UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Technology Compendium for

Energy Efficiency and Renewable Energy Technologies in

Eastern Zone Metal Industries

Volume III: Steel Re-rolling Mill Sector

September 2020

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Disclaimer

Promoting Energy Efficiency and Renewable Energy in Selected MSME Clusters in India

A GEF funded Project being jointly implemented by

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Technology Compendium for

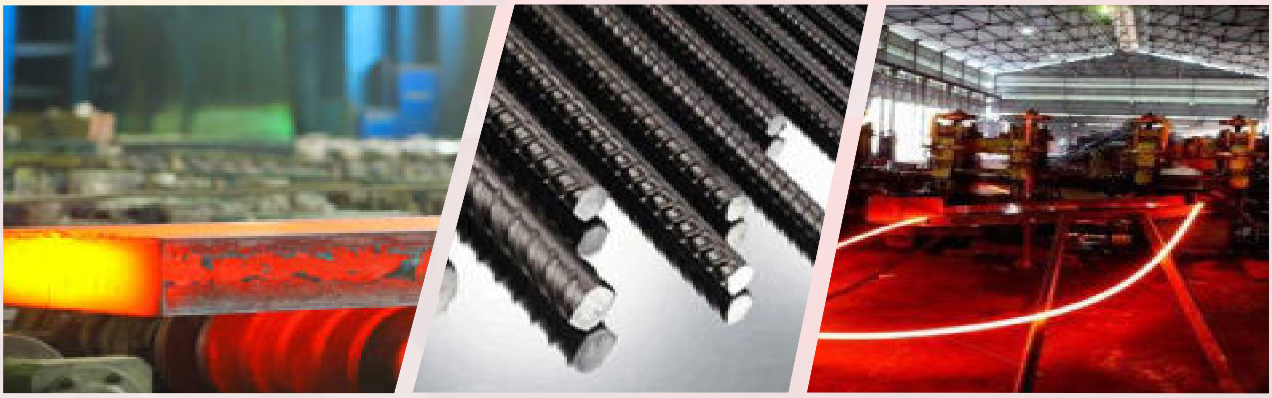
Energy Efficiency and Renewable Energy Technologies in Eastern Zone Metal Industries

[Volume III: Steel Re-rolling Mill Sector]

September 2020

Developed under the assignment

Scaling up and expanding of project activities in MSME clusters



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DESL Team

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List of Abbreviations

AISRRA	All India Steel Re-rollers Association
BEE	Bureau of Energy Efficiency
CBG	Coal Bed Gas
CBM	Coal Bed Methane
CMM	Coal Mine Methane
CSG	Coal Seam Gas
DESL	Development Environergy Services Limited, New Delhi, India
EE	Energy Efficiency
EET	Energy Efficient Technologies
GEF	Global Environment Facility
GHG	Greenhouse Gases
MNRE	Ministry of New and Renewable Energy
MoMSME	Ministry of Micro, Small and Medium Enterprises
MS	Mild Steel
MSME	Micro Small and Medium Enterprises
PMC	Project Management Cell
PNG	Piped Natural Gas
PV	Photovoltaic
RE	Renewable energy
SPM	Suspended Particulate Matter
SRRM	Steel Re-Rolling Mill
SRRMA	Steel Re-rolling Mill Association
TMT	Thermo Mechanically Treated
UNIDO	United Nations Industrial Development Organization
VFD	Variable Frequency Drive

Unit of Measurement

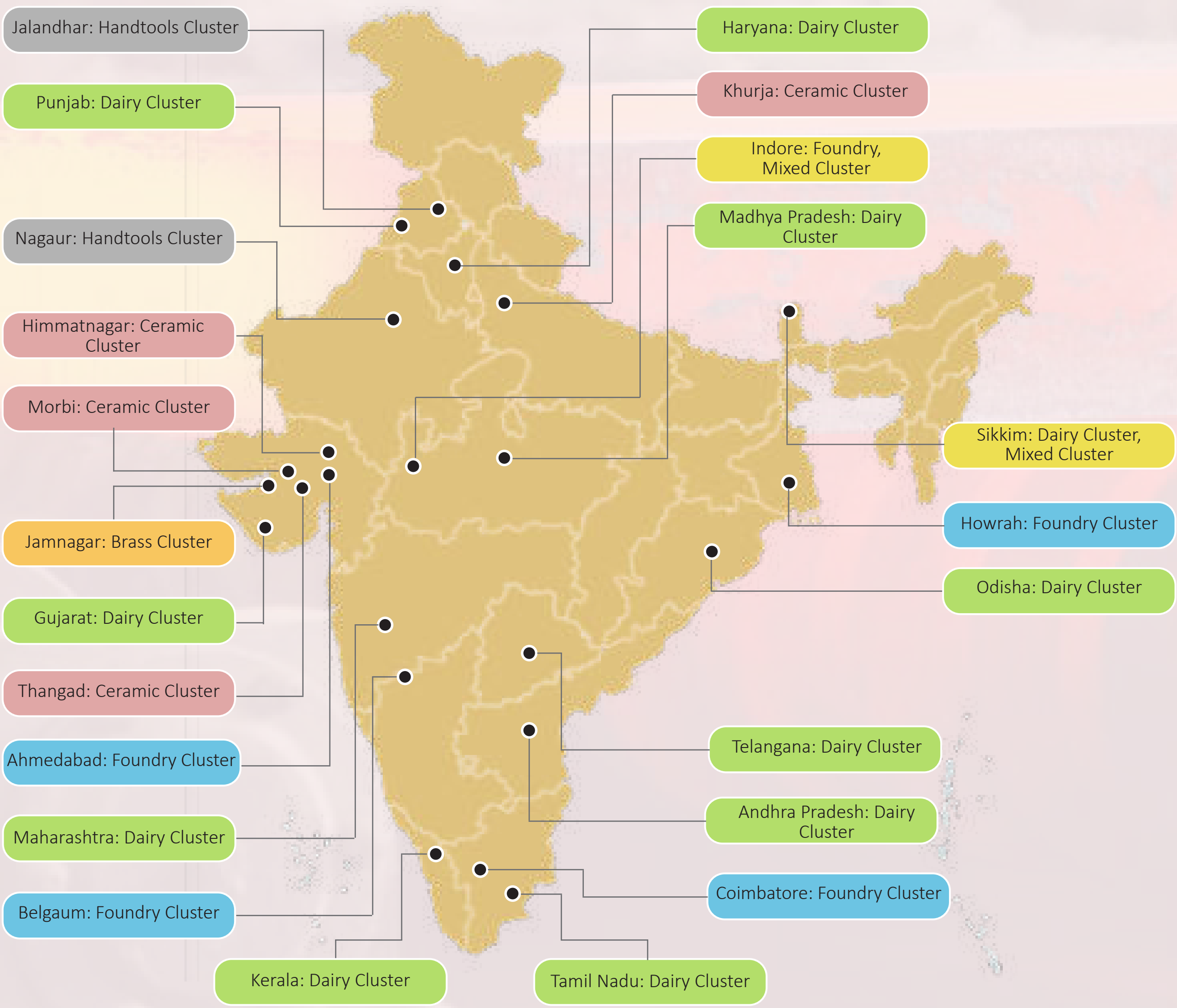
Parameters	UOM	Parameters	UOM
Ampere	A	Liter(s)	l
Approximate	~	Mega Joule	MJ
Centimeter	cm	Mega Watt Hour per Day	MWh/d
Centimeter Square	cm^2	Meter	m
Cubic Centimeter	cm^3	Meter cube	m^3
Cubic Feet per Minute	CFM	Meter Cube per hour	m^3/h
Cubic meter	m^3	Meter cube per second	m^3/s
Day(s)	d	Metric Ton	mt
Decibel	dB	Milligram	mg
Degree Centigrade	^0C	Milligram per liter	mg/l
Degree Fahrenheit	^0F	Millimeter	mm
Dry Bulb Temperature	DBT	Million	Mn
Giga Watt	GW	Million Tons of Oil Equivalent	MTOE
Giga Watt Hour	GWh	Minute(s)	min
Giga Watt Hour per Day	GWh/d	Normal Meter Cube	Nm^3
Giga Watt Hour per year	GWh/y	Normal Meter Cube per Hour	Nm^3/h
Gross Calorific value	GCV	Parts Per Million	ppm
Hertz	Hz	Per Annum	p.a.
Horse power	hp	Percentage	%
Hour(s)	h	Power Factor	PF
Hours per year	h/y	Revolution per Minute	rpm
Indian Rupee	INR / Rs	Rupees	Rs
Kilo Ampere	kA	Rupees per kilo Watt Hour	Rs/kWh
Kilo Calorie	kCal	Rupees per Metric Ton	Rs/MT
Kilo gram	kg	Second	s
Kilo Joule	kJ	Square Meter	m^2
Kilo ton	Kt	Standard meter cube	Sm^3
Kilo volt	kV	Tesla	T
Kilo volt ampere	kVA	Ton	t
Kilo Volt Root Mean Square	kV rms	Ton of CO_2	tCO_2
Kilo watt	kW	Ton per Day	t/d
Kilo watt hour	kWh	Ton per Hour	t/h
Kilocalorie per kilogram	kCal/kg	Ton per Year	t/y
Kilogram	kg	Voltage	V
Kilogram per ton	kg/t	Watt	W
Kilogram per day	kg/d	Wet Bulb Temperature	WBT
Kilo volt	kV	Year(s)	y
Kilo volt root mean square	kV-rms	Year on Year	YOY

About the Project

The United Nations Industrial Development Organization (UNIDO), in collaboration with the Bureau of Energy Efficiency (BEE), a statutory body under the Ministry of Power, Government of India, is executing a Global Environment Facility (GEF) funded national project titled 'Promoting energy efficiency and renewable energy in selected MSME clusters in India'. The project aims to develop and promote a market environment for introducing energy efficiency (EE) and enhanced use of renewable energy (RE) technologies in process applications in selected energy intensive industrial clusters, comprising micro, small and medium enterprises (MSMEs). The project is supported by the Ministry of Micro, Small and Medium Enterprises (MoMSME) and Ministry of New and Renewable Energy (MNRE). The project was operational in 12 MSME clusters across India in five sectors namely Brass (Jamnagar); Ceramics (Khurja, Thangadh and Morbi); Dairy (Gujarat, Sikkim and Kerala); Foundry (Belgaum, Coimbatore and Indore); Hand Tools (Jalandhar and Nagaur) in its first phase. The Project has now scaled-up and expanded its activities to additional 11 new clusters, namely in Dairy (Tamil Nadu, Odisha, Madhya Pradesh, Andhra Pradesh & Telangana, Haryana, Maharashtra & Punjab), Foundry (Ahmedabad & Howrah), Ceramic (Himmatnagar), Mixed Cluster (Indore & Sikkim) to reach out to MSME's at national level.

This project so far has supported 303 MSME units in implementing 603 Energy conservation Measures and thus resulted in reduction of about 10,850 TOE energy consumption and avoided 62,868 metric tons of CO_2 emissions as on date. The key components of the project include:

- Increasing capacity of suppliers of EE/RE product suppliers / service providers / finance providers
- Increasing the level of end user demand and implementation of EE and RE technologies and practices by MSMEs.
- Scaling up of the project to more clusters across India.
- Strengthening policy, institutional and decision-making frameworks.



Clusters intervened by the project

About the Technology Compendium

The Micro, Small and Medium Enterprises (MSME) sector in India are an important contributor to the country's economy. However, the sector faces challenges resulting from rising energy costs, environmental concerns and competitiveness. Most of the industries from the MSME sector use old and obsolete technologies leading to significant energy consumption. Studies show a significant potential in these units through adoption of energy efficient and renewable energy technologies.

The technology compendium has been prepared with the objective of accelerating the adoption of energy efficient and renewable energy technologies and practices applicable in the identified energy-intensive MSME sectors. The sector-wise technologies listed in the document consists of details about the baseline scenario, energy efficient alternatives available, advantages, limitations and cost benefit analysis for the same. The technology wise information is also supported by relevant case studies wherein benefits related to actual implementation of these technologies has been captured. Some notable points pertaining to the document are listed below:

- The compendium will act as a ready reckoner to the MSME units for continuously improving their energy performance leading to a cost-effective and sustainable production process.
- In the wide spectrum of technologies and equipment applicable for the sectors for energy efficiency, it is difficult to include all the energy conservation aspects in this manual. However, an attempt has been made to include more common implementable technologies across each of these sectors.
- The user of the compendium has to fine-tune the energy efficiency measures suggested in the compendium to their specific plant requirements, to achieve maximum benefits.
- The compendium also consists of a list of technology suppliers where the listed technologies can be sourced. However, in addition to the list provided in the compendium, there may be many more suppliers / consultants from where the technologies can be sourced.
- The technology compendium consists of list of energy efficient and renewable energy technologies under the broad categories of 'low investment', 'medium investment' and 'high investment measures'. Also due care has been taken to include technologies related to 'fuel switch', 'retrofit measures' as well as 'technology upgradation' options.
- The technologies collated in the compendium may not necessarily be the ultimate solution as the energy efficiency through technology upgradation is a continuous process and will eventually move towards better efficiency with advancement in technology.
- The document provides overview of the various available energy efficient and renewable energy technologies applicable in the targeted sectors. This provides an opportunity to the MSME units to implement the best operating practices and energy saving ideas during design and operations and to facilitate achieving world class energy efficiency standards.

Executive Summary

The steel re-rolling mill sector in India forms an important link to the overall steel production in the country, manufacturing close to 65% of the total long steel finished products in the country. The steel re-rolling mill unit can be a standalone unit which procures raw material in the form of ingots, billets or scraps from the market and produces finished products comprising bars and rounds, sectional products or industrial products.

The other section comprises composite units having both melting and rolling facilities under the same premises. The steel re-rolling mill units are scattered across the country and exist in clusters in and around key industrial hubs.

The eastern zone of the country includes some of the significant rolling mill clusters in the country which include Howrah and Durgapur in West Bengal; Jamshedpur and Ranchi in Jharkhand, Rourkela in Odisha and Patna and Danapur in the state of Bihar. Besides these bigger clusters, a few units also operate from clusters such as Bokaro, Hooghly, Siliguri, Burdwan, Bankura, etc.

The steel re-rolling mill sector is a highly energy intensive cluster using both thermal and electrical energy. Most of the units in the sector use old and obsolete technologies leading to significant energy bills. Significant potential for savings exists in the cluster through adoption of energy efficient and renewable energy technologies. The adoption of these technologies can make the units more cost competitive and sustainable.

The United Nations Industrial Development Organization (UNIDO) is playing a pivotal role jointly with the Bureau of Energy Efficiency (BEE), Ministry of Power, and Government of India towards scaling up the penetration of low-cost Energy Efficient Technologies (EETs) in the foundry, forging and steel re-rolling mill units located in the eastern zone of the unit. A total of 80 MSME units in the cluster comprising foundry, forging and steel re-rolling mill units in the cluster are envisaged to be supported technically to become energy efficient and cost-competitive.

This document is an outcome of the enormous research carried out in the sector, energy audits conducted in representation units and stakeholders' consultation. The extensive research and ground level deployment of various teams have made it possible to consolidate the list of energy efficient and renewable energy technologies applicable for the steel re-rolling mill sector. While most of these technologies have proven implementation record, some of the technologies are still in the developmental stage and will require efforts for implementation.

The compendium for energy efficient and renewable energy technologies has been compiled and consolidated, keeping in mind different types and capacities of the units.

This compendium can be used as a single point information booklet for various economically viable energy efficient and renewable energy technologies applicable in the cluster. Each technology has been complemented by a techno-commercial analysis report; in order to provide the readers with in-depth understanding of the technology. Each technology comes up with information on tentative investment, energy saving potential, cost savings and simple pay-back.

A vendor list has also been compiled at the end for easy reference of the units.

The technology compendium will act as a ready reckoner to the MSME unit owners and help them select relevant technologies for their units. The technology compendium also consists of case studies on actual implementation of the technologies and benefits realized thereof. Although the compendium consists of some general information on the technologies, the same will require customization based on individual unit's requirement.

The Howrah foundry cluster has significant potential in terms of energy saving. The BEE-UNIDO project thus plays a pivotal role in making a transformational change in the sector which will lead to the units becoming cost competitive; thereby resulting in a sustainable future.

The technologies identified for the sector have been categorized into three groups and comprise both energy efficient and renewable energy technologies applicable for the sector.

Table 1: Energy efficient and renewable energy technologies for steel re-rolling mill sector

Category	Description	Technology	Investment (Rs in Lakhs)	Saving Potential (Rs in Lakhs)	Simple Pay-back (Rs in Lakhs)
A	Low Investment Technologies (up to Rs 2 lakhs)	Swirl burners for pulverized coal firing	1.25 – 10	4 – 17.5	< 1 year
		Energy Efficient Motors	10959	0.03-0.55	< 1 year
		Installation of VFD in blower	1.5 – 5	4 – 20	< 1 year
B	Medium Investment Technologies (up to Rs 10 lakhs)	High Efficiency Metallic Recuperator	8.5 - 45	25- 135	< 1 years
		Re-heating Furnace Automation & Control System	10 – 26	15- 85	< 1 years
		Energy Efficient Pulverizer	6 – 25	May-25	< 1.5 years
		Modified pulverized coal feeding system	10 – 30	15 - 40	< 1 year
		Coal drying system	10 – 25	Dec-50	< 1 year
		Energy Efficient Lighting	10 – 50	3 – 15	< 3 years
		Automatic Material Handling System	10 – 60	10 – 35	< 2 years
C	High Investment Technologies (more than Rs 10 lakhs)	New Energy Efficient Furnace	15-250	55- 275	< 1.5 years
		Coal Bed Methane based re-heating furnace	100 – 150	100 – 200	< 1 year
		Optimum Refractory & Insulation	20 – 50	27668	< 2 years
		Biomass based producer gas as fuel	70 – 120	250 – 500	< 1 year
		Natural gas firing for reheating furnace	20 – 60	30 – 80	< 1 year
		Antifriction Roller Bearing	20 – 60	75 – 190	< 1 year
		Universal Coupling and Spindles	20 – 60	75 – 190	< 1 year
		Revamping of rolling mills	60 – 150	100 – 250	< 1 year
		Adoption of direct rolling in TMT mills	40-150	150 – 700	< 1 year
		Adoption of direct rolling in structural mills	100 -200	150 – 600	< 1 year

**The figures on investment and savings are tentative and are based on budgetary quotations and technical calculations; the actual figure may vary.*

1 About the Cluster

1.1 Sector overview

The first steel re-rolling mill was established in the year 1928 at Kanpur long before Independence of India. Gradually, steel re-rolling mills came up in the limelight when concept of large scale steel plants was absent in the mind of the Government. The only large steel plant at that time started to function at TATA, Jamshedpur in the year 1907. Since 1928 till today, around 1,800 re-rolling mills are functioning all over India. This is because of the fact that many of the re-rollers from West Pakistan re-established their re-rolling mills in and around Punjab within India. Re-rolling mills serve the purpose as Secondary Steel Sector and as a complement to the main steel lines.

In 1984, the first manufacturing re-rolling mill unit was established with all key functional infrastructural operations in Liluah, Howrah. Manufacturing only Mild Steel (MS) Round bars and high strength deformed steel reinforcement bars (MS TMT); these products are manufactured till date due to the ever-growing demand from the construction industry.

Figure 1: A typical steel re-rolling mill unit

The growth in construction activity and infrastructure projects in India has buoyed the demand for steel industry. There is a demand for steel products such has Thermo Mechanically Treated (TMT) bars, structural steel viz., angles, plates, channels, rounds, etc.

The steel re-rolling mill (SRRM) sector in India is one of the most important segments of the steel industry and is a key link in the supply chain of iron and steel production in the country. The sector covers long product mills with re-heating furnace and rolling mills, and a few units have completed backward integration by installing induction furnaces to melt scrap and DRI cast by ingot or continuous casting.

Steel re-rolling is an energy-intensive process. It takes nearly 35-45 litres of furnace oil (or 100-200 kg of coal) and 80-150 Kilowatt-hour (kWh) of electricity to produce one ton of long steel finished product. Among India's small and medium enterprises (SMEs), there are more than 1,800 steel re-rolling mills, majority (75 percent) of which are small-scale units. The SMEs engaged in steel re-rolling constitute an important link in the overall supply chain of steel, contributing to more than 65 percent of steel produced in the country. However, these mills have grown haphazardly, utilizing outdated technologies, and are characterized by high production costs and low investment in upgrading technologies or research and development. The direct energy use in this sector includes fossil fuels (furnace oil, natural gas and coal) and electrical energy is estimated to account for 25-30 percent of the overall production costs.

1.2 Steel Re-rolling Mill Sector in the Eastern Region

The eastern zone of the country comprising the states of West Bengal, Jharkhand, Odisha and Bihar houses close to 20% of the total steel re-rolling mills in the country. Some of the key clusters located in the eastern zone of the country that house steel re-rolling mill standalone as well as composite units are Howrah, Hooghly, Burdwan, Bankura and Durgapur in West Bengal; Jamshedpur in Jharkhand; Patna in Bihar; Rourkela in Odisha and Guwahati in Assam. While most of the units in Howrah are small units re-rolling scraps consisting of miss-rolls from bigger plants; ship breaking scraps, etc., the clusters of Durgapur house relatively bigger units comprising mostly composite units. The clusters of Rourkela and Jamshedpur house both bigger as well as smaller units. The state-wise distributions of number of units in the eastern zone are summarized in the table below:

The following associations are active in the zone, apart from the state level associations:

- Steel Re-rolling Mill Association
- All India Steel Re-rollers Association

Table 2: Tentative number of Steel Re-rolling units in Eastern region

State	West Bengal	Jharkhand	Bihar	Odisha
No. of units	265	75	46	113

**Source: Survey carried out under UNDP-GEF project 2017*

1.3 The Process

The Steel Re-rolling mill sector can be broadly categorized into two segments:

- The standalone units where ingots/billets/scraps are re-heated to the re-crystallization temperature of steel and rolled to the desired product shape and size.
- The composite units comprising both melting and rolling facilities under the same premises.

In a standalone steel re-rolling mill unit, the process starts with raw material preparation. This includes cutting the ingots/

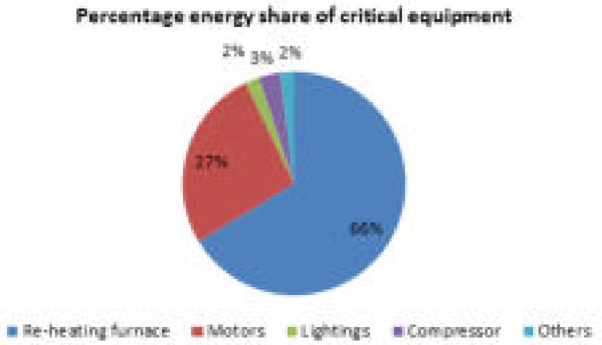
billets or scraps to the required size. These ingots/billets are then charged into a re-heating furnace which is fired either by coal, furnace oil, or natural gas. In a re-heating furnace, the charge is heated to the re-crystallization temperature which is around 1,170°C for mild steel. Steel attains the properties of ductility and malleability at this elevated temperature. The red hot charge is taken out of the re-heating furnace and rolled to desired shape and size. For rolling, two or three sets of rolls are used with grooves cut into the surface of the rolls. The rolls are placed in a vertical stand and rotated in opposite direction using a motor. The roll grooves are scientifically designed for gradual reduction of cross-sectional area of the charge. For production of an 8 mm bar from a 100 mm billet, normally 21 passes are used. The rolled product once rolled to the desired shape and size is subjected to quenching operation based on requirement. The rolled product is then cooled to atmospheric temperature in a cooling bed. The product is then packed and is ready for dispatch.

For composite units, scrap or sponge iron is purchased from the market. The raw material is fed into a melting furnace, mostly electric induction furnace. Steel is melted at an elevated temperature of around 1,600°C. The molten metal is casted into mould to form ingots or continuously casted to form billets. The ingots/billets are transferred to the rolling mill bay and the process of rolling repeats. In some units, the hot casted billets are directly fed into the rolling mill, bypassing the re-heating furnace, thus saving significant amount of energy.

1.4 Technology status and energy use

The re-heating furnace is the major energy guzzler in a typical standalone rolling mill. The re-heating furnace is fired using different types of fuels such as pulverized coal, coal based producer gas, natural gas, furnace oil and biomass based producer gas. A significant amount of fuel is burnt to heat the charge from ambient to the re-crystallization temperature of steel. It takes 35-45 liters of furnace oil or 90-120 kg of pulverized coal, 120-150 kg of coal (producer gas); 40-50 Nm^3 of Natural Gas to heat one ton of steel in the re-heating furnace. The electrical energy also forms a significant portion of the total energy consumption of the steel re-rolling mills. A typical unit manufacturing re-bars requires 100-130 units of electricity to roll one ton of steel.

