform into molten iron is about six and a half hours.

Generally, the volume of expelled hot gases from BF is about 1600 m^3 per tonne of liquid iron. The exhaust gases consist of carbon monoxide, carbon dioxide, and nitrogen. The gases travel through primary and secondary dust collectors for cleaning and the clean gases are oxidized in the combustion chamber to complete combustion and extract the heat for preheating cold blast before injected to BF as hot blast.

Box 1: Reactions in BF process	
$2C + O_2 \rightarrow 2CO$	$Fe3O_4 + CO \rightarrow CO_2 + 3FeO$
$C + H_2O \rightarrow CO + H_2$	$FeO + CO \rightarrow Fe + CO_2$
$CO_2 + C \rightarrow 2CO$	$CaCO_3 \rightarrow CaO + CO_2$
$3Fe_2O_3 + CO \rightarrow CO_2 + 2Fe_3O_4$	$CaO + SiO_2 \rightarrow CaSiO_3$
$FeS + CaO + C \rightarrow CaS + FeO + CO$	

The tapped material could be either the final product as merchant pig iron after casting or hot metal as feed to the downstream processes if any for refining to remove sulphur, silicon, and phosphorus and added alloying elements to produce desired grades of products. The principal reactions within the BF which converts charge materials into liquid iron are shown in the Box 1. A representative view[xvi] of the primary chemical reactions within the BF is shown in Figure 41.

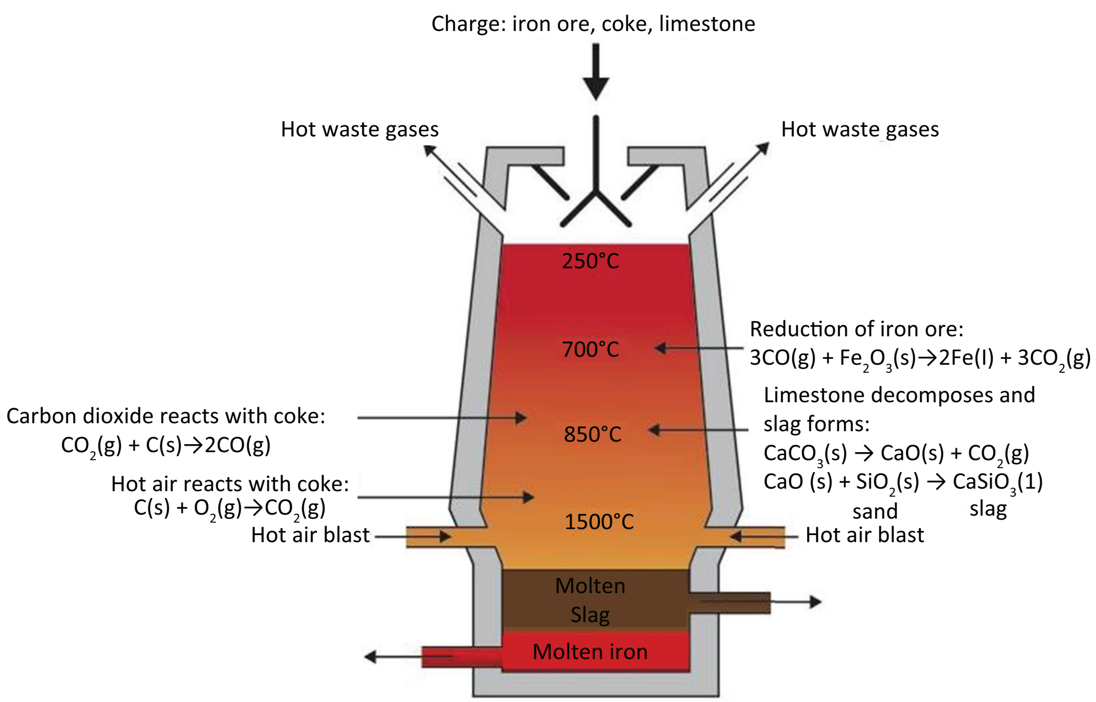

Figure 41: Details of main reaction in BF

A typical chemistry of hot metal tapped from BF is as follows:

4% C, 0.2–0.8% Si, 0.08–0.18% P, and 0.01–0.04% S. The generic process flow chart of BF is shown in Figure 42.

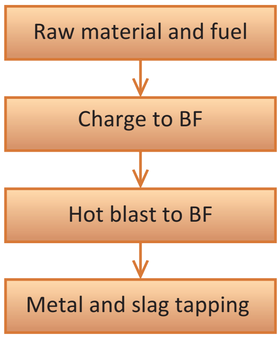

Figure 42: Process flow chart

4.4 Technology Use

A BF is a hollow cylindrical shape with a steel shell at the outermost surface and refractory lining at the inner surface. The internal open area provides space for descending charge material while heated by ascending hot gases for melting.

The BF comprises three parts such as (i) hearth (bottom area primarily holds liquid metal and slag), (ii) bosh (middle section where charge converted to liquid metal through reduction of iron ore), (iii) stack where charge mix heated by expelling ascending hot gases.

At the bottom, hot blast is injected inside through tuyere for the combustion of fuel present in the charge mixture. Occasionally oxygen enrichment and auxiliary reductant are also injected through this tuyere. The temperature profile of a BF varies alone the height starting from 2000°C (maximum at the bottom) to 300°C at the top portion of the stack. A view of the blast furnace[xvii] showing primary details of BF including internal temperature at different zones is shown in Figure 43.

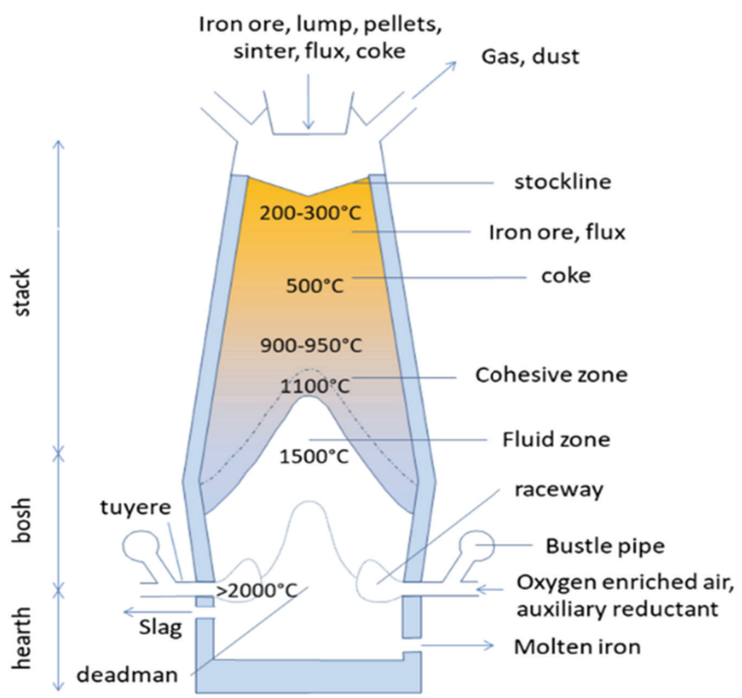

Figure 43: Schematic of blast furnace

4.5 Energy Consumption and Greenhouse Gas Emissions

Non-coking coal is the major fuel used in BF process—both for thermal energy needs and chemical reactions. The annual energy consumption of BF industries is estimated to be around 0.45 million tonne oil equivalent (mtoe). The corresponding emissions are estimated to be around 1.88 million tonne of carbon dioxide ($mtCO_2$) (Table 15).

