2023-2024

E-GUIDE
IRON & STEEL
INDUSTRY

NATIONAL PRODUCTIVITY COUNCIL

Nature Protects if She is Protected

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVEATIONS

Abbreviations	
MT	Million Tons
MTPA	Million Tons Per Annum
NSP	National Steel Policy
BOF	Basic Oxygen Furnace
EAF	Electric Arc Furnace
IF	Induction Furnace
BF	Blast Furnace
CO	Carbon Monoxide
ELV	End of Life Vehicle
RE	Resource Efficiency
GHG	Greenhouse Gas
VOC	Volatile Organic Carbons
PAHs	Polycyclic Aromatic Hydrocarbons
TSS	Total Suspended Solids
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
GSR	Government Statutory Rules
pH	Potential of Hydrogen
mg/l	Milligrams per liter
PLD	Percent Leaking Doors
PLL	Percent Leaking Lids
PLO	Percent Leaking off takes
HPLA	Aspiration through High Pressure Liquor injection in gooseneck
BaP	Benzene(a)Pyrene
AP	Ascension Pipe
NOx	Nitrogen Oxide
COG	Coke Oven Gas
CO	Carbon Monoxide
SOPRECO	Single Oven Pressure Control
ESP	Electrostatic Precipitator
SP	Sinter Plant

Mg/Nm^3	Milligrams per normal cubic meter
DE system	Dust Extraction system
MEROS	Maximum Emission Reduction of Sintering
SO_2	Sulphur Dioxide
R&D	Research and Development
NH_3-N	Ammoniacal Nitrogen
max	Maximum
Pb	Lead
TRT	Top Pressure Recovery Turbine
MW	Megawatt
ABC	After Burning Chamber
CO_2	Carbon Dioxide
WHRB	Waste Heat Recovery Boiler
CPCB	Central Pollution Control Board
CCM	Continuous Casting Machine
FE	Fume Extraction
LF	Ladle Furnace
ID fan	Induced Draught fan
PM	Particulate Matter
SO_x	Sulphur Oxide
DF	Dry Fogging
dB	decibel
MBC	Mechanical Biological and Chemical
RCC	Reinforced Cement Concrete
PM10 µg/m^3	Concentration of particulate matter of size 10 in micrograms per cubic meter air
MSW	Municipal Solid Waste
MMBtu	Metric Million British Thermal Unit
ILC	In Line Calciner
SLC	Separate Line Calciner
CPP Plant	Captive Coal Power Plant
WHRS	Cooler Waste Heat Recovery System
RO plant	Reverse Osmosis
HCl	Hydrochloric acid
HF	Hydrofluoric acid

TOC	Total Organic Carbon
Hg	Mercury

1. Introduction

1.1 Background

Human welfare depends on both the environment and their social and economic circumstances. Positive or negative changes in the socioeconomic fields will affect the earth's environment, whether they are immediate or gradual. In addition, there are many negative consequences that cannot be reversed.

A well-industrialized economy should have adequate infrastructure to support the industrial sector's growth, which drives economic activity. As part of this initiative, our Honorable Prime Minister launched the 'Make in India' campaign to encourage investment, foster innovation, develop skills, protect intellectual property, and build best in class manufacturing infrastructure.

"**Make in India**" recognizes "**Ease of Doing Business**" as the most important factor to promote entrepreneurship. Several initiatives have already been taken to ease the business environment, with the aim of delicensing and deregulation of industry throughout the life cycle of a company.

On the other hand, environmental resources are those that contain intrinsic value of their own or are valuable for human long-term sustainability and use. According to strict economic thinking, most environmental resources are intangible. Furthermore, resource use and competition for scarce resources such as clean water, land and raw materials are on the rise around the world, while environmental problems such as climate change, soil degradation, and biodiversity loss are rapidly worsening. Accordingly, the Ministry of Environment, Forest and Climate Change (MoEF&CC) issued Environmental Impact Assessment (EIA) Notification in 2006 for the purpose of reviewing all relevant information about a project or activity to evaluate (and accordingly mitigate) its potential adverse effects on the ecology of the region.

In this regard, our Constitution has also made provisions under Article 48A advocating for the protection of the environment, the forest, and wildlife. Furthermore, Article 51A of the Constitution of India requires Indian citizens to safeguard and improve the natural environment including forests, lakes, rivers, and wildlife. Thus, the Constitution has prioritized the protection and ensured adequate safeguard of the environment and natural resources. Therefore, MoEF&CC requires all project proponents to submit half-yearly reports to the regulator after the project has been cleared by the EAC/SEAC regarding compliance with the terms and conditions established in the terms of reference of the project.

Whenever a compliance condition is not fulfilled by the project proponent or violated, the Ministry of Environment, Forest and Climate Change, Government of India (MoEF&CC) can issue a show-cause notice.

This guidebook will serve as a tool for the project proponent to ensure compliance with the environmental conditions outlined in the project environmental clearance. Additionally, this guidebook will provide regulatory bodies and auditors with an understanding of the sectoral aspect and provide an evaluation of effective environmental enforcement and compliance programs.

1.2 About the e-guide

India's iron and steel industry has experienced significant growth over the past years. The installation of several integrated plants, continuous upgradation of the technologies, implementation of numerous government schemes and its efforts towards facilitating ease of doing business and development of infrastructure have altogether extensively promoted the growth of the iron and steel industry. In the past few years, countries around the world have been working on striking a balance between economic growth and nature conservation. While India has been emphasizing on the adoption of sustainable practices in the iron and steel sector, and has also been utilizing processes like Electric Arc Furnaces (EAF) and Direct Reduced Iron (DRI), there's still a huge gap that the country needs to fill up to minimize the ecological impact of iron and steel production while sustaining growth in the industry.

The project proponent can use this e-guide to ensure compliance with the project's environmental clearance conditions. E-guide will give understanding of the sectoral guidance and provide an evaluation of effective environmental enforcement and compliance programs.

Best practices tools and techniques/technologies/practices adopted by different industries are included in e-guides.

2. Sectoral Profile

2.1 Steel Industry

During the period of January – December 2022, India was the 2nd largest producer of Crude Steel in the world, which marked a momentous achievement for the growing economy. Over the last five years, the Crude Steel production has expanded from 109.25 million Tons (MT) in 2018 to 124.72 MT (provisional) in 2022. In 2022, the sector even saw an impressive year-on-year growth of 5.5% over 2021. Another remarkable feat of the nation includes the expansion in the production capacity of domestic crude steel from 142.236 million Tons Per Annum (MTPA) in 2018 to 157.585 MTPA in 2022. [source: (Annual Report). (2023). Ministry of Steel.]

2.2 Background of Iron & Steel Industry in India

In the year 1947, India had merely three steel plants – the Tata Iron and Steel Company, the Indian Iron and Steel Company and, Visveswaraya Iron and Steel Ltd, and a few electric arc furnace-based plants. The pre-independence period thus witnessed a small yet viable steel manufacturing industry, which operated with a capacity of about 1 million tonne, and was entirely a part of the private sector. Nascent at the time, and with only fledgling 1 Million Tonne capacity status, India has now risen to be the 2nd largest crude steel producer in the world, and the largest producer of sponge iron, demonstrating a pivotal achievement in the history of the nation. From a negligible global presence, the Indian steel industry is now globally acknowledged for its product quality. There are more than **2100 steel units** currently functioning in the country. [source: (Annual Report). (2023). Ministry of Steel.]

Further Readings
1) Ministry Of Steel – Annual Report 2022-23. Annual Reports | Ministry of Steel | GoI 2) World Steel Association – Crude Steel Production Home page - worldsteel.org 3) Join Plant Committee (JPC) Home jpc indiansteel.nic.in

According to the National Steel Policy (NSP) 2017, under the guidance of honorable Prime Minister, we are taking steps forward to achieve the target of 300 MT crude steel production by 2030. Overtaking Japan in the year 2018, India ranks as the 2nd largest producer of steel in the world [source: (Annual Report). (2023). Ministry of Steel.], and 1st in the world in the production of sponge iron. Furthermore, its crude steel capacity has also increased from 110 MT to 160 MT in the last 9 years, marking a growth of 46%.

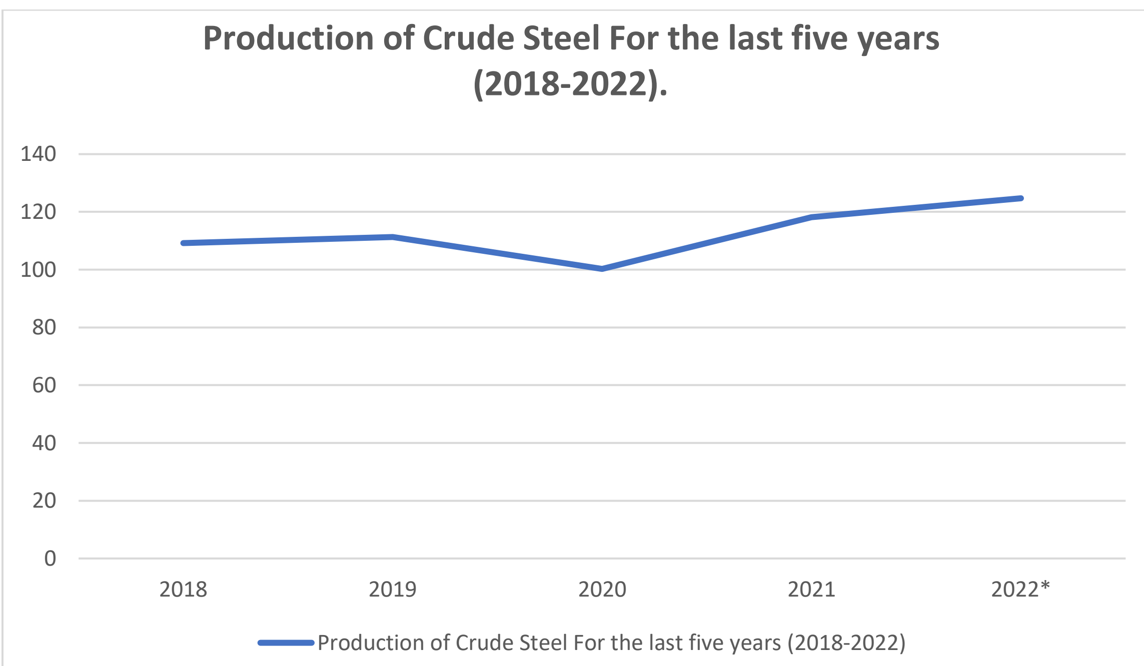
With government taking up several infrastructure development projects such as highways and roads, and further accentuating the significance of the Make in India mission, the domestic consumption went up from 77MT to 120MT, and the per capita steel consumption, grew from 60kg in 2014 to 87kg now, recording a growth of 50%. [source: Press Release Page. (n.d). Ministry of Steel.]

2.3 PRODUCTION OF CRUDE STEEL FOR THE LAST FIVE YEARS (2018-2022)

(In Million Tons)

CRUDE STEEL	2018	2019	2020	2021	2022*
PRODUCTION	109.250	111.344	100.256	118.201	124.720

[source: Annual Report (2023), Ministry of Steel]

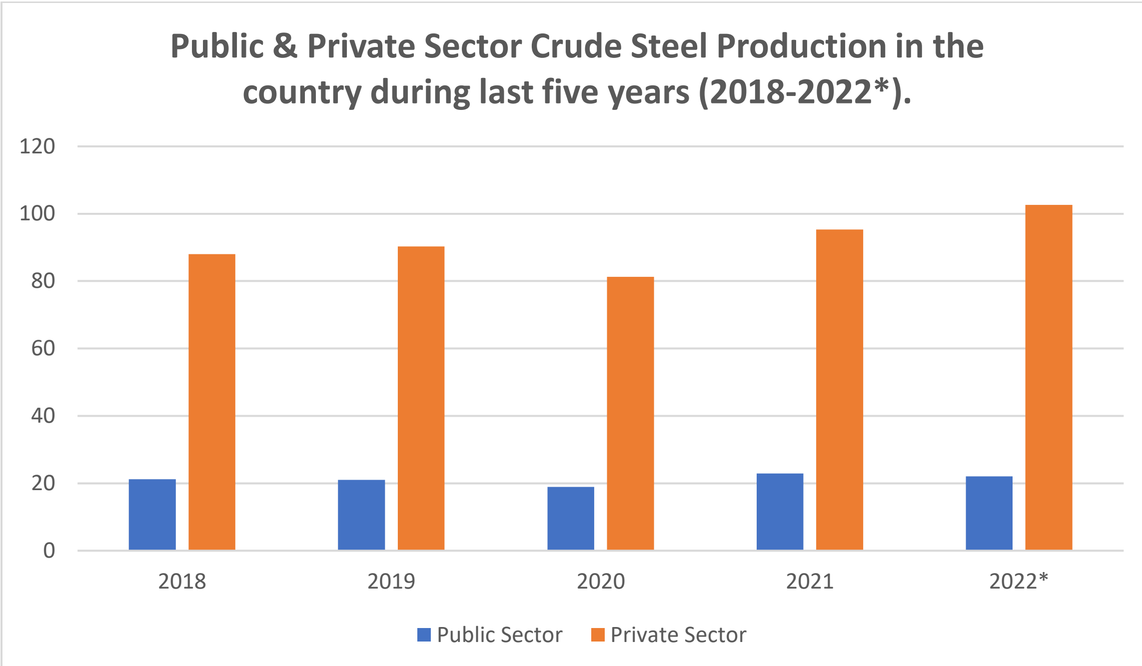


[Source: Annual Report (2023), Ministry of Steel]

2.4 Contribution of the Public and Private Sector in Crude Steel production in the country during the last five years (2018-2022*).

Indian Crude Steel Production					
Sector	**2018**	**2019**	**2020**	**2021**	**2022***
Public Sector	21.191	21.014	18.984	22.908	22.102
Private Sector	88.059	90.330	81.308	95.293	102.618
Total Production	**109.250**	**111.344**	**100.256**	**118.201**	**124.720**
Share of Public Sector In %.	19.4	18.9	18.9	19.4	17.7

[Source: Annual Report (2023), Ministry of Steel]



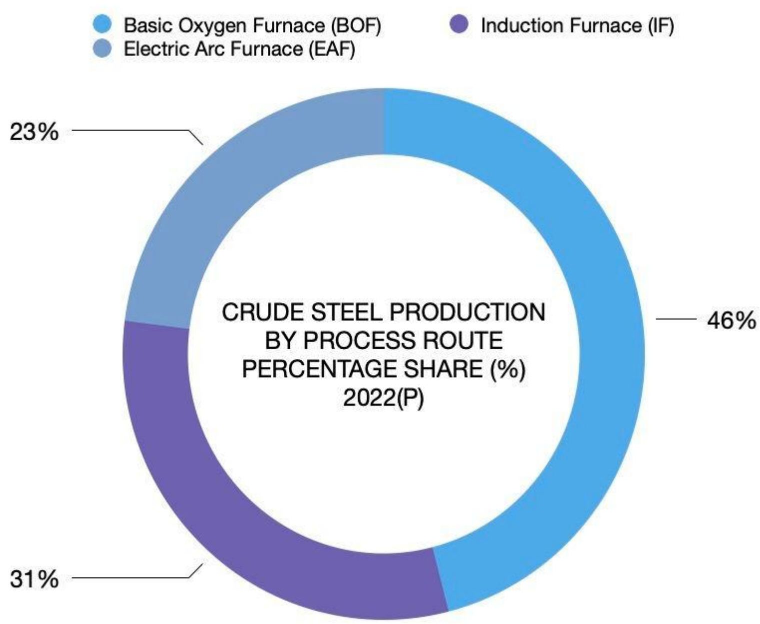
[Source: Annual Report (2023), Ministry of Steel]

2.5 PROCESS ROUTES OF IRON AND STEEL-MAKING IN INDIA

There are three most commonly used process routes of iron and steel-making in India.

1. Basic Oxygen Furnacce(BOF)
2. Electric Arc Furnace(EAF)
3. Induction Furnace(IF)

The shares of the each process route in the total production of crude steel in the country during the year of 2022* have been shown in the following pie chart.



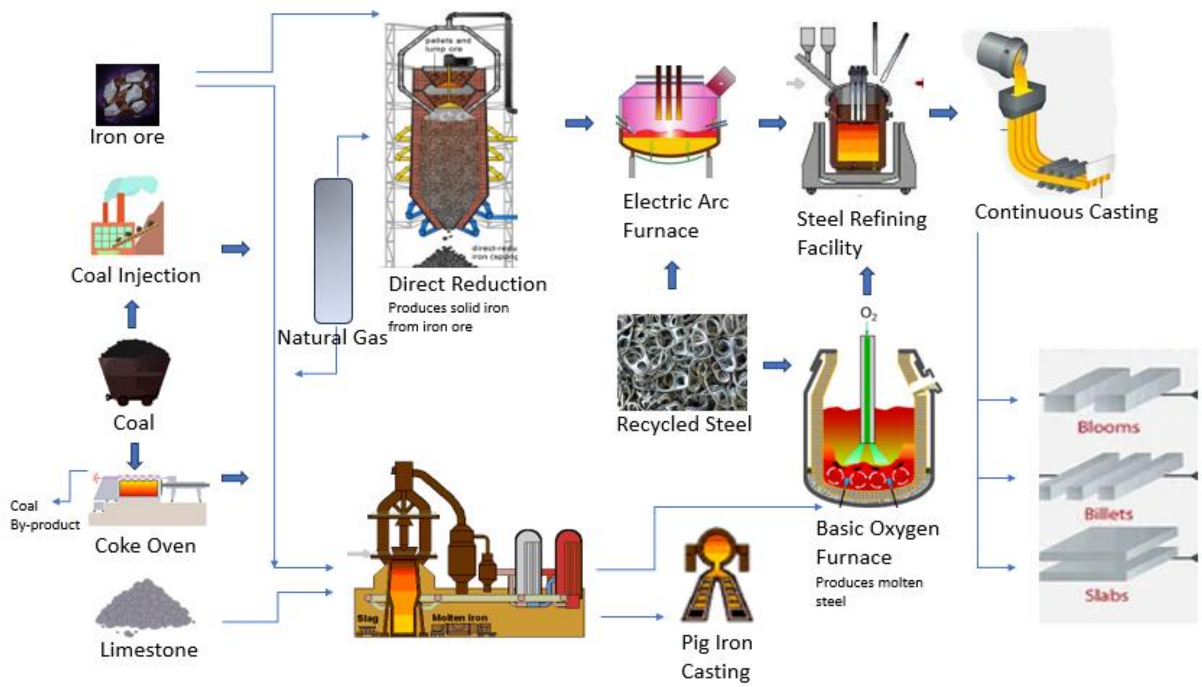
Source: JPC; *Provisional, January-December, 2022.

Process Routes of Iron & Steel Making In India.

Blast furnace→ Basic oxygen furnace →Ladle treatments→continuous casting→Rolling →flat or long products. **Adopted by Integrated Steel Plants**

ELECTRIC ARC FURNACE→ Ladle treatments→ Continuous casting→ Rolling →Mostly long products but occasionally flat products. **Adopted by Mini Steel Plants.**

The electric arc furnace is used to reduce iron from iron ore. Heat is generated from an electric arc between electrodes. Oxygen is blown into the furnace, and lime and other materials are added to combine with the impurities and form slag.