The key equipment in a typical rolling mill includes the re-heating furnace, the rolling mill strands, compressors, blowers, roller tables, over head cranes, etc. The figure below shows the energy share of different critical equipment in a typical rolling mill unit:



(Source: Energy audit carried out by DESL)

Figure 3: Energy share of critical equipment

The total energy share in steel re-rolling mill can be categorized into thermal and electrical energy. While the thermal energy share is mainly related to the fuel fired in the re-heating furnace, the electrical energy is consumed by the motors, compressors, pumps, blowers, cranes, etc. The energy share of a typical unit are shown below:

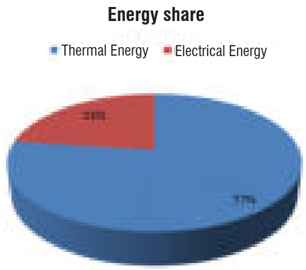


Figure 4: Energy share of typical rolling mill

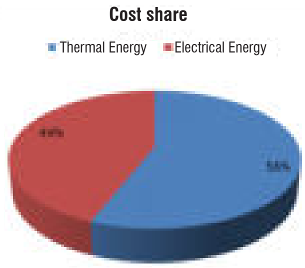


Figure 5: Cost share of energy

Most of the rolling mills in the country use old and obsolete technologies which lead to significant energy consumption. A significant opportunity exists for cost saving by adoption of energy efficient and renewable energy technologies.

In case of composite unit, the recent times have seen adoption of a path-breaking technology in the form of 'Direct rolling. In 'Direct rolling' based units, continuously casted billets are directly fed in the rolling mill at elevated temperature, thereby eliminating the re-heating furnace completely.

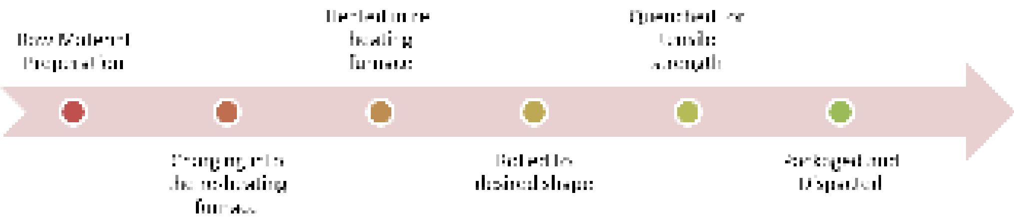


Figure 2: Typical process for standalone rolling mill

Technology 1: Energy Efficient Re-heating Furnace

2

2.1 Baseline Scenario

A re-heating furnace is considered the heart of a rolling mill. Typically, top fired pusher type re-heating furnaces are used in steel re-rolling mill units to heat the raw materials, i.e. ingots, billets or scraps to the re-crystallization temperature, i.e. around 1,170^{0}C for mild steel. The furnace is fired with a variety of fuels like lump coal, pulverized coal, furnace oil, natural gas, coal based producer gas etc. An optimum design of the furnace is important for higher productivity at least cost. A conventional furnace is not based on engineering design. Usually such furnaces are used as more heating chambers. The furnace walls are at excessive high temperature with flames gushing out of the openings. The furnace does not have any waste heat recovery system; so large quantity of heat is wasted into the atmosphere.

Figure 6: Conventional re-heating furnace

The furnaces are equipped with long pre-heating zone and heating zone is almost not present. Heavy firing is done through furnace front burners which often lead to high scale formation and energy consumption. Refractory in these types of furnaces are regularly replaced. Overall, the furnace performs at an efficiency level below 25%.

The details of re-heating furnace operating in conventional rolling mills are as follows:

Table 3: Operating parameters for conventional re-heating furnace

Furnace Capacity (tph)	Thermal Efficiency (%)	Flue gas exit temperature (^{0}C)	Specific fuel consumption
2-25	25-30	600-650	100-150 kg/t of pulverized coal or 140-160 kg/t of coal based producer gas or 40-45 l/t of furnace oil or 35-40 SCM/t of natural gas

2.2 Energy Efficient Technology

An energy efficient design of the re-heating furnace primarily aims at highest possible productivity and least possible fuel consumption and burning loss. The characteristics of an energy efficient furnace are:

- Complete combustion with minimum excess air
- Proper heat distribution
- Operation at optimum furnace temperature
- Reducing heat losses through furnace openings
- Maintaining correct amount of furnace draught
- Optimum hearth area utilization
- Maximum waste heat recovery from the flue gas
- Minimum heat loss through refractory
- Control & Instrumentation of the furnace

An energy efficient furnace is based on engineering design considering a variety of parameters. Although the capital cost for such type of furnace may be almost 1.5 times that of conventional furnace, the simple pay-back is less than a year. Designing an energy efficient furnace primarily depends on the type of fuel, raw material, productivity and discharge temperature.

Figure 7: Energy efficient pusher furnace

2.3 Benefits of the Technology

Implementation of energy efficient furnace has multi-fold benefits in a unit. Some of the key benefits include the following:

- Reduced energy consumption
- Reduced cost of production
- Reduced burning loss
- Low maintenance and breakdown

2.4 Technology Limitations

The cost of energy efficient furnace is 1.5 times more than conventional furnaces. Fuel switch over will require additional modifications.

2.5 Energy Saving; GHG Emission Reduction & Cost Benefit Analysis

In order to determine the energy saving, GHG emission reduction and cost-benefit analysis; one needs to carry out the life cycle analysis of an energy efficient furnace vis-à-vis conventional furnace.

The following table summarizes energy saving, estimated investment, cost saving and GHG emission reduction for a 15 t/h furnace fired by pulverized coal.

The investment and energy savings for new energy efficient furnace will vary based on the capacity of the furnace. The table below provides an estimate for different ranges of the furnace:

Table 4: Cost benefit analysis for a 15 t/h furnace

Sl. No.	Particulars	UoM	As is	To be
1	Rated capacity of furnace	t/h	15	15
2	Productivity	t/h	12	12
3	Operating hours	h/d	16	16
4	Operating days	d/y	330	330
5	Annual production	t/y	63,360	63,360
6	Type of fuel		Pulverized coal	Pulverized coal
7	Specific fuel consumption	kg/t	120	96
8	Gross calorific value	kcal/kg	5,600	5600
9	Annual fuel consumption	t/y	7,603	6,083
10	Saving in fuel consumption	t/y		1521
12	Cost of fuel	Rs/kg	7.5	7.5
13	Monetary savings in terms of fuel	Rs in Lakhs/y		114
14	Burning loss in furnace	%	0.8	0.76
15	Burning loss in furnace	kg/t	10	7.6
16	Saving in burning loss	kg/t		2.4
18	Annual material saving due to burning loss saving	t/y		152,
19	Material cost	Rs/t	33,000	33,000
20	Monetary savings in terms of material	Rs in Lakhs/y		50
23	Total Monetary savings	Rs in Lakhs/y		164
24	Estimated cost of furnace	Rs in Lakhs		150
25	Simple pay back	months		11
26	Annual energy savings	toe/y		852
27	Annual GHG emission reduction	tCO_2/y		94.6

**Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg*

***Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 tCO_2/TJ for sub-bituminous coal*

Table 5: Investment and energy saving potential for different furnace capacities

Furnace Capacity (tph)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
5-25	15-250	55- 275	< 1.5 years

** based on estimated figures*

2.6 Energy efficient furnace drawings

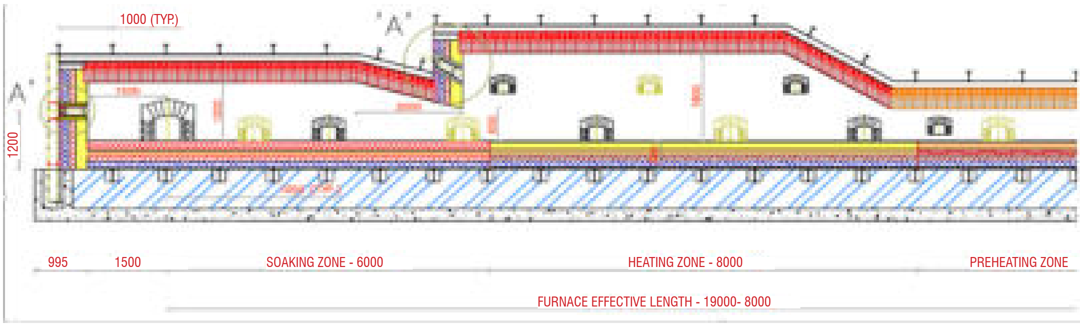


Figure 8: Sectional view of a 15 t/h pulverized coal fired top fired pusher type energy efficient furnace

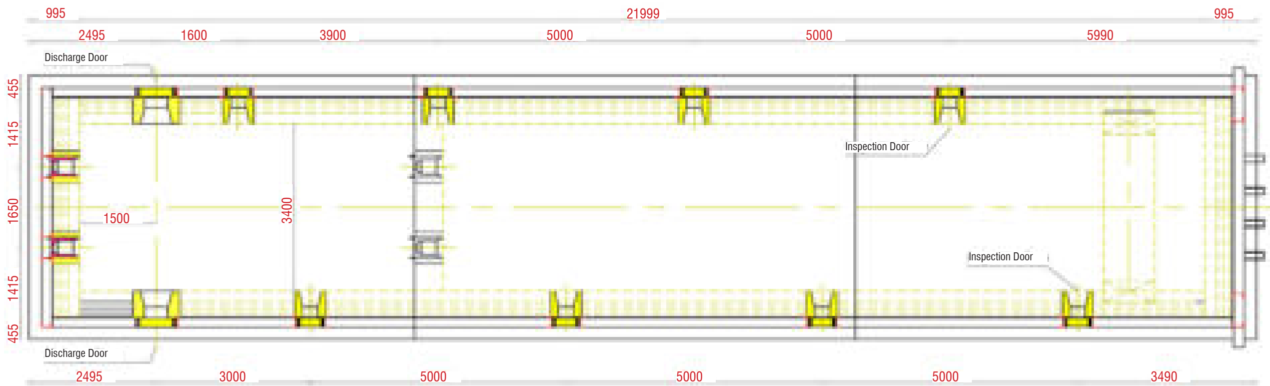


Figure 9: Plan view of a 15 t/h pulverized coal fired top fired pusher type energy efficient furnace

Case Study 1: Installation of new EE furnace

TK Steel Rolling Mill is a leading manufacturer of alloy steel industrial product, located in Ludhiana in Punjab. The plant was established in the year 1995. In 2015, the plant decided to implement a new energy efficient furnace under the guidance of the on-going UNDP-GEF project. A 10 t/h top fired pusher type re-heating furnace with furnace oil firing was installed and commissioned in the unit with expert support of the project. The plant achieved an astonishing 20% reduction in the specific fuel consumption and 5% reduction in the burning. The new furnace required an investment close to Rs 1 crore which was recovered in less than a year. The furnace is still in operation and performing extremely well.

Sl. No.	Particulars	UoM	Baseline	Post Implementation
1	Furnace productivity	t/h	10	10
2	Type of fuel		Pulverized coal	Pulverized coal
3	Specific fuel consumption	kg/t	100	70
4	Saving in fuel consumption	kg/t	30	
5	Annual fuel saving	t/y	1,584	
6	Cost of fuel	Rs/t	8,000	
7	Annual monetary savings	Rs in Lakhs/y	126	
8	Investment	Rs in Lakhs	100	
9	Simple pay back	months	10	
10	Annual energy savings	toe/y	887	
11	Annual GHG emission reduction	tCO_2/y	3,510	

**Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg*
***Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 tCO_2/TJ for sub-bituminous coal*

3 Technology 2: Installation of high efficiency metallic recuperator in re-heating furnace

3.1 Baseline Scenario

Most of the Steel re-rolling units use top-fired pusher type re-heating furnaces with solid, liquid or gaseous fuel. In a typical furnace only 30-40% of the total heat input is converted to useful heat. Rest of the energy is lost through different areas and forms.

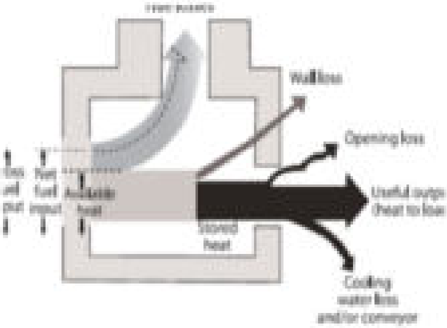


Figure 10: Sankey diagram for pusher furnace

The waste flue gas loss forms the major loss in a re-heating furnace which accounts for 30-35% of the total heat input. Exhaust flue gas from the furnace at a temperature of 500-700 ^{0}C has a potential to be re-used in the furnace. Traditionally, flue gases from the re-heating furnace were let out into the atmosphere through the chimney. Thus significant heat of flue gas was wasted.

3.2 Energy Efficient Technology

As an alternative to the conventional practice, a recuperator, i.e. a heat exchanger is installed in the flue duct and used to recover the waste heat from the flue gases. In a recuperator, heat exchange takes place between the flue gases and the inlet combustion air through metallic or ceramic walls. Ducts or tubes carry the combustion air to be pre-heated; the other side consists of the waste heat stream. The system works based on the basic principle of Physics which says energy moves from a hot body to a cold. Thus, in the process inlet combustion air from atmosphere is pre-heated using the waste gas. The pre-heated combustion air is fed directly into the burner. The result is saving in terms of fuels, increase in flame temperature and improvement in furnace efficiency.

The efficiency of the recuperator depends upon two important parameters - Surface area and time available for heat exchange and recuperator material.

Figure 11: High efficiency metallic recuperator

Table 6: Effectiveness of different types of recuperator

Sl. No.	Parameter	Symbol	Unit	Radiative cum convective recuperator	High efficiency cross-flow type recuperator	Metallic radiation recuperator
1	Current specific fuel consumption		kg/t	100	100	100
2	Annual production		t/y	30,000	30,000	30,000
3	Flue gas temperature at recuperator inlet	T_1	^{0}C	692	692	692
4	Ambient air temperature	t_1	^{0}C	35	35	35
5	Flue gas temperature at recuperator outlet	T_0	^{0}C	295	245	350
6	Combustion air preheat temperature after recuperator	t_0	^{0}C	283	395	190
7	Gain in combustion air temperature	$t_0 - t_1$	^{0}C	248	360	155
8	Drop in flue gas temperature	$T_1 - T_0$	^{0}C	397	447	342
9	Recuperator effectiveness	%	^{0}C	62.47	80.54	45.32
10	Annual fuel savings		t/y	33.81	49.09	21.13
11	Cost of fuel per tone		Rs/t	8,000	8,000	8,000
12	Annual monetary cost savings		Rs in Lakhs /y	2.70	3.93	1.69

**with every 220 C rise in combustion air pre-heat temperature there is a saving of 1% of fuel.*
***calorific value of coal taken as 5600 kCal/kg; cost of coal taken as Rs 8 /kg*
****Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 tCO_2/TJ for sub-bituminous coal*

It can be observed from the above table that the ideal effectiveness of a recuperator is 80%, wherein almost 60-70% of the waste heat can be recovered. The best effectiveness can be achieved by a high efficiency U-tube type cross-flow metallic recuperator. An effectiveness of around 60% can be achieved by a radiative cum convective recuperator where a combustion pre-heat temperature of around 250-285^{0}C can be achieved, which is around 50% of the waste heat. The worst performing recuperator is a metallic radiation recuperator, which has an effectiveness of around 40-45%, wherein the combustion preheating temperature remains below 200^{0}C. In the above table, the respective recuperator effectiveness has been compared with ideal effectiveness of 80% to determine the further scope of fuel saving by upgrading the recuperator.

At this point, it may be noted that the flue gas temperature at the chimney input should be maintained above 200^{0}C to avoid oxidation of the Sulphur particles in the flue gas which can lead to corrosion and rusting of the chimney.

Inference: While selecting a recuperator, the recuperator with highest effectiveness should be selected for optimum performance of the furnace. Although, such recuperator requires high initial investment, the same can be compensated by the relatively low pay-back.

3.3 Benefits of the technology

Installation of high efficiency metallic recuperator in steel re-heating furnace has the following benefits:

- Utilization of waste heat from flue gas to preheat combustion air
- Reduced energy consumption
- Increased productivity
- Improved furnace efficiency
- Reduced cost of production

3.4 Limitations

Installation of metallic recuperator especially in case of pulverized coal fired furnace requires special care and design modification. This is because of the possibility of the recuperator choke up due to presence of un-burnt coal particles in the flue gas. Required design modification needs to be done to avoid deposit of suspended particles in the recuperator.

3.5 Energy Savings, GHG Emission Reduction & Cost Benefit Analysis

The table below provides energy saving, GHG emission reduction and cost benefit analysis for a high efficiency metallic recuperator for a 15 tph furnace capacity.

Figure 13: Radiative cum convective recuperator

The investment and energy savings for energy efficient recuperator will vary based on the capacity of the furnace. The table below provides an estimate for recuperator for different ranges of the furnace:

Figure 14: Cross-flow U-tube type metallic recuperator

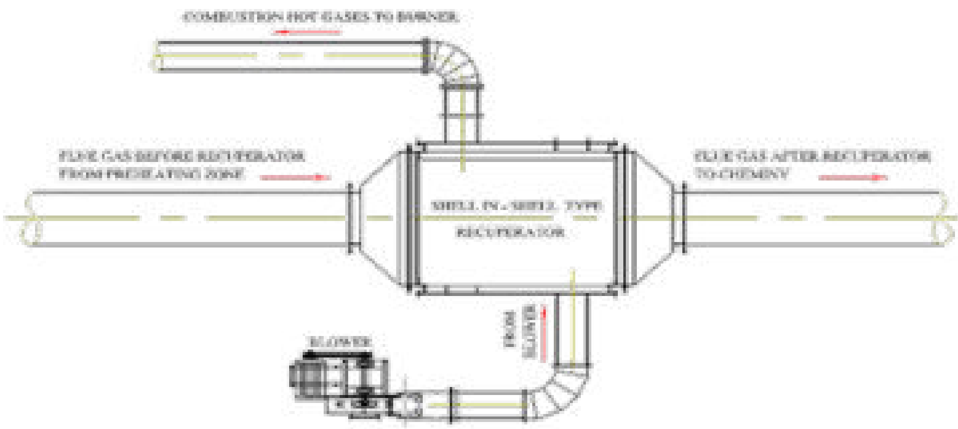


Figure 12: Flow of exhaust flue gas

Table 7: Energy & GHG saving and cost benefit analysis for a high efficiency metallic recuperator

Sl. No.	Parameter	UoM	Without recuperator	With high efficiency metallic recuperator
1	Productivity	t/ h	15	15
2	Operating hours per day	h/d	16	16
3	Operating days per year	d/y	330	330
4	Combustion air temperature	^0C	35	350
5	Gain in combustion air pre-heat temperature	^0C		315
6	Specific fuel consumption*	kg/t	90	77
7	Annual fuel consumption	t/y	7,128	6,107
8	Annual saving in coal consumption	t/y	1,021	
9	Cost of fuel	Rs/kg	8	8
9	Monetary saving due to saving in coal consumption	Rs in lakhs	81.65	
10	Investment required for a high efficiency metallic recuperator	Rs in lakhs	26.25	
11	Simple pay-back	months	4	
12	Annual energy savings	toe/y	572	
13	Annual GHG emission saving	tCO_2/y	2,262	

*with every 220C rise in combustion air pre-heat temperature there is a saving of 1% of fuel
**calorific value of coal taken as 5,600 kCal/kg; cost of coal taken as Rs 8 /kg
***Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 tCO_2/TJ for sub-bituminous coal

Table 8: Investment and saving potential for different recuperator capacities

Furnace Capacity (tph)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
5-25	8.5 - 45	25- 135	< 1 years

* based on estimated figures

Case Study 2: Installation of high efficiency metallic recuperator

Located in Bhiwadi, Rajasthan, Petropol India Limited is a leading manufacturer of TMT bars. In 2017, the plant decided to implement a new high efficiency metallic recuperator in their existing pulverized coal re-heating furnace of 15 tph capacity. The plant achieved an astonishing 15% reduction in the specific fuel consumption. The recuperator required an investment closed to Rs 25 Lakhs which was recovered in less than a year.

Sl. No.	Particulars	UoM	Baseline	Post Implementation
1	Furnace productivity	t/h	15	15
2	Type of fuel		Pulverized coal	Pulverized coal
3	Specific fuel consumption	kg/t	100	85
4	Saving in fuel consumption	kg/t	15	
5	Annual fuel saving	t/y	1080	
6	Cost of fuel	Rs/t	8000	
7	Annual monetary savings	Rs in Lakhs/y	86.4	
8	Investment	Rs in Lakhs	25	
9	Simple pay back	months	3.5	
10	Annual energy savings	toe/y	604	
11	Annual GHG emission reduction	tCO_2/y	2394	

*calorific value of coal taken as 5600 kCal/kg ; cost of coal taken as Rs 8 /kg
**Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 tCO_2/TJ for sub-bituminous coal

Technology No. 3: Installation of automation & control system in re-heating furnace

4

4.1 Baseline Scenario

A re-heating furnace is considered the heart of a rolling mill. Typically, top fired pusher type re-heating furnaces are used in steel re-rolling mill units to heat the raw material, i.e. ingots, billets or scraps to the re-crystallization temperature, i.e. around 1,200ºC. The furnace is fired with a variety of fuels like lump coal, pulverized coal, furnace oil, natural gas, coal based producer gas, etc.

Optimum efficiency of the furnace can be ensured by maintaining correct temperature regime; ensuring optimum air-fuel ration including correct amount of excess air and maintaining optimum furnace pressure. Optimum efficiency of the furnace can lead to optimum specific fuel consumption and burning loss. Even today, most of the re-heating furnaces in the country are manually operated. Such conventional furnaces are not equipped even with basic monitoring equipment system like thermocouples. Manually operated furnaces do not have any control on maintaining the correct temperature regime as well as the correct air-fuel ratio required for combustion. Such furnaces are often over-fired leading to high energy consumption and burning loss.

4.2 Energy Efficient Technology

Optimum furnace efficiency can be achieved through complete automation and control system in the furnace. To start with; all furnaces should be equipped with basic monitoring instruments like thermocouples. Automation & Control system for re-heating furnace exists in three levels:

Level 1: On-off Control

Level 2: A proportional–integral–derivative controller (PID controller) based system

Level 3: A programmable logic controller (PLC) based system

Automation & control system in re-heating furnace ensures the following:

- Maintains proper temperature regime across the length of the furnace.
- Maintains air-fuel ratio including correct amount of excess air.
- Maintains correct furnace pressure and draught.

Re-heating furnace automation & control system consists of monitoring instruments like thermocouples of measuring temperature, zirconium based online oxygen analyzer to measure the oxygen percentage in flue gas; pressure transducers to measure the furnace pressure; control instruments like Variable Frequency Drives in FD and ID fan, solenoid valves in air and fuel line, DC motor driven screw feeder and a control circuit. All instruments and control setting are installed in a closed loop.

During the running of the furnace; feedback from the monitoring instruments like thermocouple; oxygen analyzer and pressure transducers are received by the control circuit; which in turn controls the DC motor driven screw feeder to control the coal flow and VFD to control air flow. The FD and ID fan speed is synchronized to maintain proper draught and furnace pressure. The control circuit can be either PID or PLC based. The air–fuel flow is accordingly controlled based on different running conditions of the furnace. The controlling of temperature, oxygen and pressure in a furnace is known as “Tops” control. The figure below shows the process and instrumentation diagram for a typical re-heating furnace:

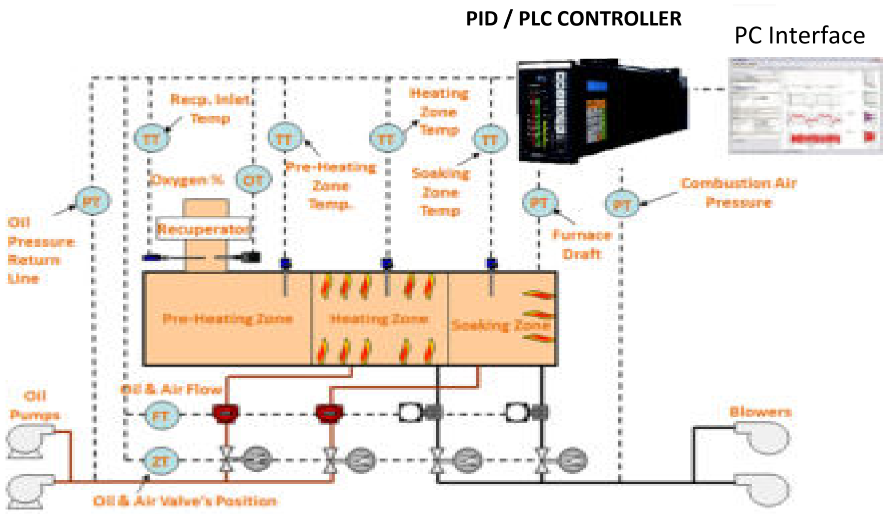


Figure 15: P&I diagram of re-heating furnace automation (Courtesy: Masibus.com)

4.3 Benefits of the technology

Installation of automation & control system in steel re-heating furnace has the following benefits:

- Complete monitoring and automatic control of furnace
- Proper air-fuel ratio control
- Furnace temperature monitoring and control
- Furnace pressure monitoring & control
- Reduced energy consumption
- Improved productivity

4.4 Limitations

The performance of the system is heavily dependent on the proper functioning of the sensors. The sensors need to be regularly maintained and calibrated. Also, the entire control loop should be checked properly. The system requires additional skilled manpower.