Table 15: Energy consumption and CO_2 emissions of BF industries

Energy type	Unit	Annual consumption	Equivalent energy (mtoe)	CO_2 emissions ($mtCO_2$)
Coal	mt/year	0.59	0.44	1.81
Electricity	million kWh/year	90	0.01	0.07
Total	0.45	1.88		

Non-coking coal accounts for about 98% of the total energy consumption of BF industries in the cluster (Figure 44). More than 96% CO_2 emissions are accounted by the consumption of non-coking coal (Figure 45).

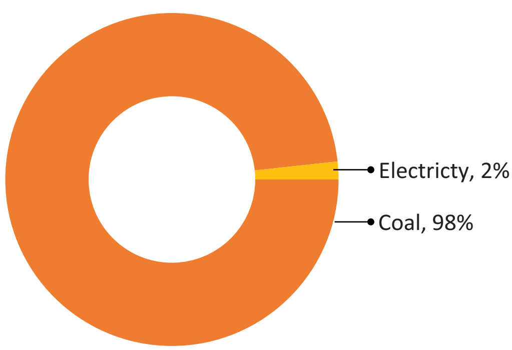

Figure 44: Share of energy consumption

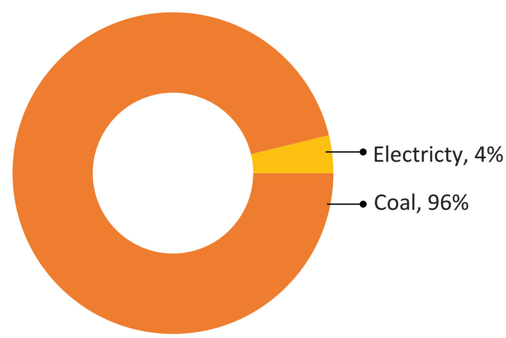

Figure 45: Share of CO_2 emissions

4.6 Energy-saving Options

There are a number of energy-efficiency measures applicable for various forward or backward process steps such as sintering, coke making, ironmaking in BF and associated auxiliaries to improve overall performance of iron and steel production. Some of the potential energy-efficiency[xviii] and technologies[xix] options for these industries are mentioned below:

- Top pressure recovery turbine for power generation
- Pulverized coal injection
- Injection of coke oven gas
- Recovery of BF gas
- Use of iron ore pellets
- Fuel substiation with biomass-derived char

5

ELECTRIC INDUCTION FURNACE

5.1 Background

There are about 25 operating electric induction furnace (EAF)-based industries[xx] in Sundergarh secondary steel cluster. About 16 EIF-based large capacity plants are of composite in nature; these are integrated facilities either through hot charging with continuous casting machine (CCM) or cold charging using ingot reheating furnace. Nine stand-alone (SA) EIF medium capacity plants produce ingots catering to the steel rerolling mills (SRRM). Composite EIF units account for about 64% of the total operating EIF units (Figure 46).

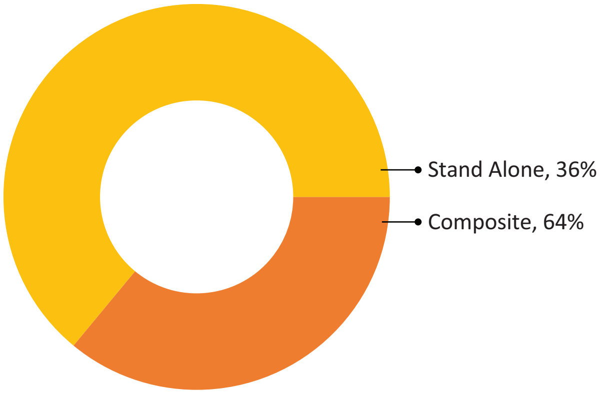

Figure 46: Structure-wise distribution of EIFs

All the composite EIF industries (64%) are designated consumers (DCs).

5.2 Production

The total production from EIF-based industries in Sundergarh cluster is estimated to be 1 million tonne (mt) per year (Table 16).

Table 16: Production of EIF in Sundergarh cluster

Industry category	Number of plants	Capacity (tonne/year)	Production (mt/ year)
Medium	9	50 to 200	0.2
Large	16	More than 200	0.8
Total	25		1.0

The large EIF plants which are designated consumers (DCs), account for about 80% of the total production in the cluster; while the non-DC EIF industries account for 20% of steel production (Figure 47).

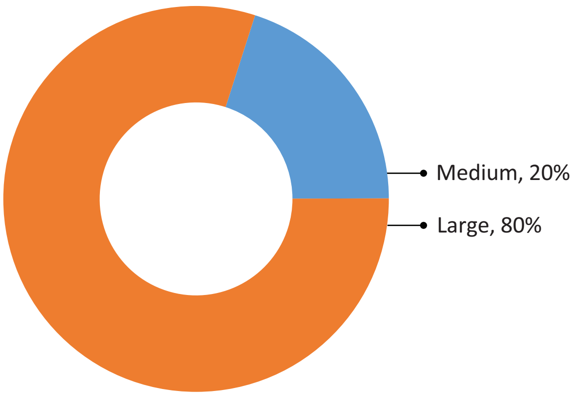

Figure 47: Production share of EIF in Sundergarh cluster

5.3 Manufacturing Process

The raw materials used in electric induction furnaces mainly depend on the product chemistries. The batch materials may include sponge iron, steel scrap, and in-house returns. Alloying elements like ferro-silicon, ferro-manganese, silicon carbide, etc. are 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 a continuous casting machine (CCM) for billets making, which is further routed to rolling mills directly. A typical batch cycle takes about 3 hour per heat.