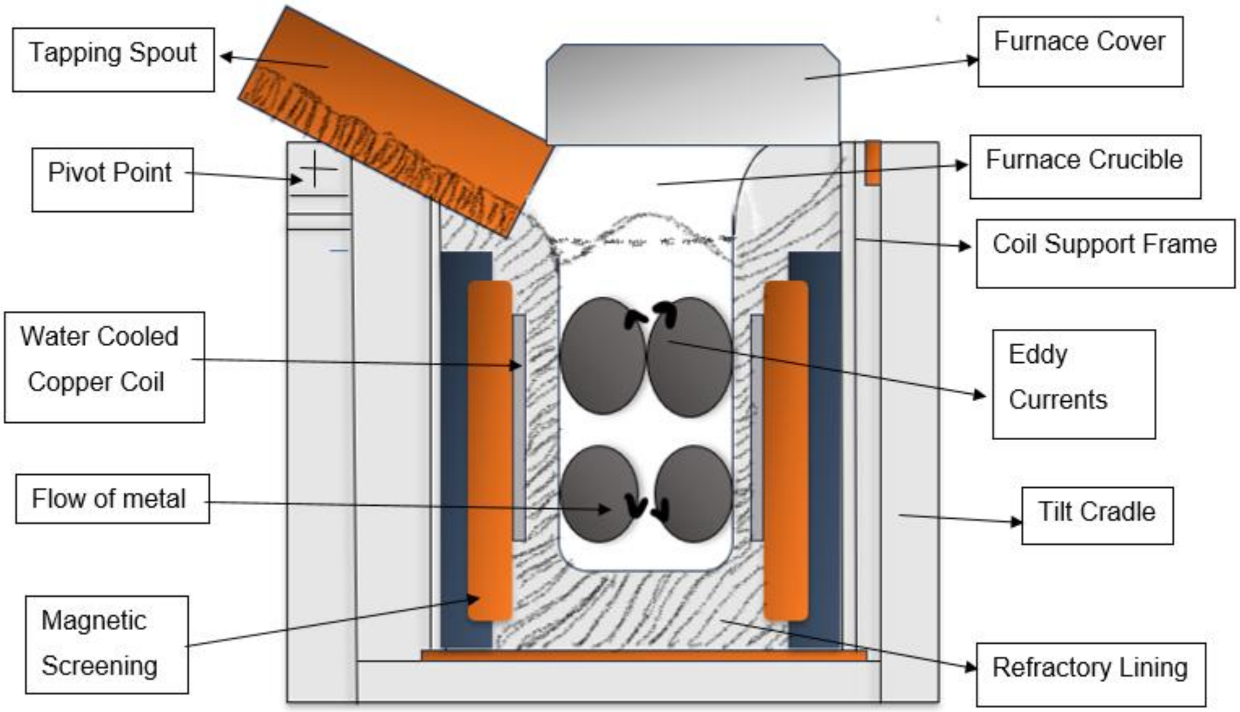


[Source: Steel Production https://www.steel.org/steel-technology/steel-production/]

Induction Furnace: Charge preparation→charging→melting→ slag removal→ make the heat ready for tapping→ Tapping and Emptying the furnace.

Induction Furnace is that type of furnace that uses the principle of electromagnetic induction for melting the metal inside. In this, a coil carrying alternating current surrounds the container of metal. Eddy currents are induced in the metal, and the circulation of these currents produce extremely high temperatures for melting the metals, and further for making alloys.

Schematic Diagram of a Coreless Induction Furnace



Source: Induction Furnace and Steelmaking

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

2.5 EVERY ROUTE INVLOVES CERTAIN BASIC UNIT PROCESSES

BASIC UNIT PROCESSES

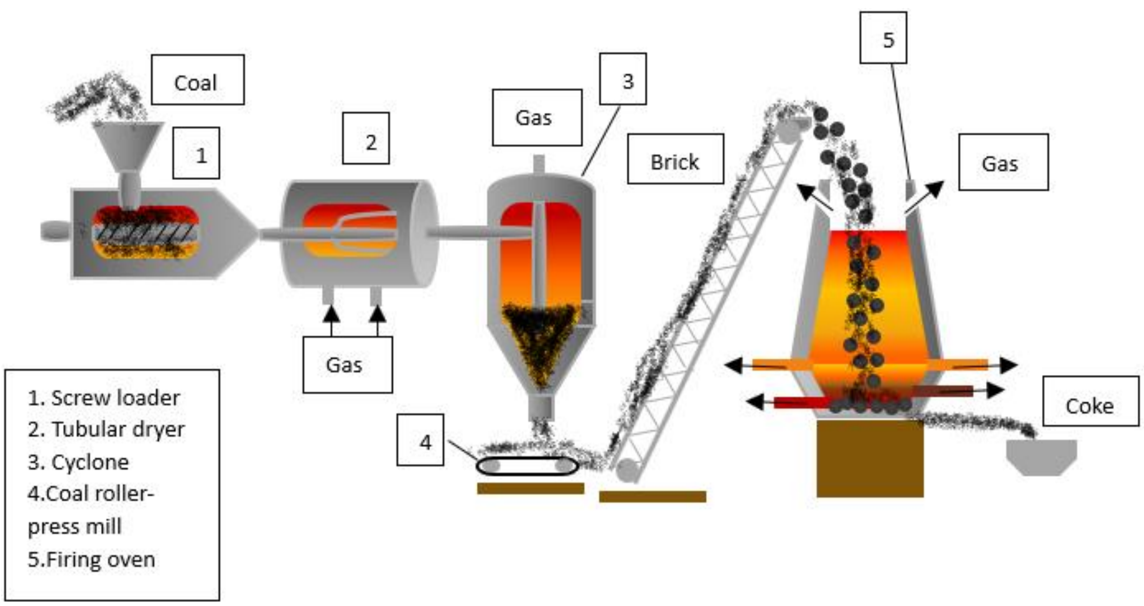
- COKE MAKING
- SINTERING
- PELLETIZATION
- IRON-MAKING
- BASIC OXYGEN STEEL-MAKING(BOF)
- ROLLING MILLS
- CALCINING PLANT

BRIEF DESCRIPTION OF UNIT PROCESSES

1.COKE MAKING

The process of coking involves heating coking coal at very high temperatures of about, in the absence of air. It is done to remove the volatile matter and transform the coal into a strong porous cake with high carbon content. During the process, the coking coal softens and swells up, and then becomes hard with sufficient porosity and strength. The pulverized coal blend in loaded into the ovens and heated at 1100 degree Celsius [source: Mukherjee, A., Chatterjee, A. (2023). *Carbon Capture Utilization and Storage (CCUS), Policy Framework and its Deployment Mechanism in India*. Niti Aayog.] over long periods of hours. The hot cake is pushed out of the ovens into a quenching car which is then taken to quenching stations for cooling before being conveyed to the blast furnace.

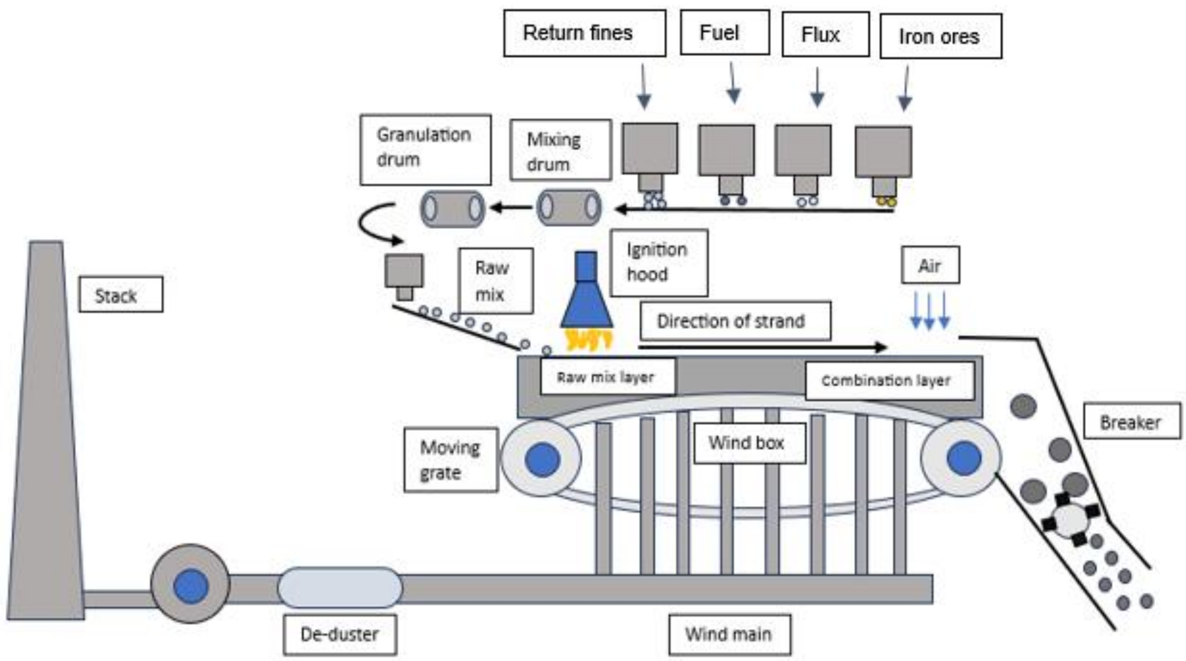
Coal – to - Coke conversion

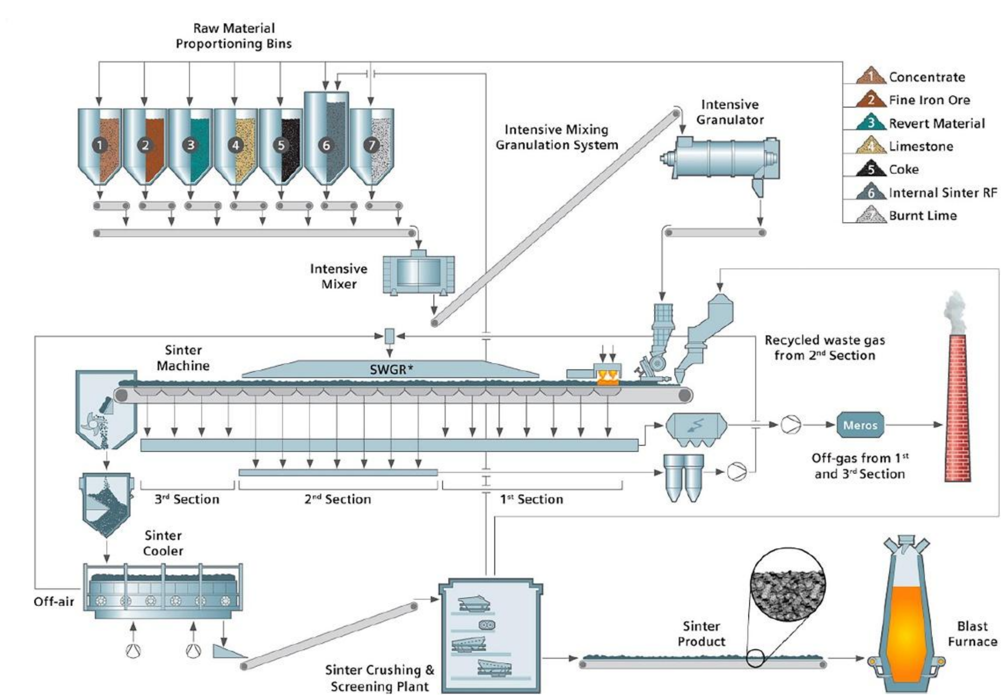


Source: Coal to Coke conversion vector image https://www.vectorstock.com/royalty-free-vector/coal-to-coke-conversion-vector-27083356

2.SINTERING

It is a process that combines ores that are too fine for efficient blast furnace use, and with flux stone the mixture is heated to form clumps, which allow better draft in the blast furnace.





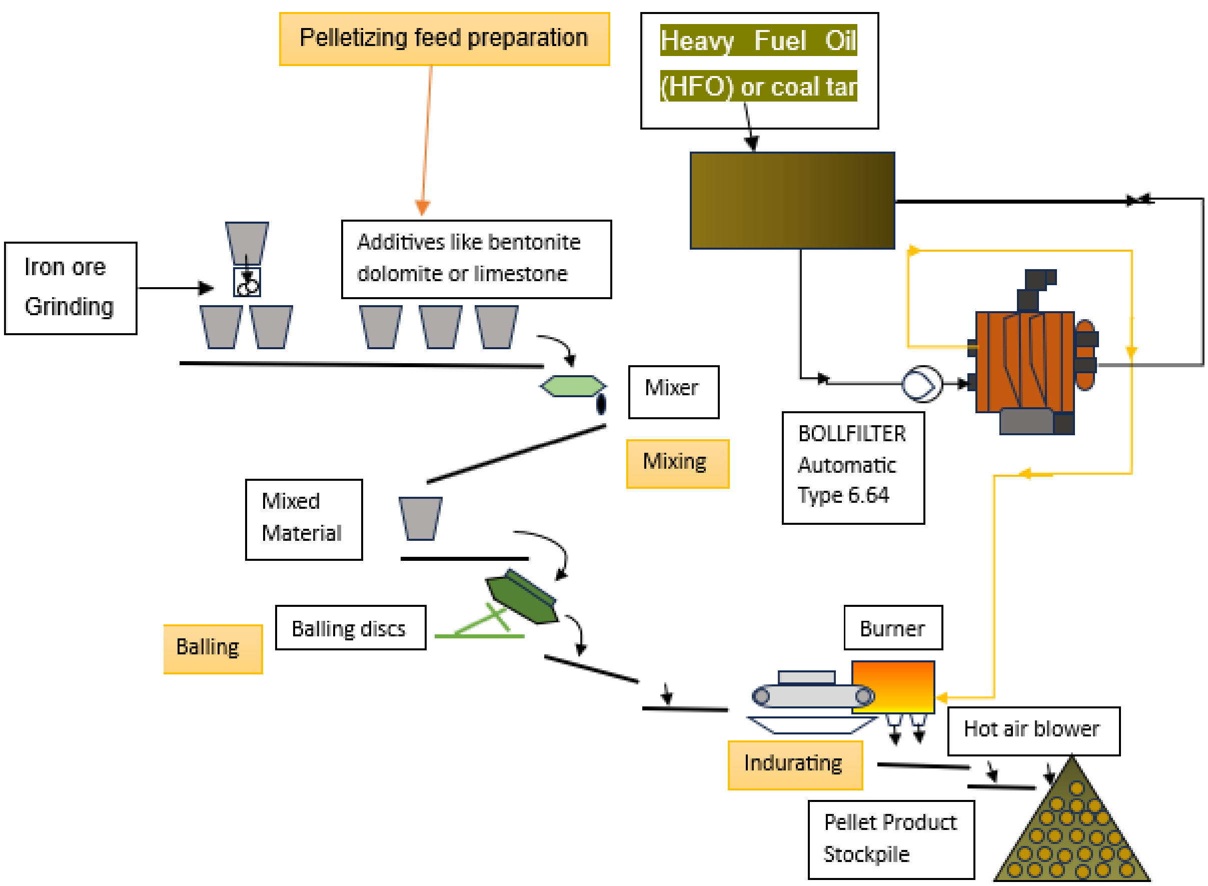
Source: Sinter Plant
https://www.sciencedirect.com/science/article/pii/S2588913322000011

3. PELLETIZATION

Pelletization is the process of clustering very fine particles of iron ore with fluxes, without any incipient melting. The pelletization consists of three main steps: mixing of the feed particle with a binder, making of raw pellet balls in a drum or disc pelletizer, and heat hardening of raw pellets in a travelling grate-rotary kiln-train at around 1300 degree Celsius.

Iron Ore Pelletizing

Protection of the burner

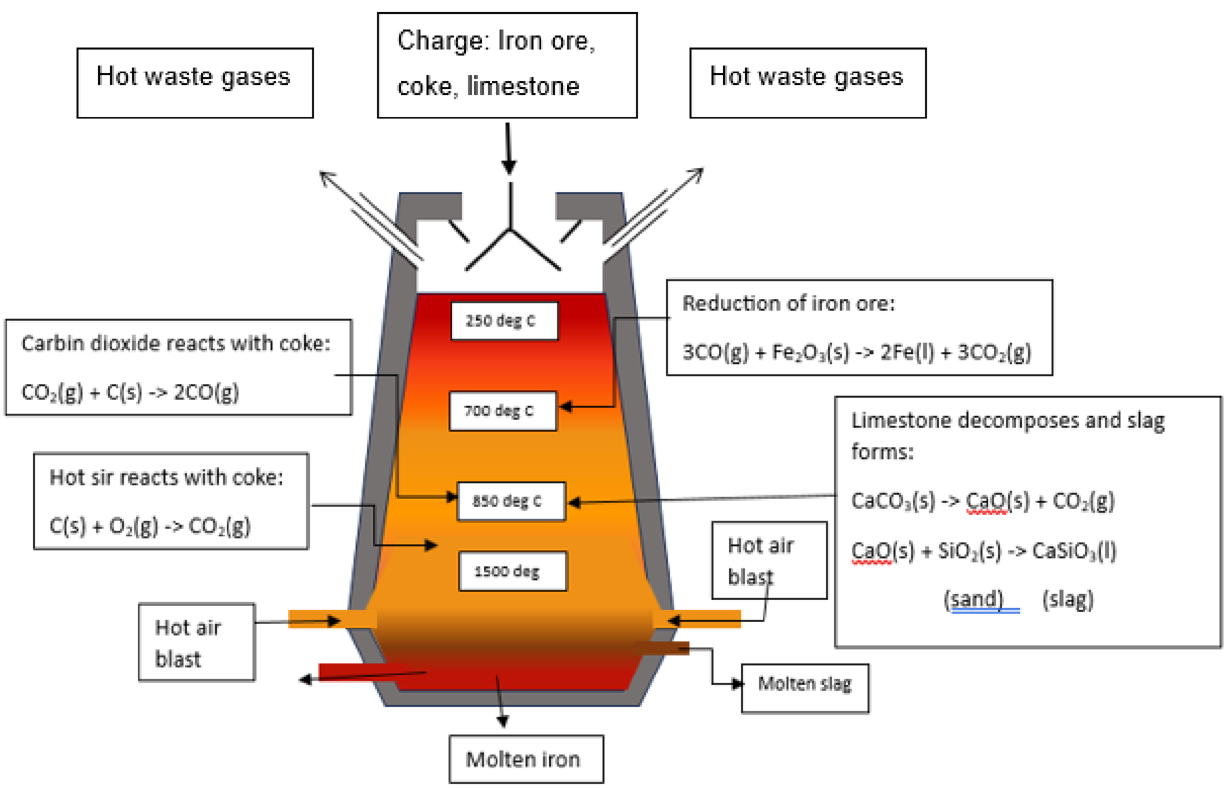


Source: Iron ore Pelletizing: Fuel oil filtration https://www.bollfilter.com/applications/care-of-machining-cleaning-systems/pelletizing-plants

4.IRONMAKING

In a blast furnace (BF), iron ore lumps and sinter or pellets are charged from the top of the furnace along with coke, limestone and dolomite. A hot blast of preheated air with a temperature of over 900 degrees Celsius is blown through the tuyeres from the bottom of the BF, which burns the coke to produce heat and carbon monoxide (CO). the coke reduces the iron-oxide to metallic iron, while producing BF gas. The fluxes help the separation of gangue from the ore, thus forming slag. A high temperature of 1400 degree Celsius in the hearth of the furnaces enables the tapping of hot metal and slag in the liquid form. [source: Mukherjee, A., Chatterjee, A. (2023). *Carbon Capture Utilization and Storage (CCUS), Policy Framework and its Deployment Mechanism in India*. Niti Aayog.]