4.5 Energy Savings, GHG Emission Reduction and Cost Benefit Analysis

The energy savings, GHG emission reduction and cost-benefit analysis for installation of PID based automation and control system in a 15 t/h furnace is summarized below:

The investment and energy savings for furnace automation and control system will vary based on the capacity of the furnace. The table below provides an estimate for automation and control system for different ranges of the furnace:

Table 9: Cost benefit analysis for reheating furnace automation

Sl. No.	Parameters	UoM	As Is	To Be
1	Furnace rated capacity	t/h	15	15
2	Productivity	t/h	12	12
3	Operating hours	h/d	16	16
4	Operating days	d/y	330	330
5	Annual Operating hrs	h/y	5,280	5,280
6	Annual Production	t/y	63,360	63,360
7	Type of fuel		Pulverized Coal	Pulverized Coal
8	Oxygen Level in exit flue gas	%	9.00	7.00
9	Excess Air	%	75.00	50.00
10	Total air supplied	kg/kg of fuel	12.43	10.65
11	Ambient temperature	^0C	35	35
12	Flue gas exit temperature	^0C	650	650
13	Sensible heat loss	kCal/kg of fuel	1982	1720
14	Dry Flue Gas loss	%	35.38	30.71
15	Sensible heat loss	kCal/t	158,522	137,563
16	Reduction in Fuel Consumption	kg/t	3.7	
17	Annual fuel saving	t/y	237	
18	Unit Cost of Fuel	Rs/kg	8	
19	Savings (Fuel saving)	Rs in Lakh/y	19	
20	Material saving due to reduced burning loss	kg/h	18	
21	Unit Cost of Material	Rs/t	33,000	
22	Savings due to material savongs	Rs in Lakh/y	31	
23	Total savings	Rs in Lakh/y	50	
24	Estimated Investment	Rs in Lakh	22	
25	Simple Payback	months	5	
26	Annual Energy Savings	toe/y	133	
27	Annual GHG Emission Savings	tCO_2/y	526	

**calorific value of coal taken as 5,600 kCal/kg; cost of coal taken as Rs 8 /kg*

****Emission factor of coal as per IPCC guideline 2006 (V2; C1& C2) is 94.6 tCO_2/TJ for sub-bituminous coal*

Table 10: Investment and saving for automation for different ranges of furnace

Furnace Capacity (tph)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
5-25	10-26	15-85	< 1 years

** based on estimated figures*

Case Study 3: Installation of furnace automation and control system

TK Steel Rolling Mill is a leading manufacturer of alloy steel industrial product, located in Ludhiana in Punjab. The plant was established in the year 1995. In 2018, the plant decided to implement Level 3 automation and control system in the re-heating furnace under the guidance of the on-going UNDP-GEF project. The automation and control system was installed in their 10 t/h furnace. The plant achieved an astonishing 10% reduction in the specific fuel consumption and 5% reduction in the burning loss. The furnace automation and control system required an investment closed to Rs 20 lakhs which was recovered in less than a year.

Sl. No.	Particulars	UoM	Baseline	Post Implementation
1	Furnace productivity	t/h	10	10
2	Type of fuel		Pulverized coal	Pulverized coal
3	Specific fuel consumption	kg/t	70	63
4	Saving in fuel consumption	kg/t	7	
5	Annual fuel saving	t/y	370	
6	Cost of fuel	Rs/t	8,000	
7	Annual monetary savings	Rs in Lakhs/y	30	
8	Investment	Rs in Lakhs	20	
9	Simple pay back	months	8	
10	Annual energy savings	toe/y	207	
11	Annual GHG emission reduction	tCO_2/y	820	

**Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg*
***Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 tCO_2/TJ for sub-bituminous coal*

5 Technology No. 4: Installation of optimum refractories and insulation in re-heating furnace

5.1 Baseline Scenario

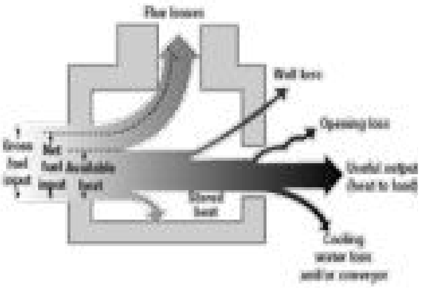


Figure 16: Furnace sankey diagram

A re-heating furnace can typically be defined as a chamber comprising four walls, hearth and roof, built with refractory bricks and insulation material enclosed within a steel structure. All the six faces of the chamber are exposed to high temperature ranging from 800 to 1,200ºC. So, material of the wall, hearth and roof should be carefully selected so as to withstand the high temperature. Since the inside temperatures of the furnace are high, considerable amount of heat energy is lost by heat conduction through the walls, roof and hearth. Therefore, it is imperative to use material of as low thermal conductivity as possible for minimizing heat loss.

Moreover, small scale re-rolling mills do not run for 24 hours on continuous basis. Every day the furnaces are cooled after stopping the rolling and then again they are lighted up on the next day. During this process, heat energy is accumulated and then dissipated during idling period of the furnace. For minimizing this loss, the wall material should be of lower thermal mass so that heat accumulation can be minimized. Also, the refractory material should be able to withstand thermal shock due to cyclic operation. Thermal shocks lead to spalling and therefore the refractory material should have good spalling resistance.

Thus, selection of correct refractory and insulation is of significance. In conventional furnaces, due care is not given towards selection of correct refractory and insulation linings. This often leads to:

- Higher heat losses through the furnace walls
- Lower life of refractory and insulation
- Higher energy consumption

Almost 10-12% of the total heat input is lost as radiation and conduction losses through the furnace walls. Higher furnace skin temperatures are common symptoms of inadequate refractory and insulation material. In addition, a large amount of radiation heat losses happen through openings in the furnace, such as inspection doors, ejector space, etc. The radiation losses increase considerably as temperature increases.

5.2 Energy Efficient Technology

Design of optimum refractory and insulation lining need to meet the following requirements:

- Selection of suitable material to meet the service requirements.
- Design of optimum lining thickness considering minimum heat loss and payback period.
- Selection of material considering cost, service life and fuel economy.

The furnace is divided into soaking, heating and preheating zones. The pattern of the refractory lining varies with these zones at the furnace roof, side walls and end walls. Constituents of lining at different locations of furnace are selected based on the temperature profile.

The suggested refractory and insulation pattern for different zones of the re-heating furnace has been tabulated in Table 10.

For effective insulation of the furnaces, it is recommended to install ceramic fibre insulation in the inspection doors. All openings in the burner blocks should be closed using ceramic fibre blankets. A significant amount of energy can be saved by adoption of optimum refractory and insulation and sealing of furnace openings. The suggestive refractory and insulation of pusher type furnace is shown in figure below:

5.3 Benefits of the technology

Installation of optimum refractory and insulation in steel re-heating furnace has the following benefits:

- Enhanced life of refractory leading to lesser background
- Improved efficiency of the furnace
- Reduced energy consumption

5.4 Limitations

It is important to quality test the refractory / insulation from each lot before installation. Even for reputed brand items, the bricks may not meet the quality standards. Installation of optimum refractory and installation requires significantly higher capital investment.

5.5 Energy Savings, GHG Emission Reduction and Cost Benefit Analysis

For the purpose of determining the energy & GHG emissions saving potential and cost benefit analysis, let us take a case

Table 11: Indicative refractory and insulation lining for re-heating furnace

Furnace surface	Furnace zone	Suggested refractory & insulation lining pattern
Roof	Soaking zone	250 mm thick special shaped bricks (hanger bricks) made of 60% Alumina refractories backed by 25 mm thick Insulating castable backed by 75 mm thick ceramic fibre blanket / mineral wool blanket.
	Heating zone	250 mm thick special shaped bricks (hanger bricks) made of 60% Alumina refractories backed by 25 mm thick insulating castable backed by 75 mm thick ceramic fibre blanket / mineral wool blanket
	Pre-Heating zone	250 mm thick special shaped bricks (hanger bricks) made of 40% Alumina refractories backed by 50 mm thick insulating castable/ ceramic fibre.
Side walls and end walls	Discharge end wall	230 mm thick 60% Alumina quality refractories backed by 115 mm hot face insulation bricks, 115 mm thick Cold (Mica) Insulation bricks (IS-2042) and 75 mm thick Hysil blocks insulation and 5 mm thick asbestos sheet backed by steel sheets.
	Side walls (Heating & Soaking zones)	230 mm thick 60% Alumina quality refractory bricks backed by 115 mm thick hot face insulation bricks, 115 mm thick Mica Insulation bricks / Cold face insulation bricks, 75 mm thick Hysil block insulation and 5mm thick asbestos sheet backed by steel sheets.
	Side walls (Pre-heating zone)	230 mm thick 40% Alumina quality (IS-8) refractory bricks backed by 115 mm thick Hot face insulation bricks, 115 mm thick Mica Insulation bricks, 75 mm thick Hysil block insulation and 5 mm thick asbestos sheet backed by steel sheets.
	End wall (Charging side)	230 mm thick 40% Alumina quality(IS-8) refractory bricks backed by 115 mm thick Hot face insulation bricks, 115 mm thick Mica Insulation bricks,75 mm thick Hysil block insulation and 5 mm thick asbestos sheet backed by steel sheets.
	Flue off take/down corners	150 mm thick ceramic fibre blanket (RT128) to be held imposition by heat resisting (Stainless steel) studs and washers in case of flue port at the roof. If the flue line is below the hearth, lining pattern will be same as that of charging side end wall.
Hearth	Soaking zone	200mm thick High Alumina fire bricks (LC-90 / TRL-88 / High Chromium Castables) backed by 115mm thick Hot Face Insulation backed by 115 mm Cold Face Insulations backed by 50 mm Insulating Castables and 5 mm thick asbestos sheet.
	Heating zone	150 mm thick High Alumina quality fire bricks (60%Alumina) backed by 115 mm 40% Alumina (IS-8) backed by115 mm Hot Face Insulations, 115 mm Cold Face Insulation, backed by 65 mm Insulating Castables and 5 mm thick asbestos sheet.
	Pre-Heating zone	190 mm thick High Alumina fire bricks (40%Alumina) backed by 115 mm Hot face insulation bricks, 115 mm thick cold face insulation bricks, 115 mm 36% (IS-6) quality fire bricks, 30 mm Insulating Castables and 5 mm thick asbestos sheet.
Others	Charging end doors	175 mm thick RT128 grade ceramic fibre module backed by 25mm thick mineral wool insulation blanket.
	Discharge end doors	225 mm thick RT128 grade ceramic fibre module backed by 25mm thick mineral wool insulation blanket.
	Recuperator area	115 mm thick IS-8 quality firebricks backed by 15 mm thick Mica insulating bricks and 50 mm thick calcium silicate block insulation.
	Flue duct from Recuperator up to chimney	115 mm thick IS-6 quality fire bricks backed by 115 mm thick Mica insulating bricks.

of revamping of a 24 t/h capacity re-heating furnace with optimum refractory and insulation.

To determine the radiation loss from the surface of the furnace, the following formulae is used:

Radiation heat loss from the surface of furnace (Q)	=	$a \times (t_1-t_2) ^\wedge (5/4) + 4.88\ E\ [((t_1+273)/100) ^\wedge 4 - ((t_2+273)/100) ^\wedge 4]$
Where, Q	=	Quantity of heat released in $kCal/W/m^2$
A	=	factor regarding direction of the surface of natural convection ceiling 2.8m, side walls=2.2m, hearth =1.5m
t_1	=	temperature of external wall surface of the furnace (^0C)
t_2	=	ambient temperature (^0C)

The table below shows a comparative of the wall losses from a re-heating furnace with and without optimum refractory and insulation. The table also establishes the energy and GHG emissions reduction and cost benefit analysis by adoption of optimum refractory and insulation:

The investment and energy savings for refractory and insulation will vary based on the capacity of the furnace. The table 13 further provides an estimate for refractory and insulation for different ranges of the furnace:

Table 12: Cost benefit analysis for optimum refractory and insulation

Sl. No.	Parameters	Units	As Is	To Be
1	Furnace rated capacity	t/h	15	15
2	Productivity	t/h	12	12
3	Operating hours	h/d	16	16
4	Operating days	d/y	330	330
5	Annual Operating hrs	h/y	5,280	5,280
6	Annual Production	t/y	63,360	63,360
7	Temperature of the Walls	^{0}C	125	60
8	Ambient Temperature	^{0}C	35	35
9	Total Wall Area	m^2	296	296
10	Heat Loss from Surface	kCal/h	296,744	60,217
11	Hourly fuel consumption	kg/h	52.99	10.75
12	Reduction in Fuel Consumption	kg/h	42	
13	Annual fuel saving	t/y	223	
14	Cost of fuel	Rs/t	8,000	
15	Annual monetary savings	Rs in Lakhs/y	17.84	
16	Estimated Investment	Rs in Lakhs	40.00	
17	Simple Payback	months	27	

** Calorific value of coal taken as 5,600 kCal/kg; Cost of coal taken as Rs 8 /kg*
***Emission factor of coal as per IPCC guideline 2006 (V2; C1& C2) is 94.6 tCO_2/TJ for sub-bituminous coal*

Table 13: Investment and saving for optimum refractory and insulation for different ranges of furnace

Furnace Capacity (tph)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
5-25	20 – 50	10- 75	< 2 years

** based on estimated figures*

Technology No. 5: Installation of Energy Efficient Pulverizer

6

6.1 Baseline Scenario

In recent times, pulverized coal has emerged as the most widely used fuel in the steel re-rolling mill sector. Easy availability of coal, cost-economics of its use and lower capital investment required for switch-over has made pulverized coal popular in the industry. However, in order to get optimum output, it is important that supply chain of coal is properly maintained. Right from procurement till feeding of coal into the furnace; each step needs to be carefully monitored and controlled for better outputs.

Most of the operators of pulverized coal lack understanding of best operating practices related to its use. The coal typically used in SRRM sector is characterized by high ash and low calorific content. Using high ash content coal leaves ash deposits on the refractory bricks that react with the iron content of the bricks. This leads to premature cracks and failure of the refractory lining. Ash deposits require more heat to be added to the charge for attaining desired temperature, thus increasing burning losses. Also, high ash content leads to choking of recuperator tubes. This necessitates frequent cleaning, thus leading to high maintenance cost and reduced performance of heat exchangers. The ideal size of pulverized coal should be at least 75-80% of 75 microns. In conventional system, fine coal ranges from only 10% to 30%. Non uniform coal particles undergo partial combustion and result in deposition on the furnace walls. These coarse particles escape from furnace with flue gas in the form of unburnt carbon or ash.

6.2 Energy Efficient Technology

The energy efficient alternative to use pulverized coal as fuel starts with the procurement of good quality coal. Coal with high calorific value and low ash content, e.g. Assam coal is most ideally suited for the use as pulverized coal. Coal quality should be regularly examined in-house in order to keep a check on the sourcing of coal. For in-house testing of coal, laboratory size bomb calorimeter should be used.

Once good quality coal is sourced, the next step is to process or pulverize the coal into the desired fineness consistently. To do so, certain modifications in pulverizer are required. The critical components of a pulveriser are:

- a hammer,
- a mild steel liner,
- a classifier,
- an inbuilt blower

In order to achieve pulverized coal to the desired fineness in a consistent manner, the following modifications to existing pulverizer are suggested:

Hammer: Improve metallurgy with the addition of manganese (13%), carbon (1.13%), silicon (0.4%), sulphur (0.003%), and phosphorus (less than 0.2%) to increase its resistance to wear and tear.

Liner: Use grooved EN-31 hardened steel plates or casted high manganese.

Classifier: Ensure proper dimensions and thickness (gap between the classifier tip and casing to be less than 1 mm) to classify the pulverized coal to achieve 65%–80% of desired (–) 200 mesh size. The classifier should be high chrome, high nickel alloy.

The performance of a coal pulverizer can be gauged from the size and uniformity of the coal output. Thus, it becomes imperative to measure and maintain the fineness of coal coming out of the pulverizer. A metal sieve of minus 200 mesh size or 75 microns can be used for the purpose.

6.3 Benefits of the technology

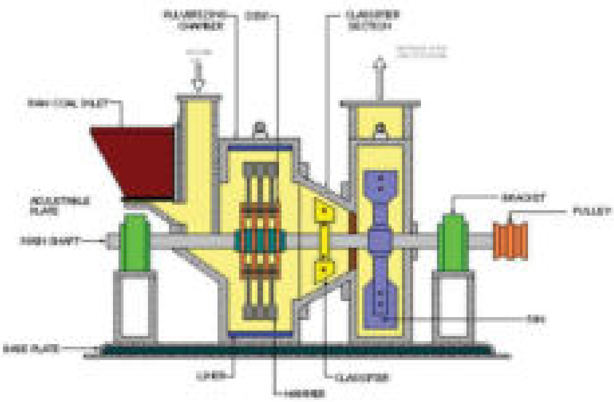


Figure 17: Sectional view of a pulverizer

Installation of energy efficient pulverizer has the following benefits:

- Enhanced combustion efficiency of furnace
- Increased flame temperature
- Reduced energy consumption

6.4 Limitations

There are no limitations for this technology.

6.5 Energy Savings, GHG Emission Reduction & Cost Benefit Analysis

The following section provides the details of use of energy efficient pulverizer in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 10 t/h SRRM plant.

Table 14: Cost benefit analysis for energy efficient pulverizer

Sl. No.	Parameter	UoM	As Is	To Be
1	Productivity	t/h	10	10
2	No. of operating hours	h/d	12	12
3	No. of working days	d/y	300	300
4	Specific fuel consumption (Baseline)	kg/t	90	-
5	Percentage saving in specific fuel consumption after installation of energy efficient pulverizer	%	5	
6	Specific fuel consumption (post implementation)	kg/t	-	85.5
7	Annual production	t/y	36,000	36,000
8	Annual fuel consumption	t/y	3,240	3,078
9	Annual saving of coal	t/y	162	
10	Cost of coal	Rs/t	8,000	
11	Annual monetary savings	Rs in lakh/y	12.96	
12	Estimated investment (including recurring cost of critical components for a period of 6 months)	Rs in lakh	8	
13	Simple pay-back period	months	7	
14	Annual energy savings	toe/y	91	
14	Annual GHG emission reduction	tCO_2/y	359	

** Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg*

***Emission factor of coal as per IPCC guideline 2006 (V2; C1& C2) is 94.6 tCO_2/TJ for sub-bituminous coal*

Table 15: Investment and saving for energy efficient pulverizer for different ranges of furnace

Furnace Capacity (tph)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
5-20	6 – 25	5 - 25	< 1.5 years

** based on estimated figures*

Case Study 4: Installation of Energy Efficient Pulverizer

Laxmi Steel Rolling Mill is a leading manufacturer of industrial products, located in Mandi Gobindgarh in Punjab. In 2018, the plant decided to implement an energy efficient pulverizer in the re-heating furnace under the guidance of the UNDP-GEF project. The energy efficient pulverizer was installed in their 7 t/h furnace. The plant achieved an astonishing 6% reduction in the specific fuel consumption. The EE pulverizer required an investment close to Rs 7 lakhs which was recovered in less than a year.

Energy efficient pulverizeer

Sl. No.	Particulars	UoM	Baseline	Post Implementation
1	Furnace productivity	t/h	7	7
2	Type of fuel		Pulverized coal	Pulverized coal
3	Specific fuel consumption	kg/t	70	65
4	Saving in fuel consumption	kg/t	5	
5	Annual fuel saving	t/y	126	
6	Cost of fuel	Rs/t	8,000	
7	Annual monetary savings	Rs in Lakhs/y	10.8	
8	Investment	Rs in Lakhs	7	
9	Simple pay back	months	8	
10	Annual energy savings	toe/y	70	
11	Annual GHG emission reduction	tCO_2/y	729	

**Calorific value of coal taken as 5,600 kCal/kg ; Cost of coal taken as Rs 8 /kg*

***Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 tCO_2/TJ for sub-bituminous coal*

Technology No. 6: Installation of Modified Pulverized Coal Handling and Feeding System

7

7.1 Baseline Scenario

Conventionally, the pulverized coal is conveyed with cold combustion air, without the provision of recuperator, and fired by a four-inch pipe. As there is no proper control on the fuel and air, the process results into improper combustion resulting in unburnt coals. Also, pulverizer in most cases is inefficient.

7.2 Energy Efficient Technology

In the energy efficient process, high quality lump coal is first fed into a pre-crusher, wherein coal is crushed to tea leaf size. The pre-crushed coal is passed through the dryer where the surface moisture of coal is removed using hot air from the recuperator. The coal is then fed into the pulverizer, where it is powdered to 75 micron size. Finer coal means more surface area available for combustion, and hence more heat output. Pulverized coal is transferred to the overhead furnace hopper which allows storing of coal of required quantity at the furnace head. DC motor run screw feeder controls the coal flow to the burner, based on the furnace temperature.

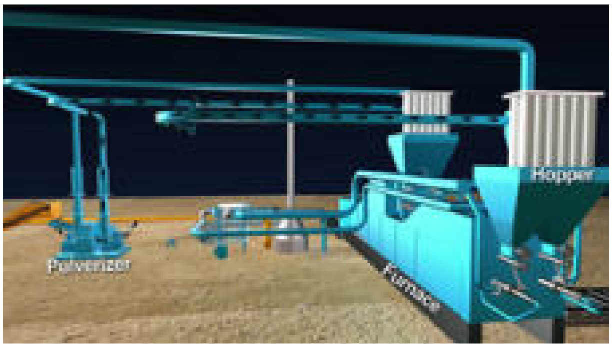


Figure 18: Modified pulverized coal feeding system

A swirl type burner with annual arrangement for separate entry of coal and hot air and equipped with circumferential vanes is used in the system to ensure proper turbulence and mixing of air and fuel.

The process is completed by feeding pre-heated combustion air from the recuperator to the burner tip which along with the swirling motion improves the combustion significantly leading to lower specific fuel consumption and burning loss.

The process flow of the modified coal handling and feeding system is shown in the figure below:

A typical specification of the pulverized coal handling and feeding system for a 15 t/h furnace is tabulated below:

7.3 Benefits of the technology

Installation of modified pulverized coal handling and feeding system has the following benefits:

- Separate feeding lines for coal and hot air
- Removal of surface moisture from coal increasing combustion efficiency
- Swirl burner provide optimum time, temperature and turbulence required for combustion
- Enhanced combustion efficiency of furnace
- Monitoring and control of air fuel ratio
- Reduced energy consumption

7.4 Limitations

The installation of the hopper close to the furnace increases the danger of burning of coal at elevated temperature. Due care should be taken to avoid over-heating of coal. Also, the possibility of sticking can occur due to moisture in the coal. The hopper can be internally insulated with a stainless steel plate to avoid sticking of coal. The construction of the over head hopper needs to be carefully done to avoid over-heating.

7.5 Energy Savings, GHG Emission Reduction & Cost Benefit Analysis

The following section provides the details of the modified pulverized coal handling and feeding system in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 10 t/h SRRM plant.