The major steps involved in induction furnace based industries include batch preparation and charging, melting, pouring and finishing (Figure 48). The brief descriptions of the process steps are provided below.

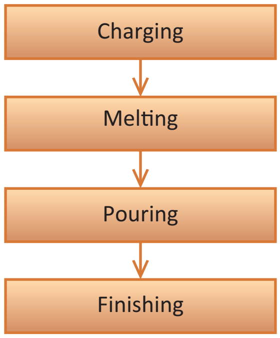

Figure 48: Process flow for EIF furnace unit

5.3.1 Preparation of charge material

Measured quantities of metal scrap, pig iron, and other alloys are loaded into the furnace for melting. The ratios of different raw materials depend on final casting properties.

5.3.2 Melting

The charge is melted in the induction furnace. The temperature requirement for the casting varies between 1500°C and 1650°C, depending on grade of steel being melted.

5.3.3 Pouring

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

5.3.4 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 reheating furnace within the same premises if exists or sold as ingots in the market for onward processing to final products.

5.4 Technology Use

The designed power rating of the electric induction furnaces in Sundergarh cluster varies between 2500 kW and 4000 kW for capacity of 6–12 tonne per batch with cycle time of 2–3 hours. EIF consists of a non-conductive crucible surrounded by a coil of copper wire for supply of powerful alternating current (Figure 49). EIFs use silicon-controlled rectifier (SCR) or insulated gate bipolar transistor (IGBT) for controlling power circuit; of these IGBT is more energy efficient.

Figure 49 : Pictorial view of copper coil in induction furnace

The main parts of EIF are crucible, power circuit, cooling system for power panel, and furnace coil. A schematic view[xxi] of coreless EIF is shown in Figure 50.

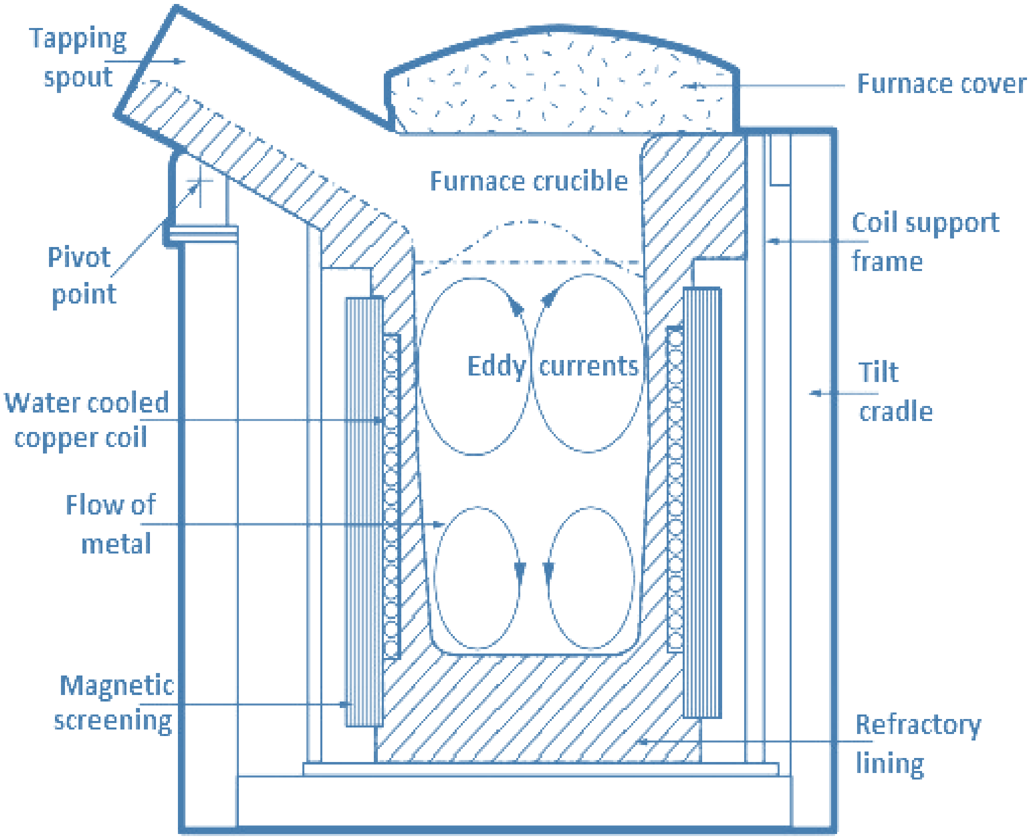

Figure 50 : Schematic view of electric induction furnace

5.5 Energy Consumption and Greenhouse Gas Emissions

The EIF industries use only electricity for melting as well as other associated auxiliaries like cooling water circulation and compressed air systems. The specific energy consumption (SEC) including associated downstream processes of integrated EIF-based industries are provided in Table 17.

Table 17: SEC of EIF and downstream process areas of integrated industries

Energy consumption area	SEC (kWh/t)
Induction furnace	800
Continuous casting machine	50
Rolling mill and utilities	100

5.5.1 Cluster-level energy consumption and greenhouse gas emissions

The cluster-level energy consumption of EIF-based industries is estimated to be 0.09 mtoe per year. This includes induction furnaces as well as downstream process areas like CCM, rolling mill, and utilities for liquid metal utilization to produce finish steel products. The equivalent emissions are about 0.79 million tonne of carbon dioxide ($mtCO_2$) (Table 18).

Table 18: Details of energy consumption and emissions

Energy type	Unit	Annual consumption	Equivalent energy (mtoe)	Emissions ($mtCO_2$)
Electricity	million kWh/year	1000	0.09	0.79

5.6 Energy-saving Options

The potential energy-saving opportunities for EIF-based industries in Sundergarh cluster include the following:

- Installation of scrap-bundling system
- Adoption of continuous casting and direct hot charging for rolling system
- Installation of Variable frequency drives (VFDs) in cooling water system and air compressors
- Use of energy efficient air compressor
- Installation of multi-stage centrifugal cooling water pumps

6

STEEL REROLLING MILL INDUSTRY

6.1 Background

There are about 16 steel rerolling mills (SRRM)[xxii] operating in Sundergarh cluster. Of these 9 mills are 'stand-alone' and 7 mills are of composite type with cold ingot charging to reheating furnace (Figure 51). All the composite mills[xxiii] qualify under the Perform, Achieve, and Trade (PAT) scheme as designated consumer (DC).