The Blast Furnace



Source: Pig Iron Production - Blast Furnace route https://www.metallics.org/pig-iron-bf.html

5.BASIC OXYGEN STEEL MAKING

This is a refining process whereby oxygen is blown through hot metal in a converter to remove impurities like carbon, silicon and phosphorus to produce liquid steel. The oxygen blowing results in the formation of an emulsion of gas, molten metal and fluxes, leading to high reaction rates and making this a rapid process. The oxidized impurities and making this a rapid process. The oxidized impurities and fluxes from a basic slag that is tapped at the end, separate from the oxidation reactions, scrap or iron ore is added as coolant.

6.ROLLING MILLS

Semis from the steel melt shop are rolled for production of final products like rebars, wire roads, structural sections and hot rolled coils.

Cold billets/slabs are charged to a reheating furnace, fueled by mixed gas, to reheat the semis to around 900-1000 degree Celsius. The hot semis are passed through multiple rolling stands before being cooled down in a cooling station. [source: Mukherjee, A., Chatterjee, A. (2023). *Carbon Capture Utilization and Storage (CCUS), Policy Framework and its Deployment Mechanism in India*. Niti Aayog.]

7.CALCINING PLANT

For the refining of hot metal, calcinated lime and Dolo are required.

For the production of lime and Dolo, raw limestone/dolomite is charged into a kiln (vertical shaft or horizontal kiln), where calcination occurs at a temperature of around 1000 degree Celsius. Heat is supplied by in-plant fuel gas or purchased fuel. [source: Mukherjee, A., Chatterjee, A. (2023). *Carbon Capture Utilization and Storage (CCUS), Policy Framework and its Deployment Mechanism in India*. Niti Aayog.]

2.6 SECTORWISE STEEL USAGE IN INDIA

In India, steel is primarily consumed in growth driving sectors such as

- Housing and Construction (43%),

- Infrastructure development (25%),
- Engineering and packaging (22%),
- Automotives (8-9%),
- Defence and Jal-Shakti (1-2%).

During the FY22, the total steel consumption in the country was 106 million Tonne.

India's annual per capita steel consumption is 77 kg per annum and is one-third the global average (233kg).

India's rural per capita consumption of steel is 21.3kg per annum.

[Source: Annual Report (2023), Ministry of Steel]

Ferrous Scrap:

Ferrous scrap is used in EAF/IF process to produce steel. Stainless steel is produced exclusively from stainless steel scrap. Scrap consumption in total charge mix is BOF – 15%, EAF – 2%, and IF – 20%.

In 2021-22, India generated about 25-30 MT & imported about 4-5 MT of ferrous scrap. Import of ferrous scrap has been declining since the past 3 years. Implementation of **End-of-Life Vehicle (ELV) policy** is also expected to boost the availability of scrap domestically.

An increased use of scrap is an important way of reduction of carbon intensity in the steel sector. Hence it is expected that both domestic & international demand for ferrous scrap will increase in the coming years.

The ferrous scrap generated through recycling used for production of steel will help in judicious use of valuable natural resources like iron ore, coal, and limestone, leading to Resource Efficiencies (RE) and energy savings and reduce GHG emission. [Source: Annual Report (2023), Ministry of Steel]

Indian Automobile Industry is expected to be the world's third-largest automotive market in terms of volume by 2026.

2.7 References

1. Ghosh, A., & Chatterjee, A. (2008). *IRON MAKING AND STEELMAKING: THEORY AND PRACTICE*. PHI Learning Pvt. Ltd.
2. Brush, J. E. (1952). The Iron and Steel Industry in India. *Geographical Review*, *42*(1), 37–55. https://doi.org/10.2307/211250
3. Mallett, A., & Pal, P. (2022). Green transformation in the iron and steel industry in India: Rethinking patterns of innovation. *Energy Strategy Reviews*, *44*, 100968. https://doi.org/10.1016/j.esr.2022.100968

3. Chapter: Environment Issues

3.1 Background

While iron and steel plants are essential for the industrial developments and thus economic growth of the nation, they have extensive environmental implications. With growing concern over the need of environmental stewardship and adopting green practices, the following chapter has been designed to explain the various repercussions of iron & steel making activity on the ecological system, and further advise upon the best practices that should be followed to mitigate the impact of the industrial activity on the ecosystem.

3.2 Air Pollution

Air pollution is one of the major concerns of iron and steel production processes as they release large amounts of volatile organic carbons (VOCs), emissions from stacks, and fugitive emissions from open and closed areas. It is a prime contributor to greenhouse gas emissions, mainly due to the carbon-intensive nature of the production activity. These include carbon dioxide, methane and nitrous oxide. These gases are produced during various high temperature processes of the activity including mining and extraction of coal, combustion of fossil fuels, heating and melting of the metal among others.

Further the production of steel involves processes like sintering, coke making, iron ore smelting and others, all of which release fine particles known as particulate matter into the atmosphere. These emissions inflict adverse effects on the health of the general public, causing asthma and various other respiratory illnesses.

Constructional Phase

Recommended Measures for control of Fugitive Emissions during construction

Emission Source	Recommended Control methods
Debris handling	**Wind speed reduction, Wet suppression#**

Truck transport##	**Wet suppression, Paving Chemical stabilization^**
Bulldozers	**Wet suppression^^**
Pan scrappers	**Wet suppression of travel routes**
Cut/fill material handling	**Wind speed reduction, Wet suppression**
Cut/fill haulage	**Wet suppression, Paving, Chemical stabilization**
General construction	**Wind speed reduction, Wet suppression, Early paving of permanent roads**

#: Dust control plans should contain precautions against watering programs that confound track out problems.

##: Loads could be covered to avoid loss of material in transport, especially if material is transported offsite.

^: Chemical stabilization usually cost-effective for relatively long-term or semi-permanent unpaved roads.

^^: Excavated materials may already be moist and not require additional wetting. Furthermore, most soils are associated with an "optimum moisture" for compaction.

Operational Phase

a. Coke oven plant

In coke ovens, naturally found coal is converted into coke. Water is used in large quantities for quenching hot coke and the washing of gas produced from the ovens. Thus, liquid effluents generated during the process operations are highly polluted and difficult to handle. However, coke plant waste water contains ammonia, cyanide, thiocyanate, and many toxic organic contaminants such as phenols mono and polycyclic nitrogen containing compounds and PAHs3•4. As a result, this effluent shows high value of TSS, BOD, COD 1•

The government has set certain standards for the iron and steel plants to keep a check on the amount of effluents and emissions released. The standards stipulated as per GSR GS.R.277(E), dated March 2012, are as follows:

A) Effluent Standards

Parameter	Standard
	Limiting concentration in mg/l, except for pH
pH	6.0 – 8.50
Suspended Solids	100
BOD, 3 days at 27 degrees Celsius	30
COD	250
Oil and grease	10
Ammonical nitrogen as N	50
Cyanide	0.2
Phenol	1.0

B) Emission Standards

Parameter	Standard		
	New Batteries (at green field site)	Rebuild Batteries	Existing Batteries
	(i) Fugitive Visible Emissions		
Leakage from door	5(PLD)	10(PLD)	10(PLD)

Leakage from charging lids	**1(PLL)**	**1(PLL)**	**1(PLL)**
Leakage form AP Covers	**4(PLO)**	**4(PLO)**	**4(PLO)**
Charging emission (Second/ charge)	**16 (with HPLA)**	**50 (with HPLA)**	**75**
PLD - Percent leaking doors; PLL - Percent leaking lids; PLO – Percent leaking off takes; HPLA – Aspiration through high pressure liquor injection in gooseneck.			
SO_2 (mg/ Nm^3)	**800**	**800**	**800**
NOx (mg/Nm^3)	**500**	**500**	**500**
Particulate matter (mg/ Nm^3)	**50**	**50**	**50**
Particulate matter during charging of stamp charging batteries (mg/ Nm^3)	**25**	**25**	**25**
Sulphur in Coke oven gas used for heating (mg/ Nm^3)	**800**	**-**	**-**
(ii) Fugitive Emissions: Benzo (a) Pyrene (BaP)			
Battery area (top of the battery)	**5**	**5**	**5**
Other units in coke oven plant	**2**	**2**	**2**

Emissions from coke ovens mainly result from coal charging and coke pushing.

Fugitive emissions may result from various leakages from oven doors, charging lids, ascension pipe (AP) covers etc. Therefore, charging emissions should be controlled by High Pressure Liquor Aspiration (HPLA) injection in goose neck during charging. Coking emissions should be controlled by efficient sealing of oven doors, water sealing arrangement of AP cap etc. Land based fume extraction system should also be adopted for controlling pushing emissions. NO_X emissions during oven firing should be controlled by incorporation of low NO_X stage combustion burners and recycle of flue gas. Further, the raw coke oven gas (COG) should be cleaned in by-product recovery plant. Desulphurization of coke oven gas should be carried out using the Clauss process wherein the hydrogen sulphide in the coke oven gas should be recovered as elemental Sulphur. Crude Tar and benzol should also be recovered from CO gas as a value addition from coke oven gas.

Air pollution control measures like **Single Oven Pressure Control (SOPRECO)** and **Pushing Emission Control** should also be implemented.

SOPRECO is a technology which controls individual oven at a predefined pressure. In this, an auto control valve that is installed at the exit gas duct of every oven, and a pressure transmitter that is installed to continuously monitor Oven pressure, are synchronized to ensure that at any given time the oven is maintained at a set pressure.

b. <u>Sintering plant</u>

In order to reduce the impacts on ambient environment, efforts should be made to adopt the latest state of art technology, install adequate pollution control measures for different processes like de-dusting stacks and different fugitive emission sources. Some of the practices that can be adopted are as follows:

a. Best Practices in line with European Union best available technologies
b. Design limit for dust emission from bag filters -< 30 mg/nm3
c. Additional high-performance bag filters in all sinter plants, with emission limit of <

d. 10 mg/nm3
e. High efficiency ESPs along with bag filters in pellet plant to limit dust to < 10
f. mg/nm3
g. Switching over from highly polluting sinter plants (SP-6) to pellet plant.

The standards stipulated as per GSR GS.R.277(E), dated March 2012, are as follows:

(a). Effluent Standards

Parameter	Standard
	Limiting concentration in mg/l, except for pH
pH	**6.0 – 8.50**
Suspended solids (mg/l)	**100**
Oil and grease	**10**

(b). Emission Standards

Particulate matter (mg/Nm^3)	**150**

The conventional air pollution systems like DE systems of sinter stock house based on electrostatic precipitator (ESP) and waste flue gas cleaning by ESP should be considered. The particulate dust emission from the product sinter screening units should be controlled by DE systems complete with duct, fabric filters and stack of adequate height. High-performance bag filters should also be provided in all sinter plants. Further, low NO_X burner should be used.

Emission reduction via MEROS (Maximum Emission Reduction of Sintering):

The maximum emission reduction of sintering is a latest technology that can be implemented to reduce emissions from sintering operations.

The off gases that are produced in the sinter plant have lime content as a result of which the gases have high resistivity, and they therefore reduce effectiveness of ESPs for dust control. Now, MEROS has been a game-changing development in the industry of iron and steel. It has unlocked the opportunity to reduce outlet emissions by significant margins with the provision of a gas conditioning tower and high temperature from 140 degree Celsius to 100 degrees Celsius before passing through a pulse jet bag filter equipped with high performance fabrics. This also results in condensation of dioxins and furans, which is removed along with the collected particulates from the bag filter. There is additional provision for Sodium bicarbonate/ Lime injection into gas stream (after ESP) can also accelerate SO_2 removal upto 60% to 70%.

There are two procedures to convert ore into iron: Blast furnace and Direct Reduced Iron

c. Blast Furnace

The blast furnace is primarily used in the carbothermic reduction of oxides, such as iron, zinc and lead. All these heavy metal emissions can contaminate the environment, and can have toxic effects on the health of a human being. Accordingly, requisite actions need to be taken to mitigate its impact on the ecological balance, such as encouraging recycling of steel scrap, fugitive dust emissions should be minimized in the stockpiles, and further more investments should be made into R&D of advanced technologies like the Direct reduced iron procedure, which is more eco-friendly than the traditional blast furnaces, in terms of the emissions released into the atmosphere.

The standards stipulated as per GSR GS.R.277(E), dated March 2012, are as follows:

(a). Effluent Standards

	Limiting concentration in mg/l, except for pH
pH	**6.0 – 8.50**
Suspended solids (mg/l)	**50**

Oil and grease (mg/l)	10
Cyanide (mg/l)	0.2
Ammoniacal Nitrogen, as $NH_3 - N$ (mg/l)	50

(b). Emission standards

<table>
<tr><th colspan="2">Parameter</th><th colspan="2">Standard</th></tr>
<tr><td colspan="4">(i) Stack Emissions</td></tr>
<tr><td colspan="2"></td><td>Existing Units</td><td>New Units</td></tr>
<tr><td colspan="4">BF Stove</td></tr>
<tr><td colspan="2">Particular matter (mg/Nm³)</td><td>50</td><td>30</td></tr>
<tr><td colspan="2">SO_2 (mg/Nm^3)</td><td>250</td><td>200</td></tr>
<tr><td colspan="2">NO_X (mg/Nm^3)</td><td>150</td><td>150</td></tr>
<tr><td colspan="2">CO (vol/vol)</td><td>1% (max)</td><td>1% (max)</td></tr>
<tr><td colspan="4">(iii) Space Dedusting / Other stacks of BF area</td></tr>
<tr><td colspan="2">Particular matter (mg/Nm^3)</td><td>100</td><td>50</td></tr>
<tr><td colspan="4">(iv) Fugitive Emission</td></tr>
<tr><td colspan="2"></td><td>Existing Units</td><td>New Units</td></tr>
<tr><td colspan="2">Particular Matter (Size less than 10 microns) PM_{10}</td><td>4000</td><td>3000</td></tr>
<tr><td colspan="2">SO_2</td><td>200</td><td>150</td></tr>
<tr><td colspan="2">NO_x</td><td>150</td><td>120</td></tr>
<tr><td rowspan="2">Carbon Monoxide</td><td>8 hours</td><td>5000</td><td>5000</td></tr>
<tr><td>1 hour</td><td>10,000</td><td>10,000</td></tr>
<tr><td colspan="2">Lead, as Pb in fugitive dust at Cast House</td><td>2</td><td>2</td></tr>
</table>

Other main sources of air pollution are **stock house** and **cast house**.

The BF stock house should be provided with DE systems complete with dust extraction hoods, ESP/ Bag Filter, ID fan and stack of adequate height. Similarly, the cast houses should have separate fume collection system during tapping of hot metal and slag, and it should be equipped with FE systems along with bag filter/ESP for separation of particulates before venting through a stack of appropriate height. The ESPs are designed for <30 mg/Nm^3. A TRT of 27 MW should be installed for waste energy recovery. Heat recovery from stove waste gas should also be installed for preheating of BF Gas and combustion air for stoves.

d. <u>Direct Reduced Iron</u>

i. The flue gas coming out from the rotary kiln should be passed through a dust settling chamber, in which the heavier dust is settled down. The bottom of the dust settling chamber should then be immersed in the wet scrapper water which works as the sealing to avoid the gas leakage and false air entry.

ii. Then the gas should pass through the After Burning Chamber (A.B.C.) in which the carbon monoxide and un-burnt carbon are burnt completely and converted into CO2.

iii. The flue gas should be taken to the Waste Heat Recovery Boiler (WHRB), where the recoverable heat is utilized for generation of high-pressure steam.

iv. The flue gas should next be passed through an electrostatic precipitator (ESP), where the particulate matter concentration is reduced to less than 100 mg/Nm3.

v. Control of SO_2 should also be achieved by provision of adequate height to the stack. The heights of the stacks should be determined by estimated ‘S’ contents in coal and CPCB guideline. Sulphur from coal should be absorbed by the limestone upto 90-95%.

<u>There are three methods for Steelmaking: Electric Arc Furnace (EAF), Induction Furnace (IF), and Blast Oxygen Furnace (BOF)</u>

e. Electric Arc Furnace

Electric arc is generated between electrodes which heats the metallic charge. In both furnaces, the melted contents separate into liquid metal and slag. The slag is removed and considered as waste. The liquid metal is sent to the continuous casting machine (CCM) where semi-finished product is made. The electric arc furnace (EAF) is thus particularly well suited to the production of the full range of alloy steel grades.

Emission Standards

Parameter	Standards
Particulate matter (mg/Nm^3)	150

f. Induction Furnace

Induction furnace works on the principle of induction melting of scrap/ sponge iron with the help of electric power. An alternating electromagnetic field induces eddy current in the metal so that the electrical energy converts into heat, whose quantity depends on the resistivity of the charge. Induction furnaces operate on current of commercial frequencies (50Hz) or on current of higher frequencies from 500 to 2000 Hz. These furnaces are beneficial in steel making for low melting loss.

To minimize the consumption of electric power and cut down the melting period, the crucible wall must be as thin as possible. The inside of crucible lining is in contact with liquid metal while it's outside surface contacts the water-cooled induction.

Emission Standards

Parameter	Standards
Particulate matter (mg/Nm^3)	150

g. Basic Oxygen Furnace (BOF)

Since it involves removal of oxides from iron oxide, carbon dioxide is also produced among other gases, which can again have hazardous effects on the environmental well-being. The high temperature combustion processes also release toxic gases like carbon monoxide and sulphur dioxide, which contribute to acid rain and several respiratory problems. For the treatment of these polluting gases separate systems like scrubbers, electrostatic precipitators and filters need to be installed. These emissions would be generated mainly from charging and tapping operations, and so they should be controlled by providing separate bag filters for individual converters.

The standards stipulated as per GSR GS.R.277(E), dated March 2012, are as follows:

(a) Effluent Standards

Parameter	Standard
pH (mg/l)	**6.0 – 8.5**
Suspended solids (mg/l)	**100**
Oil and grease (mg/l)	**10**

(b) Emission Standards

Parameter		Standard	
(i) Stack Emissions			
		Existing Units	**New Units**
Converters			
Particular Matter (mg/Nm^3)	**Blowing/Lancing operation**	**300**	**Should be with gas recovery**
	Normal operation	**150**	**Should be with gas recovery**
Secondary Emission Stack: De-dusting of desulphurization, Secondary refining etc.			

Particulate matter (mg/Nm^3)		**100**	**50**
(ii) Fugitive Emissions			
		Existing Units	**New Units**
Particulate Matter (mg/Nm^3)		**4000**	**3000**
SO_2		**200**	**150**
NO_x		**150**	**150**
Carbon Monoxide	**8 hours**	**5000**	**5000**
	1 hour	**10,000**	**10,000**
Lead, as Pb in fugitive dust at Cast House		**2**	**2**

h. Pellet Plant

Emissions from Pellet Plant would be from Induration Process, central plant dedusting area, and waste flue gas. The emissions should be controlled by installation of Bag Filter / ESP with adequate height of chimneys. High efficiency ESP along with bag filters should be provided in the proposed unit to limit the PM concentration in outlet flue gas to <10 mg/Nm3.

i. Ladle furnace

The primary emissions of LF should be collected by fume extraction (FE) devices. Dust laden fumes should be indirectly cooled and cleaned through a bag filter for separation of particulates, and the clean gas should be vented into the atmosphere through a tall stack of adequate height. The secondary emissions should be controlled through canopy hood extraction, which should further be integrated with the main system to clean the fugitive emissions during charging and tapping operations. The gas cleaning system should be complete with water cooled duct, fume and gas cooler, bag house, ID fan and stack of appropriate height.

j. Caster area

The water required for cooling the hot cast slabs and billets should generate hot fumes comprising mainly water vapor, hot waste water and suspended particulates. The slab casting area should be provided with adequate ventilation in order to have the water vapor properly dispersed.

k. Rolling Mills

The process of rolling mills again release harmful emissions into the air, especially NO_X and SO_X, dust emissions from product handling, rolling or mechanical surface treatment, oil and solid containing effluents, and oil containing wastes.