The investment and energy savings for modified pulverized coal feeding system will vary based on the capacity of the furnace. The table below provides an estimate for modified pulverized coal feeding system for different ranges of the furnace:

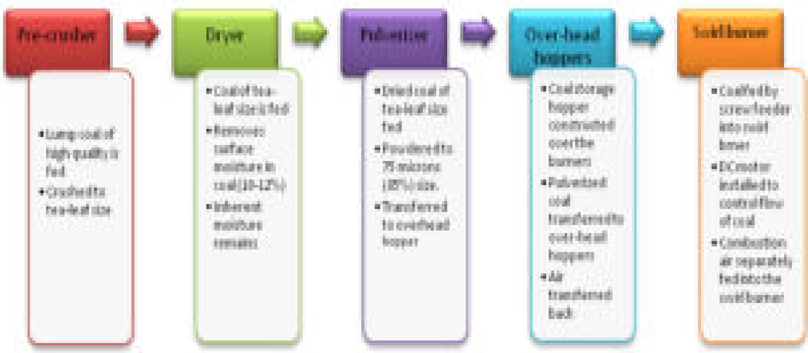


Figure 19: Process flow of pulverized coal handling and feeding system

Table 16: Technical specification of pulverized coal handling and feeding system

Sl. No.	Parts	Standard Specification
1	Pre-crusher	Type: Primary Crusher Processing capacity: Up to 1.5 t/h Feeding size : 10 – 30 mm Output size : 2-5 mm Motor: 10 hp/ 1440 RPM
2	Coal dryer	Type: Cyclone type Drying capacity: Up to 12% surface moisture Hot air input: from recuperator No. of conveyors for transferring dried coal : 2 Additional feature: ID fan to throw away moisture laden air; air lock to restrict the entry of air into the conveyors. Conveyor Motor: 5 hp / 1440 RPM – 3 no's. ID Fan motor: 7.5 hp / 1440 RPM – 1 no. Air lock motor: 2 hp / 1440 RPM – 2 no's.
3	Pulverizer	Type: Hammer Type Hammer Material: High Chrome Manganese Liner Material : EN-31 hardened steel plates Classifier: Minimum gap maintained with casing Feeding input: 2-5 mm crushed coal Output: 75 microns pulverized coal No. of pulverizing units : 2 Size of pulverizing unit: 38" Motor: 75 hp / 1440 RPM – 2 no's.
4	Burner	Type: Swirl burner Numbers: 4 Control: Screw feeder (DC motor driven) Inputs: Separate entry for coal, primary and secondary air

Table 17: Cost benefit analysis for modified pulverized coal feeding system

Sl. No.	Parameter	UoM	As Is	To Be
1	Productivity	t/h	10	10
2	No. of operating hours	h/d	12	12
3	No. of working days	d/y	300	300
4	Specific fuel consumption (Baseline)	kg/t	90	-
5	Percentage saving in specific fuel consumption after installation of modified pulverized coal feeding system	%	10	
6	Specific fuel consumption (post implementation)	kg/t	-	81
7	Annual production	t/y	36,000	36,000
8	Annual fuel consumption	t/y	3,240	2,916
9	Annual saving of coal	t/y	324	
10	Cost of coal	Rs/t	8,000	
11	Annual monetary savings	Rs in lakh/y	25.92	
12	Estimated investment	Rs in lakh	20	
13	Simple pay-back period	months	9	
14	Annual energy savings	toe/y	181	
14	Annual GHG emission reduction	tCO_2/y	718	

** Calorific value of coal taken as 5,600 kCal/kg; Cost of coal taken as Rs 8 /kg*

***Emission factor of coal as per IPCC guideline 2006 (V2; C1& C2) is 94.6 tCO_2/TJ for sub-bituminous coal*

Table 18: Investment and saving for modified pulverized coal feeding system for different ranges of furnace

Furnace Capacity (tph)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
5-25	10 – 30	15 - 40	< 1 year

** based on estimated figures*

Case Study 5: Installation of Modified Pulverized Coal Feeding System

T.K. Steel Re-rolling Mills is a leading manufacturer of alloy steel industrial products, located at Ludhiana in Punjab. In 2018, the plant decided to implement the modified pulverized coal feeding system in the re-heating furnace under the guidance of the UNDP-GEF project. The energy efficient system was installed in their 7 t/h furnace. The plant achieved an astonishing 10% reduction in the specific fuel consumption. The EE pulverizer required an investment close to Rs 15 lakhs which was recovered in close to a year.

Modified pulverized coal feeding system at TK Steel

Sl. No.	Parameter	UoM	Baseline	Post Implementation
1	Productivity	t/h	7	7
2	No. of operating hours	h/d	12	12
3	No. of working days	d/y	300	300
5	Specific fuel consumption	kg/t	70	63-
6	Annual production	t/y	25,200	25,200
7	Annual fuel consumption	t/y	1764	1587.6
8	Annual saving of coal	t/y	176.4	
9	Cost of coal	Rs/t	8,000	
10	Annual monetary savings	Rs in lakh/y	14.11	
11	Estimated investment	Rs in lakh	15	
12	Simple pay-back period	months	13	
13	Annual energy savings	toe/y	99	
14	Annual GHG emission reduction	tCO_2/y	391	

**Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg*
***Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 tCO_2/TJ for sub-bituminous coal*

8 Technology No. 7: Installation of Coal Drying System

8.1 Baseline Scenario

Coal is the predominantly used fuel in re-heating furnaces. Coal will normally have an inherent moisture of 8% and surface moisture of 10%. Such moisture content takes away substantial heat during combustion process as latent heat of vapour. Such high moisture also leads to chocking of coal storage hoppers leading to frequent breakdowns. Although many industries have attempted drying coal using crude methods (spreading coal on top of re-heating furnace, in open area etc.), they have not been able to get the desired results.

8.2 Energy Efficient Technology

Flue gas comes out of re-heating furnace at temperature of 600 to 700°C. Partial heat recovery is achieved in a recuperator for pre-heating combustion air. A bypass line from the pre-heated combustion air is fed into the cyclone dryer wherein it is mixed with the moisture laden air. Dried coal is dropped into two conveyors. An ID Fan throws out the moisture laden air. An air lock system is provided to block the entry of air into the conveyors. The two conveyors are used to carry dried coal to the pulverizer. In this process, the cyclone dryer is used to remove the surface moisture of the coal, which is around 10-12%. The inherent moisture in coal however remains intact. The entire coal drying system works on a principle of removing the moisture content by using the waste heat available in flue gas.

8.3 Benefits of the technology

Installation of coal dryer has the following benefits:

- Feeding of moisture free dry coal for combustion
- Avoiding formation of vapour during combustion
- Enhanced combustion efficiency of furnace
- Reduced energy consumption

8.4 Limitations

The dryer should be placed close as possible to the pulverizing. Over heating should be avoided.

8.5 Energy Savings, GHG Emission Reduction & Cost Benefit Analysis

The following section provides the details of coal drying technology in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h SRRM plant:

Table 19: Cost benefit analysis for coal dryer

Sl. No.	Parameter	UoM	Value
1	Latent heat of evaporation of water vapour	kCal/kg	542
2	Amount of coal used in 15 t re-heating furnace operating for 16 hours per day (considering specific coal consumption of 75 kg/t)	kg/d	18,000
3	Mass of 1% of moisture present in coal	kg/d	180
4	Heat taken away by this 1% of moisture through latent heat of evaporation	kCal/d	97,560
5	Reduction in moisture by installing coal drying system	%	6
6	Total heat saved due to reduction in moisture content by installing coal drying system (Sl. No. 5 x Sl.No.4)	kCal/d	5854
7	Calorific value of coal used in re-heating furnace	kCal/kg	5,600
8	Saving in coal consumption due to installation of coal drying system	kg/d	1.05
9	Increase in calorific value of coal due to reduction in moisture (assuming 10% increase)	kCal/kg	560
10	Coal consumption due to increased calorific value	kg/d	16,364
11	Total reduction in coal consumption	kg/d	1637
12	Saving in fuel consumption	%	9.10
13	Annual coal saving	t/y	540
14	Cost of fuel	Rs/t	8,000
15	Monetary saving	Rs in Lakhs /y	43
16	Estimated Investment	Rs in Lakhs	17
17	Simple pay back	Months	5
18	Annual energy savings	toe/y	303
19	Annual CO_2 emission reduction	tCO_2/y	1,198

** Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg*

***Emission factor of coal as per IPCC guideline 2006 (V2; C1& C2) is 94.6 tCO_2/TJ for sub-bituminous coal*

The investment and energy savings for coal dryer will vary based on the capacity of the furnace. The table below provides an estimate for coal dryer for different ranges of the furnace:

Table 20: Investment and saving for coal dryer for different ranges of furnace

Furnace Capacity (tph)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
5-20	10 – 25	12 - 50	< 1 year

** based on estimated figures*

Case Study 6: Installation of Coal Dryer System

Located in Jaipur, Rajasthan, Premier Bars Limited is a leading manufacturer of TMT bars. In 2018, the plant decided to implement a coal dryer system in the re-heating furnace under the guidance of the UNDP-GEF project. The energy efficient system was installed in their 20 t/h furnace. The plant achieved an astonishing 10% reduction in the specific fuel consumption. The EE pulverizer required an investment close to Rs 15 lakhs which was recovered in close to a year.

Sl. No.	Parameter	UoM	Baseline	Post Implementation
1	Productivity	t/h	20	20
2	No. of operating hours	h/d	16	16
3	No. of working days	d/y	330	330
5	Specific fuel consumption	kg/t	70	63
6	Annual production	t/y	105,600	105,600
7	Annual fuel consumption	t/y	7,392	6,653
8	Annual saving of coal	t/y	739	
9	Cost of coal	Rs/t	8,000	
10	Annual monetary savings	Rs in lakh/y	59.13	
11	Estimated investment	Rs in lakh	15	
12	Simple pay-back period	months	3	
13	Annual energy savings	toe/y	414	
14	Annual GHG emission reduction	tCO_2/y	1,638	

**Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg*
***Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 tCO_2/TJ for sub-bituminous coal*

9 Technology No. 8: Swirl Burner Used for Pulverized Coal Firing

9.1 Baseline Scenario

Pulverized coal is the most preferred fuel used in a re-heating furnace, because of its easy availability, low cost and ease of operation. Combustion depends on three "T's" namely "Time, Temperature & Turbulence". Efficient burning of coal depends on proper air-fuel mixture. In most of the SRRM units, a 4-inch pipe is used as a burner for pulverized coal. This 4-inch pipe is inserted into the front and side walls of the re-heating furnace. Only primary air in ambient temperature is used for combustion in such conventional burners and the air-fuel ratio is neither monitored nor controlled. This crude practice of using 4-inch pipe as a burner leads to incomplete combustion, inefficient heat transfer to ingot/billet/scrap, and higher fuel consumption.

9.2 Energy Efficient Technology

In order to have proper control of the air-fuel mixture in a re-heating furnace and also to ensure optimum combustion of coal, swirl burners for pulverized coal-fired re-heating furnaces can be used. The purpose of using a swirl burner is to achieve a stable flame and to ensure proper mixing of air and fuel. In a swirl burner, secondary air is supplied along with primary air in annular arrangement. Both primary air and secondary air are hot air drawn from the recuperator. The swirl burner typically has three inputs; the closest input towards the furnace is for primary air, which is directly fed from the recuperator; coal is fed from the next input on a controlled manner from the screw feeder attached to the over-head hopper. The third input is for the secondary air which pushes the coal into the burner. The hot secondary air is also utilized for complete combustion of powder coal. This burner works on the basis of three T's of combustion:

- Time: Sufficient time for burning
- Temperature: Lgnition temperature must be achieved
- Turbulence: Proper mixing of fuel and air, which is achieved by swirlers

Vanes are fabricated in between the annular pipes. The turbulence caused due to the rotation of air-fuel mixture being generated by the vane swirl generator results in proper air-fuel mixing and better combustion of fuel.

9.3 Benefits of the technology

Installation of swirl burners in pulverized coal fired furnace has the following benefits:

- Provides sufficient time for burning
- Increased flame temperature
- Ensures proper air fuel mixture.
- Enhanced combustion efficiency of furnace
- Reduced energy consumption

9.4 Limitations

There are no limitations for this technology.

9.5 Energy Savings, GHG Emission reduction & Cost Benefit Analysis

The following section provides the details of the pulverized coal swirl burners in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h SRRM plant.

The investment and energy savings for swirl burners will vary based on the capacity of the furnace. The table below provides an estimate for swirl burners for different ranges of the furnace:

Table 21: Cost benefit analysis for swirl burners for pulveirized coal firing

Sl. No.	Parameter	Unit	Furnace with pipe burner	Furnace with swirl burner
1	Productivity	t/h	15	15
2	Operating hours per day	h/d	16	16
3	Operating days per year	d/y	330	330
4	Specific fuel consumption	kg/t	75	72.75
5	Annual fuel consumption	t/y	5,940	5,762
6	Saving in fuel consumption	t/y	178	
	Cost of fuel	Rs/t	8,000	
7	Annual monetary saving due to fuel savings	Rs in Lakhs/y	14.3	
8	Investment for say 6 nos. of swirl burners with required accessories	Rs in Lakhs	7.5	
9	Simple pay back	months	6	
10	Annual energy savings	toe/y	100	
11	Annual GHG emission reduction	tCO_2/y	395	

** Calorific value of coal taken as 5,600 kCal/kg; Cost of coal taken as Rs 8 /kg*
***Emission factor of coal as per IPCC guideline 2006 (V2; C1& C2) is 94.6 tCO_2/TJ for sub-bituminous coal*

Table 22: Investment and saving for pulverized coal swirl burners for different ranges of furnace

Furnace Capacity (tph)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
5-20	1.25 – 10	4 – 17.5	< 1 year

** based on estimated figures*

Case Study 7: Installation of Swirl Burner in Pulverized Coal Fired Furnace

TK Steel Rolling Mill is a leading manufacturer of alloy steel industrial product, located at Ludhiana in Punjab. The plant was established in the year 1995. In 2017, the plant decided to implement swirl burners in their existing re-heating furnace. The plant achieved a 3% reduction in the specific fuel consumption. The investment was recouped in less than a year.

Pulverized coal swirl burner

Sl. No.	Particulars	UoM	Baseline	Post Implementation
1	Furnace productivity	t/h	10	10
2	Type of fuel		Pulverized coal	Pulverized coal
3	Specific fuel consumption	kg/t	70	67.9
4	Saving in fuel consumption	kg/t	2.1	
5	Annual fuel saving	t/y	166	
6	Cost of fuel	Rs/t	8,000	
7	Annual monetary savings	Rs in Lakhs/y	13.3	
8	Investment	Rs in Lakhs	5	
9	Simple pay back	months	5	
10	Annual energy savings	toe/y	83	
11	Annual GHG emission reduction	tCO_2/y	369	

**Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg*
***Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 tCO_2/TJ for sub-bituminous coal*

10 Technology No. 9: Replacement of Fossil Fuel Firing to Coal Bed Methane (CBM) Firing in Re-heating Furnace

10.1 Baseline Scenario

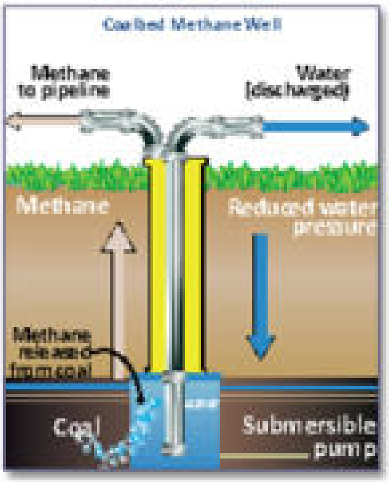


Figure 20: Extraction of coal bed methane

Traditionally, fossil fuels in the form of lump coal, pulverized coal, furnace oil, natural gas or producer gas have been the commonly used fuels to fire a re-heating furnace. The use of fossils fuels not only adds to the country's worries but also emits green-house gases which are proven threat to the universe. Under such scenario, there is a quest for alternate source of energy worldwide, to combat the harmful threats of global warming.

The details of re-heating furnace operating in conventional rolling mills are as follows:

Table 23: Operating parameters for conventional re-heating furnace

Furnace Capacity (tph)	Thermal Efficiency (%)	Flue gas exit temperature (ºC)	Specific fuel consumption
2-25	25-30	600-650	100-150 kg/t of pulverized coal or 140-160 kg/t of coal based producer gas or 40-45 l/t of furnace oil or 35-40 SCM/t of natural gas

10.2 Energy Efficient Technology

Coal bed methane (CBM or coal-bed methane), coal bed gas, coal seam gas (CSG), or coal-mine methane (CMM) is a form of natural gas extracted from coal beds. Methane adsorbed into a solid coal matrix (coal macerals) is released if the coal seam is de-pressurized. Methane is extracted by drilling wells into the coal seam.

The goal is to decrease the water pressure by pumping water from the well. The decrease in pressure allows methane to desorb from the coal and flow as a gas up the well to the surface. Methane is then compressed and piped to market.

The objective is to avoid putting methane into the water line, but allow it to flow up the backside of the well (casing) to the compressor station. If the water level is pumped too low during dewatering, methane may travel up the tubing into the water line causing the well to become "gassy".

Although methane may be recovered in a water-gas separator at the surface, pumping water and gas is inefficient and can cause pump wear and breakdown. Extraction of coal bed methane in large quantity is being currently done in areas of West Bengal in and around Raniganj-Panagarh, etc.

Coal bed methane (CBM) can be used in rolling mill as a piped gas and has features similar to that of natural gas. Use of coal bed methane is considered as a carbon neutral fuel as the main component of the gas is methane (CH_4) which is a green-house gas, which is burnt in the combustion process.

10.3 Benefits of the technology

Switching over to coal bed methane as fuel has the following benefits:

- Utilization of methane which is a green-house gas
- Better combustion efficiency compared to solid fuel firing

10.4 Limitations

The technology is applicable only in areas where piped CBM gas is available. Also, the piped gas needs to be supplied in constant pressure. Cost of fuel will decide the economic feasibility of the technology.

10.5 Investment Required, Energy & GHG Saving Potential & Cost Benefit Analysis

The following section provides the details of energy & GHG saving potential, investment required and cost benefit analysis for implementation of CBM based unit as a replacement to furnace oil for a 15 t/h furnace.

The investment and energy savings for switching over from furnace oil to CBM as fuel will vary based on the capacity of the furnace. The table below provides an estimate for switching over from furnace oil to CBM as fuel for different ranges of the furnace:

Table 24: Cost benefit analysis for switch over from furnace oil to CBM based reheating furnace

Sl. No.	Parameter	Unit	Furnace oil fired re-heating furnace	CBM fired re-heating furnace
1	Productivity	t/h	15	15
2	Operating hours per day	h/d	20	20
3	Operating days per year	d/y	300	300
4	Specific fuel consumption	l/t ; Nm^3/t	35	32
5	Cost of fuel	Rs/l ; Rs/ Nm^3	35	30
6	Annual fuel consumption	kl/y ; Nm^3/y	3,150	2,880,000
7	Annual cost of fuel	Rs in Lakhs/y	1,102.5	864
8	Annual monetary savings	Rs in Lakhs /y	239	
9	Investment towards modification of furnace and piped gasoline	Rs in Lakhs	150	
10	Simple pay-back	Months	8	
11	Annual energy savings	toe/y	635	
12	Annual GHG emission savings	tCO_2/y	9,365	

**Calorific value of furnace taken as 9,600 kCal/kg; calorific value of CBM taken as 10,500 kCal/kg*

***Density of furnace oil is 0.96 kg/l; Density of CBM is 0.7 kg/Nm^3*

***Cost of furnace oil taken as Rs 35 /l and cost of CBM taken as Rs 30/Nm3*

**** Emission factor for furnace oil as per IPCC Guideline 2006 (C1; V1 & V2) taken as 77.2 tCO_2/TJ; GHG emission from CBM considered as 'zero'*

Table 25: Investment and saving for CBM as fuel for different ranges of furnace

Furnace Capacity (t/h)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
10 -20	100 – 150	100 – 200	< 1 year

** based on estimated figures*

11 Technology No. 10: Replacement of Fossil Fuel Firing to Biomass Based Producer Gas in Re-heating Furnace

11.1 Baseline Scenario

Traditionally, fossil fuels in the form of lump coal, pulverized coal, furnace oil, natural gas or producer gas are the commonly used fuels to fire a re-heating furnace. The use of fossil fuels not only adds to the country's worries but also emits green-house gases which are proven threat to the universe. Under such scenario, there is a quest for alternate source of energy worldwide, to combat the harmful threats of global warming.

The details of re-heating furnace operating in conventional rolling mills are as follows:

Table 26: Operating parameters for conventional re-heating furnace

Furnace Capacity (tph)	Thermal Efficiency (%)	Flue gas exit temperature (⁰C)	Specific fuel consumption
2-25	25-30	600-650	100-150 kg/t of pulverized coal or 140-160 kg/t of coal based producer gas or 40-45 l/t of furnace oil or 35-40 SCM/t of natural gas

11.2 Energy Efficient Technology

Biomass generated from agricultural waste such as groundnut shell, coconut shell, bagasse, etc. formed into briquettes by a suitable binding medium can be used as input to a biomass based producer gas plant; the producer gas in-turn can be used as a fuel for the re-heating furnace. Gasification is a thermos-chemical process where biomass is converted into a combustible producer gas. The main components in producer gas are N_2; H_2; CO; CO_2 and CH_4. Producer gas from biomass gasification is available in two forms, viz., (i) hot raw gas and (ii) cleaned cold gas.

Typical Schematic arrangement of biomass gasification for furnace is shown below:

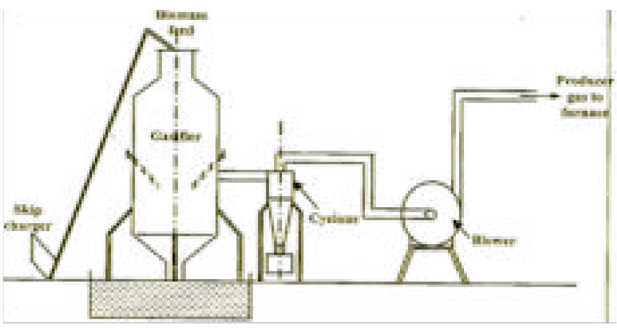


Figure 21: Schematic diagram showing biomass gasification for re-heating

The hot raw gas is obtained by tapping from an appropriate point of the reactor, where the gas is at a temperature of about 500⁰C. In this gas, all tar and naptha will be in vapour form. Therefore, the CV is high about 1,350 to 1,400 kCal/Nm². Also, since this gas is at high temperature, adiabatic flame temperature by combustion of this gas with air at 350⁰C will be above 1800⁰C, which is adequate for re-heating furnaces. However, the raw gas will be available at low pressures, about 50 mm WC, which is just sufficient level for typical burners. This means it is not possible to introduce any measurement and auto control system with hot raw gas, since the pressure is not adequate. With lack of flow measurement and flow control furnace temperature control cannot be maintained at optimum levels. Boosting the hot raw gas with tar, to the required pressure level by a booster is not practical. Biomass based producer gas can be effectively used in a rolling mill using suitable producer gas burners. Cold gas is tapped from top of the reactor after the heat content of the gas is recovered for drying and preheating of the coal charge. The gas further processed for removal of tar and naphtha in scrubbers, and ultimately the gas will be free from tar. Since the gas is free from tar, this can be boosted to the desired pressure. However, since tar has been removed, CV of the gas will be in the range of 1,050 to 1,100 kCal/Nm². Adiabatic flame temperature of cold gas with this CV and with combustion air temperature of 350⁰C will be about 1,600⁰C. With this adiabatic flame, temperature furnace cannot be heated to 1,280⁰C, which is required in the re-heating furnaces. Therefore, when this gas is used, support of high CV fuel like furnace oil is required.

GHG (CO_2) emissions from the biomass are high as compared to other fuels in the reheating furnace but it cannot be considered as GHG emission because CO_2 emission from biomass is considered as a part of natural carbon cycle. Thus, use of biomass based producer gas in the re-heating furnace is a carbon neutral process.

11.3 Benefits of the technology

Adoption of biomass based producer gas plant as fuel has the following benefits:

- Utilization of renewable source of energy
- Better combustion efficiency compared to solid fuel firing
- Reduced cost of production

11.4 Limitations

Continuous availability of biomass is a limiting factor for the technology. Also, cost of biomass briquettes will determine the feasibility of the technology.

11.5 Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of replacement of furnace oil with biomass based producer gas in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h SRRM unit.

The investment and energy savings for switching over from furnace oil to biomass based producer gas as fuel will vary based on the capacity of the furnace. The table below provides an estimate for switching over from furnace oil to biomass based producer gas as fuel for different ranges of the furnace:

Table 27: Cost benefit analysis for biomass based reheating furnace

Sl. No.	Parameter	Unit	Furnace oil fired re-heating furnace	Biomass based re-heating furnace
1	Productivity	t/h	15	15
2	Operating hours per day	h/d	20	20
3	Operating days per year	d/y	300	300
4	Specific fuel consumption	l/t ; kg/t	45	100
5	Cost of fuel	Rs/l ; Rs/ kg	35	6
6	Annual fuel consumption	kl/y ; t/y	4,050	9,000
7	Annual cost of fuel	Rs in Lakhs/y	1,418	540
8	Annual monetary savings	Rs in Lakhs/y	878	
9	Investment for gasifier & furnace modification	Rs in Lakhs	120	
10	Simple pay-back	Months	2	
11	Annual energy savings	toe/y	454	
12	Annual GHG emission savings	tCO_2/y	11,915	

**Emission factor of furnace oil as per IPCC guideline 2006 (V2; C1& C2) is 77.2 tCO_2/y; calorific value of furnace oil taken as 9,600 kCal/kg; calorific value of biomass taken as 3600 kCal/kg. GHG emission from biomass is taken as zero.*

Table 28: Investment and saving for biomass based producer gas as fuel for different ranges of furnace

Furnace Capacity (tph)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
10 -20	70 – 120	250 – 500	< 1 year

** based on estimated figures*

Case Study 8: Installation of Biomass Based Producer Gas Plant

Located in Pondicherry, Pulkit Steel Rolling Pvt. Ltd. is a leading manufacturer of TMT bars. In 2016, the plant decided to implement a biomass based producer gas plant under the guidance of the on-going UNDP-GEF project. The biomass gasifier fed to the 20 tph top fired pusher type re-heating furnace. The plant achieved significant savings in terms of energy cost reduction.