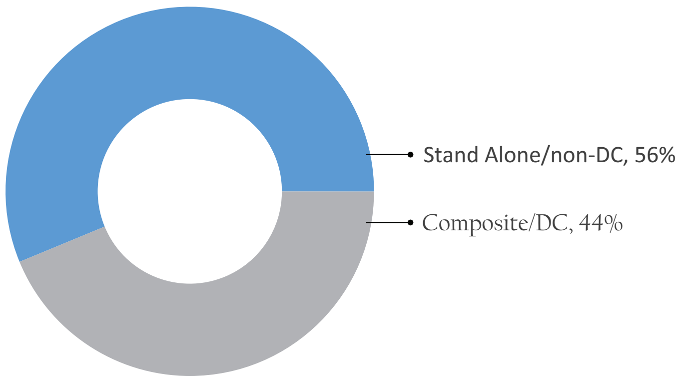

Figure 51 : Share of units

6.2 Production

Composite SRRMs use in-house ingots whereas stand-alone SRRMs procure ingots/ billets from outside. The total production from SRRM industries in Sundergarh cluster is estimated to be 0.5 million tonne (mt) per year (Table 19). Composite mills account for 80% share of the total production in the cluster (Figure 52).

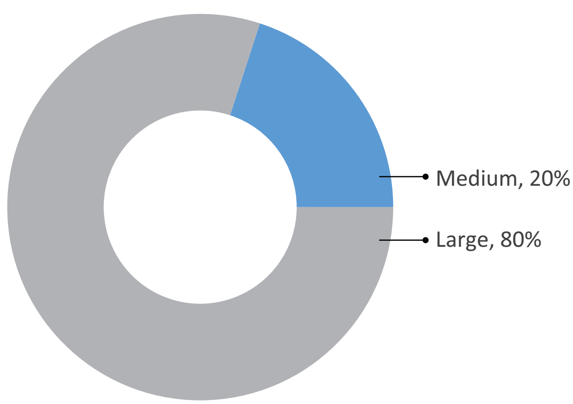

Figure 52 : Capacity-wise production share

Table 19: Production from SRRMs in Sundergarh cluster

Industry category	Number of plants	Capacity (tonne/year)	Production (mt/year)
Stand-alone	9	< 200	0.1
Composite	7	≥ 200	0.4
Total	16		0.5

6.3 Manufacturing Process

Steel rerolling mills are used to roll different kinds of metal objects to impart desired shape, thickness, and curves. Typical feed materials include bars, billets, ingots, and blooms. SRRM industries in Sundergarh cluster use coal as energy source for reheating; electricity is used for motive loads like coal pulverizer, feed pusher, rolling stands, etc. The major products manufactured in the cluster are 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 (Figure 53). Pre-sized ingot or billets in a single or double row are gradually pushed inside the furnace using a pusher motor at pre-set speed. The feed materials pass through three zones inside the furnace, namely preheating (using exhaust gases), heating and soaking (using burners).

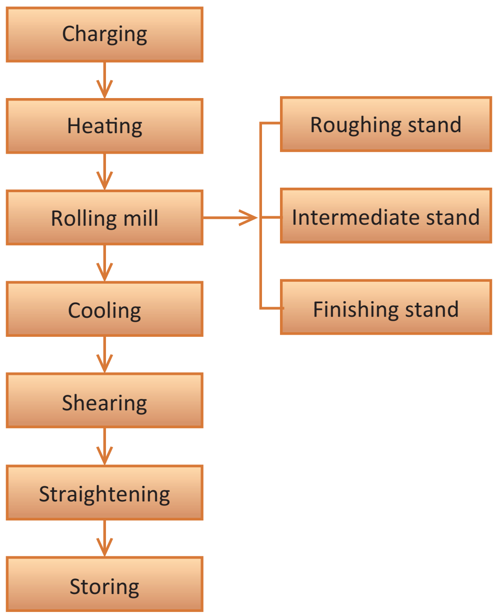

Figure 53 : Process flow of SRRM in Sundergarh cluster

Rolling mills 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 stand. Multiple passes within a stand squeeze and stretch the fed feed material into various finished steel products.

On completion of rolling, hot products are allowed to cool down before being transferred for sizing to the shearing machine and onward straightening and storing yard.

6.4 Technology Use

The major technologies or equipment used in steel rerolling mills include reheating furnace and rolling mills.

6.4.1 Reheating furnace

Reheating furnaces (Figure 54) are used in hot rolling mills to heat the steel feedstock to about 1050–1100°C. The temperature of feedstock is gradually increased while it moves inside the furnace through preheating zone, heating zone, and soaking zone. The rerolling mills in Sundergarh cluster use mostly pusher hearth type furnace with pulverized coal-fired systems. These mills have very low level of automation. Some of the furnaces are equipped with waste heat recovery (WHR) system, namely recuperator to utilize waste heat from hot exhaust gases. A few mills have installed coal gasification system and recuperator to optimize furnace performance.

Figure 54 : Reheating furnace

The feed material may be pushed inside either in one row or double row depending on design features. Most of the reheating furnace in the cluster have a feed rate capacity of about 10 tonne per hour (tph). The furnaces are operated either continuously or in batch mode of 10–12 hours per day. The reheating furnace may have associated systems such as coal gasification and recuperator and are shown in Figure 55 and Figure 56, respectively.

Figure 55 : Coal gasifier system

Figure 56 : Recuperator

6.4.2 Rolling mill

In rolling mill the hot ingot is shaped into thinner and longer products through successive rolling mill stands. The heated slab is rolled in a roughing stand, in which the thickness is gradually reduced in various passes, back and forth. The roughening stand generally has three passes. The intermediate stand has multiple passes and finally the desired shape is achieved in the finishing stand, which will also have multiple passes.

In Sundergarh cluster, rolling mills that produce 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 (Figure 57), which is connected through a set of belts to a rolling motor (Figure 58). The design rating of motor in rolling mill varies in the range of 1200–1500 horsepower (hp).

Figure 57 : Rolling motor

Figure 58 : Rolling stands

6.5 Energy Consumption and Greenhouse Gas Emissions

In SRRM-based finished secondary steelmaking industry in Sundergarh, cluster consumes coal for heating feedstock and electricity for connected rolling mill and other motive load in utilities. The specific coal consumption of rerolling mills in the cluster is in the range of 90– 130 kg per tonne of feedstock. The variations in coal consumption may be attributed to physical properties of feedstock, quality of coal and other add-on systems such as coal gasification, WHR, etc. The specific energy consumption (SEC) of stand-alone mills-based finished steelmaking including associate downstream process areas is provided in Table 20.