(a). Effluent Standards

Parameter	Standard
pH	6.0 – 9.0
Suspended solids (mg/l)	100
Oil and grease (mg/l)	10

(b). Emission Standards

Parameter	Standard	
Particulate matter (mg/Nm^3)	150	
Re- Heating (Reverberatory) Furnaces		
	Sensitive Area	Other Area
Particulate matter (mg/Nm^3)	150	250

Burning of the by-product flue gases in reheating furnace would give rise to the emissions of particulates, SO2 and NOx. Therefore, NOx emissions should be controlled by optimizing the excess air supply and installing low NOx burners. In addition, fume extraction (FE) system should be installed. The flue gas, which is clean, should be vented through a stack of adequate height after heat recovery.

l. <u>Fugitive dust control on all roads</u>

Water sprinklers, dry fog system at coal transfer points, wind curtains of about 3.5 km length should be provided for coal yard to control fugitive emissions. Raw Material should be transported by covered trucks and covered rakes. Regular road sweeping should be carried out through machine. In addition, thick green belt should also be planned along roads. Dust extraction systems should be provided at blast furnace, basic oxygen furnace and bag filter at lime & dolomite plant.

m. <u>Raw material handling</u>

Fugitive dust emissions generating from the handling and stockpiling of raw material in open stockyards should be controlled by water sprinkling at regular intervals. All closed zone working areas such as raw materials handling zone, conveyor transfer points, dust generation points at screens should be provided with dust extraction (DE) systems/dry fogging (DF) at several emission points to control the fugitive dust emissions. DE system should consist of suction hood followed by bag filter / ESP, ducts, extraction fans and stack of appropriate height.

3.3 Noise Pollution

The continuous noise can arise from the operation of pumps, compressors, exhausters, blowers, fans, and mill machineries. Intermittent noise would arise from the steam ejection and impacts due to metal to metal contact, during handling of scraps and finished metal products.

In order to mitigate the continuous noise within the working area, measures like selection of low noise prone rotary equipment and vibration dampening should be one of the plant design aspects. In addition, noisy equipment should be housed separately with adequate enclosures for noise reduction. Operational people should run those noise prone machines from the sound proof control room/cabins. Steam ejectors should be provided with silencers. With all these mitigation measures, it should be planned to have a work zone noise level of Leq for continuous 8 hours duration within 85 dB (A), if measured at 3m distance from the noise source.

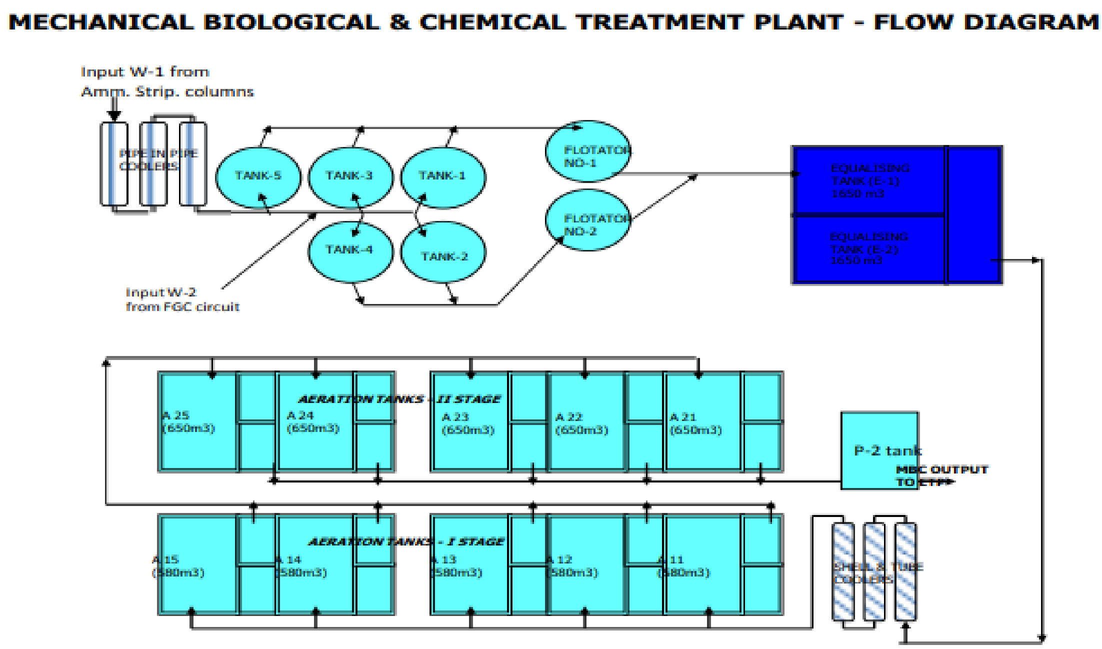
3.4 Water Pollution

Iron and Steel plants use a large amount of water for a variety of usage which includes cooling, dust suppression, cleaning, temperature control (heat treatment), transport of waste materials (ash, sludge, and scale etc.), and other usages. Water is an essential part of some processes such as moisture content of coking coal, pelletizing of sinter mix, making of green pellets during the production of iron ore pellets, production of steam and hence power, and granulation of blast furnace slag etc.

Use of large amount of water also generates huge quantities of waste water which contain suspended solids and many dissolved substances and chemicals. The quality of waste water depends on the process where the water is used and for the purpose for which it is used. Waste water from iron and steel works, where smelting of pig iron in blast furnaces and of steel in open hearth furnaces, Bessmer converters, etc. takes place, contains a considerable amount of oil, dust, acid, iron and other metals. The main sources of waste are from the purification of blast furnace gas, crushing of slags, cooling of bearing and shafts of rollers and final cooling of pig iron. Blast furnace gas is treated by water spraying to remove dust and that waste water contains cyanides, Sulphur compounds, phenol, dust, metal ions, ash, slag and ore particles. Rolling mills produce waste water during the cooling of bearings 3 and shafts. In the final cooling of pig iron and melting pots, the basic impurities in the waste water are scales, lime and other additives. Further, the waste water from pickling of ferrous metal contains sulphuric or hydrochloric acid.

When this untreated water is discharged into the, it can be detrimental to the aquatic life as it contains toxic substances like phenol, cyanides, thio-cyanades, and ammonical nitrogen all of which lead to depletion of dissolved oxygen, high chemical oxygen demand (COD level), silting due to suspended oils, formation of oil slicks, and temperature rise among other. They therefore affect aquatic life.

Mechanical Biological and Chemical (MBC) Treatment Plant is a treatment unit which is considered to be efficient in removing many impurities from the waste water.



MBC flow Diagram

Collection of Wastewater

The treatment begins with the collection of the wastewater it pumped into the pre-aerators (distribution tanks) and cooled from 90 degree Celsius to 50 degree Celsius – 55 degree Celsius with the help of recirculating pipe. Further BDS effluent is added to it, and this mixed affluent is distributed in equal positions in tar settling tanks by gravity where our next step of tar removal is carried out.

Tar Removal

In this, five numbers of mild steel fabricated circular tar settling tanks of size 230cm are installed. These are provided for removing tar and oil from the effluent, wherein the oil keeps floating on the surface while the tar settles down in the conical bottom, which is then pumped into the tar collecting tank. We then move onto the oil removal stage.

Oil Removal

Two MS air flotation tanks of size 270 cum each are installed. The over flow from the tar settling tanks is collected in vertical steel tanks named phenolic water collecting tanks from where it is pumped to the oil floatation tank No.1 through pressurised head tank No.1. Then air (5% by volume of water) is injected into the delivery line of the pumps before it is pumped to the pressure tank. In the flotation tank, air bubbles through the water as the water is de-pressurised and the oil is entrained by air bubbles which floats at the water surface. The entrained oil is skimmed with oil skimmer mechanism of floatation tank and is collected through the oil discharge through to a tank. Tar and oil from the collecting tanks are finally pumped to tar acid utilization plant.

Equalization Tank

After removal of tar and oil the effluent is collected in equalization tank. Equalization tank is an RCC tank with two chambers each of 1650 cum capacity. Each chamber has one over flow tank. In equalization tank phenolic effluent is thoroughly equalized with the help of air. Ortho-phosphoric acid is added to the overflow of equalization tank as nutrient for the bacteria. 73% strong ortho-phosphoric acid is added at the rate of 20 g/cum of effluent.

Biological Treatment (1st stage)

In the 1st stage of purification, purification is done with the help of phenol destructive bacteria. Five numbers of RCC aeration tanks are provided. Each aeration tank is a comprehensive treatment unit within built sludge settling and sludge regeneration chambers. To maintain the vital activity of bacteria compressed air from the air blower is supplied to the aeration tanks. The over flow from each tank first goes to the settling chamber where sludge gets settled down and the supernatant water over flows to the 1st stage purified water collecting tank (P-1) of 90 cum capacity. The settled sludge then flows to the attached regeneration tank from where it is recycled back to the aeration tank with the help of air lifting pump. Phenol degradation is takes place with the help of phenol destructing bacteria of activated sludge process.

Biological Treatment (2nd stage)

After degradation of phenol at 1st stage purification water from P-1 tank is pumped into aeration tanks of 2nd stage purification. In the 2nd stage purification, Rhodanides and cyanides are destroyed with the help of Rhodanide destructive bacteria. In second stage also five numbers RCC aeration tanks (650 cum capacity each) are provided. The construction and activity in 2nd stage is like 1st stage aeration tanks. Treated effluent from 2nd stage aeration tanks is collected by gravity into two RCC tanks (P-2) of size 90 cum each. The treated effluent is then pumped to effluent treatment plant for further treatment along with plant fecal sewage water and to Sludge treatment plant of C&CCD for using in the dust extraction systems.

Sludge Drying Beds

RCC sludge drying bed with three compartments is provided with a facility to take back excess water. The sludge from any aeration tank and equalizing tank can be pumped to these beds. The dried sludge is taken out and recycled in coke oven batteries by adding it to the charging coal.

3.5 Hazardous Waste

The production operations of iron and steel industry generate significant amounts of wastes, some of which pose serious health risks for the public, and therefore demand appropriate disposal management. Almost all these wastes can be reused or reutilized either within the facilities itself or some other units. The Ministry of Environment, Forest and Climate Change, Government of India has specified a list of hazardous waste generated from the iron and steel plants that necessarily need to be managed properly at the time of disposal. This is published in the gazette of India, extraordinary, part ii, section 3, sub-section (i) in Schedule 1, point (13): Production of iron and steel including other ferrous alloys (electric furnace; steel rolling and finishing mills; Coke oven and by products plant) –

13.1 Spent pickling liquor

13.2 Sludge from acid recovery unit

13.3 Benzol acid sludge

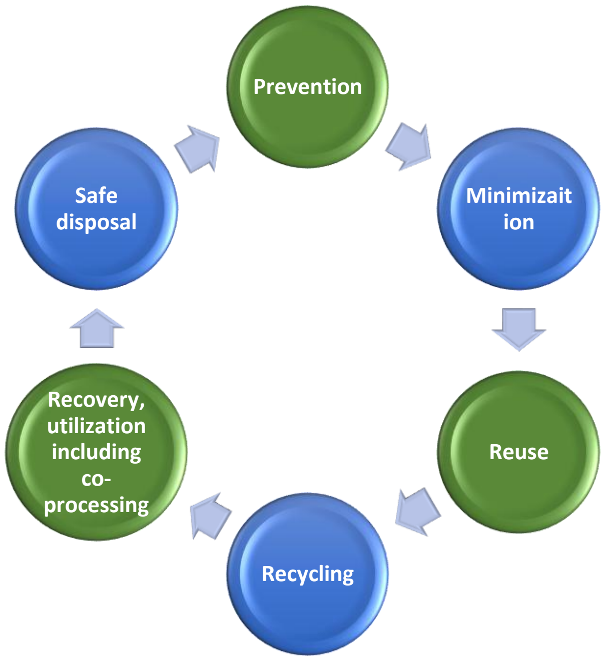
13.4 Decanter tank tar sludge

13.5 Tar storage tank residue

13.6 Residues from coke oven by product plant.

In the same notification, the government has mentioned some indispensable mandates regarding the procedure for management for hazardous and other wastes.

The rule no. 4 says that for the management of hazardous and other wastes, an occupier shall follow the following steps:



It says that the occupier is responsible for installing an environmentally sound and safe management of hazardous wastes and other wastes. The hazardous and other wastes generated in the establishment of an occupier shall be sent or sold to an authorized actual user or shall be disposed of in an authorized disposal facility. And the transportation of the toxic wastes from the facility to the user must be done in accordance with the green practices mentioned.

2) Further, it gives a directive on getting the grant of authorization for managing the hazardous wastes. It says that every occupier of the facility who is engaged in handling, generation, collection, storage, packaging, transportation, use, treatment, processing, recycling, recovery, pre-processing, co-processing, utilization, offering for sale, transfer or disposal of the hazardous and other wastes should be required to make an application in Form 1 to the State Pollution Control Board and obtain an authorization from them.

3) It also punctuates the responsibility of the treatment, storage and disposal facility for hazardous and other wastes. It states that the State Government, occupier, operator of a facility or any association of occupiers shall individually or jointly or severally be responsible for identification of sites for establishing the facility for treatment, storage and disposal of the hazardous and other waste in the State.

Generation and Action plan for 100% utilization or disposal of non-hazardous solid wastes

Source of Generation	Hazardous Waste	Action Plan for Disposal or Utilization
By product plant of Coke Ovens	Acidic tar sludge	Should be disposed in Captive secured land fill
	Spent vanadium pentoxide	Should be disposed in captive secured land fill (SLF)
	Sulphur sludge	Should be disposed in captive SLF
	Decanter tar sludge	Should be partly charged in Coke oven & partly disposed in SLF
	Tar muck with sand etc.	Should be disposed in captive SLF
Mills area	Oil & grease muck	Should be disposed in captive SLF. Also, should be used in proposed Incinerator (BOO)

Coke oven area	Asbestos Rope	Should be disposed in captive SLF
DNW	Transfer oil	Should be sold to authorized buyer
Oil regeneration unit	Oil Sludge from oil regeneration unit	Should be disposed in captive SLF. Also, should be used in proposed Incinerator (BOO)
HDGC/CRM	Zinc dross	Should be sold to authorized buyer
	Zinc ash	Should be sold to authorized buyer
Mills/Iron zone/OG/Traffic	Used batteries	Should be sold to authorized buyer
BOD plant of COBPP	ETP sludge	Should be charged in Coke Oven batteries
Submerged Arc Furnace (SAF)	Dust from SAF (Submerged Arc Furnace)	Should be disposed off in landfilling
Induction Furnace	Slag from IF	Should be sold to Authorized vendor
Induction Furnace	Dust from IF	Should be used in road construction
SAF	Slag from SAF	Should be used within the facility
Wind box exhaust ESP	Dust collected from APC treatment	Should be converted to slurry and reused in thicker

Hearth layer Bin scrubber	Dust collected from APC	Should be converted to slurry and reused in thicker
Hearth layer separation scrubber	Dust collected from APC	Should be converted to slurry and reused in thicker
Mixture bag filter	Dust collected from APC	Should be conveyed through pneumatic to respective bin
Lime/ Anthracite coal bag filter	Dust collected from APC	Should be pneumatically transported to respective bin
Dust collected from APC	Others	Should be converted to slurry and reused in thicker
Blast Furnace (BF)	BF slag	Can be 100% utilized in SGP and in cement making
Blast Oxygen Furnace (BOF)	BOF slag	~80% can be reused in sinter plant/SMS, and used to make bricks by combining with Fly ash/road making and rest sold
Rolling Mill	Mill Scale	100% can be reused in sinter plant
Furnaces	Waste Refractory	100% can be used for Refractory / mortar production
Blast Furnace	Ferric Oxide	100% can be sold as scrap

ESP	ESP (RMP) dust	100% can be reused in sinter plant
BF	BF sludge	Can be sold in secondary market
BOF	BOF sludge	Can be sold in secondary market
Coke Breeze	Coke Breeze	100% can be reused in sinter plant
BF	BF Flue Dust	100% can be reused in sinter plant
**Calculated based on existing generation rates as sourced from Annual Statistics of Bokaro Steel Plant, 2017-18* ***Based on existing utilization schemes and practice at Bokaro steel plant*		

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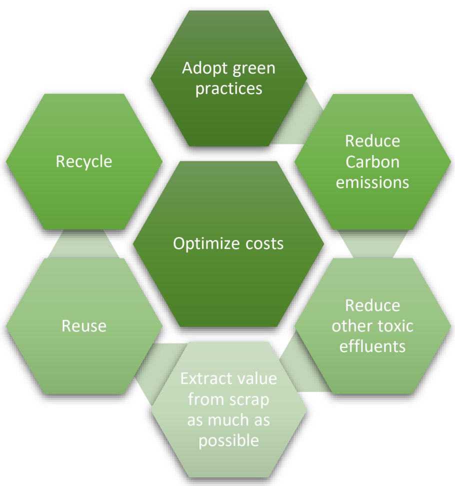
Chapter 4: Success Stories

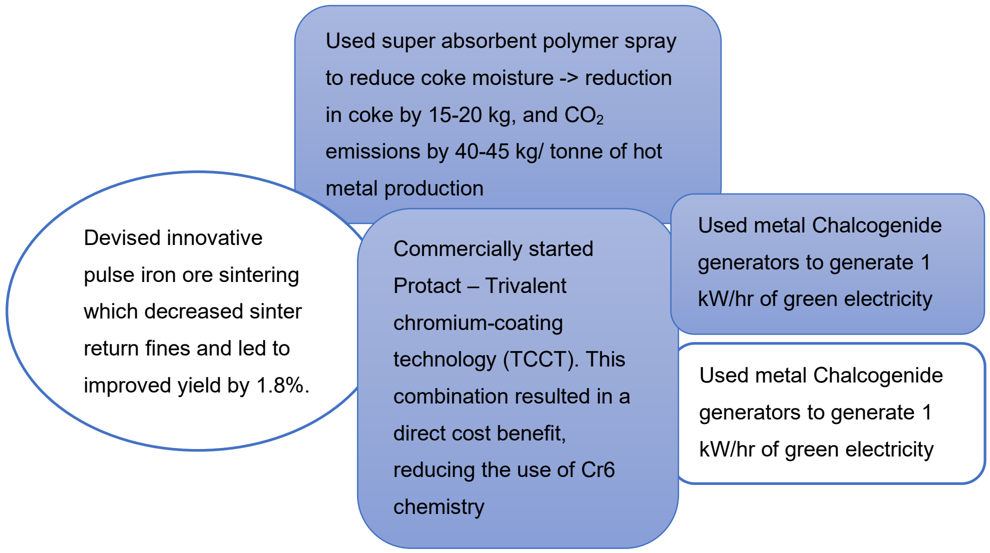
In the recent years, the shift to a low carbon economy is becoming increasingly fast-paced as the newfound awareness of the devastating impact on the environment grapples the planet earth, and the climate change doesn't cease to show its fury. Industries around the world are acknowledging their significant contribution in releasing greenhouse gases and various other toxic emissions and effluents into the nature, adding to the carbon footprint on the ecological system. Iron and steel industries are also reciprocating to the urgent transition to adopting sustainable practices and are therefore embracing innovative methods and technologies to reduce the impact of the production activities on the ecosystem. This chapter intends to present examples of some of the leading steel producers of the country that are abiding by the following principles.