Biomass based producer gas plant

Sl. No.	Particulars	UoM	Baseline	Post Implementation
1	Furnace productivity	t/h	20	20
2	Type of fuel		Furnace Oil	Biomass based producer gas
3	Specific fuel consumption	kg/t	40	110
4	Cost of fuel	Rs/kg	30	6
7	Annual monetary savings	Rs in Lakhs/y	518	
8	Investment	Rs in Lakhs	90	
9	Simple pay back	months	2	
10	Annual energy savings	toe/y	(-)300	
11	Annual GHG emission reduction	tCO_2/y	11297	

**Calorific value of coal taken as 5600 kCal/kg ; Cost of coal taken as Rs 8 /kg*
***Emission factor of coal as per IPCC guideline 2006 (V2; C1 & C2) is 94.6 tCO_2/TJ for sub-bituminous coal*

12 Technology No. 11: Replacement of Coal Firing to Natural Gas Firing in Re-heating Furnace

12.1 Baseline Scenario

Coal has been traditionally used as the most common form of energy used in re-heating furnace. However, firing coal into the re-heating furnace is a dirty process and also causes threat to health of the workers due to the local level pollution. Coal also increases the suspended particulate matter (SPM) level of the factory's environment thus causing threat to the nearby locality. Also, burning of coal leads to formation of accretion in the furnace walls; primarily due to un-burnt coal and formation of soot.

The details of re-heating furnace operating in conventional rolling mills are as follows:

Table 29: Operating parameters for conventional re-heating furnace

Furnace Capacity (tph)	Thermal Efficiency (%)	Flue gas exit temperature (°C)	Specific fuel consumption
2-25	25-30	600-650	100-150 kg/t of pulverized coal or 140-160 kg/t of coal based producer gas

12.2 Energy Efficient Technology

Use of natural gas as fuel as replacement of coal leads to cleaner and healthier production. Piped gas line is available in some parts of the country which can be used as fuel for the re-heating furnace. Natural gas as fuel not only allows a better environment for the unit; but also provides significant improvement in the furnace internal environment. Natural gas firing, if controlled in a proper fashion, can lead to optimum specific fuel consumption and burning loss. Also, the efficiency of the furnace improves significantly leading to a longer furnace life.

12.3 Benefits of the Technology

Replacement of coal fired furnace with natural gas fired furnace has the following benefits:

- Utilization of a clean fuel
- Better combustion efficiency compared to solid fuel firing
- Reduced burning loss
- Better life of furnace

12.4 Limitations

The technology is applicable only in areas where piped natural gas is available. Also, the piped gas needs to be supplied at constant pressure. Cost of fuel will decide the economic feasibility of the technology.

12.5 Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of replacement of coal firing with natural gas firing in re-heating furnace in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h furnace.

The investment and energy savings for switching over from furnace oil to natural gas as fuel will vary based on the capacity of the furnace. The table below provides an estimate for switching over from furnace oil to natural gas as fuel for different ranges of the furnace:

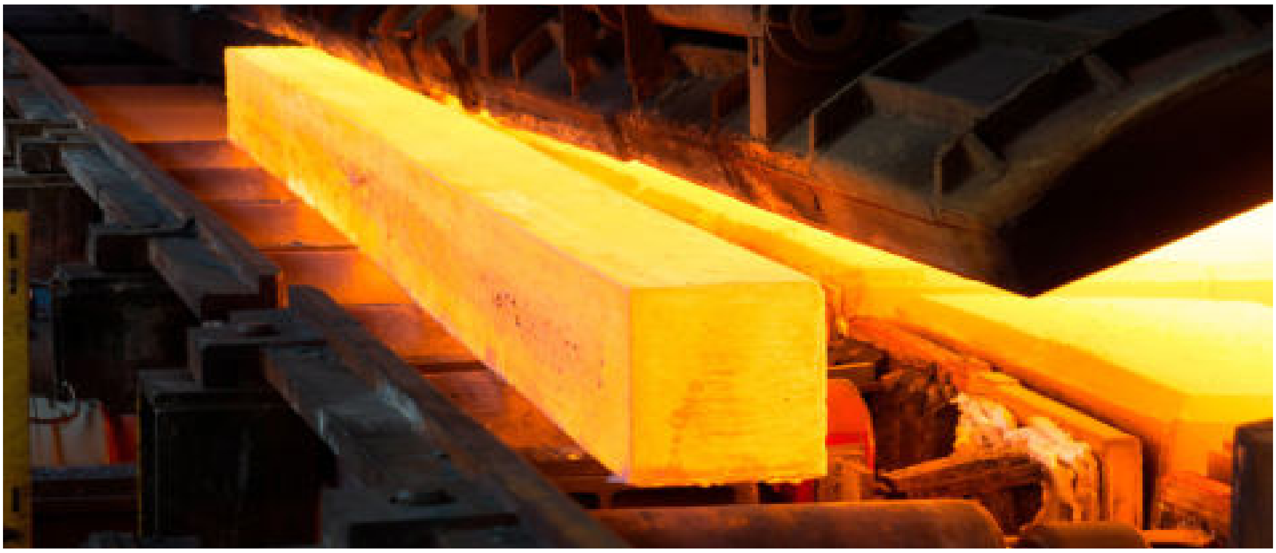


Table 30: Cost benefit analysis for switching over from coal fired furnace to NG fired furnace

Sl. No.	Parameter	Unit	Coal fired re-heating furnace	Natural Gas fired re-heating furnace
1	Productivity	t/h	15	15
2	Operating hours per day	h/d	16	16
3	Operating days per year	d/y	300	300
4	Specific fuel consumption	kg/t ; Nm^3/t	120	30
5	Cost of fuel	Rs/kg ; Rs/ Nm^3	8	30
6	Annual fuel consumption	t/y; Nm^3/y	8,640	2,160,000
7	Annual cost of fuel	Rs in Lakhs/y	691.2	648
8	Annual monetary savings	Rs in Lakhs/y	43.2	
9	Estimated Investment for furnace modification	Rs in Lakhs	40	
10	Simple pay-back	Months	11	
11	Annual energy savings	toe/y	3,137	
12	Annual GHG emission savings	tCO_2/y	14,800	

**Calorific value of coal taken as 5,600 kCal/kg; calorific value of NG taken as 10,500 kCal/kg*
***Density of NG is 0.7 kg/Nm^3*
***Cost of coal taken as Rs 8000/t and cost of NG taken as Rs 30/Nm^3*
**** Emission factor for coal as per IPCC Guideline 2006 (C1; V1 & V2) taken as 94.6 tCO_2/TJ; GHG emission from NG considered as 65.5 tCO_2/TJ*

Table 31: Investment and saving for natural gas as fuel for different ranges of furnace

Furnace Capacity (tph)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
10 -20	20 – 60	30 – 80	< 1 year

** based on estimated figures*

13 Technology No. 12: Installation of Anti-friction Roller Bearing in Rolling Mill Strands

13.1 Baseline Scenario

Bearings are one of the most critical equipment in a rolling mill and they perform three basic functions:

- Carrying a load
- Reducing friction
- Positioning moving machine parts

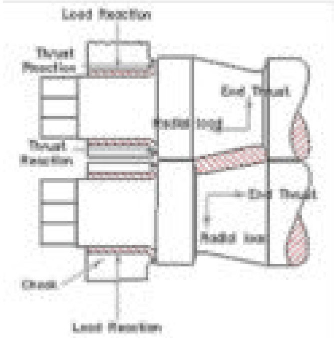


Figure 22: Various Loads in bearing

Rolling mill bearings are required to withstand extremely severe operating conditions, including heavy shock loads, varying speeds and extreme temperature variations. In most of the cases, the bearing has to withstand both the radial roll separating force and the roll end thrust as illustrated in figure.

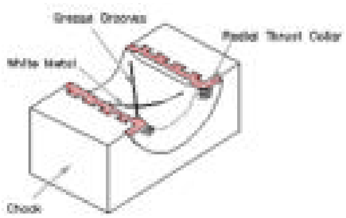


Figure 23: Plain metal bearing

The proposition of end thrust varies considerably being quiet low in flat rolling but high in section rolling. Traditionally, many types of bearings are used in a rolling mill. The plain metal bearings (e.g. bronze and white metal) were used extensively in the past, but is now being superseded by the other bearings; although examples can still be found today which are giving very satisfactory performance.

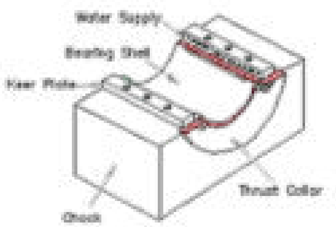


Figure 24: Fabric bearing

Figure 25: Fiber bearing in rolling mill

Fabric bearing have in many cases replaced the plain metal bearing and often represent the most economical bearing for particular equipment. They are composed of a fabric such as cotton impregnated with a resin, and are manufactured by moulding or wrapping accordingly to the type of resin used.

Figure 26: Fiber bearing key

A fabric bearing is subjected to a linear contact with the rotating rolls. Thus, these bearings lead to more friction, thereby leading to significant mechanical losses and lead to comparatively higher power consumption.

13.2 Energy Efficient Technology

As an alternative to the conventional metal & fabric bearing, is an anti-friction roller bearing.

A typical roller bearing consists of rolling elements or rollers, an inner ring, an outer ring, and a retainer. In a typical installation, the outer ring is fixed and doesn't move and the inner ring is fitted to the shaft. As the shaft rotates, the inner ring also rotates. The rollers are held into position by the retainer which positions the rollers equally around the rings and ensures that the load is distributed equally on each roller when the shaft is rotating.

Figure 27: Roller bearing

Ball and roller bearings are finding wide use in all types of mills due to their close tolerance and low power loss. Parallel, taper and spherical taper races are available and even ball races vary considerably in form – angular contact and deep-seated types being used for thrust races. Taper rollers can take thrust as well as radial loads but parallel rollers require a separate thrust race. Two typical arrangements are shown in Fig 29 and 30. The method of mounting the inner races varies with the duty – for slow-speed applications, a loose fit on the roll neck might suffice whereas in high-speed application a shrink fit on a parallel or taper neck may be required. Lubrication may be by grease pack or automatic feed of grease, oil or oil mist.

Figure 28: Roller bearing based mill stand

13.3 Benefits of the technology

Adoption of roller bearings has the following benefits:

- Less friction compared to metal or fabric bearing
- Improved transmission efficiency
- Improved life of rolls
- Reduced energy consumption
- Improved mill utilization

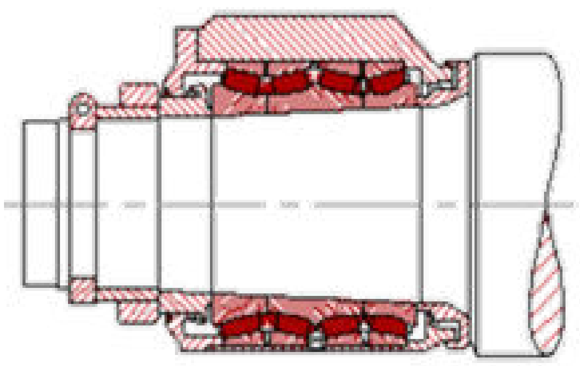


Figure 29: Taper roller bearing for radial load and thrust

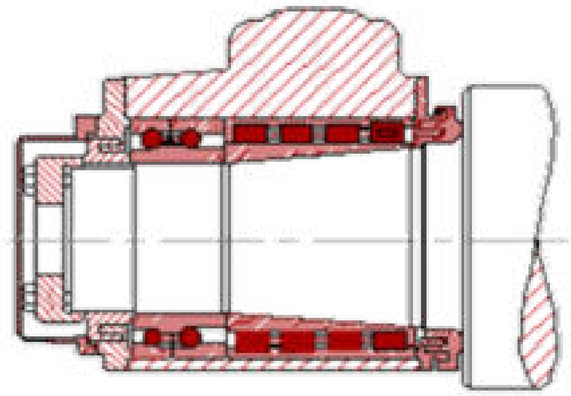


Figure 30: Parallel roller for radial load and angular contact ball bearing for thrust

13.4 Limitations

The bearings must be lubricated properly to avoid failure. The roll alignment may be checked properly before installation. Conversion from fabric to roller bearing depends on the roll strand.

13.5 Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of replacement of conventional bearing with roller bearing in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h plant.

The investment and energy savings for installation of roller bearing will vary based on the capacity of the rolling mill and number of stands to be changed.

The table below provides an estimate for installation of roller bearing for different ranges of rolling mills:

Table 32: Cost benefit analysis for roller bearing

Sl. No.	Parameter	UoM	With conventional bearings	With roller bearings
1	Productivity	t/h	15	15
2	Annual operational hours	h/y	5,280	5,280
3	Mill Utilization	%	85	89
4	Annual production	t/a	67,320	70,686
5	Specific power consumption (average)	kWh/t	120	108
6	Saving in specific power consumption	kWh/t	12	
7	Annual power savings	kWh/y	848,232	
8	Power Tariff	Rs/kWh	7.5	
9	Annual monetary saving due to power saving	Rs in Lakh/y	64	
10	Annual monetary profit due to increase in productivity**	Rs in Lakh/y	50	
11	Total annual saving	Rs in Lakh	114	
12	Investment for replacement of conventional bearing with roller bearing***	Rs in Lakh	50	
14	Payback Period	months	5	
15	Annual energy saving	toe/y	73	
16	Annual saving in CO_2 emission due to reduction in coal saving*	tCO_2/y	763	

**Emission factor of electricity as per IPCC guidelines 2006 (V2; C1 &C2) is 0.90 tCO_2/MWh*
***Profit margin of Rs 1,500 per ton of production has been considered*
**** The cost includes replacement of bearings in roughing mill and intermediate mill strand only. It is assumed finishing mill is already equipped with finishing stands. Also, cost of change of stand has not been considered.*

Table 33: Investment and saving for installation of roller bearing for different ranges of rolling mills

Rolling Mill Capacity (tph)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
10 -25	20 – 60	75 – 190	< 1 year

** based on estimated figures*

Case Study 9: Replacement of Fibre Bearing with Roller Bearing

Located in Jaipur, Rajathan, Premier Bars Limited is a leading manufacturer of TMT bars. In 2017, the plant replaced their roughing and intermediate mill stand from fibre bearing to roller bearing. The plant achieved significant savings in terms of energy cost reduction.

Sl. No.	Parameter	Unit	Baseline	Post Implementation
1	Productivity	t/h	20	20
2	Annual operational hours	h/y	5,280	5,280
3	Mill Utilization	%	85	89
4	Annual production	t/a	89,760	94,248
5	Specific power consumption (average)	kWh/t	120	108
6	Saving in specific power consumption	kWh/t	12	
7	Annual power savings	kWh/y	1,130,976	
8	Power Tariff	Rs/kWh	7.5	
9	Annual monetary saving due to power saving	Rs in Lakh/y	85	
10	Annual monetary profit due to increase in productivity**	Rs in Lakh/y	67	
11	Total annual saving	Rs in Lakh	152	
12	Investment for replacement of conventional bearing with roller bearing***	Rs in Lakh	50	
14	Payback Period	Months	4	
15	Annual energy saving	toe/y	97	
16	Annual saving in CO_2 emission due to reduction in coal saving*	tCO_2/y	1,018	

**Emission factor for electricity as per IPCC guideline 2006 (V2: C1 & C2) taken as 0.9 tCO_2/MWh*

Technology No. 13: Installation of Universal Couplings/ Spindles in Rolling Mill

14

14.1 Baseline Scenario

Couplings are devices used to connect two pieces of rotating equipment or shafts together. Couplings are used for transmitting power. Spindles are used for transmitting rotation to the rolls from pinion stands or from electric motors. Careful selection, installation and maintenance of couplings and spindles will ensure substantial savings. The savings will be in terms of reduced power consumption, reduced maintenance costs and downtime.

Figure 31: Wobbler Couplings

Traditionally, wobblers are the most commonly used couplings in steel re-rolling mill units. These wobbler couplings are made of cast iron, either three fluted or four fluted, and are used in un-machined condition. These couplings are usually used with nylon or wooden packing's. The roughness or improper pairing gives rise to low metal to metal contact. Further, the wobbler connections do not allow flexibility towards inclination from the roll axis beyond 1-20C. The disadvantages of using wobbler couplings are:

- Jerking loads on drive motor due to wear out of Nylon/ Wooden pads owing to repeated biting of rolling stocks in various parts
- Higher load on drives due to limited flexibility of inclination of the Spindles owing to differential wear diameter of the rolls

Higher mill downtime and lower mill utilization

14.2 Energy Efficient Technology

As an alternative to the wobbler couplings and spindles, the energy efficient way is to use universal couplings and spindles.

Universal spindles allow rotation to be translated to the rolls at considerable angles, up to 8-100 between the axis of the spindle and the axes of the rolls or pinion of a pinion stand. The horizontal projection of the spindle's length alters in accordance with the angle of inclination. For this reason, one of the hinges of a spindle is usually fixed at the end of the driving shaft and the other, at the roll end; in not fixed, i.e. it floats in an axial direction.

An improvised form for a universal coupling is the cardon shaft coupling and spindles. In case of cardon shaft, the flexibility of inclination is even more. The advantages of Universal couplings over wobbler couplings are:

- They have high torque transmission capacity.
- Their simplicity of design results in easy maintenance; this reduces the down time.
- They have negligible backlash and radial clearance.
- They have high operational life and low operational costs.
- They lead to uniform loading on drive motors.
- They lead to increased roll life due to the higher flexibility of the spindle inclination.
- Reduces power: increased mill utilization.

14.3 Benefits of the technology

Adoption of universal coupling and spindles has the following benefits:

- Increased margin for roll usage
- Improved transmission efficiency
- Reduced energy consumption
- Improved mill utilization

14.4 Limitations

The roll alignment may be checked properly before installation. Conversion from wobbler coupling to universal coupling and spindle will depend on the roll strand. For optimum performance, universal coupling and spindle should be clubbed together with roller bearing

Figure 32: Univeral coupling and spindles in rolling mill

14.5 Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of replacement of conventional couplings/spindles with energy efficient universal couplings / spindles in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h SRRM unit.

The investment and energy savings for installation of universal spindle/couplings will vary based on the capacity of the rolling mill and number of stands to be changed. The table below provides an estimate for installation of universal spindle/couplings for different ranges of rolling mills:

Table 34: Cost benefit analysis for universal couplings and spindles

Sl. No.	Parameter	UoM	With Wobbler couplings / spindles	With Universal couplings / spindles
1	Productivity	t/h	15	15
2	Annual operational hours	h/y	5,280	5,280
3	Mill Utilization	%	85	86.7
4	Annual production	t/y	67,320	68,666
5	Specific power consumption (average)	kWh/t	120	114
6	Saving in specific power consumption	kWh/t	6	
7	Annual power savings	kWh/y	411,998	
8	Power Tariff	Rs/kWh	7.5	
9	Annual monetary saving due to power saving	Rs in Lakh/y	31	
10	Annual monetary profit due to increase in productivity**	Rs in Lakh/y	20	
11	Total annual saving	Rs in Lakh/y	51	
12	Investment for replacement of wobbler coupling / spindles with universal coupling/ spindle***	Rs in Lakh	50	
14	Payback Period	Months	12	
15	Annual energy saving	toe/y	35	
16	Annual saving in CO_2 emission due to reduction in coal saving*	tCO_2/y	371	

**Emission factor of electricity as per IPCC guidelines 2006 (V2; C1 & C2) is 0.90 tCO_2/MWh*
***Profit margin of Rs 1,500 per ton of production has been considered*
**** The cost includes replacement of coupling in roughing mill and intermediate mill strand only. It is assumed finishing mill is already equipped with universal couplings & spindles. Also, cost of change of stand has not been considered.*

Table 35: Investment and saving for installation of universal spindles/couplings for different ranges of rolling mills

Rolling Mill Capacity (t/h)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
10 -25	20 – 60	75 – 190	< 1 year

** based on estimated figures*

Technology No. 14: Installation of Y-table / Tilting Table / Repeaters in Rolling Mill

15

15.1 Baseline Scenario

To improve upon the efficiency of operation of a rolling mill, one has to improve upon the mill utilization factor which can be done through combating mill delays. A large portion of mill delays can be avoided by minimizing manual intervention and adoption of automatic material handling machines3 Hi Roughing Mill stand forms the major bottleneck towards increased mill speed of a rolling mill.

The roughing mill is generally used for heavy reduction of charge. The hot charge is alternatively processed between middle-bottom and top-middle rolls.

Conventionally, after a pass rolling, the charge is transferred to the next pass using a guide through manual intervention. The manual handling is done by a tongues man; who usually holds the rear end of the hot charge and enters it into the next pass. Delays in the process of charging also sometimes lead to cooling of the charge, which in turn reduces the life of the machine.

Traditionally, manual intervention can also be seen in cross-country mill, wherein unskilled workers use tongues to hold a hot charge and put it into the next pass. Manual handling of charge is a unsafe process which can lead to threats on one's life.

15.2 Energy Efficient Technology

Automatic material handling system is the energy efficient alternative for manual handling systems. For automatic handling of hot charge in the 3 Hi Roughing Mill stand, a Y-table or Tilting Table are used. Y-tables are usually used for material weight of less than 150 kg. A Y-table is a steel fabricated structure in the shape of a Y.

The structure is made of roller conveyors. A metal lid is used in the Y-joint, which allows only one-way travel of the charge. The charge after rolling from the bottom-middle rolls passes through the rear end of the table; the metal lid falls once the charge has completely passed through. During return, the metal charge passes through the top end; thus transfer of billet to next pass is facilitated. A Y-table is common in TMT mills, wherein in one side of the stand Y-tables are installed and on the opposite side drop tilters are present.

Tilting machine is quite similar to Y-table and used for higher cross-sections especially in structure mills. Here the steel structure, fitted with roller conveyor, is mounted to a motor. The structure is operated by an operator; and on his instruction the entire steel structure moves up and down as per requirement.

Repeaters are steel fabricated pathways connected between two consequent rolling stands. The repeaters are fitted to guides and allow free movement of hot charge between two rolling mill stands. Twisting of charge, if required, can also be facilitated by the design of a repeater.

15.3 Benefits of the technology

Adoption of Y-table/ tilting table/repeaters has the following benefits:

- Automatic handling of material
- Reduced temperature loss during material handling
- Reduced energy consumption
- Improved productivity
- Improved mill utilization

15.4 Limitations

Installation of Y-Roller Table / tilting table can be done only in 3 high mills. Installation of Y-roller table / tilting table / repeaters depends on the mill layout.