Table 20: SEC of stand-alone SRRM including associate process areas

Energy consumption area	Coal	Specific Energy Consumption	
	(kg/tonne)	Thermal (million kcal/tonne)	(kWh/tonne)
Reheating furnace	100	0.5	5
Rolling mill and utilities	–	–	100

6.5.1 Cluster-level energy consumption and greenhouse gas emissions

The total energy consumption of stand-alone SRRM mills is estimated to be 0.008 mtoe per year. The downstream process includes rolling mill and utility to produce finished steel products. The equivalent carbon dioxide emissions are about 0.15 $mtCO_2$ (Table 21).

Table 21: Details of energy consumption and CO_2 emission

Energy type	Unit	Annual consumption	Equivalent energy (mtoe/year)	CO_2 emissions ($mtCO_2$/year)
Coal	mt/year	0.05	0.003	0.11
Electricity	million kWh/year	53	0.005	0.04
Total			0.008	0.15

Thermal energy accounts for 36% of the total energy consumption (Figure 59) and 72% of CO_2 emissions (Figure 60). The share of electricity in total energy consumption is 64%, however, it accounts for only 28% of CO_2 emissions.

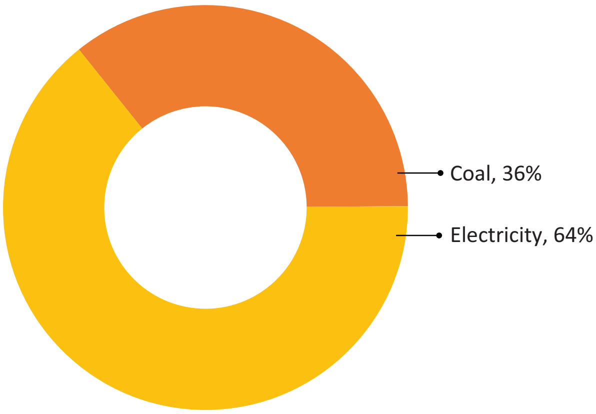

Figure 59 : Energy consumption share

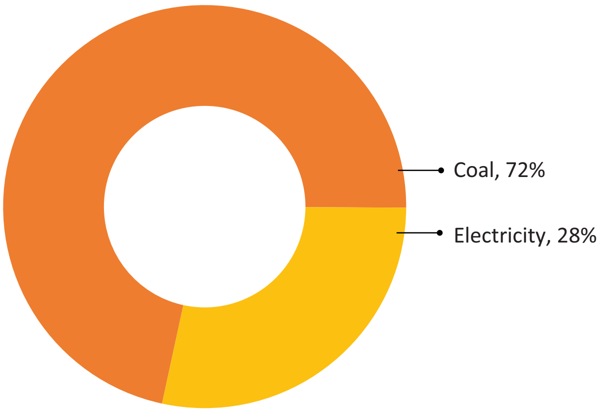

Figure 60 : CO_2 emission share

6.6 Energy-saving Options

The potential energy-saving opportunities for stand-alone SRRM mills in Sundergarh cluster include the following:

- Installation of coal gasification system
- PLC-based automatic fuel-firing system
- Adoption of WHR system
- Installation of multi-stage centrifugal cooling water pumps
- Switch over to gas-fired system, e.g. natural gas, hydrogen
- Electrification of reheating furnaces
- Implementation of continuous casting and direct rolling

7

FERRO ALLOY INDUSTRY

7.1 Background

There are only two (2) ferro alloy[xxiv] manufacturing industries in Sundergarh secondary steel cluster.

7.2 Production

The ferro alloy industries in the cluster produce ferro manganese, silicon manganese, ferro silicon, chrome alloys, etc. The total production of ferro alloys in the cluster is estimated as 0.014 mt per year.

7.3 Manufacturing Process

The general 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 to provide the arcing at the hearth of the furnace and a temperature of more than 2000°C is generated. 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:

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

$$Fe + X \longrightarrow FeX$$

FeX is the alloy of element 'X' and iron. The alloy is mainly used as a de-oxidant and an alloying element in the production of steel and cast iron. The 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 grades of coal, charcoal, and coke. The shares of different feed raw materials including carbon feed depends on the target product line.

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 61). The final alloying metal is cooled and crushed into pieces of variable sizes.

Figure 61 : Ferro silicon

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 atmosphere. A view[xxv] of submerged electric arc furnace is shown in Figure 62.

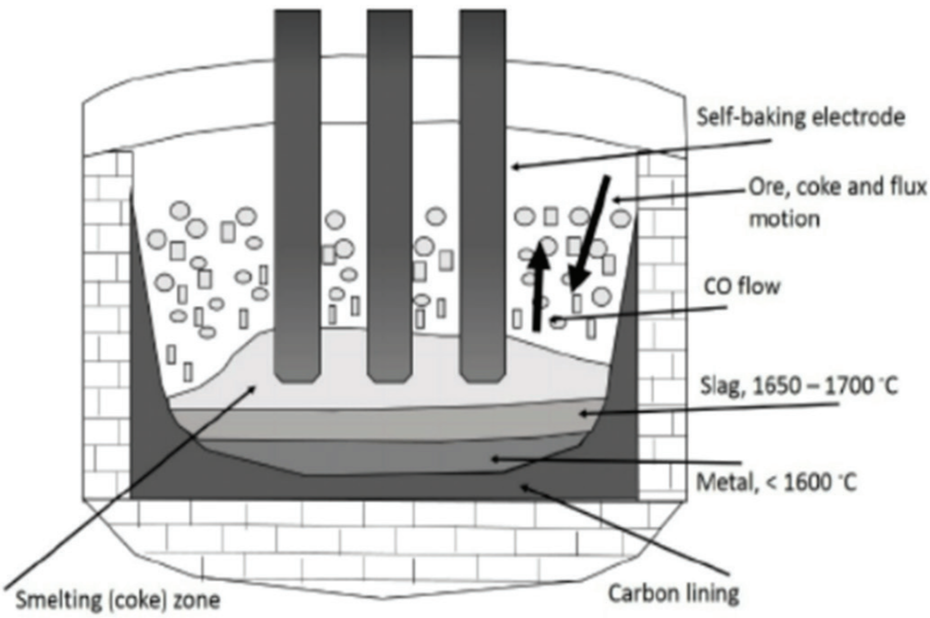

Figure 62 : View of submerged arc furnace

7.3.1 Manufacturing process

The process steps involved in ferro alloy production include (1) handling and charging of raw materials, (2) stroking, (3) smelting, (4) tapping of liquid metal (Figure 63).