Tata Steel

The company has been actively engaged in using sustainable business practices and formulating ecologically responsible strategies while scaling up new heights in the industry. It had already recognized its environmental stewardship as a core to its purpose long ago and has since been implementing a series of measures to curtail its carbon footprint. They continuously seek innovative ways for this transition, through continuous experimentation, and investments in research, technological innovations, and partnerships. Adoption of Direct Reduced Iron (DRI) using green hydrogen, injection of hydrogen in blast furnaces, carbon capture & utilization technologies, and use of alternate low-carbon fuels, such as biomass, are some of the key areas in their approach.

Specific initiatives intended to reduce environmental impact taken by them, and their outcomes:

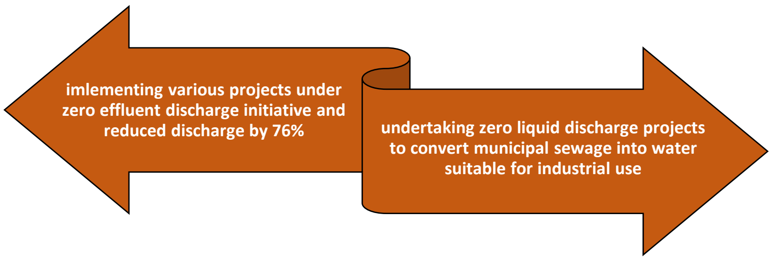


1. Made thorough improvements in one of their washeries by improving concentrate thickener operation by new design feed well. This has led to improved resource efficiency through higher fine clean coal yield.
2. Deployed High-Turbulence Roll Cooling in Hot Strip Mill. The advantage of using HTRC is that 2 of the 3 high-pressure pumps which are needed for the high-pressure conventional spray cooling, are now redundant. The average, monthly electricity consumption of the pumps dropped from ~2,600 MWh to ~900 MWh.
3. Increased slab temperature at the Direct Sheet Plant. New spray water cooling patterns were introduced, reducing the cooling intensity in small steps to increase the slab temperature at the tunnel furnace entrance, so that less reheating is needed. Successful trials in FY2022-23 have already saved 17,000 m^3 of natural gas. Potential savings of up to 1.5 million m^3 per annum are foreseen when introducing further reduction of spray cooling.

Measures taken towards controlling water discharge and pollution caused.

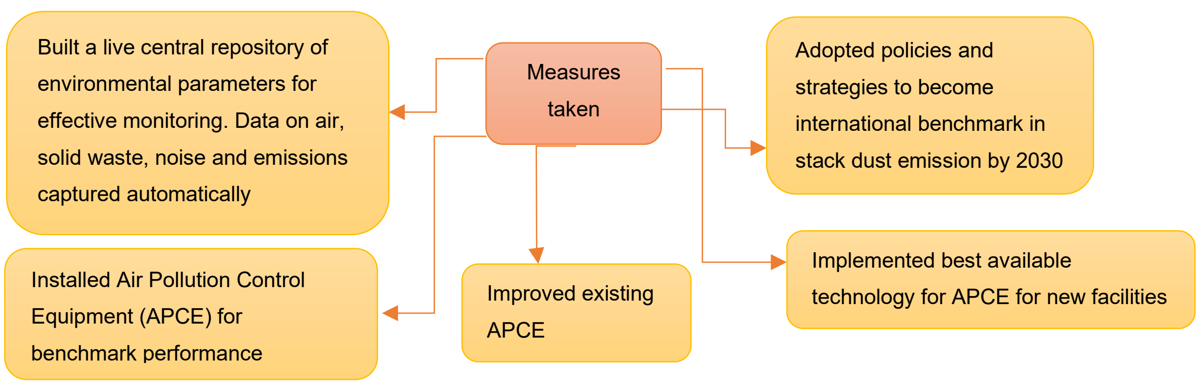
Tata Steel is in the process of putting in place a system for achieving zero liquid discharge at all its locations in India. The Company's objective is to attain a state of zero effluent discharge at all its Indian steel production facilities by FY2024-25. At all of Tata Steel's facilities, proactive measures are being implemented to mitigate the potential contamination of local water sources and to attain a goal of zero effluent discharge.

In line with Tata Steel's commitment towards
water risk mitigation, Tata Steel has enhanced its sustainability efforts by

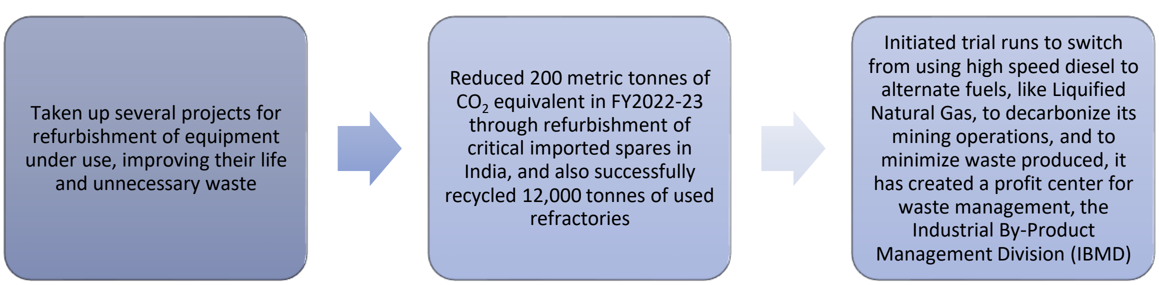


Measures taken towards controlling air emissions

The company unceasingly works towards reducing the negative impact of its operations on the quality of air through maintenance and upgradation of its Air Pollution Control Equipment. It's continuous efforts for reducing stack emission load have resulted in significant reduction in the dust emission intensity across all its operating units in India.



Sustainability measures taken towards waste management by the company, and its achievements:



Initiatives that are currently in progress:

1. It is deploying the Roadmap+ scheme to minimize the short-term impact of dust, noise, odor and NOx emission in the Netherlands. Its key initiatives include an environmental installation at the Pellet Plant, to reduce NOx emission by more than 80% from the current levels, is scheduled to be completed in 2025. It is also constructing a dedusting facility at the Pellet Plant with a planned completion in 2023, which will result in reduction of emissions by 70%.
2. In April 2022, the Company commissioned several new slag pits with a mobile covering to reduce dust, which is expected to reduce dust emissions by approximately 80%
3. It has committed to be Net Zero emission by 2045. This strategy includes producing steel through recycling of scrap, the use of hydrogen to produce steel using the Direct Reduced Iron Route and pilots of new technologies such as the carbon capture and utilization, the use of hydrogen in blast furnaces and the HIsarna technology.
4. To reduce its dependence on fossil fuel, it is partnering with Tata Power Renewable Energy Limited to set up c.950 MW solar & wind hybrid renewable power capacity under captive arrangement. This will cater to 379 MW of Tata Steel and its subsidiaries power requirements with 70% load factor and enable reduction of over 2 million tonnes of CO2 per annum.
5. It has set up a Benchmarking Energy Efficiency IMPACT Centre under its Shikhar25 improvement program, which has enabled Tata Steel's Jamshedpur plant to become the Indian Benchmark on Energy Performance. Its objective is to drive energy efficiency campaign across the Company, ensuring rigor, visibility, ownership, and wider involvement on Tata Steel's employees and all stakeholders.

Chapter 5: Towards Net Zero Carbon

Achieving net zero carbon in iron and steel industry is a critical aspect of the broader goals to combat climate change, and the transition to a sustainable and low-carbon economy. The industry has significant contribution in the global greenhouse gas emissions, and therefore by taking proactive measures it can reduce its carbon footprint and can potentially cause the climate change to subside eventually. India is currently the 2nd largest steel producer in the world after China. The country produced about 88 million tonnes of crude steel in 2014-15 against a capacity of around 108 MT.

The Indian iron and steel industry is primarily based on the processing of virgin materials like iron ore, coal, etc. and is hence an energy-intensive sector, responsible for about 10% of the total CO2 emissions in India. Production of iron largely through the blast furnace and coal-based DR route, combined with low availability of scrap in India, make the Indian steel industry a coal-intensive sector. In the traditional steelmaking process, iron ore is smelted in a blast furnace with coke which is a carbon rich material derived from coal, and alongside large amounts of carbon dioxide, other greenhouse gases and air pollutants are generated. Consequently, the iron and steel industry has been a major contributor to climate change, with a significant impact on global warming, air quality, and overall environmental degradation. Such conventional methods of processing iron and producing steel make it imperative for the country to strive for advancements in technology, make changes in industry practices, and work towards achieving a net zero carbon status.

Indian steel industry is quite fragmented wherein steel companies adopt a diversified process routes for production of iron/steel. While iron is produced in Blast Furnace (BF), Corex Furnace, Gas based DRI & Coal based DRI plants, steel is produced adopting Basic Oxygen Furnace (BOF)/LD Converter, Electric Arc Furnace (EAF) & Induction Furnace (IF) process routes. Presently, proportion of BOF, EAF & IF steel making routes is roughly 45%, 23% & 32% respectively. Further, besides the large integrated steel plants, there are stand-alone DRI/sponge iron units, stand-alone mini steel plants alone EAF/IF, steel re-rolling mills (SRRM), Cold Rolling Mills and Coating Units.

Going by the energy efficiency and GHG emission, gas based DRI-EAF route is considered the best with minimum energy consumption and GH emission, while the coal based DRI-EAF/IF route is considered most energy intensive with highest GHG emission. However, production of gas based DRI has been diminishing over the years for non-availability of natural gas leading to very limited production of steel through the gas based DRI-EAF route. Secondly, the technology profile of the gas based DRI and EAF based plants is world class adopting most of the energy efficient clean and green technologies.

5.1 Integrated Steel Plants

India is home to 12 integrated steel plants, each having the capacity in the range of 2-10 million tonnes per annum. While three plants adopt steel producing EAF technology, others adopt BOF technology. These plants play a crucial role in the country's industrial and economic development. Some prominent integrated steel plants in India include Tata Steel at Jamshedpur, Steel Authority of India Limited (SAIL) plants in Bhilai, Rourkela, and Bokaro, JSW Steel plant in Vijayanagar, Essar Steel Plant in Hazira, among others. The steel industry, driven by integrated steel plants, is a significant contributor to India's Gross Domestic Product (GDP). These plants are massive industrial facilities with significant production capacities, and they even utilize resources efficiently, and are therefore critical components of India's industrial landscape, supporting infrastructure development, manufacturing, and driving growth in various other sectors.

Limitations of the Integrated Steel Plants

- The energy consumption and GHG emission per tonne of crude steel in these plants is much higher when compared with the benchmark plants abroad. Specific energy consumption in Indian plants varies in the range of 6.5-6.8 Gcal/tcs as compared to international benchmark of around 5 Gcal/tcs.
- GHG emission in Indian plants varies in the range of 2.43-3.2 Tonnes/tcs (BF-BOF: 2.43-3.0 & Coal DRI-EAF/IF: 3.0-3.2)) which is almost 1.5 times the international benchmark of 1.8 Tonnes/tcs.
- The higher consumption/emission norms are mainly because of obsolescence in iron and steel making technology in most of the older plants, limited adoption of technologies for harnessing waste heat/energy and constraints in the quality of raw material particularly, high alumina content in Indian iron ore and high ash content in Indian coking coal.

The steel industry needs to evolve well within the defined time bound action plans and strategies for renovation, and phasing out of old /obsolete technologies/facilities, as well as beneficiation of iron ore/coal to address all the bottlenecks.

5.1.2 Current scenario of Energy Efficiency Technologies & Investment requirements in the country

Developed countries have been at the forefront of adopting energy-efficient technologies in the iron and steel industry as part of their efforts to reduce carbon emissions and enhance sustainability. These technologies focus on optimizing resource utilization, minimizing waste, and reducing greenhouse gas emissions. Advanced economies like Japan, Europe have developed and adopted a large number of clean and green technologies for harnessing waste heat/energy. These technologies are very costly and the required average investment per unit is roughly estimated at around Rs 3000-3500 crores. Moreover, such technologies are not available in the country and have to be imported, that too subject to availability of fund.

Even though the implementation of such cutting-edge technologies comes with the substantial investment requirements, the long-term benefits of reduced energy consumption, lower operational expenses, and improved environmental performance makes these investments extremely attractive for industries striving to create a more sustainable future.

A detailed list of such technologies as available in the Technology Customized List (prepared jointly by Indian steel industry /MoS and Japanese steel companies/METI) is as follows:

Recommended List of Energy Saving Technologies in Integrated Steel Plants

S. No.	Title of Technology	Effect of Eco-conscious technologies on operational efficiency of the plants		
		Electricity Savings (kWh/t of product)	**Fuel Savings (GJ/t of Product)**	**CO_2 Reduction (Kg/t of Product)**
Sintering				
1.	Sinter Plant Heat Recovery (Steam Recovery from Sinter Cooler Waste Heat)	-	0.251/t-sinter	23.9/t-sinter
2.	Sinter Plant Heat Recovery (Power Generation from Sinter Cooler Waste)	22.1 kWt/t-sinter	-	19.9/t-sinter
3.	High Efficient (COG) Burner in Ignition Furnace for Sinter Plant	-	0.011/t-sinter	0.50/t-sinter
Coke making				

4.	Coke Dry Quenching (CDQ)	-	1.9/t-coke	135/t-coke
		150kWh/t-coke	-	74.9/t-coke
5.	Coal Moisture Control (CMC)	-	0.3/t-coke	27.6/t-coke
Iron making				
6.	Top Pressure Recovery Turbine (TRT)	50 kWh/t-pig iron	-	45.0/t-pig iron
7.	Pulverized Coal Injection (PCI) System	-	1.55/t-pig iron (at 125kg coal injection)	147/t-pig iron
8.	Hot Stove Waste Heat Recovery	-	0.08/t pig iron	7.8/t-pig iron
Steel making				
9.	Converter Gas Recovery Device	-	0.84/t-steel	79.8/t-steel
10.	Converter Gas Sensible Heat Recovery Device	-	0.126/t-steel	12.0/t-steel
11.	Ecological and Economical Arc Furnace	150 kWh/t-steel	-	135/t-steel
12.	Waste Heat Recovery from Electric Arc Furnace	87.7 kWh/t-steel	-	78.9/t-steel
Common System				
13.	Regenerative Burner Total System for reheating furnace	-	0.17 – 0.21/t-billet	16.2 – 20.0/t-billet
General Energy Savings & Environmental Measures				
14.	Energy monitoring and management system	-	0.12/t-steel	11.4/t-steel
15.	Cogeneration (including gas turbine combined cycle (GTCC))	47.5% (HHV)	*	56.1/t-steel

5.2 Best practices to reduce GHG and Carbon emissions

The iron and steel industry has been associated with carbon emissions since time immemorial, posing considerable challenges in the fight against global warming and climate change. At this point in time, there's an alarming need to adopt best practices that optimize the production operations, enhance resource utilization, and minimize GHG emissions, all of which together can significantly reduce the industry's carbon footprint. Achieving net zero carbon is a long-term goal that requires sustained efforts, and the best practices are designed to provide a structured and systematic approach, enabling companies to maintain their commitment to reducing carbon emissions over time.

<u>Following are the Energy Conservation options that have been identified/ implemented by the units so as to reduce the carbon emissions:</u>

1) Generate Electrical Power from Waste Gas of DRI Kiln

In the sample sponge, iron production produces Sponge Iron through Direct Reduced Iron (DRI) process, and has a kiln with production capacity of 350 TPD, flue gases of about 90,000 Nm3 /hr at 950 degrees to 11000 degrees Celsius are generated. The volume of the flue gases depends on the production of the DRI kiln. Under normal process operations, this heat is lost to the atmosphere as the gases are vented to atmosphere without heat recovery. A Waste Heat Recovery (WHR) based power project can be installed on the new Direct Reduction Iron (DRI) kiln. The project activity is installation of a Waste Heat Recovery Boiler (WHRB) with a steam generation capacity of 38 tons per hour (TPH) by recovery of latent heat from in the flue gases of the DRI kiln. The waste flue gases of sponge iron kiln are passed through WHRB and steam is generated at a pressure of 66 kg/cm2, and temperature of 4900 degrees Celsius. The exhaust gases after heat recovery at 160 degrees Celsius – 180 degrees Celsius are passed through Electrostatic Precipitator (ESP) and released to the atmosphere. The steam produced in WHRB can produce power of about 8 MW, when the DRI kiln is operated at its rated capacity. The plant can also install a 24 TPH rated Atmospheric Fluidized Bed Combustion (AFBC) boiler, where char and coal rejects are used as fuel. Steam generated by both WHRB and AFBC boilers is combined at a common header and supplied to steam turbine generator set of 12 MW for electricity generation which is used for captive consumption. In the absence of the project activity, the flue gases at high temperature would have been released to the atmosphere, which is a common practice in the sponge iron industries, and the equivalent amount of electricity would have been generated by coal-based power plant or imported from grid. Hence, the utilization of waste heat by project activity will reduce carbon emissions.

Requirements for generating Electrical Power from Waste Gas of DRI Kiln		
Parameters	**Unit**	**Value**
Actual Gas Flow rate	Nm^3/Hour	900,000
Temp. of Flue Gas	Degree Celsius	950-1100
Actual Steam Generation	MT/Hr	38
Steam Pressure	Kg/cm^2	66
Steam Temp.	degree Celsius	490
Power Generated	MW	8
Total Energy Generation in One Day	UNITS (Kwh)	192,000
Daily GHG saving (kg CO_2)	Kg CO_2/Day	192,000*.537=103,104
Annual GHG saving	TCO_2/Year*	25776
*Sponge Iron Sector Annual GHG saving (TCO_2) for Total 12 ** Such Plants*	Million TCO_2/Year	0.31
*Note: Total Operating Days in One year are assumed to be 250 days		
**Note: As per CPCB data, there are around 12 such plants with capacity of 100,00 to 120,000 tpa		

2) Use Heat of Kiln Exhaust Gas to Produce Chilled Water for Retrofitting Absorption Chiller

From the available DRI kiln off gas, a part of this kiln exhaust gas can be used to generate steam at 8.00 Kg/cm^2, and this can be used to run absorption chiller, which will meet administrative office as well as plant control room A/c load. In tropical zone, the average temperature during summer months shoots up to above 420 degrees Celsius, and falls in the hot and dry zone for about ten months, causing human discomfort. It is recommended to use DRI kiln off gas partially to generate steam at 8 Kg/cm2 in a waste heat boiler. The steam thus produced will be driving force for absorption chiller replacing the energy consuming air conditioners. The chilled water at 50 degrees Celsius, if circulated through AHUs, will provide desirable comfort without appreciable consumption of electricity. However, the payback period depends on the cost of electricity per unit.

3) Install cogged type Flat Belt for motor Drives

Most of the drives in this sponge iron plant are V-belt drive. The V-belt use trapezoidal cross section to create wedging action on the pulleys to increase friction, and improve the belts power transfer capability. V-belt drive can have peak efficiency of 95-98% at the time of installation. The transmission efficiency drops over time if slippage occurs because V-belts are not periodically tensioned apart from increase in electricity consumption due to higher resistance and frictional losses. Cogged belts have slots that run perpendicular to the belt's length. The slots reduce the interface resistance of the belts without compromising the transmission efficiency, and at the same time reducing the electricity consumption. Cogged belts can be used with the same pulley as equivalent rated V-belts. They run & lasts longer and have an efficiency margin of at least 2% over V-belts.