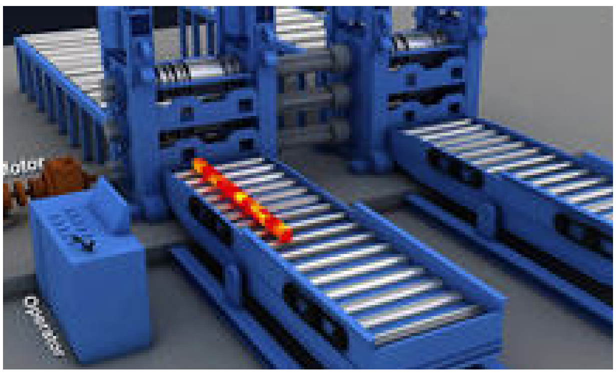


Figure 33: Tilting Table

Figure 34: Repeater in steel rolling mill

15.5 Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of replacement of manual handling with automatic handling in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h SRRM unit:

The investment and energy savings for installation of automatic material handling system will vary based on the capacity of the rolling mill and number of stands to be changed. The table below provides an estimate for installation of automatic material handling system for different ranges of rolling mills:

Table 36: Cost benefit analysis for automatic material handling system

Sl. No.	Parameter	Unit	Rolling mill with manual handling	Rolling mill with automatic handling
1	Design Capacity of rolling mill	t/h	15	15
2	Mill Utilization	%	75	82.5
3	Operating hours per day	h/d	16	16
4	Operating days per year	d/y	330	330
5	Annual production	t/y	59,400	65,340
6	Additional production due to increased mill utilization	t/y	5,940	
7	Annual monetary benefit due to increased production	Rs in lakh/y	89	
8	Specific fuel consumption	kg/t	90	85.5
9	Annual saving in coal consumption	t/y	356	
10	Monetary saving due to fuel saving	Rs in lakh/y	29	
11	Specific power consumption	kWh/t	110	106.7
12	Annual saving in power consumption	MWh/y	261	
13	Monetary saving due to power saving	Rs in Lakhs/y	20	
14	Total monetary saving	Rs in Lakhs/y	137	
15	Investment	Rs in Lakhs	50	
16	Simple pay back	months	4	
17	Annual energy savings	toe/y	222	
18	Annual GHG emission savings	tCO_2/y	1,025	

**Emission factor of electricity as per IPCC guidelines 2006 (V2; C1 & C2) is 0.9 tCO_2/MWh; emission factor of coal as per IPCC guidelines in 94.6 tCO_2/TJ for sub-bituminous coal; cost of coal is Rs 8/kg, cost of electricity taken as Rs 7.5/kWh; profit margin taken as Rs 1500/t*

Table 37: Investment and saving for installation of automatic material handling system for different ranges of rolling mills

Rolling Mill Capacity (t/h)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
10 -25	10 – 60	10 – 35	< 2 years

** based on estimated figures*

Technology No. 15: Revamping of Rolling Mill

16

16.1 Baseline Scenario

Layout of a rolling mill is significant while determining the mill's productivity, energy consumption and efficiency. In earlier days, rolling mill was haphazardly built without proper layout design. Also, most of the units were driven by manual material handling and equipped old outdated machines. These, in turn, led to increase in mill downtime, cobble formation and high energy consumption. Also, productivity of such mills was low. As and when a rolling mill unit decided to enhance the production, required numbers of stands were added haphazardly, without giving due consideration to the overall layout. Thus, these units usually have very high energy consumption. Conventional bar mills consumes 120 – 140 units of electricity per tonne of production.

16.2 Energy Efficient Technology

Energy efficient design of a rolling mill consists of design of proper layout, selection of proper size of equipment and considering the correct roll pass design including temperature profile across stands. Following are some of the general considerations for revamping a rolling mill into an energy efficient one:

- Maintaining correct temperature profile in the furnace.
- Reducing the distance between furnace discharges and roughing mill stand; in case of long distance, use automatic roller conveyor.
- Uniform feeding of raw material, i.e. installation of ingot turning table.
- Proper distribution of draft across roughing, intermediate and finishing mill.
- Maintaining angle of bite to the optimum level (around 210).
- Conversion of cross-country mill configuration to continuous configuration.
- Adoption of automatic material handling.
- Increasing speed of rolling.
- Addition of roughing mill continuous side.
- Reduction of mill downtime by adoption of cantilever stands and housing less stands.

16.3 Benefits of the technology

Adoption of better rolling mill layout has the following benefits:

- Improved utilization
- Increased mill efficiency
- Reduced energy consumption

16.4 Limitations

Energy efficient design of mill should be executed properly under the supervision and guidance of technical expertise. Energy efficient mill layout depends on space availability

16.5 Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

Revamping of rolling mills do not have any fixed investment and the same is dependent on the layout of the existing mill, scope for improvement and space available for the same. The following section provides the details of revamping carried out worth Rs 1 crore in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h SRRM unit.

The investment and energy savings for revamping of rolling mill will vary based on the capacity of the rolling mill and number of stands to be changed. The table below provides an estimate for revamping of rolling mill for different ranges of rolling mills:

Table 38: Cost benefit analysis for energy efficient rolling mill design

Sl. No.	Parameter	UoM	Conventional Rolling Mill Design	Energy Efficient Rolling Mill Design
1	Design capacity of rolling mill	t/h	15	15
2	Mill Utilization	%	75	86.25
3	Operating hours per day	h/d	16	16
4	Operating days per year	d/y	330	330
5	Annual production	t/y	59,400	68,310
6	Additional production due to increased mill utilization	t/y	8,910	
7	Annual monetary benefit due to increased production	Rs in lakh/y	134	
8	Specific fuel consumption	kg/t	90	81
9	Annual saving in coal consumption	t/y	713	
10	Monetary saving due to fuel saving	Rs in lakh/y	57	
11	Specific power consumption	kWh/t	110	104.5
12	Annual saving in power consumption	MWh/y	436	
13	Monetary saving due to power saving	Rs in Lakhs/y	33	
14	Total monetary saving	Rs in Lakhs/y	223	
15	Investment	Rs in Lakhs	100	
16	Simple pay back	months	5	
17	Annual energy savings	toe/y	437	
18	Annual GHG emission savings	tCO_2/y	1,972	

**Emission factor of electricity as per IPCC guidelines 2006 (V2; C1 & C2) is 0.9 tCO_2/MWh; emission factor of coal is 94.6 tCO_2/TJ for sub-bituminous coal; cost of coal is Rs 8/kg, cost of electricity taken as Rs 7.5/kWh; profit margin taken as Rs 1500/t*

Table 39: Investment and saving for revamping of rolling mill for different ranges of rolling mills

Rolling Mill Capacity (tph)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
10 -25	60– 150	100 – 250	< 1 years

** based on estimated figures*

Technology No. 16: Replacement of Existing Motors with IE3 Class Efficiency Energy Efficient Motors

17

17.1 Baseline Scenario

Three-phase induction motors are most commonly used to run various applications in a steel re-rolling mill unit. Apart from the heavy capacity motors driving the rolling mill strands, numerous smaller capacity motors ranging from 1 hp to 30 hp are used in numerous applications like blower, pump, roller tables, overhead cranes etc.

The 3-phase induction motors have 2 main parts: the stator or the stationary part and the rotor or the rotating part. Stator is made by staking thin slotted highly permeable steel lamination inside a steel cast or cast iron frame. Windings pass through slots of stator. When a 3-phase AC current is passed through it, it produces a rotating magnetic field. The speed of rotation of the magnetic field is called as the synchronous speed.

The rotor similar to a squirrel cage is placed inside the magnetic field; current is induced in bars of squirrel cage which is shortened by end ring. In effect, the rotor starts rotating. To aid such electromagnetic induction, insulated iron core laminas are packed inside the rotor; such small slices of iron ensure that the eddy current losses are minimal. The rotor always rotates at a speed slightly less than the synchronous speed; the difference is referred to as slip. Rotational mechanical power is transferred through a power shaft. Energy loss during motor operation is dissipated as heat; so a fan at the other end helps to cool down the motor.

Motor efficiency is defined as the ratio of mechanical power output to electrical power input. In most of the applications in a hand-tool unit, conventional motors (of IE 1 rating) are used with an efficiency range from 75 to 88% depending on the size. At times, motor fail and work of a unit may come to complete stand still. Motor failures can attribute to mechanical and electrical failures. Causes such as improper voltage, voltage fluctuations, improper lubrication and damaged bearings lead to rise in motor winding temperature ultimately leading to failure. These electrical failures lead to the next obvious step, i.e. motor re-winding.

The motor efficiency further decreases with each re-winding campaign; as it is mostly carried out by unskilled workers. Normally, a unit carries out 7-8 times motor rewinding within its life span of 10 years. Considering 1% efficiency drop in each rewinding campaign; it may lead to a loss of approximately Rs 40,000 per kWh.

17.2 Energy Efficient Technology

Compared to conventional motors, the efficiency of energy efficient motors (Premium Efficiency class-IE3), available in the market ranges from 80-95% depending on the size. Energy efficient motors operate at higher efficiencies compared to conventional motors, due to the following design improvements:

- Stator and rotor copper losses constitute for 55-60% of the total losses. Copper losses are reduced by using more copper conductors in stator and by using large rotor conductor bars
- Iron loss accounts for 20-25% of the total losses. Using a thinner gauge, low loss core steel and materials with minimum flux density reduces iron losses. Longer rotor and stator core length, precise air gap between stator and rotor also reduce iron losses
- Friction and Windage losses constitute about 8-10% of the total losses. Friction loss is reduced by using improved lubricating system and high quality bearings. Windage loss is reduced by using energy efficient fans
- Stray load loss accounts for 4-5% of the total losses. Use of optimum slot geometry and minimum overhang of stator conductors reduces stray load loss
- Conventional motors operate in a lower efficiency zone when they are loaded less than 60%. The efficiency of energy efficient motors drop when they are loaded less than 50%. However, efficiency of energy efficient motors is always higher than conventional motors, irrespective of the loading

When old motors are rewound more than 5 times, energy efficient motors can be considered as an ideal replacement. The Technical Specification of 7.5 hp energy efficient motor presented in Table 41:

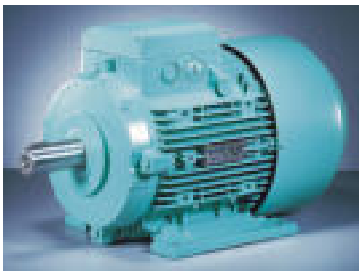


Figure 35: Energy efficient motor

Motor efficiency as per IEC 60034-30 for 2-pole, 4-pole and 6-pole at 50 Hz frequency is tabulated in Table 42.

The efficiency graph for 4-pole IE 1 to IE 4 class efficiency motors at 50 Hz frequency is shown in Figure 36.

17.3 Benefits of technology

The implementation of IE 3 class efficiency motors in place of conventional motors leads to following benefits:

Reduced specific energy consumption

- Lower breakdown
- Improved process efficiency
- Improved productivity
- Less operation and maintenance cost

Table 40: Specification of 7.5 hp energy efficient motor

Sl. No.	Parameter	Unit	Value
1	Capacity of Motor	hp	7.5
2	Duty type		Continuous duty
3	Performance		Premium IE 3 class efficiency conforming to IEC: 60034-30.
4	Type of Motor		AC Induction
5	Motor Power	kW	5.5
6	Rated Current	A	10
7	Rated Voltage	V	415
8	PF		0.8
9	Frequency	Hz	50
10	Efficiency at full load	%	89.63

Table 41: Motor efficiency values as per IEC 60034-30

kW	2-Pole			4 Pole			6 Pole		
	Frame Size	Efficiency %		Frame Size	Efficiency %		Frame Size	Efficiency %	
		IE2	IE3		IE2	IE3		IE2	IE3
0.37	71	72.2	75.5	71	70.1	73	80	69	71.9
0.55	71	74.8	78.1	80	75.1	78	80	72.9	75.9
0.75	80	77.4	80.7	80	79.6	82.5	90S	75.9	78.9
1.1	80	79.6	82.7	90S	81.4	84.1	90L	78.1	81
1.5	90S	81.3	84.2	90L	82.8	85.3	100L	79.8	82.5
2.2	90L	83.2	85.9	100L	84.3	86.7	112M	81.8	84.3
3.7	100L	85.5	87.8	112M	86.3	88.4	132S	84.3	86.5
5.5	132S	87	89.2	132S	87.7	89.6	132M	86	88
7.5	132S	88.1	90.1	132M	88.7	90.4	160M	87.2	89.1
11	160M	89.4	91.2	160M	89.8	91.4	160L	88.7	90.3
15	160M	90.3	91.9	160L	90.6	92.1	180L	89.7	91.2
18.5	160L	90.9	92.4	180M	91.2	92.6	200L	90.4	91.7
22	180M	91.3	92.7	180L	91.6	93	200L	90.9	92.2

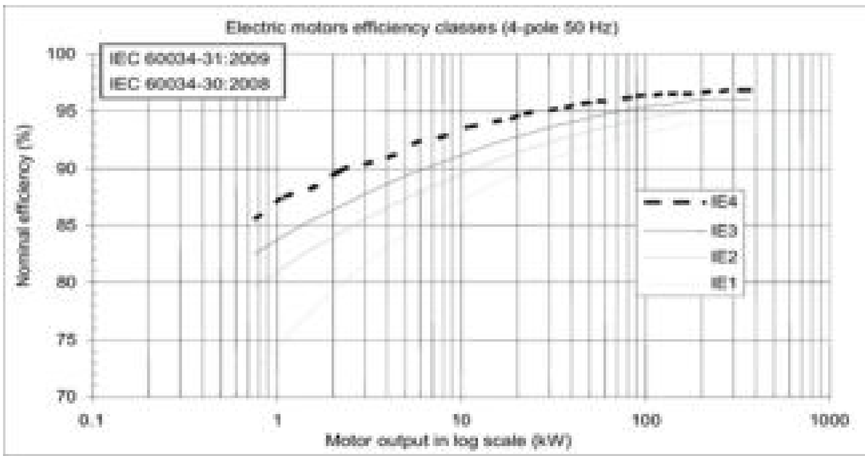


Figure 36: IE efficiency classes for 4 pole motors at 50 Hz

17.4 Limitation of technology

An energy efficient motor requires a higher initial capital investment compared to conventional motors.

17.5 Energy & GHG emission saving potential, Investment Required & Cost Benefit Analysis

To understand the cost-benefit analysis, let us consider a 20 hp motor. The cost-benefit analysis for adoption of the technology is tabulated below:

The investment required, energy savings and simple payback for different ratings of IE class efficiency energy efficient motor (4 pole motors) are tabulated below:

Table 42: Cost benefit analysis for 20 hp IE 3 class efficiency motor

Sl. No.	Parameter	Unit	Baseline	Post Implementation
1	Rated Power of motor	hp	20	20
2	Rated Power of motor	kW	14.9	14.9
3	Motor Efficiency	%	83	92.1
4	Motor Loading	%	90	90
7	Annual operating hours	h/y	5,280	5,280
9	Annual energy consumption	kWh/y	85,421	76,981
10	Annual energy saving	KWh/y		8,440
11	Average power tariff	Rs/KWh		7.5
12	Annual monetary saving	Rs in lakhs /y		0.63
13	Investment	Rs in lakhs		0.44
14	Simple Payback	months		8
15	Annual energy saving	toe/y		0.73
16	Annual GHG emission reduction	tCO_2/y		7.60

**Motor efficiency as per IEA*
****Emission factor of electricity as per IPCC guidelines 2006 (V2; C1 & C2) is 0.9 tCO2/MWh*

Table 43: Investment, savings and simple pay back for IE 3 motors

Parameters	Motor Rating	Investment	Annual monetary savings	Simple payback
Units	hp	Rs in Lakhs	Rs in Lakhs	Years
	1-30	0.03-0.55	0.06-0.34	< 2 years

Case Study 10: Installation of EE Motors

Established in 1973, Sterling Cast & Forge is one of the leading manufacturer, supplier & exporter of hand tools & garden tools, tower pincers, water pump pliers, lock grip pliers, end cutting, nippers, long- nose, side cutter & carpenter pincer. Machining is one of the most energy intensive processes in the industry, which has a large numbers of motors of varied rated capacity. The company took a significant step towards conserving energy by replacing their old motors in energy efficient IE-3 class motors. The unit installed one number of 4 kW, two 2 kW and three numbers of 1.5 kW IE-3 class efficiency motors in place of the existing 7.5 kW, 4 kW and 2 kW motors in the shank grinder, stone grinder and furnace blower respectively. The plant was able to make a reduction of 9 kW in the rated capacity, thus saving significantly in the production cost.

Parameters	UoM	Baseline	Post Implementation
Rated Capacity of Motors	kW	21.5	12.5
Annual operating hours	h/y	3,600	3,600
Reduction in rated capacity	kW	9	
Annual energy consumption	kWh/y	61,920	36,000
Annual energy saving	kWh/y	25,290	
Power Tariff	Rs/kWh	7.5	
Annual Monetary Saving	Rs in Lakh/y	1.94	
Investment	Rs in Lakh	2.00	
Simple Pay-back	Months	12	
Annual Energy Savings	toe/y	2.22	
Annual GHG Emission Reduction	tCO_2/y	23.33	

**Emission factor of Electricity as per IPCC Guideline 2006 (V2) is 0.9 tCO_2/MWh*
***Source: Implemented under GEF-UNIDO-BEE project*

18 Technology No. 17: Energy Efficient Lightings

18.1 Baseline scenario

Lighting accounts on average for about 15% of total electricity used in industry. Most of the conventional units use a variety of lighting fixtures like fluorescent tubes, incandescent & mercury vapour lamps, metal halide (MH), etc. in their offices and factory sheds. These conventional lighting fixtures consume lot of energy. Also, lives of such fixtures are limited. Most of the rolling mills operate for whole day long and consume a significant portion of energy on account of lightings and fixtures. Also, due care is not given towards the lux level of different areas. Most of the units have sheds covered with asbestos sheet with negligible or no provisions for natural lightings.

18.2 Energy Efficient Technology

Recent developments in lighting technology combined with planned lighting control strategies can result in very significant cost savings, typically in the range of a third to a half of the electricity traditionally used for lighting. In new installations, energy efficient lighting costs little more to provide than the older less efficient kind. In retrofit situations, pay-back periods generally of between 1 and 5 years can be anticipated. Some of the important areas of energy conservation in a typical rolling mill are:

- Replacement of conventional lighting with energy efficient LED lighting
- Maximize the use of daylight to reduce the need for electric lighting. Roof lights are particularly efficient as they disperse light evenly over the whole floor area. Provision of natural lighting in the rolling mill bay using translucent sheets in the shed is suggested.
- Painting of surfaces (including the ceiling) with matt colours of high reflectance to maximize the effectiveness of the light output. Light/bright colours can reflect up to 80% of incident light; dark/deep colours can reflect less than 10% of incident light.

For the purpose of establishing benefits from energy efficient lighting, let us consider a case study of a rolling mill unit of 25 t/h capacity.

18.3 Benefits of technology

The implementation of energy efficient lighting in place of incandescent lighting leads to following benefits:

- Reduced energy consumption
- Longer life of lighting
- Less operation and maintenance cost

18.4 Limitation of technology

The lux level needs to be properly checked before deciding of lighting loads.

18.5 Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of replacement of conventional lighting with energy efficient lightings in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 15 t/h SRRM unit.

The investment and energy savings for energy efficient lighting will vary based on the rolling mill layout and total lighting load. The table below provides an estimate for energy efficient lighting for different ranges of rolling mills:

Table 44: Cost benefit analysis for energy efficient lighting

Sl. No.	Parameter	Unit	With conventional lighting	With energy efficient lighting
1	Productivity	t/h	15	15
2	Operating hours per day	h/d	16	16
3	Operating days per year	d/y	330	330
4	Total Connected Load	kW	1,800	1,760
5	Total lighting load (considering 15% of total connected load as lighting load)	kW	270	230
7	Annual energy consumption due to lighting (Considering 5% energy savings on the lighting load by switching over to energy efficient lighting, total power saved)	kWh/y	1,425,600	1,354,320
	Annual energy saving	kWh/y	71,280	
8	Power Tariff	Rs/kWh	7.5	
	Annual monetary savings	Rs in Lakhs/y	5	
9	Investment	Rs in Lakhs	26	
10	Simple Pay-back	Month	58	
11	Annual energy saving	toe/y	6	
12	Annual saving in CO_2 emission due to saving in power	tCO_2/y	64	

**Emission factor of electricity as per IPCC guidelines 2006 (V2; C1 & C2) is 0.9 tCO2/MWh*

Table 45: Investment and saving for revamping of rolling mill for different ranges of rolling mills

Rolling Mill Capacity (tph)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
10 -25	10 – 50	3 – 15	< 3 years

** based on estimated figures*

19 Technology No. 18: Combustion air flow regulation using variable voltage variable frequency drives

19.1 Baseline scenario

In the SRRM sector, centrifugal fans are used as forced draft (FD) fans in re-heating furnaces with the main aim of supplying ambient air for the combustion of fuel. Performance of centrifugal fans depends on various factors like type of fan, proper sizing of the fan, and the specification and design of ducting for the fan.

Generally, air flow to a re-heating furnace is kept constant irrespective of temperature, draft and excess air in the re-heating furnace. It has been observed that due to inadequate draft and supply of excess air, the flame continuously gushes out of various openings of the re- heating furnace, which poses a threat to the safety of the men and machines working near the re-heating furnace.

The most general practices of the flow regulation mechanisms in FD fans currently employed in the SRRM sector include damper control, suction control or change of pulley. All of the above methods for controlling the air flow require manual interventions. Thus, most of the time combustion air flow is not monitored and controlled under the conventional system leading to higher energy consumption and high burning loss.

19.2 Energy Efficient Technology

As an energy efficient alternative, it is recommended to regulate the air flow of the combustion air blower by variable frequency drives (VFDs). VFDs reduce the speed of the fan for reduced air flow demand, and this speed reduction is achieved by altering the frequency of input power. Hence, power consumption of FD fans will be proportional to the air flow being delivered to the re-heating furnace. The feedback for VFDs can be taken from an oxygen analyzer installed in the flue gas line. This analyzer will measure the excess air content in the flue gas. Along with stoichiometric air required for combustion, a certain amount of excess air needs to be supplied and this excess air varies based on the type of fuel used in the re-heating furnace.

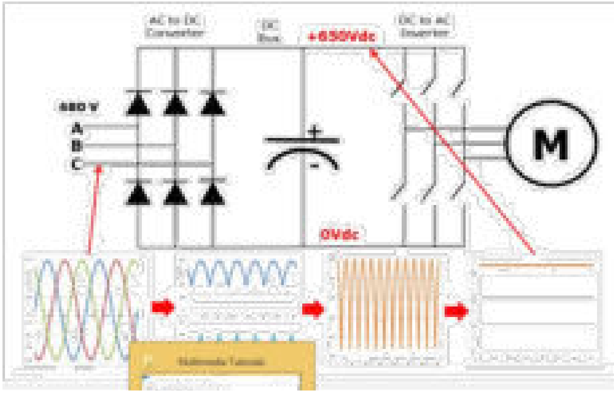


Figure 37: Circuit of a typical VFD unit

VFD is a device introduced in 1980's to effectively run a 3 phase AC motor at variable speed. AVFD consists of 3 diodes which allow flow of current only in the direction of the arrows. So, we have a convertor which converts the 3 phase AC power into DC. The DC which comes out of this is not very smooth; so a capacitor is used in order to clean that DC up. The capacitor works as a reservoir in the plumping circuit which smoothens everything out and gives a nice clean DC. Then going to the right, there are six switches. These switches compose of the DC to AC invertor, By switching these switches on and off, we can create any frequency that we like and that frequency would regulate the speed of the motor.

The Technical Specification of VVVF drive for a 40 hp blower is presented below:

19.3 Benefits of technology

The implementation of VFD in blower leads to following benefits:

- Helps in controlling flow in blower as per air requirement
- Helps in maintaining correct air fuel ratio
- Helps in improving combustion efficiency
- Reduced fuel consumption in furnace

Table 46: Specification of VFD

Sl. No.	Parameter	Unit	Value
1	Power rating	kW	0.18 to 4
2	Voltage supply	V	120 (single phase) 240 (single phase or three phase
3	Fan management	-	Required above 0.75 kW
4	Noise level	dba	< 50
5	Commissioning	Type	Plug & Play
6	PF		0.8
7	Frequency	Hz	50
8	Operating ambient temperature	^{0}C	-10 to +40 (without derating) Upto 60 with a derating

- Reduced power consumption
- Can be integrated with furnace automation

19.4 Limitation of technology

The VFD in blower needs to be integrated with a close loop monitoring and control system of furnace for optimum performance.

19.5 Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of optimum air flow regulation using VFD and online oxygen analyzer with in terms of energy & GHG saving potential, investment required and cost benefit analysis. The calculations have been provided considering a 10 t/h rolling mill.