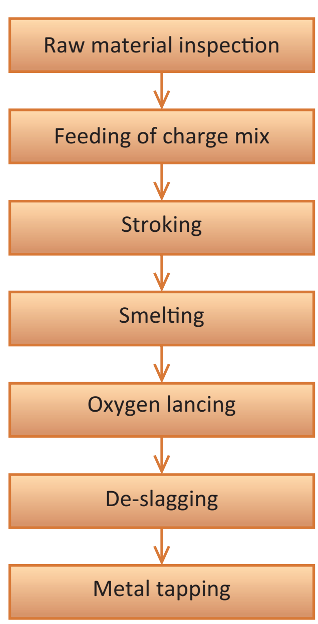

Figure 63 : Ferro alloy manufacturing process

Raw material handling

Raw materials from storage yard are screened and transported through conveyor belts to respective storage bins for further weighing and sample analysis for their composition. The analysis is done for each raw material before feeding into furnace.

The raw materials are mixed and carried through a bucket elevator into circulating feed hopper located at the top of the furnace at stroking floor for feeding inside the furnace (Figure 64).

Figure 64 : 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 65).

Figure 65 : Stroking in progress

Smelting

Smelting process is the 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 that supply high-voltage electricity to generate high-temperature arcing at the core of the furnace. This arcing is required to complete the smelting reaction at the furnace core. A reaction temperature of about 2000°C is maintained inside the furnace (Figure 66).

Figure 66 : 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 67). The generic production process showing different energy sources, raw materials input and off gases, etc. for a ferro silicon manufacturing process is shown in Figure 68.

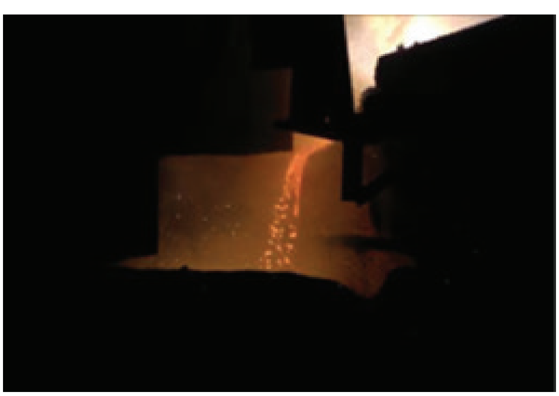

Figure 67 : Tapping in progress

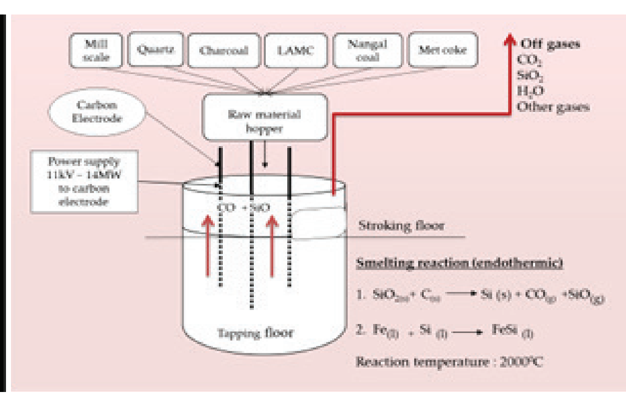

Figure 68 : Production process of ferro silicon

The furnace is cooled through cooling water circulation. 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 69).

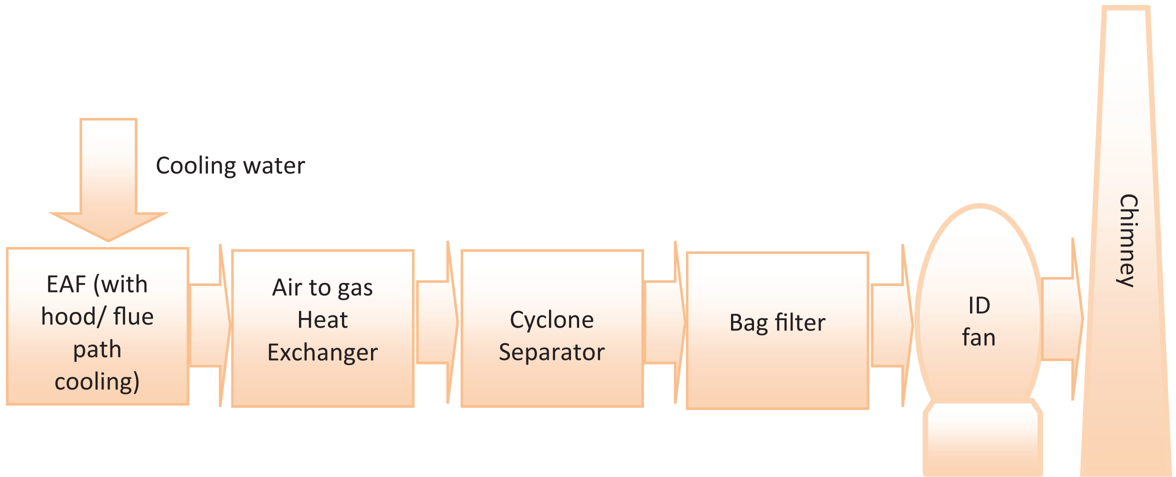

Figure 69 : Off-gas cooling and cleaning system

7.4 Technology Use

The technology description related to ferro alloy manufacturing process is restricted to submerged electric arc furnace which is the principal 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 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 70.

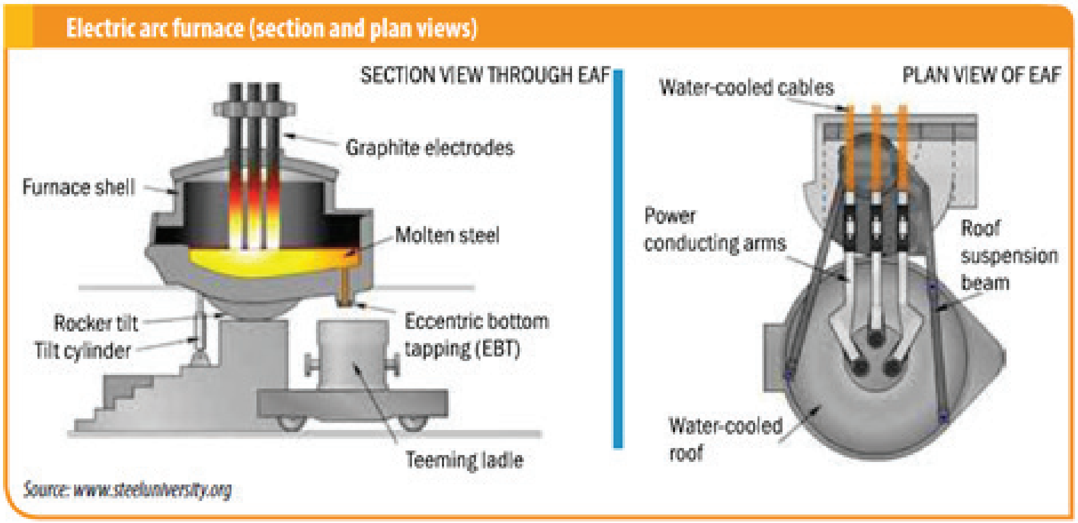

Figure 70 : Schematic views of electric arc furnace

7.5 Energy Consumption and Greenhouse Gas Emissions

Electricity is the major energy source used in ferro alloy industries. Other energy forms used are carbon-rich charcoal and coke. The SEC[xxvi] of ferro alloy industries varies widely in the country[xxvii] from 3,000 to 12,000 kWh per tonne. The SEC of ferro alloy's production is provided in Table 22.