Install cogged type Flat Belt for motor Drives		
Parameters	**Unit**	**Value**
*Specific Power Consumption	Kwh/Ton	217
**Annual Production	Tonnes/Year	100,000
Annual Power Consumption for Belt Driven Equipments	Units (Kwh)	217×10^5
Power saving by installing Cogged Type Belts	Units/Year	4.34×10^5
Annual GHG saving	TCO_2/Year	233
*Note: Specific Power Consumption as per Section 5.4 of report		
**Note: As per available module sizes Section 5.1 of report		

4) Waste Heat Utilization by Iron Ore preheating in Sponge Iron Plant

Proportionate amount of Iron Ore along with feed coal, and dolomite is fed at ambient temperature to the kiln through a feed pipe. It is recommended to install iron ore pre-heater (rotary drier) to utilize a part of heat content of kiln off gases released during manufacture of sponge iron in rotary kiln. The charge pre-heater will utilize sensible heat content of flue gas released at 9500 degrees Celsius from individual kiln to preheat incoming iron ore from 400 degrees Celsius to 7500 degrees Celsius, thus reducing coal consumption.

Requirements for Utilization of Waste Heat by Iron Ore preheating in Sponge Iron Plant		
Parameters	**Unit**	**Value**

*Specific Iron Ore Requirement	T/Ton	1.65
**Daily Iron Ore feeding rate for 350 TPD capacity Plant	Tonnes/day	1.65 x 350 = 577
**Hourly Iron Ore feeding rate for 350 TPD capacity Plant	T/Hr	24
**Hourly Coal feeding rate for 350 TPD capacity Plant Specific Heat of Iron Ore	T/Hr	23
Specific Heat of Iron Ore	Kcal/Kg/degrees Celsius	0.140
Temp Range Iron Ore required to Heated	Degrees Celsius	750 – 45 =705 degrees Celsius
Total heat energy utilized and required from Kiln Exhaust Gas	Kcal/Hr	$24 \times 10^3 \times 140 \times 705 = 2.36 \times 10^6$
Total Heat supplied by Burning Coal at Existing Rate	Kcal/Hr	23 x 1000 x 4100*** $= 94.3 \times 10^6$
Total quantity of coal saved by Pre-Heating Ore	T/Hr	0.575
Annual Coal savings	T/Year	0.575 x 24 x 250 =3454
Annual GHG Emission Reduction Potential	TCO_2/Year	3454 x 2.6**** =8980
*Note: Specific Iron ore Consumption as per Section 5.4 of report		
**Note: As per available module sizes Section 5.1 of report		
***Note: GCV of Coal is taken 4100 Kcal/Kg for calculation		
****GHG Emission Equivalence for Coal is 2.6 TCO_2/Ton of Coal		

5) Removal of Moisture from iron ore by waste gas

DRI kiln off gas is available at 24,000 Nm3 /hr and 9500 C, while iron ore contains around 1.29% moisture. This wet iron ore is fed to the DRI kiln. A part of kiln off gas can be used counter currently to remove moisture from Iron Ore. It is recommended to remove the moisture in the iron ore up to the bone-dry condition. It is also recommended to divert a part of the off gas through a rotary drier, and counter currently admit iron ore against gas stream. Rotary feeder may be used to avoid false air entry.

6) Injecting oxygen with combustion air in the kiln

Oxygen enrichment is a flexible, efficient, and cost-effective technology that can improve combustion in all types of kilns. Oxygen enhances the combustion of all fuels, enabling improved burning zone control, greater kiln stability, and lower emissions. By increasing the oxygen concentration of combustion air through the addition of relatively pure oxygen, flame temperatures rise, heat transfer rates improve, and the overall combustion efficiency increases.

7) Install Energy Efficient Motor

Motors are used in most buildings for compressors, HVAC systems, and pumps. A motor is considered energy efficient if it meets or surpasses the efficiency value. Factors that set the efficient motors apart from the regular motors are design, materials, and manufacturing techniques. These improved features help motors obtain a higher level of efficiency, and thus perform tasks using less energy than their less efficient counterparts. The upfront cost of an energy efficient motor is higher than a conventional motor, but the payback is relatively quick, roughly 1-2 years, depending on the model. Because these motors are made with better designs, materials, and manufacturing techniques, they need to be replaced less and are more reliable. Thus, upgrading the motors leads to both cost and energy savings.

8) Suitable options towards Installation of variable speed drive for major electrical drives

A variable-frequency drive (VFD) (also termed as adjustable-frequency drive, variable speed drive, AC drive, micro drive or inverter drive) is a type of adjustable-speed drive used in electro-mechanical drive systems to control AC motor speed and torque by varying motor input frequency and voltage. VFDs may be installed for major electrical drives, such as kiln & cooler main drive motor, lobe compressor, volumetric feeder, coal crusher, kiln shell air fans, ID fan etc., thus reducing the energy consumption.

9) Kiln Shell Painting with heat resistant Paint to reduce the radiation temperature

The thermal losses depend largely on the surface temperature. Every 25 degree Celsius increase in the surface temperature will increase the thermal loss by approximately 17%, with the same surface emissivity at 0.9. The paint emissivity has a significant effect on the kiln surface heat transfer. Lower emissivity paint decreases thermal losses but increases the kiln surface temperature. A large increase of the kiln surface temperature is not ideal because it will cause structural problems induced by large differential thermal expansion between the metal shell, and the bricklayer. Therefore, the proposed paint with an emissivity of 0.65 is appropriate to reduce the paint temperature.

10) Use of "Thermact" as additives in feed coals for proper combustion of coal inside the Kiln (efficiency improvement)

The unburnt particles in fly and bottom ash, and the SPM and SOx levels have been the major problems for DRI units from the environmental point of view. This acts as a major constraint in selection of coal, especially in situations where the company is forced to go for a low-ranking coal. In such a scenario, the need of the hour is to reduce the cost of fuel as well as the emission levels, and overcome operational problems.

THERMACT, a multifunctional solid fuel additive, specially developed to improve the combustion efficiency of solid fuels and contains proprietary combustion catalyst, which help in complete combustion of coal thereby reducing the unburnt particles in ash. THERMACT also helps in reduction of SPM. The unique catalyst present in THERMACT takes advantage of the inherent moisture present in solid fuels to generate gases like CO, H_2, and Oxygen which help in extraction of more heat from the fuel. THERMACT also helps in reduction of excess air requirement thereby preventing heat losses. This helps in reduction of problems related to combustion and associated costs of energy generation, thereby resulting in Efficiency Improvement.

11) Covering the coal heap at yard to reduce wind loss

The stockpiles in the coal yard area should be kept limited to reduce the number of exposed surfaces from prevailing wind. This will reduce the quantity of coal from being carried away by wind, thereby reducing the wind losses.

12) Covering coal in transit (wagon & truck) to reduce loss

The procurement of coal in most of the Sponge Iron units is done through truck, train or conveyor. As a result, loss of coal occurs during transit of coal to the plant. It is recommended to cover the coal in transit (wagon & truck) to reduce coal loss.

13) Robust preventive and Predictive maintenance

Frequent kiln breakdown due to mechanical, electrical and operational interruptions has a significant effect on Kiln availability, which leads to poor efficiency. It can be overcome by implementing the best maintenance planning, and robust preventive and predictive maintenance.

14) Improving campaign life

The reasons for Low Production rate, which leads to low-capacity utilization, are Low Yield, Process Interruptions at Central Burner, Feeding and Injection systems which can further lead to increased energy consumptions.
This can be prevented through:
• Proper blending of Imported & Domestic coal to maintain required F.C.
• Utilization of high TI Pellet
• Conducted Fe Balancing to analyze yield losses.
• Fabrication of CB & Coal Injector Trolley for fast operation.
• Restriction of Undersize in material

15) Improvement in Operational losses

Various operational losses like emission of flue gas from slip seal, cooler discharge and stack cap, radiation losses, spillages from feed and injection area, and yield losses among others, need to be saved for efficient energy conservation.
Following initiatives can be taken:
• Better sealing done in stack cap to capture fugitive emission;
• For Better sealing, pneumatic cylinders installed at slip seal to maintain gaps in seals;
• Thorough inspection of old and worn-out refractory and application of best quality refractory which reduced in radiation losses;
• Inspection of spillages if any and arresting;
• Using minimum coal during Shut down & Light up and following Ramp up plans;
• D.P. Valve Installation at Cooler Discharge.

5.3 References

1. Mukherjee, A., Chatterjee, S. (2022). Niti Aayog. *Carbon Capture, Utilization and Storage (CCUS)*, *Policy Framework and its Deployment Mechanism in India.*

2. (*Background Note on Assumptions to Arrive at Probable INDC Values and Investment*). (n.d). https://steel.gov.in/en/tentative-intended-nationally-determined-contributions-indcs-calculations-steel-sector-context-2015

3. (*Annex-I : Recommended List of Energy Saving Technologies in Integrated Steel Plants*). (n.d). https://steel.gov.in/en/tentative-intended-nationally-determined-contributions-indcs-calculations-steel-sector-context-2015

4. (*Annex – II : Energy efficient technologies for induction furnace units*). (n.d). https://steel.gov.in/en/tentative-intended-nationally-determined-contributions-indcs-calculations-steel-sector-context-2015

5. (*Annex – III: Energy efficient clean and green technologies for steel rerolling mills (SRRMs*). (n.d). https://steel.gov.in/en/tentative-intended-nationally-determined-contributions-indcs-calculations-steel-sector-context-2015

The national ambient air quality Standards for maintaining ambient air quality for PM 10 and PM 2.5 prescribed by CPCB is given in **table 4.3**:

Table: Standards for maintaining ambient air quality for PM 10 and PM 2.5

Pollutant	Time Weighted Average	Concentration in Ambient Air	
		Industrial, Residential, Rural, and other Areas	Area (Notified by Central Government)
Particulate Matter, PM10, µg/m^3	Annual*	60	60
	24 Hours**	100	100
Particulate Matter, PM 2.5, µg/m^3	Annual*	40	40
	24 Hours**	60	60

* Annual Arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.
** 24 hourly or 8 hourly or 1 hourly monitored value, as applicable, shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.

4.2.3 NOx Emission

A high level of NOx is emitted from the kiln stack as a result of excessive primary air, nitrogen content in fuel, and combustion at high temperature during clinkerization.

NOx reduction

NOx is formed by thermal oxidation at high temperatures (1200-1600 degrees Celsius). A reaction with water results in the formation of acidic compounds A consequence of this is acidification of water bodies, such as streams and artificial lakes, which poses a threat to aquatic life leads to increase in global temperatures.

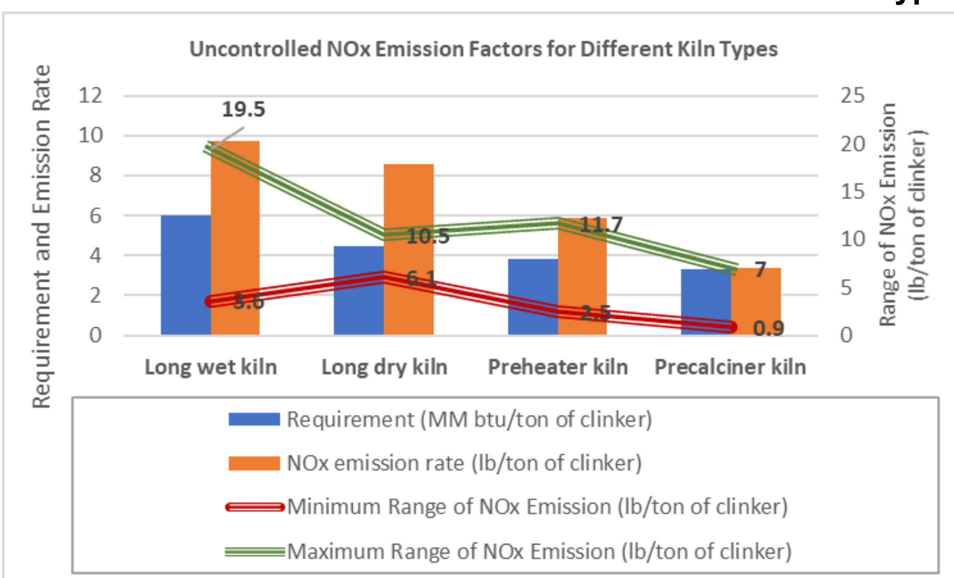
Cement kilns are generally the source of all NOx emissions in cement manufacturing. Fuel combustion in cement kilns produces NOx emissions in two primary ways:

- Oxidation of molecue nitrogen present in the combustion air which is termed thermal NOx formation
- Oxidation of nitrogen compounds present in the fuel which is termed fuel NOx formation
- The raw material feed to the kiln may also contain a significant amount of nitrogen compounds
- Other Waste such as Plastic, Flyash,Hazardous Watse,Distelley spent wash,MSW etc.

(Source: Emission Standards Division, 1994)

The following **figure 4.3** includes the heat input requirement for the different cement kiln types which indicates a good correlation with the NOx emission rates

Figure no. 4.3: Uncontrolled NOx emission factors for different kiln types



(Source: Emission Standards Division, 1994)

4.2.4 SOx Emission

It is captured by raw material during grinding cement raw material has high Sulphur content, and the combustion and oxidation of Sulphur forms Sulphur oxides. These oxides in turn react with water vapor and other chemicals, leading to the formation of sulfuric acid in the presence on sunlight.

The sulfur is introduced into the kiln system from the two mains feeding sources: The fuel and the raw materials (HORKOSS, 2004).

- From the fuel: In the main burner flame of the kiln and in the pre-calciner burner, all the sulfur in the fuel will burn to SO_2.
- From the raw material: The sulfide and sulfur combined in organic compounds burn to SO_2 in the upper stages of the pre-heater.

Factors influencing the SO_2 Emission: Direct (the sulfur form in the raw materials) and Indirect (the stabilization of the sulfur compound in the clinker phases).

The ministry of environment forest and climate change has notified Emission Standards for SOx, NOx as vide GSR No. 612(E) dated 25.04.2014 for rotary kiln without coprocessing and amended it vide GSR 497(E) dated 10.05.2016 for cement industries with co-processing of wastes in their cement kilns is given **table 4.4:**

Table 4.4: Rotary Kiln – without co-processing of Wastes

	Date of Commissioning	**Location**	**Concentration not to exceed, in mg/Nm3**
Sulphur Dioxide (SO_2)	irrespective of date of commissioning	anywhere in the country	100
Nitrogen Dioxide (NO_2)	on or after the date of notification	anywhere in the country	600 (With effect from 01.06.2015)
	Before the date of notification	anywhere in the country	800 (With effect from 01.01.2016)

Table 4.5: Rotary Kiln – with co-processing of wastes			
	Date of Commissioning	**Location**	**Concentration not to exceed, in mg/Nm3**
SOx	Irrespective of date of commissioning	anywhere in the country	100, 700 and 1000 when pyritic Sulphur in the limestone is less than 0.25%, 0.25 to 0.5% and more than 0.5% respectively.
NOx	After the date of notification (25.8.2014)	anywhere in the country	1) 600
	Before the date of notification (25.8.2014)	anywhere in the country	2) 800 for rotary kiln with In Line Calciner (ILC) technology. 3) 1000 for rotary kiln using mixed stream of ILC, Separate Line Calciner (SLC) and suspension pre-heater technology or SLC technology alone or without calciner.

The national ambient air quality Standards for maintaining ambient air quality for SOx and NOx prescribed by CPCB is given in **table 4.6**:

Table 4.6: Standards for maintaining ambient air quality for SOx and NOx

Pollutant	Time Weighted Average	Concentration in Ambient Air	
		Industrial, Residential, Rural, and other Areas	Area (Notified by Central Government)
Sulphur Dioxide (SO_2) µg/m^3	Annual*	50	20
	24 Hours**	80	80
Nitrogen dioxide (NO_2) µg/m^3	Annual*	40	30
	24 Hours**	80	80

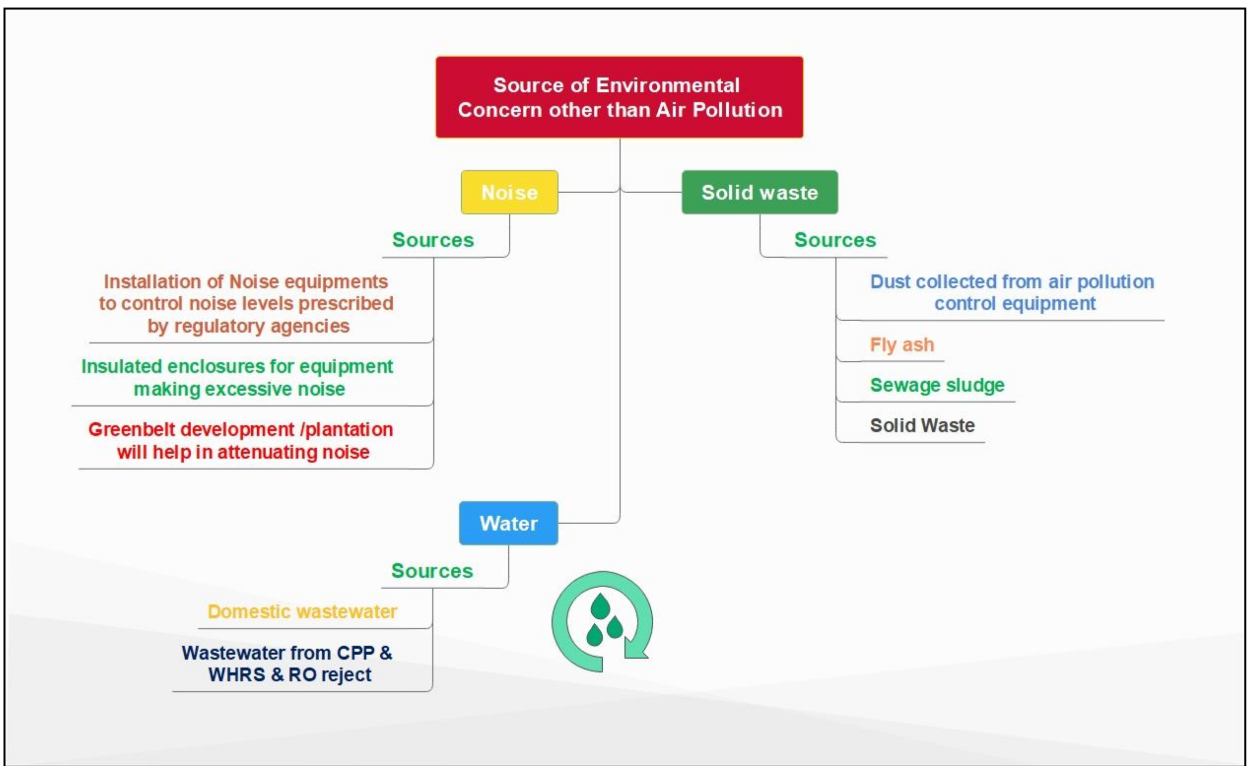
* Annual Arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.
** 24 hourly or 8 hourly or 1 hourly monitored values, as applicable, shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.