The investment and energy savings for installation of VFD in blower will vary based on the capacity of the furnace. The table below provides an estimate for VFD in blower for different ranges of reheating furnace:

Table 47: Cost benefit analysis for VFD in blower

Sl. No.	Parameter	UoM	Blower with damper control	Blower with VFD
1	Productivity	t/h	10	10
2	No. of operating hours	h/d	12	12
3	No. of working days	d/y	300	300
4	Specific fuel consumption	kg/t	90	88.2
5	Annual production	t/y	36,000	36,000
6	Annual fuel consumption (considering 2% energy saving due to better air fuel ratio)	t/y	3,240	3,175.2
7	Annual fuel savings due to air-fuel ratio control using VFD	t/y	64.8	
8	Cost of fuel	Rs/t	8000	
9	Annual monetary saving due to fuel saving	Rs in Lakh/y	5	
10	Electrical energy consumption in blower (considering 20% reduction in energy due switch over from damper control to VFD)	kWh/h	149.2	119.36
11	Annual energy saving due to VFD	kWh/y	107,424	
12	Power Tariff (average)	Rs/kWh	7.5	
13	Total monetary saving due to energy saving	Rs in Lakh/y	8	
14	Total monetary saving	Rs in Lakh/y	13	
15	Estimated investment	Rs in Lakh	2.5	
16	Simple payback	months	2	
17	Annual energy saving	toe/y	46	
18	Annual saving in CO_2 emission due to reduction in coal saving	tCO_2/y	240	

**Emission factor of coal as per IPCC guidelines 2006 (V2; C1 & C2) is 94.6 tCO2/TJ for sub-bituminous coal and for electricity is 0.9 tCO_2/MWh.*
***Calorific value of coal taken as 5,600 kCal/kg*

Table 48: Investment and saving for installation of VFD for different ranges of reheating furnace

Furnace Capacity (tph)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
5 -25	1.5 – 5	4 – 20	< 1 year

** based on estimated figures*

20 Technology No. 19: Adoption of Direct Rolling in TMT Mills

20.1 Baseline scenario

A composite unit consists of a rolling mill and an induction furnace in the same premises. Sponge iron or scrap sourced from the market is fed into an induction furnace; wherein electricity is used for melting of steel at 1,600⁰C. The molten steel is casted into moulds to form ingots or through a continuous casting machine to form billets or blooms. The casted ingot / billet or bloom is cooled to ambient temperature and stored in the billet yard. For the rolling process, the ingot, billets or blooms are used as raw material. They are charged into the pusher type re-heating furnace. The raw materials are re-heated to the re-crystallization temperature of steel which is around 1,200⁰C. The red hot charge is then processed in a rolling mill to the desired shape and cross-section. A large number of composite units in the country followed the above process till the introduction of direct rolling. In this conventional process; a significant portion of energy was lost in the process of cooling the billets in the CCM cooling bed and then again re-heating the same in the re-heating furnace.

20.2 Energy Efficient Technology

The energy efficient way of rolling in case on composite units has been dictated by a revolutionary technology in the last few years. Hot charging or direct rolling of hot billets from continuous casting machine (CCM) to rolling mill; eliminating the re-heating furnace in the process, has transformed the entire sector to a new dimension of energy saving. The process of direct rolling / hot charging of billets is shown in the process flow below:

The process flow for direct rolling starts with tapping of molten metal from induction furnace at a slightly higher temperature (around 1,650⁰C) compared to conventional system. Due care is taken for minimum heat loss during ladle transfer. Hot metal at 1,600⁰C is poured into the tundish of the continuous casting machine. Secondary cooling at CCM is controlled with a PLC system to maintain billet temperature at CCM outlet at 1,100⁰C. Subsequently, there is a slight temperature loss during the shearing process. Preferably, hot billet shearing should be used in place of gas cutting for minimum temperature loss. Once, the hot billet is cut to piece, the next step involves transferring of billet in a high speed conveyor to the rolling mill first stand. It should be ensured that minimum heat loss occurs during the process. For this, refractory made canopy covers should be used in the conveyors. Also, high rpm motors to be used for the conveyors for minimum time travel of the billets. Bends should be avoided in the conveyor to the extent possible. Billet reaching the first pass will be processed at a temperature of 1,045⁰C. In the direct rolling process, the core of the billet is at higher temperature than the surface. During 2 to 3 passes of the rolling, the charge attains a uniform temperature at the core is exposed in such case. The roll pass design needs to be revamped in case of switch over to direct rolling. Also, if the temperature drop is high, it should be ensured that the gear box for the first stand should be of heavier capacity. The temperature maintained at different processes of a direct rolling unit is shown in the figure below:

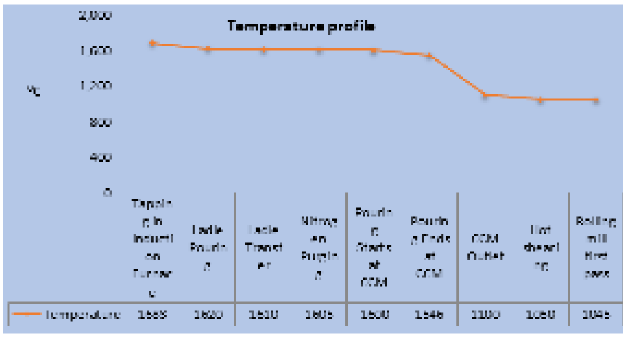


Figure 39: Temperature profile for different processes of direct rolling

Conventional process of melting and casting differs with the direct rolling process mainly on the temperature profile. Since the metal coming out of the cooling bed should be solidified, the temperature profile needs to be very precisely maintained. A PLC based control system is suggested for the purpose. The temperature difference in the various processes for conventional melting and casting with direct rolling is shown in the figure below:

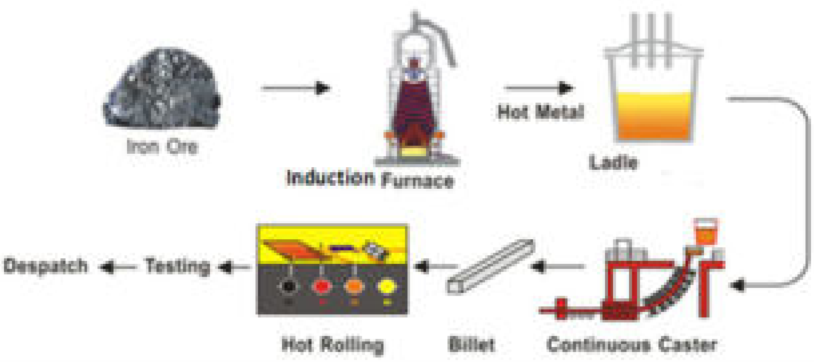


Figure 38: Process flow diagram of direct rolling mill

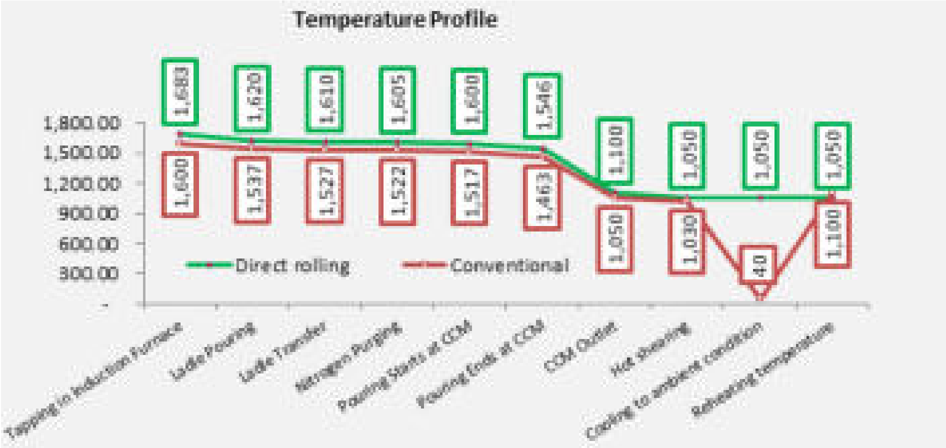


Figure 40: Conventional Vs Direct Rolling

20.3 Benefits of technology

The adoption of direct rolling leads to following benefits:

- Complete elimination of re-heating furnace
- Avoids burning loss due to re-heating
- Avoids operation and maintenance cost related to re-heating furnace
- Significant reduction in energy cost
- Significant reduction in cost of production

20.4 Limitation of technology

Direct rolling technology is applicable only for composite units. The feasibility of the technology is hugely dependent on the layout. Also, it is important to ensure correct temperature required for rolling. The rate of melting and casting should match the rolling mill rate to avoid lower utilization of the plant.

20.5 Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of replacement of conventional rolling with direct rolling in terms of energy & GHG saving potential, investment required and cost-benefit analysis. The calculations have been provided considering a 15 t/h rolling mill.

The investment and energy savings for adoption of direct rolling will vary based on the capacity of the melting furnace, layout and rolling mill capacity. The table below provides an estimate for adoption of direct rolling for different ranges of rolling mills:

Table 49: Cost benefit analysis for direct rolling for TMT units

Sl. No.	Parameter	Unit	Conventional mill	Direct Rolling
1	Productivity	t/h	15	15
2	Operating hours per day	h/d	16	16
3	Operating days per year	d/y	330	330
4	Specific fuel consumption (no fuel consumption post implementation due to elimination of reheating furnace)	kg/t	90	-
5	Specific electrical energy consumption (electrical energy consumption increases in direct rolling due to addition of roller tables)	kWh/t	110	121
6	Annual savings in terms of coal	t/y	7,128	
7	Annual increase in power consumption	kWh/t	871,200	
8	Net monetary savings	Rs in Lakhs	504.9	
9	Investment required	Rs in Lakhs	100	
10	Simple pay back	months	2.38	
11	Annual net energy saving (Thermal – Electrical)	toe/y	3,917	
12	Annual net saving in CO_2 emission due to reduction in coal saving and increase in power consumption	tCO_2/y	15,015	

**Emission factor of electricity as per IPCC guidelines is 0.9 tCO_2/MWh; emission factor of coal as per IPCC guidelines is 94.6 tCO_2/TJ; cost of coal has been taken as Rs 8/kg; cost of coal has been taken as Rs 7.5/kWh.*

***Only rolling mill has been taken as boundry for calculations. Increase in energy consumption due to increase in melting temperature has not been considered for calculations.*

****It has been assumed that the plant already has requisite melting facility. Investment cost includes cost towards facilities for transferring of hot billets and required modification in rolling mills.*

Table 50: Investment and saving for adoption of direct rolling for different ranges of rolling mills

Rolling Mill Capacity (tph)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
10-25	40-150	150 – 700	< 1 year

** based on estimated figures*

Case Study 11: Adoption of Direct Rolling

Located in Chennai, Tamil Nadu ARS Metals Limited is a leading manufacturer of TMT bars. In 2017, the plant implemented direct rolling thereby completely eliminating the re-heating furnace. The plant achieved significant cost saving. The investment made was recouped in less than 6 months' time.

Sl. No.	Parameter	Unit	Baseline	Post Implementation
1	Productivity	t/h	20	20
2	Operating hours per day	h/d	16	16
3	Operating days per year	d/y	330	330
4	Specific fuel consumption (no fuel consumption post implementation due to elimination of reheating furnace)	kg/t	80	-
5	Specific electrical energy consumption (electrical energy consumption increases in direct rolling due to addition of roller tables)	kWh/t	115	126.5
6	Annual savings in terms of coal	t/y	8,448	
7	Annual increase in power consumption	kWh/t	1,214,400	
8	Net monetary savings	Rs in Lakhs	584.76	
9	Investment required	Rs in Lakhs	100	
10	Simple pay back	months	2.05	
11	Annual net energy saving (Thermal – Electrical)	toe/y	4626	
12	Annual net saving in CO_2 emission due to reduction in coal saving and increase in power consumption	tCO_2/y	17,632	

**Emission factor for electricity as per IPCC guideline 2006 (V2: C1 & C2) taken as 0.9 tCO_2/MWh*

Technology No. 20: Adoption of Direct Rolling in Structural Mills

21

21.1 Baseline scenario

In composite units, billets / blooms, suitable for rolling of structures are casted in a continuous casting machine. The billets/blooms are cut into required sizes using gas cutting and cooled to ambient temperature. The cold billet/bloom is transferred to the rolling mill bay, wherein the same is re-heated using a fuel fired re-heating furnace. Rolling of structures requires heating to 1,200^{0}C or more.

The heated billets are then rolled to desired shape and size. Due to the requirement of higher rolling temperature, direct rolling or hot charging of billets / blooms directly from the continuous casting machine to the rolling mill has not been preferred.

While the concept of direct rolling was touching new heights in TMT rolling during the last few years; the same remained unattended in structural rolling especially in case of medium and heavy structures.

21.2 Energy Efficient Technology

The technological innovation of direct rolling can be made successful even in the case of structural rolling by introducing induction heating in between. This means, billets or blooms at around 1,050-1,100^{0}C are received from the continuous casting machine.

The temperature of the hot billets or blooms at this stage is not sufficient for rolling. So, to heat the material to the desired temperature, intermittent heating is done through induction heating.

A series of induction heaters are installed and the hot billets or blooms are passed through it at a relatively slow speed. This raises the temperature of the billet by 100^{0}C, thus making it suitable for structure rolling.

The process flow diagram of direct rolling in case of rolling of structures is shown in the figure below:

The technical specification of induction heater required for intermittent heating is tabulated below:

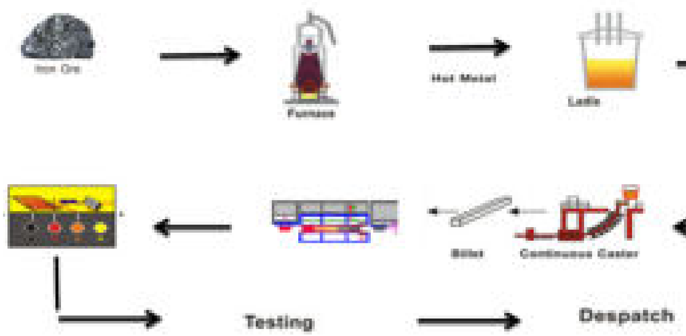


Figure 41: Process flow of direct rolling in structural mill

Table 51: Specification of in-line induction heater

Sl. No.	Parameter	Unit	Value
1	Equipment Type		In-line induction heating for hot rolling
2	Frequency	Hz	50 Hz to 6000 Hz
3	Power	kW	500 kW to 10000 KW
4	Heating time		Instantaneous
5	Rated Voltage	V	415
6	PF		0.8
7	Efficiency	%	60-65%

21.3 Benefits of technology

The adoption of direct rolling leads to following benefits:

- Complete elimination of re-heating furnace
- Avoids burning loss due to re-heating
- Avoids operation and maintenance cost related to re-heating furnace
- Significant reduction in energy cost
- Significant reduction in cost of production

21.4 Limitation of Technology

Direct rolling technology is applicable only for composite units. The feasibility of the technology is hugely dependent on the layout. Also, it is important ensure correct temperature required for rolling. The rate of melting and casting should match the rolling mill rate to avoid lower utilization of the plant. Rolling temperature is key for structural steel production.

21.5 Investment required, Energy & GHG Saving Potential, Cost Benefit Analysis

The following section provides the details of adoption of direct rolling in structural units in terms of energy & GHG saving potential, investment required and cost-benefit analysis. The calculations have been provided considering a 15 t/h unit.

The investment and energy savings for adoption of direct rolling will vary based on the capacity of the melting furnace, layout and rolling mill capacity. The table below provides an estimate for adoption of direct rolling for different ranges of rolling mills:

Table 52: Cost benefit analysis for direct rolling for structural units

Sl. No.	Parameter	Unit	Conventional mill	Direct Rolling
1	Productivity	t/h	15	15
2	Operating hours per day	h/d	16	16
3	Operating days per year	d/y	330	330
4	Specific fuel consumption (no fuel consumption post implementation due to elimination of reheating furnace)	kg/t	90	-
5	Specific electrical energy consumption (electrical energy consumption increases in direct rolling due to addition of roller tables & induction heater)	kWh/t	110	137.5
6	Annual savings in terms of coal	t/y	7128	
7	Annual increase in power consumption	kWh/t	2,178,000	
8	Net monetary savings	Rs in Lakhs	406.89	
9	Investment required	Rs in Lakhs	100	
10	Simple pay back	months	3	
11	Annual net energy saving (Thermal – Electrical)	toe/y	3,804	
12	Annual net saving in CO_2 emission due to reduction in coal saving and increase in power consumption	tCO_2/y	13,839	

**Emission factor of electricity as per IPCC guidelines is 0.9 tCO_2/MWh; emission factor of coal as per IPCC guidelines is 94.6 tCO_2/TJ; cost of coal has been taken as Rs 8/kg; cost of coal has been taken as Rs 7.5/kWh.*

***Only rolling mill has been taken as boundry for calculations. Increase in energy consumption due to increase in melting temperature has not been considered for calculations.*

****It has been assumed that the plant already has requisite melting facility. Investment cost includes cost towards facilities for transferring of hot billets and required modification in rolling mills including installation of billet induction heater.*

Table 53: Investment and saving for adoption of direct rolling for different ranges of rolling mills

Rolling Mill Capacity (t/h)	Investment (Rs in Lakhs)	Savings Potential (Rs in Lakhs)	Simple pay back (years)
15-25	100 -200	150 – 600	< 1 year

** based on estimated figures*

Case Study 12: Adoption of Direct Rolling in structural mill

Located Located in Raipur, Chhattisgarh, Nandan Steel & Power Limited is a leading manufacturer of medium sectional products. In 2017, the plant implemented direct rolling thereby completely eliminating the re-heating furnace. The plant achieved significant cost saving. The investment made was recouped in less than 6 months' time.

Sl. No.	Parameter	Unit	Conventional mill	Direct Rolling
1	Productivity	t/h	15	15
2	Operating hours per day	h/d	16	16
3	Operating days per year	d/y	330	330
4	Specific fuel consumption (no fuel consumption post implementation due to elimination of reheating furnace)	kg/t	90	-
5	Specific electrical energy consumption (electrical energy consumption increases in direct rolling due to addition of roller tables & induction heater)	kWh/t	80	100
6	Annual savings in terms of coal	t/y	7128	
7	Annual increase in power consumption	kWh/t	1,584,000	
8	Net monetary savings	Rs in Lakhs	451	
9	Investment required	Rs in Lakhs	100	
10	Simple pay back	months	3	
11	Annual net energy saving (Thermal – Electrical)	toe/y	3,855	
12	Annual net saving in CO_2 emission due to reduction in coal saving and increase in power consumption	tCO_2/y	14,374	

**Emission factor for electricity as per IPCC guideline 2006 (V2: C1 & C2) taken as 0.9 tCO_2/MWh*

Conclusion

The compendium consists of a list of energy efficient and renewable energy technologies applicable for the micro, small and medium enterprises (MSME) units in the targeted sectors. The listed technologies have been grouped into three broad categories of 'low investment', 'medium investment' and 'high investment' technologies. In most cases, MSME units use old and obsolete technologies leading to higher energy consumption. There is a significant potential for cost savings through the adoption of these energy efficient and renewable energy technologies. The compendium consists of a list of commonly applicable energy efficient and renewable energy technologies in the cluster. These technologies need to be customized based on individual unit's requirements. The techno-commercial feasibility depends on the process, operational conditions and other variable parameters in a particular unit. Also, all technologies may not be applicable in every unit.

In order to achieve maximum benefits of a particular technology, the same should be supported by good operating practices. Continuous capacity enhancement of the operators is important to achieve maximum benefits from technology up-gradation.

Micro, small and medium enterprises (MSMEs) are the growth accelerators of the Indian economy, contributing about 30% of the country's gross domestic product (GDP). Under such scenario, it becomes important for these industries to adapt to efficient technologies and practices. Accelerated adoption of energy efficient and renewable energy technologies can ensure a cost effective and energy efficient production process. With an overarching objective of bringing in a transformational change in the sector, the technology compendium provides information on options available to do so.

The eastern zone of the country comprising the states of West Bengal, Jharkhand, Odisha and Bihar houses close to 20% of the total steel re-rolling mills in the country. Some of the key clusters located in the eastern zone of the country that house steel re-rolling mill standalone as well as composite units are Howrah, Hooghly, Burdwan, Bankura and Durgapur in West Bengal; Jamshedpur in Jharkhand; Patna in Bihar; Rourkela in Odisha and Guwahati in Assam. While most of the units in Howrah are small units re-rolling scraps consisting of miss-rolls from bigger plants; ship breaking scraps, etc., the clusters of Durgapur house relatively bigger units comprising mostly composite units. The clusters of Rourkela and Jamshedpur house both bigger as well as smaller units. The technologies listed in the compendium cater to various sections of the industry.

The implementation of the technologies listed in the compendium will lead to multi-fold benefits including improvement in the factory environment, productivity, energy performance as well as the environmental sustainability. The technologies listed in the compendium have saving potentials in the range of 5% to 35%. The technologies discussed in the document include:

Low Investment Technologies (less than Rs 2 lakhs):

- Swirl burners for pulverized coal firing
- Energy efficient motors
- Installation of VFD in blower

Medium Investment Technologies (up to Rs 10 lakhs):

- High efficiency metallic recuperator
- Re-heating furnace automation & control system
- Energy efficient pulverizer
- Modified pulverized coal feeding system
- Coal drying system
- Energy efficient lighting
- Automatic material handling system

High Investment Technologies (more than Rs 10 Lakhs):

- New energy efficient furnace
- Coal bed methane based re-heating furnace
- Optimum refractory & Insulation
- Biomass based producer gas as fuel
- Natural gas firing for re-heating furnace
- Antifriction roller bearing
- Universal coupling & spindle
- Revamping of rolling mills
- Adoption of direct rolling in TMT mills
- Adoption of direct rolling in structural mills

Through this technology compendium the project hopes to maximize the environment benefits that would lead to Energy savings and GHG emission reduction. The project titled "Promoting energy efficiency and renewable energy in selected MSME clusters in India" provides a unique opportunity to the MSME units to progress towards a sustainable future.

List of Vendors

1. List of Suppliers- Rolling Mills Equipment

SN	Name of Company	Address	Phone No.	E-mail / Website
1	A.R Engineering Works	22, Okhla Industrial Estate, Phase-Iii, New Delhi 110020 India	011-41612339	info@argroup.net
2	P.P Rolling Mill Mfg. Pvt. Ltd.	D-820, New Friends Colony, New Delhi 110065 ,India	011-26848885	ppeng@vsnl.com
3	SMT Machines Limited	Post Box 71, G.T. Road, Sirhind Side, MandiGobindgarh 147301 Punjab ,India	01765-255199	smtindia@sancharnet.com, info@ smtmachinesindia.org
4	Kathuria Rollmill Pvt. Ltd.	A-7/56-58, S.S.G.T. Road Industrial Area, Gaziabad-201009, UP	011-22934986 / 22931475	kathuriarollmill@gmail.com, info@ kathuriarollmill.com web: www.kathuriarollmill.com
5	Rana Udyog (P) Ltd.	18-D, Everest House 46-C, Jawaharlal Nehru Road	033-3052-1116 033-2288-9247	ranaudyog@hotmail.com
6	Jatindra Engineering Corporation	A-10/11, Jhilmil Industrial Estate G.T. Road, Shahdra New Delhi-110095	91-011-22110211 91-011-22592321	jec@ndf.vsnl.net.in
7	Nav Bharat Engg. Works	C-233, Site First Ghaziabad-201120 (U.P)	0120-2866715 0120-2867252	bkmakkad@del3.vsnl.net.in

2. List of Suppliers- Energy Efficient Motors

Sl. No.	Name of Company	Address	Phone No	E-mail /Website
1	Kirloskar Electric Company Ltd.	P.B. No. 5555, Malleswaram West, Bangalore -560055	+91-80-23572111 +91-80-23371771	enq@vrkec.com www.kirloskar-electric.com
2	Crompton Greaves Limited.	CG House, 6th Floor, Dr. Annie Besant Road. Worli, Mumbai - 400 030	+91-22-24237777	www.cglonline.com
3	ABB	49 Race Course Road KhanijaBhavan, 2nd floor, Eastern Wing, Bangalore 560001 Karnataka	+91-80-22949150	www.abb.com
4	Siemens India Limited	Electric Mansion, 134/ A, Dr. A. B. Road Worli Mumbai, Maharashtra 400018	+91-22-4938786 +91-22-4937403	www.siemens.co.in
5	Alstom India Ltd.	1, Taratola Road, Kolkata – 700024	+91-33-24695036 +91-33-24693751	www.alstom.co.in

3. List of Supplier – Variable Voltage Variable Frequency Drives (VVFDs)

SN	Name of Company	Address	Phone No..	E-mail
1	ABB India	49, Race Course Road, Bangalore, India	91-9845193809 / 91-80-22949355 Mr. N. Venu	nvenu@in.abb.com
2	Siemens Ltd.	384,Phase-II, UdyogVihar, Gurgaon, Haryana, India	0124-4578100 Contact Person : Mr. L. Maheswari	
3	Simatech Automation Contact Person: Sushil Kumar Dubey	Gala No. 3, Saraswati Building Tungareshwar Industrial Complex, Sativali, Vasai (East), Thane - 401208, Maharashtra	Phone: 250 2481692 Fax: 250 2481692	
4	Power Tech System Contact Person: Jitendra Patel, Proprietor	No. 22, Shukan Mall, Science City Road, Sola Ahmedabad - 380060, Gujarat	Mob:8447565164	powertechsystem@ yahoo.com

4. List of Supplier- Thermo-mechanical Treatment Plants

SN	Name of Company	Address	Phone No.	E-mail
1	P.P Rolling Mill Mfg. Pvt. Ltd.	D-820, New Friends Colony, New Delhi 110065 India	011-26848885	ppeng@vsnl.com
2	SSS Engineering Co. Ltd.	114, MG Road, 3rd Floor, Banglore-560001		srikantjois@hotmail.com
4	Jet Therm Technologies	61/C, Laxmi Market, Supela BHILAI-490023 (C.G)	09329235363 Mr. Sanjay Choudhary, Director	jettherm@hotmail.com , jettherm@rediffmail.com
5	H&K Rolling Mill Engineers Pvt. Ltd.,	401, Balarama, BandraKurla Complex, Bandra East, Mumbai 400051.	+91-22-30622004 (8 lines)	handk.india@gmail.com
6	Evotech Pvt. Ltd., Bhilai INDIA.	17, 18 Commercial Complex, IT Tower, Nehru Nagar (East), Bhilai-490020 (CG)	+91-0788-4075901 4075999, 4075900, 4040539.	