Table 22: SEC of ferro alloy production

Process area	Specific energy consumption	
	Thermal$ (Gcal/tonne)	Electrical (MWh/tonne)
Submerged arc furnace	3.75	7.5

$ - GCV of fuel is 7500 kcal/kg

7.5.1 Cluster-level energy consumption and greenhouse gas emissions

The total energy consumption of ferro alloy industries in Sundergarh cluster is estimated to be 0.012 mtoe per year. The equivalent CO_2 emissions are 0.10 $mtCO_2$ (Table 23).

Table 23: Energy consumption and CO_2 emission of ferro alloy industries

Energy type	Unit	Annual consumption	Equivalent energy (mtoe)	CO_2 emissions ($mtCO_2$)
Coal	mt/year	0.01	0.003	0.02
Electricity	million kWh/year	105	0.009	0.08
Total			0.012	0.10

Electricity accounts for 77% of the total energy consumption (Figure 71) and 79% of CO_2 emissions (Figure 72) in ferro alloy production.

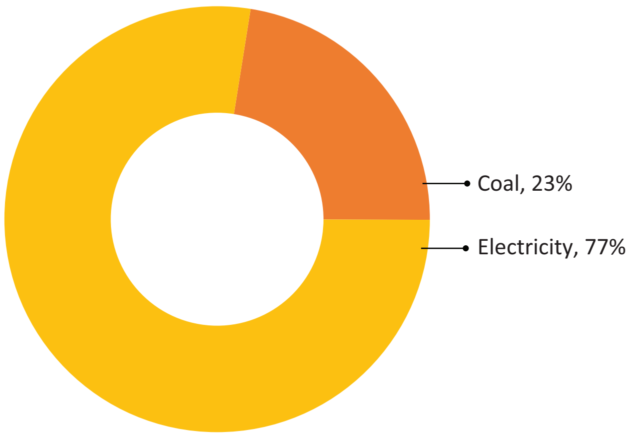

Figure 71 : Share of energy consumption

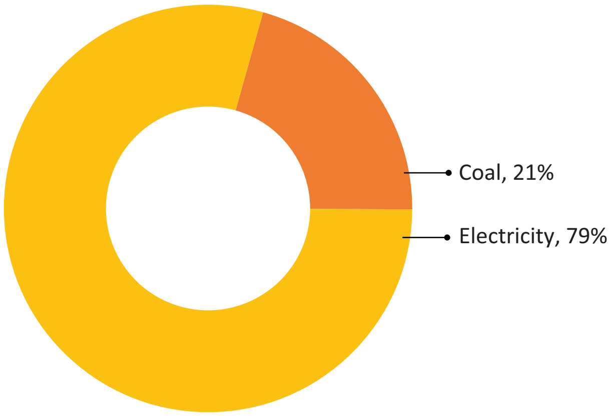

Figure 72 : Share of CO_2 emissions

7.6 Energy-saving Options

A significant scope for improving energy efficiency and reducing SEC level exists in ferro alloy manufacturing process. Waste heat in off-gases from arc furnace forms the major share of heat losses. Thus, 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:

- WHR for power generation and/or 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) VFDs for air compressors, (ii) arresting compressed air leakages, and (iii) reduction of pressure setting in air compressor.

8

KEY STAKEHOLDERS

The industry associations are one of the key stakeholders in Sundergarh cluster, facilitating networking and addressing pertinent issues relevant to the cluster. A few industry associations also facilitate technical support to the member industries by organizing awareness events like workshops, training, etc. The key stakeholders and their contact details are provided in Table 24.

Table 24: Key stakeholders of Sundergarh iron and steel cluster

Institution/ organization	Contact details
District Industries Centre	General Manager Sundergarh Odisha – 770001 Phone: 06622-272236 Email: dicsng@nic.in
Utkal Chamber of Commerce and Industry Limited (UCCIL)	Bhubaneswar Odisha-751015 Phone: +91 (771) 2539275, 4034572 Whats app: +91 89089 78183, Email: contactus@utkalchamber.in Web: http://www.utkalchamber.in/
Rourkela Chamber of Commerce and Industry	Rourkela Chamber of Commerce and Industry Chamber Bhavan, By pass road, Rourkela Odisha – 769004 Phone: 0661 2664572 Email: rccirkl@gmail.com
Orissa Sponge Iron Manufacturers Association (OSIMA)	OSIMA, Odisha chapter N-2, Civil Township, Rourkela Sundergarh, Odisha Email: osima_bbsr@rediffmail.com

9

CONCLUSION

9.1 Snapshot of Secondary Steel Industries in Sundergarh Cluster

Sundergarh is an important secondary steel cluster in micro, small, and medium enterprises (MSME) sector, comprising diverse categories of industries in operation. There are about 87 secondary steel industries operating in the cluster. The major industries in the cluster are direct reduced iron (DRI) industries, electric induction furnace units, steel rerolling mills, etc. (Figure 73). Other industries in the cluster include pellet industries, blast furnace (BF) plants, and ferro alloy industries.