Link for Guideline & GSR:
GSR 612(E): https://moef.gov.in/wp-content/uploads/2017/08/SO612.pdf
GSR 497(E): https://moef.gov.in/wp-content/uploads/2017/08/Cement_Co_processing_Gazette.pdf
NAAQMS Guidelines:
https://cpcb.nic.in/openpdffile.php?id=UmVwb3J0RmlsZXMvMjdfMTQ1ODExMDQyNl9OZXdJdGVtXzE5Nl9OQUFRTVNfVm9sdW1lLUkucGRm

4.2.5 Sources of Environmental Concerns other than Air Pollution

The Sources of Environmental Concerns including Noise, Water and Solid waste is discussed in **figure 4.4**.

Figure no. 4.4: Sources of Environmental Concerns



4.2.6 Other Emissions

Other emissions such as CO_2, CO, HCL, HF, TOC, heavy metals, total dioxins and furans etc. have been found from some cement plants (Voicu et al., 2020). These may be generated from wastes containing chlorine, fluorides, heavy metals, etc. being co processed in the cement plants.

The emission standards for HCl, HF, TOC, Hg, Heavy metals, Dioxins and Furans prescribed for cement plants with co processing of wastes is prescribed in G.S.R. 497 (E). – Dated 10 May 2016 as given in **table 4.7**:

Table 4.7: Standards for HCl, HF, TOC, Hg, Heavy metals, Dioxins and Furans

HCl	10 mg/Nm^3
HF	1 mg/Nm^3
TOC	10 mg/Nm^3
Dioxins and Furans	0.1 ngTEQ/ Nm^3
Hg and its Compound	0.05 mg/Nm^3
Cd + Tl and their compounds	0.05 mg/Nm^3
Sb + As + Pb+ Co+ Cr+ Cu+ Mn+ Ni+ V and their compounds	0.5 mg/Nm^3

4.2.7 Environmental Guidelines for Prevention and Control of Fugitive Emissions from Cement Plants

For achieving effective prevention and control of potential fugitive emission sources in cement manufacturing plants, specific requirements along with guidelines have been evolved. In order to establish proper management practices, requirements such as Operation and Maintenance aspects, trained manpower and documents & records to be maintained are also prescribed. In addition, general guidelines are also evolved for the sources otherwise not specified.

Link for Guideline:
https://cpcb.nic.in/openpdffile.php?id=UmVwb3J0RmlsZXMvTmV3SXRlbV85Nl8yMi5wZGY=

4.3 Noise Pollution

Sources of noise pollution in cement plants (Crusher, grinding mills, kiln, cooler, packing plants) comprise of following:

A) Operation of Blowers, air compressors, and dust collectors operate.
B) Mechanical noise due to operation of machines, such as crushers, mills.
C) Electric–magnetic noise, due to operation of electric motors.

The Noise Pollution (Regulation and Control) Rules, 2000 under Environment (Protection) Rules, 1986, prescribes standards for regulation and control of noise producing and generating sources. National Ambient Noise level standards prescribed under the rules is given in the **table 4.8**.

Table 4.8: National Ambient Noise level standards

Area Code / Category of Area	Limits in dB (A) Day Time	Leg- Night Time
Industrial area(A)	75	70
Commercial **area (**B)	65	55
Residential area (**C)**	55	45
Silence Zone (D)	50	40

Note:
1. Day time is reckoned in between 6 a.m. and 9 p.m.
2. Nigh time is reckoned in between 9 p.m. and 6 a.m.
3. Silence zone is defined as areas upto 100 metres around such premises as hospitals, educational institutions, and courts. The Silence zones are to be declared by the Competent Authority. Use of vehicular horns, loudspeakers and bursting of crackers shall be banned in these zones.
4. Mixed categories of areas should be declared as one of the four above mentioned categories by the Competent Authority and the corresponding standards shall apply.)

Further Readings
1.https://www.ncbindia.com/wp-content/uploads/technology digests/NCBsApproachToCombatNoisePollutionInCementIndustry.pdf 2. http://cimfr.csircentral.net/682/

3.https://www.engr.psu.edu/ce/courses/ce584/concrete/library/construction/curing/Composition%20of%20cement.htm
4. https://civiltoday.com/civil-engineering-materials/cement/10-cement-ingredients-with-functions
5. https://theconstructor.org/concrete/ordinary-portland-cement/23181/

4.4 Non compliances/concerns/issues observed in Indian Iron & Steel Industry

Non compliances observed in the monitoring reports of various projects uploaded in PARIVESH portal have been classified as given from **Figure 4.5 to figure 4.11**:

Figure 4.5: Types of broad concerns/issues identified

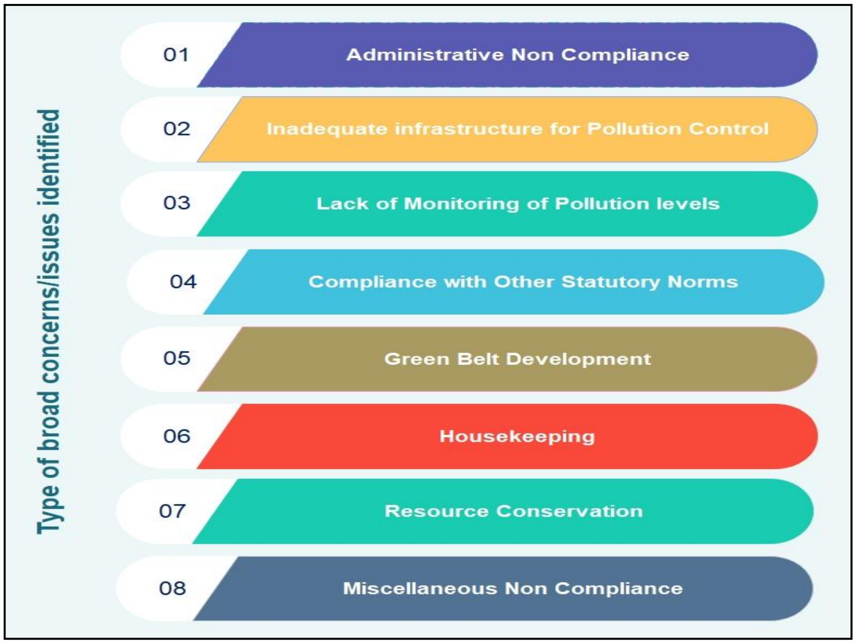
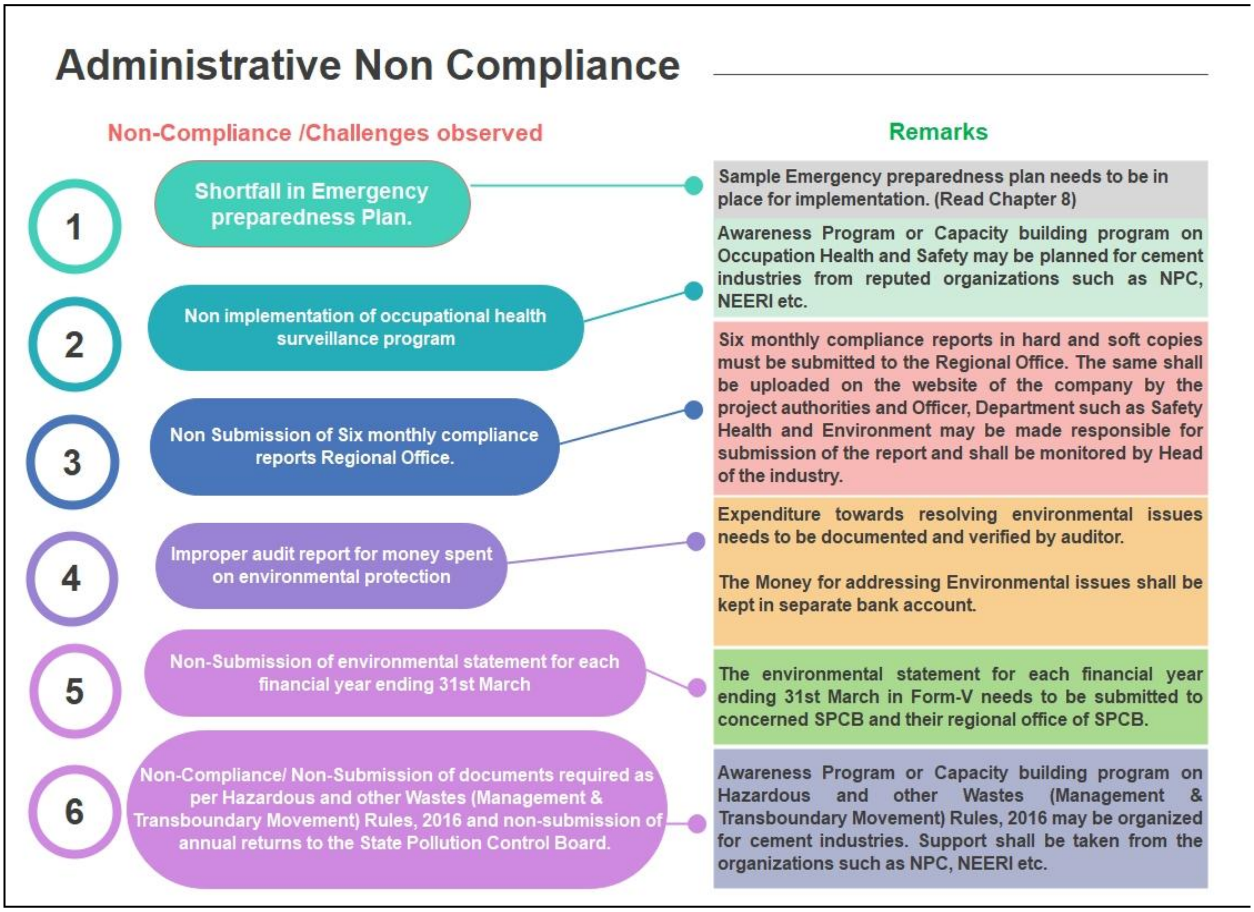


Figure 4.6: Administrative non-compliance



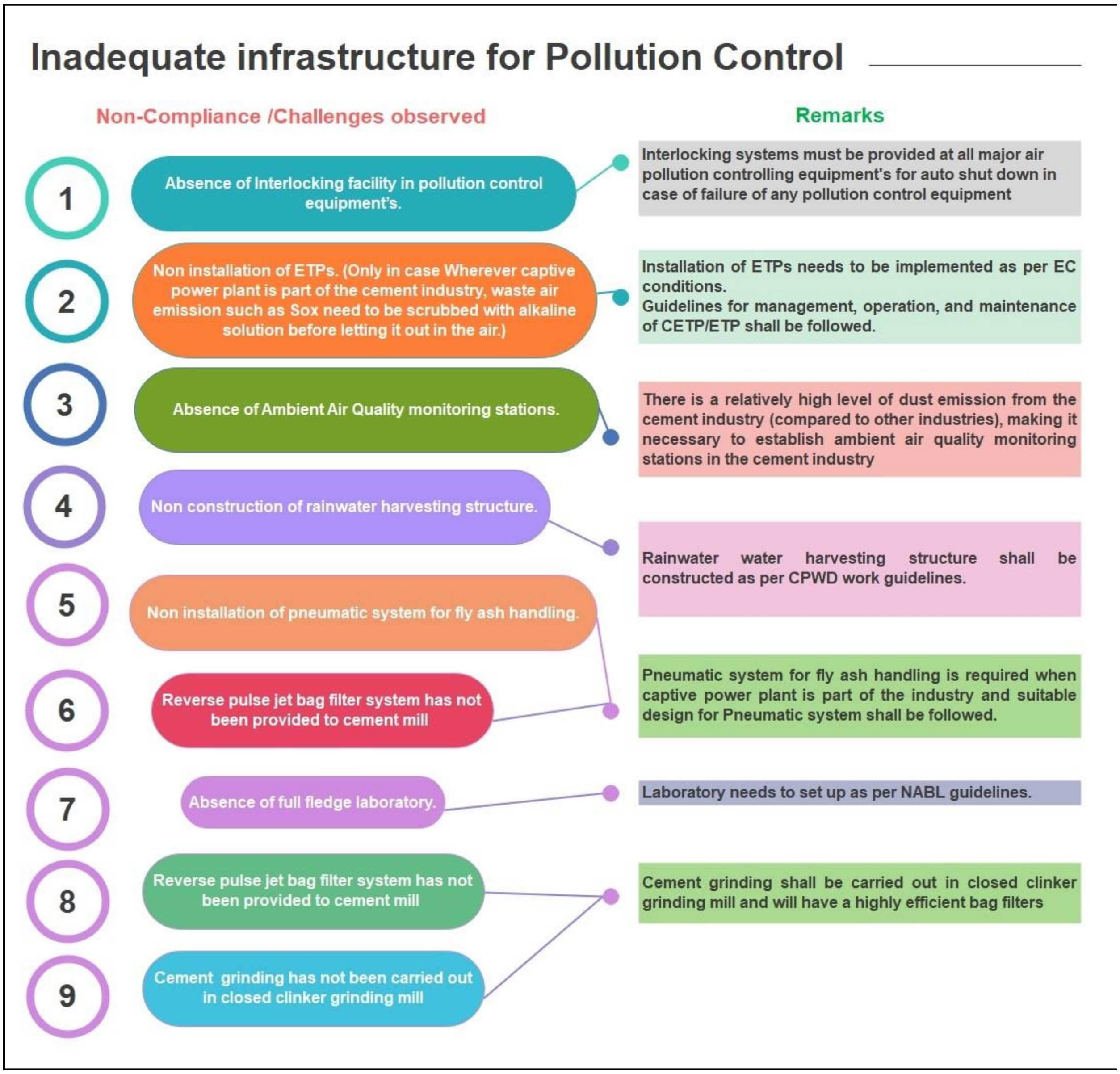
Links for Further Readings:

1) Chapter 8 – Emergency Preparedness Plan

4) Form-IV Sample for Environmental Statement:

http://goaspcb.gov.in/Media/Default/Application%20forms/17)%20Environmental%20Statement.pdf

Figure 4.7: Inadequate infrastructure for pollution control



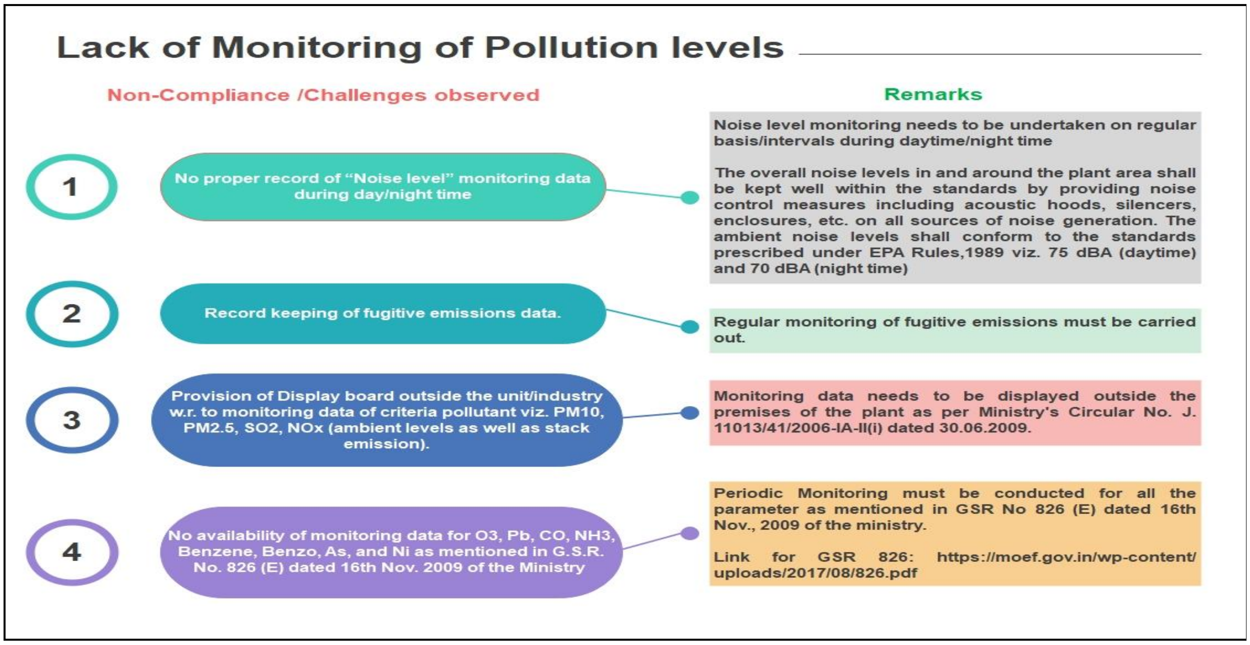
Links for Further Readings:

2) Guidelines for Management, Operation and Maintenance of CETP/ETP: http://cpcbenvis.nic.in/scanned%20reports/GUIDELINES%20FOR%20MANAGEMENT,%20OPERATION%20AND%20MAINTENANCE%20OF%20COMMON%20EFFLUENTIREATMENT%20PLANTS.pdf

4) Rainwater harvesting and Conservation Manual:

https://cpwd.gov.in/Publication/rain_wh.pdf

Figure 4.8: Lack of monitoring of pollution levels



Links for Further Readings:

4) GSR 826: https://moef.gov.in/wp-content/uploads/2017/08/826.pdf

Figure 4.9: Compliance with other statutory norms

Compliance with Other Statutory Norms

Non-Compliance /Challenges observed	Remarks
1. No transportation of fly ash in a closed containers and No records keepings and monitoring of vehicular emissions.	Efforts shall be made to reduce impact of the transport of the raw materials and end products on the surrounding environment including agricultural land. All the raw materials including fly ash shall be transported in the closed containers only and shall not be overloaded. Vehicular emissions shall be regularly monitored, and records maintained.
2. Prior Permission of SGWB/CGWB is not obtained for withdrawal of ground water.	Prior permission of SGWB/CGWB shall be obtained for withdrawal of ground water. All industries abstracting ground water in excess of 100 m3/d shall be required to undertake annual water audit through Confederation of Indian Industries (CII)/ Federation Indian Chamber of Commerce and Industry (FICCI)/ National Productivity Council (NPC) certified auditors and submit audit reports within three months of completion of the same to CGWA. Link for Obtaining NOC: 1)http://cgwb.gov.in 2)https://www.mpcb.gov.in/sites/default/files/water-quality/standards-protocols/Ground_Water_NewGuidelinesNotifiedeng24092021102020.pdf 3)Documents/Draft%20revised%20guidelines%202017(24.7.2017).pdf
3. Non-compliance of recommendations made in CREP for cement plants.	Recommendations made in CREP for cement plants is placed must be implement by project proponent. As per CREP document: 1) Control fugitive emissions from all the raw material and products storage and transfer points. 2) Tripping in kiln ESP to be minimized 3) performance evaluation of various types of continuous monitoring equipment Link for CREP Guidelines: 1)https://www.indiansugar.com/PDFS/CREP-2003-FullText.pdf 2)https://www.indiansugar.com/PDFS/CREP-2003-FullText.pdf
4. Spent oil is not disposed off in accordance with SPCB conditions.	Spent oil needs to be disposed off in accordance with Hazardous and other Wastes (Management & Transboundary Movement) Rules, 2016 and its Amendments. Treatment and disposal of spent oil is as per HWM Rules. (Refer Part A of Schedule V for Specifications of Used Oil Suitable for recycling). Link: https://cpcb.nic.in/displaypdf.php?id=aHdtZC9lV01fUnVsZXNfMjAxNi5wZGY=
5. Gaseous emissions from unit process are not complied.	The gaseous emissions from various process units shall conform to the load/mass-based standards notified by the is Ministry on 19 May, 1993 and standards prescribed bed from time to time. The State Pollution Control Board may specify more stringent standards for the relevant parameters keeping in view the nature of the industry and its size and location.