5. List of Supplier- Re-Heating Furnace

SN	Name of Company	Address	Phone No.	E-mail
1	Fuel Save Systems & Devices Contact Person: S.B.Sharma	Plot No-65, Crossing Road, 3&6, Vill- Saroorpur Industrial Area, Near Sohna Road, Faridabad (Haryana)	Phone: 0129-2470298/0129-3955434 Fax: 0129-2503075/4047266	moonlightmail@yahoo.com
2	Zooks International Contact Person: Mr. U. Nandy, Director	EC-277, Sector-I, Salt Lake, Kolkata-700064 (WB)	Phone: 033-23341839 Fax: 033-23349731	thermal@cal12.vsnl.net.in
3	K N Engineering Works Contact Person: Mr. A. Nandi, Managing Director	Plot No. 2, New DLF Industrial Area, Faridabad-121003 (Haryana)	Phone: 129-2278868/ 129-2273932 Fax:129-2273055	nandi_a@hotmail.com kn_engineeringindia@yahoo.com Web: www.knengg.tradeindia.com
4	ENCON Thermal Engineers (P) Ltd Contact Person: Mr. V B Mahendra, MD	297, Sector-21 B Faridabad – 121001 Haryana	Phone: 0129-4041185 Fax: 0129-4044355	sales@encon.co.in Web: www.encon.co.in
5	Allied Consulting Engineers (P) Ltd. Contact Person: Mr. V.N. Nasta, Director	Allied House, First Road, Opp. B.M.C Office, Chembur-400071(Maharashtra) Factory Plot No- A-373, Road No-27, Wagle Industrial Estate, Thane-400604	Phone: 022-2528-4028-32/ 022-6797-3018-20 Fax: 022-2528-3805	ace@bom3.vsnl.net.in Web: www.alliedfurnaces.com
6	The Wesman Engineering Co. (P) Ltd.	Wesman Center, 8-Mayfair Road, Kolkata-700019 (WB)	Phone: 033-40020300 Fax:033-22908050, 033-22816402	mailbox@wesman.com furnace@wesman.com Web: www.wesman.com
7	Centro Combustion Furnaces Pvt. Ltd.	Giga Space, Alpha 2, 101 A Viman Nagar Pune 411014 Maharashtra – India	Mobile : 9370546015 (AbhijitParanjape)	a.paranjape@india.danieli.com
8	R.K.Industrial Enterprises*	Plot No. 82, Parvatiya Colony, Sohna Road, Near Peer Baba N.I.T. Faridabad – 121005	Mobile: 9350543850 ShriNaresh Gupta	rkindenterprises@yahoo.co.in Web: www.rkindenterprises.com
9	Refined Structures & Heat Control Unit*	A-227. Nehru Nagar, Jaipur – 302016 (Raj.)	Mobile : 09829060615 ShriV.K.Sharma Chief executive	refinefurance@gmail.com

** specialized in pulverized coal fired furnaces*

6. List of Supplier- Furnace Instrumentation

SN	Name of Company	Address	Phone No.	E-mail
1	S.S. Engineering Industries (dealers of Kent Oil Flow Meters)	C-15, Sector - 7 Noida, U.P. - 201301 (INDIA)	Tel : +91-120-2423191/ 207/ 523/ 382 Fax : +91-120-2423654 Contact Person : Mr. Mahesh Gupta	sales@ssengg.com
2	Fuji Electric India (P) Ltd.	409-410, Meadows, Sahar Plaza, AndheriKurla Road, J.B. Nsagar, Andheri (E) Mumbai 400 059	Phone: 022-4010 4870/71 Fax:022-4010 4872	info@fein.fujielectric.com www.fujielectric.co.in

7. List of Supplier – Pulverizer

SN	Name of Company	Address	Phone No.	E-mail
1	Pinesap Machine Tools (Regd.)	G.T Road Hanna Side, Opp.Power House, MandiGobindgarh, Punjab 147301	91-1765-241304	panesarmachinetools@ hotmail.com
2	Prithvi Steel Re-Rolling Machine Contact Person: Sudesh Sharma, Director	B-230, Road No. 9 Vishwakarma Industrial Area, Jaipur-302013	Phone: 0141-2330478 Mob: 9314466666	E-mail: info@prithvisteel. com

8. List of Supplier – Automation & Control System

SN	Name of Company	Address	Phone No.	E-mail
1	Masibus Automation And Instrumentation Pvt. Ltd.	B-30, G.I.D.C Electronic Estate, Sector - 25, Gandhinagar - 382044. Gujarat - India.	+91 79 23287275-79 Fax +91 79 23287281-82	sales@masibus.com
2	Pyramid Automation	214/215, Gauri Commercial Complex, Navghar, Vasai Road (E), Dist. Thane – 401 210. INDIA.	Contact Person : Mr. RakeshPatil Cell No. : +91- (0) 99677 55779 / 93266 92106	info@pyramidautomation.co.in www.pyramidautomation.co.in
3	Ragtron India	1449/116, Street No. 3, Durgapuri, Shahdara, Delhi - 110093, India		www.ragtron.com
4	Yokogawa India Limited	Plot No. 36, Electronics City Complex, Hosur Road, BANAGLURU – 560 100	Phone: 080-41586000	
5	Tata Honeywell Limited	ESTATE HADAPSAR, PUNE - 411013, MAHARASHTR	Tel: 56039909	
6	SIEMENS Limited Industry Sector Metal technologies	130, PandurangaBudhakarMarg Worli, MUMBAI – 400 018	Phone: 022-3967 2068	
7	ABB India	BU Measurement & Analytics 14, Mathura Road, Faridabad, INDIA - 121003	Phone: 0129-2279627, 2275592	tejbir.singh@in.abb.com

9. List of Supplier – Furnace Oil / Producer Gas Burners

SN	Name of Company	Address	Phone No.	E-mail
1	The Wesman Engineering Co. (P) Ltd.	Wesman Center, 8-Mayfair Road, Kolkata-700019 (WB)	Phone: 033-40020300 Fax:033-22908050, 033-22816402	mailbox@wesman.com furnace@wesman.com Web: www.wesman.com
2	ENCON Thermal Engineers (P) Ltd Contact Person: Mr. V B Mahendra, MD	297, Sector-21 B Faridabad – 121001 Haryana	Phone: 0129-4041185 Fax: 0129-4044355	sales@encon.co.in Web: www.encon.co.in
3	Continental Engineers	477, SIDCO Industrial Estate, Ambattur, Chennai - 600 098.	Phone : +91-44-26254266, 26259988, 26257239, 26257303	info@contitherm.com http://www.contitherm.com

9. List of Supplier – Metallic Recuperator

SN	Name of Company	Address	Phone No.	E-mail
1	Eastern Equipment & Engineers P Ltd	7B, Kiran Shankar Roy Road, 3rd Floor, Kolkata 700 001	+ 91 33 2243 0468 / 0469 Fax + 91 33 2248 7130	vka@recuperators.in
2	Refined Structures & Heat Control Unit*	A-227. Nehru Nagar, Jaipur – 302016 (Raj.)	Mobile : 09829060615 Shri V.K. Sharma Chief executive	refinefurance@gmail.com
3	R.K. Industrial Enterprises*	Plot No. 82, Parvatiya Colony, Sohna Road, Near Peer Baba N.I.T. Faridabad – 121005 (Haryana)	Mobile: 9350543850 ShriNaresh Gupta	rkindenterprises@yahoo.co.in rkindustrialenterprises@yahoo.co.in
4	ENCON Thermal Engineers (P) Ltd Contact Person: Mr. V B Mahendra, MD	297, Sector-21 B Faridabad – 121001 Haryana	Phone: 0129-4041185 Fax: 0129-4044355	sals@encon.co.in Web: www.encon.co.in

*specialized in pulverized coal recuperator

10. List of Supplier –Refractories & Insulation

SN	Name of Company	Address	Fax No.	E-mail
1	Nilachal Refractory	Plot No. 4, Bapujinagar, Bhubaneswar-751009, Orissa	Phone: 033-22496507 Fax: 033-22499511	info@nilachal.in
2	SAIL Refractory Unit,	Indira Gandhi Marg, Sector-IV, Bokaro Steel City– 827004 Jharkhand	Ph: (06542) 233179, 233673 Fax: (06542) 233672	edsrubokaro@gmail.com
3	SKG Refractories Ltd.	B 193 MIDC, Butibori, Nagpur 441108	+91-9423105484	Psengupta@skgrl.com
4	TRL Krosaki Refractories Limited (formerly Tata Refractories Limited)	Belpahar Jharsuguda, Odisha, India Pin : 768218	06645 258486 Fax : 06645 250243	pkjana@trlkrosaki.com
5	HIL Limited	Sanatnagar, Hyderabad-500018, A.P, India.	+91 40 30999000 Fax : +91 40 23701227 / 23702400	contactus@hil.in
6	ACC Limited	Cement House 121, MaharshiKarve Road, Mumbai - 400 020	Tel: 91-22-33024321; Fax: 91-22-66317440	
7	New Bharat Refractories	1-B, Trikut, 181, Block 'G' New Alipore, Kolkata - 700 053	Phone : +91 33 2445 7566	

11. List of Supplier – Ceramic Fibre

SN	Name of Company	Address	Phone No.	E-mail
1	Murugappa Morgan Thermal Ceramics Limited	Post Box No 1570, DARE House Complex, Old No. 234, New No. 2 NSC Bose Road, Chennai 600 001 India	Tel +91 (44) 2530 6876, 2534 5986 Fax: +91 (44) 2534 5985	mmtcl.india@morganplc.com http://www.murugappamorgan.com
2	Lloyds Insulations (India) Limited Mr. K. K. Mitra (Vice President)	Punj Star Premises, Kalkaji Industries Area, New Delhi - 110019.	+91-11-30882874 / 75 Fax: +91-11-44-30882894 /95	kk.mitra@lloydinsulation.com
3	Unifrax India Ltd.	C - 102, Business Square, Andheri-Kurla Road, Nr.Chakala, Andheri (East), Mumbai - 400 093	Cell No.+91 98694 24830	

12. List of Supplier – Oxygen Analyser

SN	Name of Company	Address	Phone No.	E-mail
1	ABB India	BU Measurement & Analytics 14, Mathura Road, Faridabad, INDIA - 121003	Phone: 0129-2279627, 2275592	tejbir.singh@in.abb.com
2	Ecolibrium Energy (P) Ltd	1-4, CIIE, IIM New Campus, Vastrapur , Ahmedabad-380015, Gujarat	Phone :079-663241919 Mobile: 9871582246	himanshu.nagpal@ ecolibriumenergy.com
3	Jupiter Integrated Senser System Pvt. Ltd. Contact Person: Mr. BipinGhelani, Director	Kailash Industrial Complex A-401, Behind Godrej Colony, Park Site Vikhroli, Mumbai-400079, India	Phone : 022-25186470 Fax: 022-25186471 Mob: 9819575467	bipin@jupiterelectronics.co.in
4	Swan Environmental Private Ltd.	House no. 1 – 5017, 3rd floor, SMR Chamber Opposite St annes College Medinaguda, Seringapally, Hyderabad, (AP)	Tel: 040-23043328, Fax: 040-23041905	
5	Testo India Pvt. Ltd.	Plot-23, Sind Colony, Boner Road, Aundh, Pune Maharastra – 411007, India	Tel : 020-65600203, Fax: 020-25850080 Mob : 9370319654	

13. List of Supplier – Coal / Gas Analysis

SN	Name of Company	Address	Phone No.	E-mail
1	N.D. International	107B, Block-F, New Alipur Kolkata – 700 053	Mr. Debasis De, Managing Partner Mob : 9830238048 Off : 4021-6600-17 (18 lines) 4021-6600 (Direct)	
2	Bharat Foundation	25/11A, K. P. Ray Lane, Kolkata – 700 031	Tel : 2415-2145 / 2405-5015, Mob: 9831857775 Mr. S.Niyogi, Partner	bharatfoundation@gmail. com
3	Envirocheck	180/190, Rastraguru Avenue, Kolkata – 700 028	2579-2889/2579-2891 Dr. SumitChowdhury Mob : 9830067043	envcheck@cal2.vsnl.net.in
4	Indian Institute of Chemical Technology Contact Person: Dr. Ahmed Kamal, FNASc	Hyderabad-500004	Phone: 040-27193030 Fax: 040-27160387	ahmedkamal@iict.res.in
5	Central Institute of Mining & Fuel Research	Digwadih Campus PO: FRI, Dhanbad-828 108, Jharkhand, India	Tel. :+91-326-2381111 2388202 Fax : +91-326-2381113	dnb_dcfri@sancharnet.in
6	Sigma Test & Research Centre	BA-15, Mangolpuri Industrial Area Phase-II Delhi-110034(India)	Ph: +91-11-49491440 49491444, +91- 987327 2900 (M) Fax: +91-11-4385 2040	info@sigmatest.org
7	SGS India	226, UdyogVihar, Phase 1, Gurgaon 122 016, India	t +91 9871701549 f +91 (0) 124 239 9762	http://www.sgsgroup.in

14. List of Supplier – Continuous Casting Machine

SN	Name of Company	Address	Phone No.	E-mail
1	Concast (India) Limited	CONCAST HOUSE, 1/5 Marol Co-op Industrial Estate, Andheri (E), Mumbai - 400 05	Telephone +91 22 2850 1789 Fax:+91 22 2851 5145	concasti@bom4.vsnl.net.in http:// www.concastindia.com
2	Inductotherm (India) Pvt. Ltd.	Building Ambli-Bopal Road, Bopal, Ahmedabad 380058	Phone : +91-2717- 306196 Cell : +91-9374578586 ShriKishorebhai D. Vyas	sales@inductothermindia.com

15. List of Supplier – Coal / Biomass Based Producer Gas Plant

SN	Name of Company	Address	Phone No.	E-mail
1	Ankur Scientific Energy Technologies (P) Ltd. Contact Person: Mr. Ankur Jain, Director	"Ankur"Near Old SamaJakat Naka, Sama Road Vadodara-390008	Phone: - 0265-2793098/2794021, Fax: - 0265-279404	ascent@ankurscientific.com Mob: - 94-265-10863
2	Radhe Renewable Energy Development (P) Ltd. Contact Person: Shri Sunil Mittal, Marketing Mgr	Plot No-2621/2622, Gate No. 1, Road D/2, Lodhika G.I.D.C, Kalawad Road PO-Metoda Tal- Lodhika, Dist-Rajkot-360021 (Gujarat)	Phone:-2827-287888/287889 Fax: 2827-287887 Mob:98980 92843	info@radhegroup.com Web: www.radhegroup.com
3	MPR Refractories Ltd.	1-10-114, Ashok Nagar, Hyderabad-500020	Phone: 040-27644381/27637420 Mobile: 8870460191	ceo@afetechpl.com
4	Ashutosh Engg. Consulting Contact Person: P. Trivedi	749/2 A-2, 1st Floor, GIDC, Makarpura, Vadodara – 10 (Gujarat)	Phone: 0265-6590225 Fax: 0265-3047088 Mobile: 9825955157	ashutoshengg1969@yahoo.co.in
5	COSMO Power Tech Pvt. Ltd.	Near Jain Public School, Devpuri, Dhamtari Road, Raipur - 492 015, Chhattisgarh	Phone : 0771-4011262 Fax : 0771-4013016 Mob: 9893030085	cosmo_powertech@yahoo.co.in www.cosmogasifiers.com
6	CASE	117, Charmwood Plaza, Charmwood Village, Surajkund, Faridabad, Haryana - 121009, India	Telefax : +91-129-4266699 Ph: +91-129-4266666	info@casepl.com , case@casepl.com http://www.casepl.com
7	Dev Knitfab Ltd. Contact Person: Mr. Varun Kumar, Director	23, Motiakhan, Rani Jhansi Road, New Delhi-110055	Phone: 011-23551758 Fax: 011-23647528 Mob: 9810085165	varun@devknitfab.com

16. List of Supplier – Blowers

SN	Name of Company	Address	Phone No.	E-mail
1	KAY International Ltd.	Registered & Head Office 205-206 Lusa Tower, Azadpur Commercial Complex, Delhi - 110 033	+91-11-27674703	kayintl@vsnl.com / kayintl@eth.net
2	Everest Pressure &Vaccum Systems	435, Modern Industrial Estate, Phase-1, Bahadurgarh-124507, Haryana, India.	91-1276-267029, 267030	info@everestblowers.com
3	AMETEK Precision Motion Control	1st Floor, Prestige Featherlite Tech park, Plot 148, EPIP Phase II Whitefield, Bangalore 560 066 Karnataka,India	Dir No - 080 67823237 Mob no – 9686679509	
4	Ventilair India Pvt. Ltd.	201 Guru ArjunDevBhawan Ranjeet Nagar Comercial Complex New Delhi	011 - 25701825 011 – 25708240	
5	Maxtech Engineers	Plot No. 22, Tribhuvan Industrial Estate, Opp. Road No. 8, Kathwada G.I.D.C., Ahmedabad - 382430.	Tele Fax : 079 - 22901299 Phone : +91-9427609165 +91-79 - 22871576, 22900657	maxtechengineers@yahoo.com info@maxtechengineers.com Web : www.maxtechengineers.com

17. List of Supplier – Oxy Fuel Burners / Regenerative Burners

SN	Name of Company	Address	Phone No.	E-mail
1	Qingdao Olympia Heat Energy Equipment Co. Ltd	East Of Seven Road, Second Zone, Jiaozhou Bay Industrial Park, Jiaozhou City, Qingdao, China - 266300	Tel: 86-0532-82279618 Fax: 86-0532-82279617	qdolpy@olpy.net http://www.olpy.net
2	ENCON Thermal Engineers (P) Ltd Contact Person: Mr. V B Mahendra, MD	297, Sector-21 B Faridabad – 121001 Haryana	Phone: 0129-4041185 Fax: 0129-4044355	sales@encon.co.in Web: www.encon.co.in
3	Bloom Combustion India	City Centre Apartments, Office No. 405 AErand Centre Apartments, Office No. 405 A, Erandawane, Karve Road, Pune - 411004, Maharashtra, India	Mobile +919881001342 Contact Person Mr. Rahul Pathak (Manager Sales)	
4	Wesman Center	8 Mayfair Road Kolkata 700 019, India	Tel:+91 (33) 40020300 Fax: +91 (33) 22908050,	mailbox@wesman.com, furnace@wesman.com Web: www.wesman.com
5	Precimax Engineers Limited	Shahani House, Raj Palace Society, Plot 16, Sector 2, opar Khairane Navi Mumbai – 400709	+(91)-(22)-64568712 +(91)-(22)-64568714	lalitshahani@precimaxonline.com varshahotchandani@precimaxonline.com
6	Maxon (A Honeywell Company)	53, 54, 56, 57 Hadapsar Industrial Estate, Environmental & Combustion Controls, Sapphire Building, A-Wing, 2nd Floor Pune 411013	91-98-50907894 91-20-66008330 91-20-66008509 91-20-66039979	https://www.maxoncorp.com

18. List of Supplier – Roller Bearings

SN	Name of Company	Address	Phone No.	E-mail
1	TIMKEN India Limited	2nd Floor, Ramnath Building, 18, Community Centre Yusuf Sarai, New Delhi 110 016, India	Phone: 91-1-4604 3444	http://www.timken.com/india
2	SKF India	Mahatma Gandhi Memorial Building NetajiSubash Road, Charni Road, Mumbai - 400 002	Tel: +91 22 6633 7777 Fax: +91 22 2281 9074	http://www.skfindia.com
3	FAG Bearings India Ltd.	B-1504, Statesman House 148, Barakhamba Road New Dehli 110 001, India	Tel. +91 11 237382-77/-78, 415214-76/-77 Fax +91 11 51521478	info.fag.delhi@schaeffler.com http://www.schaeffler.co.in

19. List of Supplier – Antifriction Roller Entry / Exit Guides

SN	Name of Company	Address	Phone No.	E-mail
1	Morgards hammer India Ltd., New Delhi	1400 Modi Tower, 98 Nehru Place New Delhi - 110019	Tel: +91-11-26286641/ 66504555	http://www.morgardshammar.in
2	SMT Machines Limited	Post Box 71, G.T. Road, Sirhind Side, MandiGobindgarh 147301 Punjab ,India	01765-255199	smtindia@sancharnet.com, info@smtmachinesindia.org

20. List of Consultant- Hot Charging / Direct Rolling

SN	Name of Company	Address	Phone No.	E-mail
1	SEVAT	Walden- Charis, C/o. Greenhome Landscape (P) Ltd..Dheenampalayam. P.O, Coimbatore-641109 PrateekshaMadona, Thittamel, Chengannur, Kerala - 689121	Mobile: +9387676039 Mr. Philip George Ittyerah,	philip.ittyerah@gmail.com, sevati@yahoo.co.in
2	SOMA Consultancy Services	625 Sundar Nagar Raipur. CG.	Mobile: +91-9303278071	

21. List of Supplier – Universal / Cardon Shaft Couplings / Spindles

SN	Name of Company	Address	Phone No.	E-mail
1	Voith Turbo Private Limited - Contact Person Mr. K. Chakraborti	AB-06, Sector-1, Salt Lake City, Kolkata, West Bengal - 700064, India	91-33-23592356 /23587641 Fax No : 91-33-913323592356	
2	Cardan India	G. T. Road Panagarh Bazar Durgapur - 713 148 WB, India	Mobile : +91 98000 46890 / +91 94343 33326 / +91 98322 88664 Fax : +91 343 2527065	sales@cardanindia.com / cardanindia@gmail.com Website : www.cardanindia.com
3	Dullabh Commercials	386, Ahmmed chambers, Opp. Swastik Cinema, Lamington Rd, Near Opera House, Mumbai - 400 004, Maharashtra (India)	Mobile No +91- 9820967337 Contact Person Mr. Raj Mistry	raj@dullabhcommercials.com
4	Cardan Shaft India	Plot No. 308, Sector -3, Block - C Loha Bazar, MandiGobindgarh–147301, Punjab, INDIA	Tel : +91 - 81466-22027, 09357755555	info@cardanshaftsindia.com rsingh@cardanshaftsindia. www. cardanshaftsindia.com com |
5	A.R Engineering Works	22, Okhla Industrial Estate, Phase-Iii, New Delhi 110020 ,India	011-41612339	info@argroup.net
6	P.P Rolling Mill Mfg. Pvt. Ltd.	D-820, New Friends Colony, New Delhi 110065 ,India	011-26848885	ppeng@vsnl.com
7	Kathuria Roll mill Pvt. Ltd.	A-7/56-58, S.S.G.T. Road Industrial Area, Gaziabad-201009, UP	011-22934986 /22931475	kathuriarollmill@gmail.com, info@kathuriarollmill.com web: www.kathuriarollmill.com
8	RanaUdyog (P) Ltd.	18-D, Everest House 46-C, Jawaharlal Nehru Road	033-3052-1116 033-2288-9247	ranaudyog@hotmail.com

22. List of Supplier – FRP blades

SN	Name of Company	Address	Phone No.	E-mail
1	Poly Fans	S-4,Amita Apartments,118,New Baradwari, Sakchi,Jamshedpur, Jharkhand	Mobile :+91-9470351780;0812340691	bksinha@gmail.com
2	Parag ' Fans & Cooling systens Ltd	Plot no. 1/2B & 1B/3A, Industrial Area no.1 AB Road, Dewas-455001, Madhya Pradesh	07272-425100/01/02/03/04 Mobile:09993027026	info@impactgroupindia.com
3	Dew –pond Engineering Pvt. Ltd	Plot no.A-478, Road 26, wagle Ind. Estate, Thane-400604, Maharashtra	022-25829208	dewpond@gmail.com;sunil@ dewpondcoolingtowers.com
4	Paharpur Cooling Towers Ltd	Paharpur House, 8/1/B Diamond Harbour Road, Kolkata-700027, West Bengal.	033-40133000	pctccu@paharpur.com

For more details, please contact

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