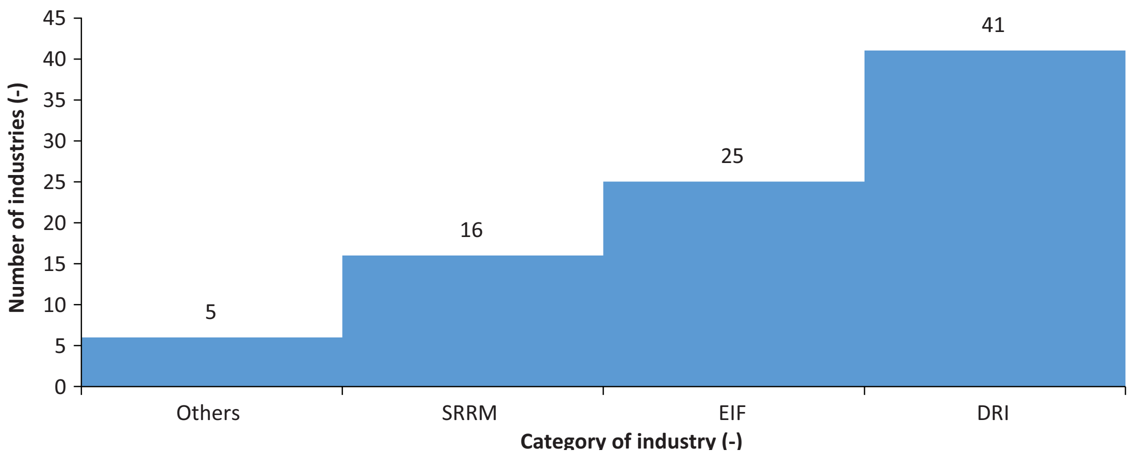

Figure 73 : Category-wise secondary steel industries in Sundergarh cluster

9.2 Cluster-level Energy Consumption and Emissions

Fossil fuel (coke, coal, etc.) consumption is predominant across different secondary steel industries in Sundergarh cluster. Induction furnaces and ferro alloy industries use electricity for melting. The cumulative energy consumption of Sundergarh cluster is estimated to be 3.63 million tonne of oil equivalent (mtoe) per year with the corresponding emissions of 7.29 million tonne of carbon dioxide ($mtCO_2$) (Table 25).

Table 25: Energy consumption and emissions in Sundergarh secondary steel cluster

Industry	Number	Production	Energy consumption				Total	
			Thermal		Electricity		Energy	Emission
		(tpy)	(mt/year)	(toe/year)	(m kWh/ year)	(toe/ year)	(mtoe/ year)	($mtCO_2$/ year)
Pellet	1	0.9	0.05	0.02	32	0.00	0.03	0.13
DRI	41	2.5	2.50	1.25	200	0.02	1.27	5.41
BF	2	1	0.59	0.44	90	0.01	0.45	1.88
EIF	25	1	0	0	1000	0.09	0.09	0.79
SRRM	16	0.5	0.05	0.003	53	0.005	0.01	0.15
Ferro	2	0.014	0.01	0.003	105	0.009	0.012	0.10
Total	87	5.81	3.19	1.72	1479	0.13	1.85	7.29

Fossil fuels account for about 93% of the total energy consumption at cluster level (Figure 74). Among all industries in the cluster, DRI industries account for major share—69%—total energy consumption (Figure 75) and 64% of the total emissions (Figure 76).

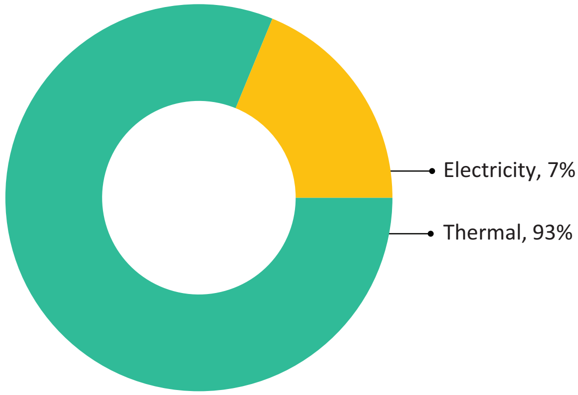

Figure 74 : Share of energy consumption

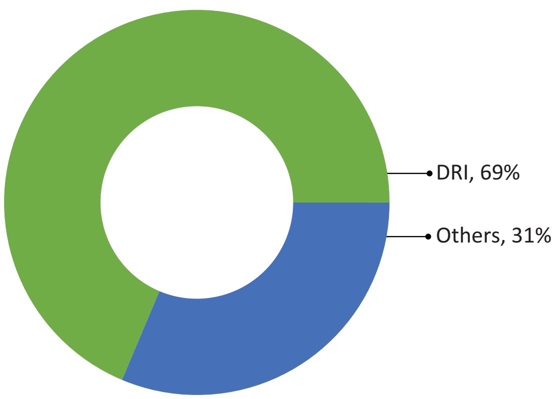

Figure 75 : Energy consumption (industry type-wise)

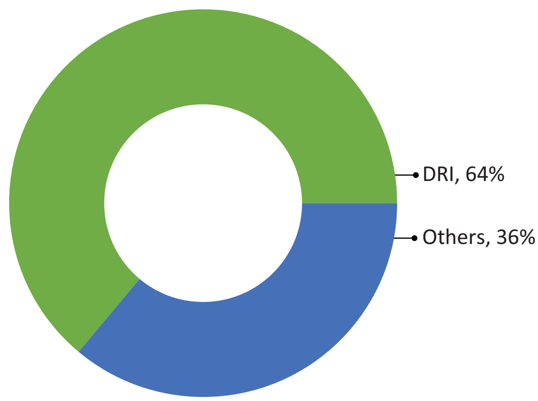

Figure 76 : Share of emissions (industry type-wise)

9.3 Energy Performance of Secondary Steel Industries

The SEC level of different secondary steel industries in Sundergarh cluster is shown in Table 26. The SEC levels vary widely across different industries based on product profile, technology use, operating practices, etc.

Table 26: SEC levels of secondary steel industries in Sundergarh cluster

Industry type	Specific energy consumption		
	kWh/t	Coal (kg/t)	Coke (kg/t)
Pellet	30–35	50–55	–
DRI	70–80	1000–1200	
Electric induction furnace including Continuous casting machine	850–950	–	–
Reheating furnace (in SRRM)	4–6	90-120	–
Rolling mill	80–120	–	–
Ferro alloy	7000–8000	–	450–550

9.4 Conclusion

The technology status and energy consumption levels of different secondary steel industries in Sundergarh cluster indicate there exists a significant scope for improving energy efficiency and reducing emissions. Detailed assessment studies of industries in the cluster are required to identify thrust areas for energy efficiency improvements.

The secondary steel industries in Sundergarh cluster would require robust technical backup support and suitable policy and finance instruments to adopt energy-efficiency measures. This would require long-term interventions at the cluster level. Aligning with India's Nationally Determined Contributions (NDCs) to achieve net-zero emissions by 2070, the secondary steel industries in Sundergarh cluster need to switch over to customized decarbonization technology options in the long-term. To facilitate deep decarbonization among industries, pilot demonstrations of net-zero technologies need to be initiated to suit the industries at the cluster level.

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