SCHEDULE V
[See rules 3 (35) and 3 (39)]

PART A
Specifications of Used Oil Suitable for recycling

S.No.	Parameter	Maximum permissible Limits
(1)	(2)	(3)
1.	Polychlorinated biphenyls (PCBs)	< 2ppm *
2.	Lead	100 ppm
3.	Arsenic	5 ppm
4.	Cadmium+Chromium+Nickel	500 ppm
5.	Polyaromatic hydrocarbons (PAH)	6%

Links for Further Readings:

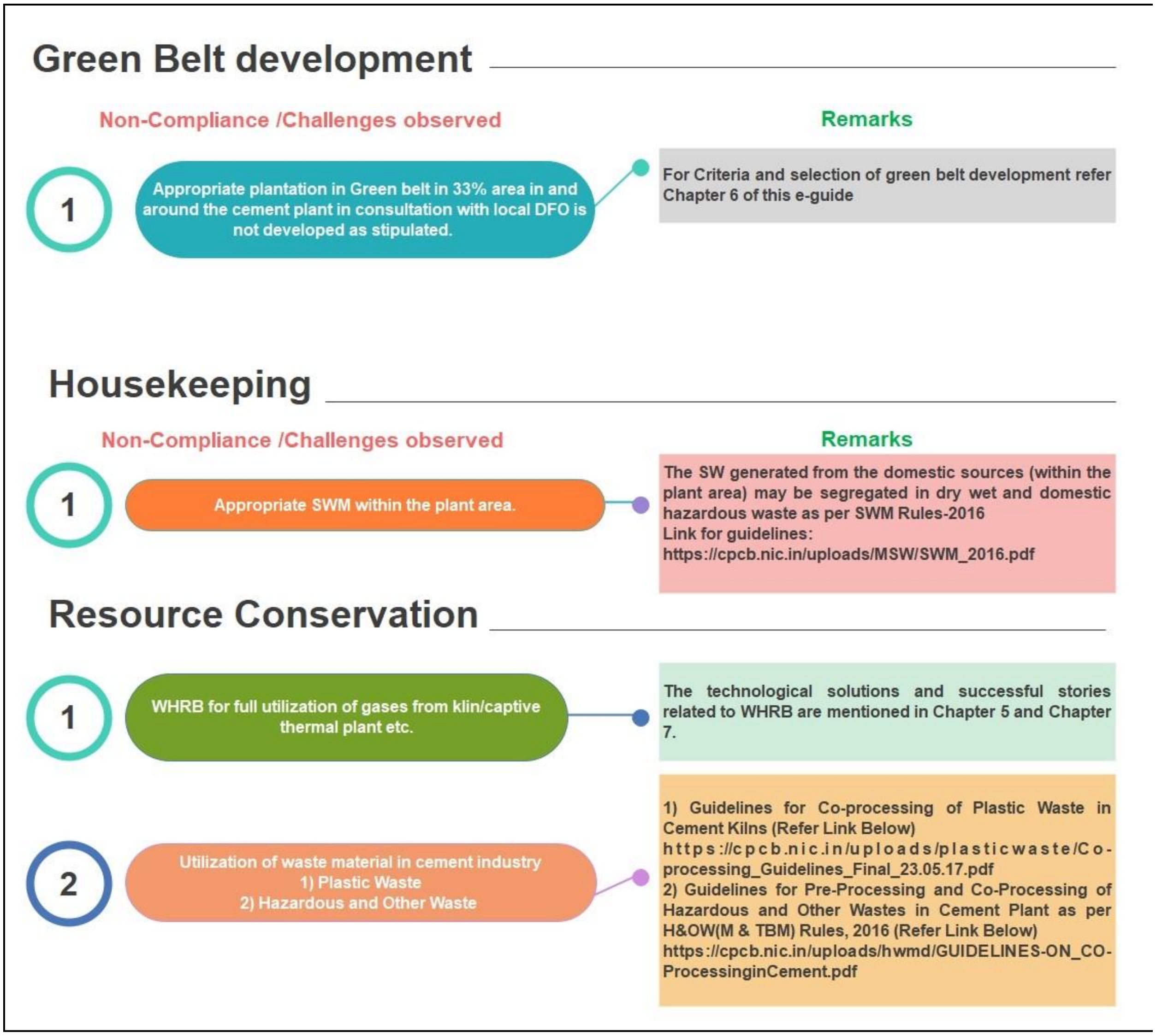
2) For Obtaining NOC:

- http://cgwb.gov.in
- https://www.mpcb.gov.in/sites/default/files/water-quality/standards-protocols/Ground_Water_NewGuidelinesNotifiedeng24092021102020.pdf
- Documents/Draft%20revised%20guidelines%202017(24.7.2017).pdf

4) HWM Rule, 2016-

https://cpcb.nic.in/displaypdf.php?id= aHdtZC9IV01fUnVsZXNfMjAxNi5wZGY=

Figure 4.10: Green belt development and Housekeeping

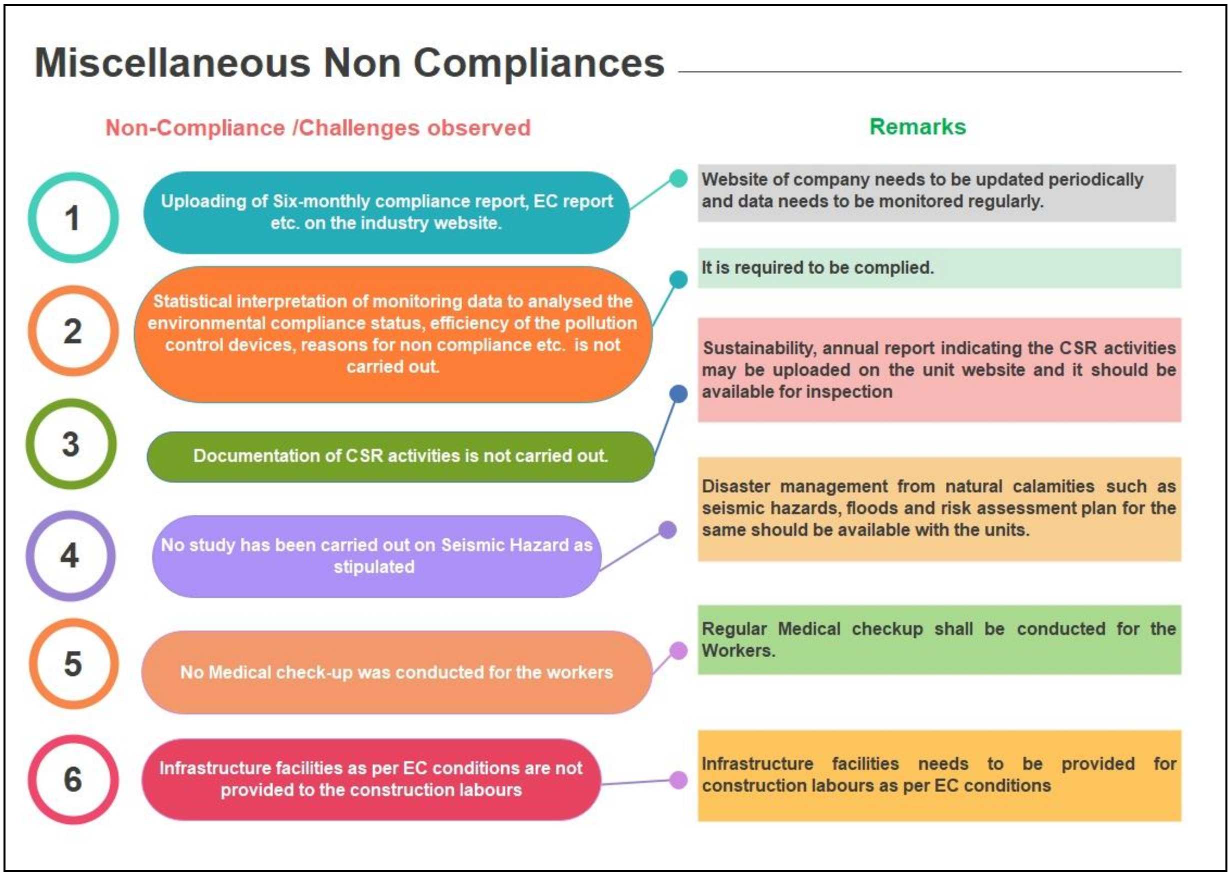


Links for Further Readings:

GRD: 1) Read Chapter 6 of this e guide
Housekeeping: SWM Rule 2016- https://cpcb.nic.in/uploads/MSW/SWM_2016.pdf
1) Guidelines for Co-processing of Plastic Waste in Cement Kilns
https://cpcb.nic.in/uploads/plasticwaste/Co-processing_Guidelines_Final_23.05.17.pdf

2) Guidelines for Pre-Processing and Co-Processing of Hazardous and Other Wastes in Cement Plant as per H&OW(M & TBM) Rules, 2016
https://cpcb.nic.in/uploads/hwmd/GUIDELINES-ON_CO-ProcessinginCement.pdf

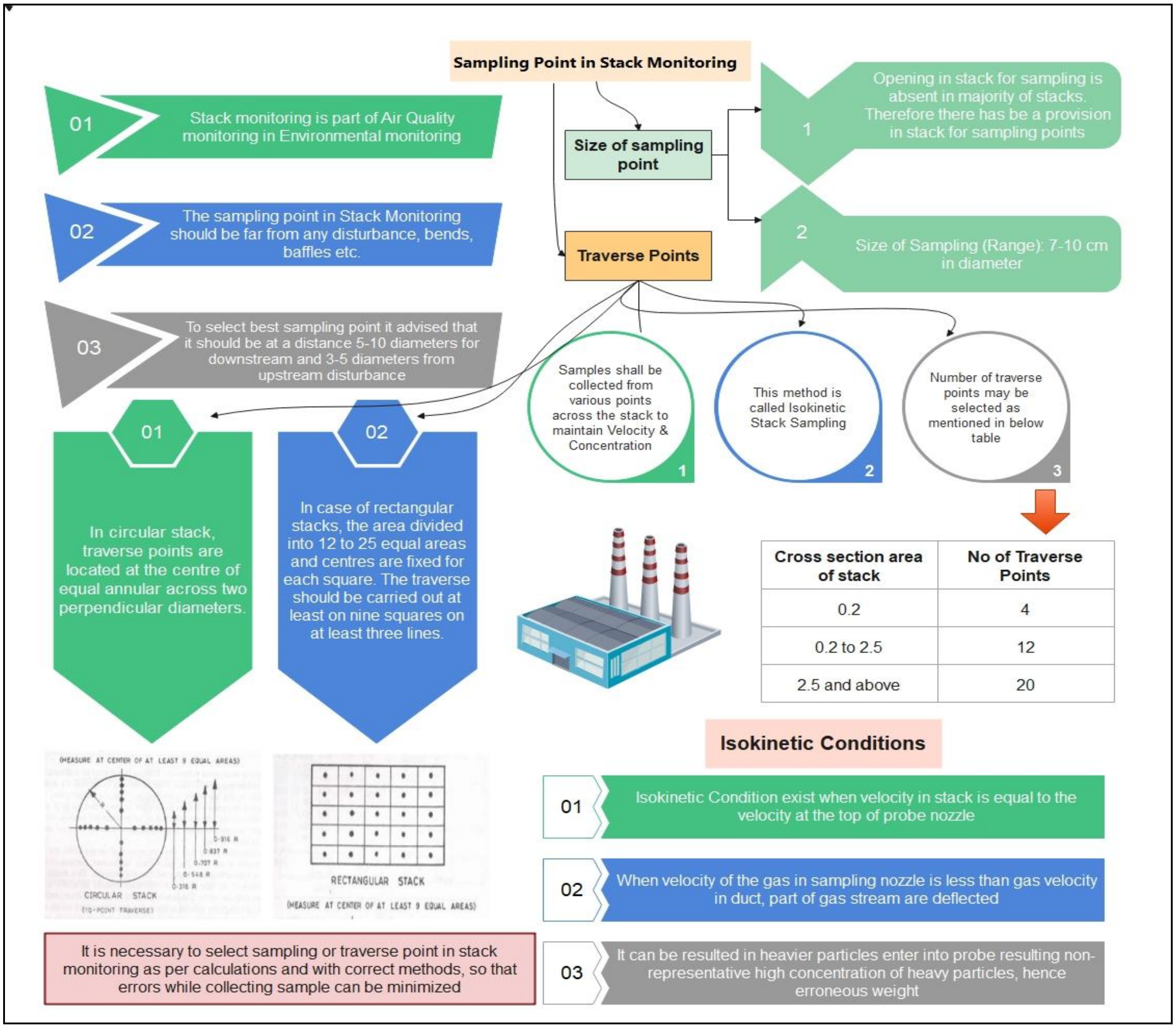
Figure 4.11: Miscellaneous non compliances



4.5 Monitoring of Environmental Parameters

The **figure 4.12** described sampling point in stack monitoring with size of sampling point, traverse point, and isokinetic conditions

Figure 4.12: Sampling point in stack monitoring



Source: Perfect Pollucon services,n.d. https://www.ppsthane.com/blog/sampling-point-in-stack-monitoring#:~:text=The%20sampling%20point%20in%20Stack,5%20diameters%20from%20upstream%20disturbance

Further Readings
Link for Guideline: Methods and SOP for Emission Testing in hazardous Waste Incinerator https://cpcb.nic.in/openpdffile.php?id=UmVwb3J0RmlsZXMvTmV3SXRlbV8xMTBfaHppbmNpbmVyYXRvci5wZGY=

https://indsteel.org/pdf/environment-related-notifications/guidelines_for_source_emission_monitoring_CPCB.pdf
http://cpcbenvis.nic.in/scanned%20reports/EMISSION%20REGULATIONS%20PART_3.pdf

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ssword=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

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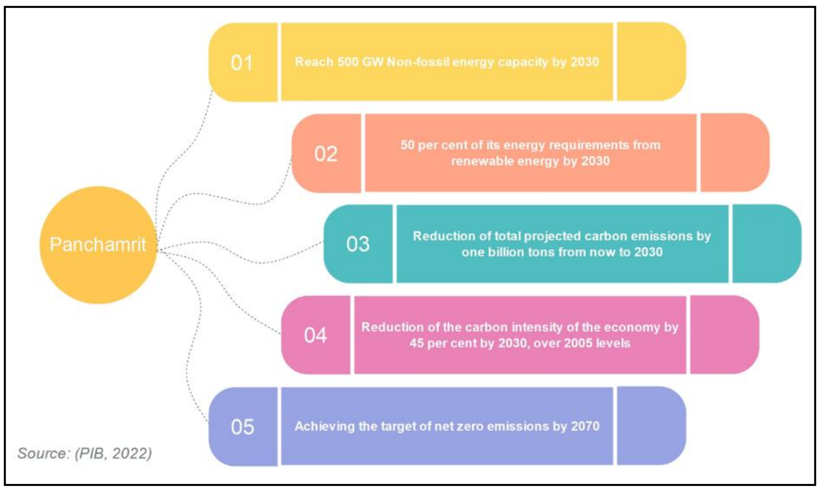
Chapter 5: Technological Solutions and Best Practices

5.1 Background

This section provides the benchmark techniques/practices being followed in India and other countries towards achieving a high level of environmental protection in the cement sector.

For the cement sector, major sources of emissions include particulate emissions, NOx emissions, SO_2 emissions, CO and organic emissions, mercury, and heavy metal emissions. In Glasgow, United Kingdom, India expressed the concerns of developing countries at the 26th Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC). As part of India's climate action, the following five nectar elements (Panchamrit) have been presented in **figure 5.1**:

Figure 5.1: Panchamrit- five nectar elements



The cement industry has always been among the largest CO_2 emission sources. Cement plants cause almost 5-7% of global CO_2 emissions. Additionally, the government has made norms stricter for the cement industry, capping the emissions of PM to not more than 30 milligrams per cubic metre, in March 2017.

Accordingly, this chapter deals with best practices for emissions management, resource conservation and tackling climate change with vis-à-vis the cement industry.

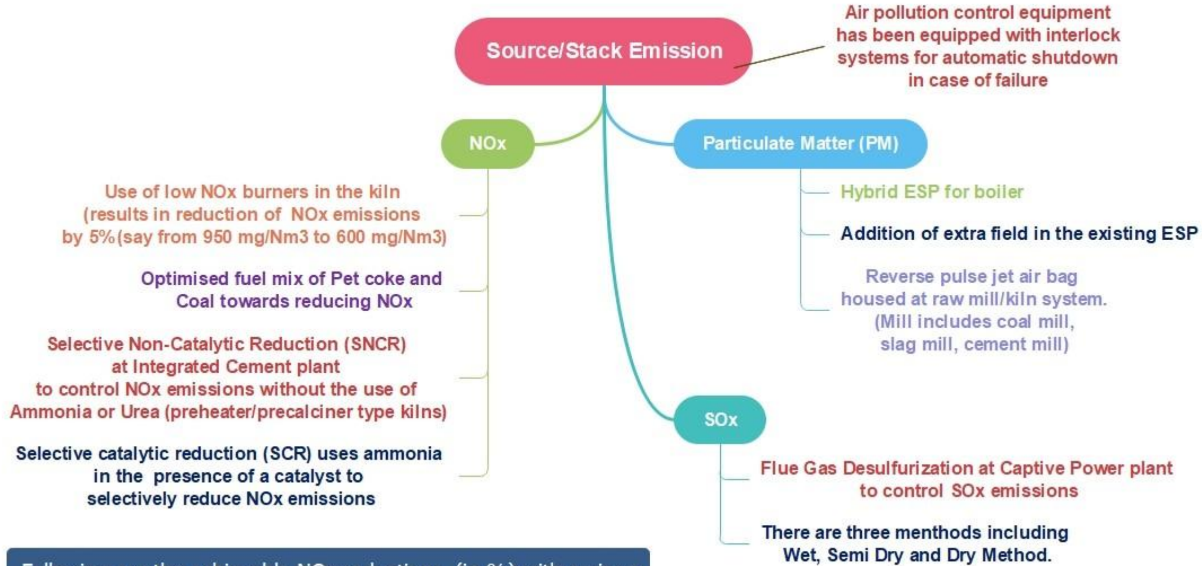
To achieve these targets, India needs to reduce its carbon emissions, and the cement sector, which is heavily dependent on coal contributes to more than 7% of annual anthropogenic Greenhouse Gas Emissions.

The pressure on the cement industry is high, thus urgent interventions are required to ensure timely mitigation. Fuel substitution is one of the most straightforward routes to emissions reduction, as the easy availability of technology ensures faster adaptability by different cement units. However, there is a lack of technical knowhow/ knowledge of newer and cleaner technologies, their functionalities and scope of use which is also industry specific. In this regard, different areas like reduction of CO_2, dust emissions, NO_x, SO_X, etc must be targeted with specific technological interventions as mentioned in subsequent sections.

5.2 Emission Management

Best practices observed in emission management in Indian cement industry is depicted in **figure 5.2**:

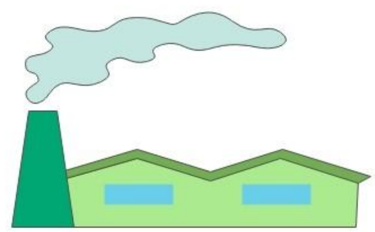
Figure 5.2: Best practices observed in emission management in Indian iron & steel

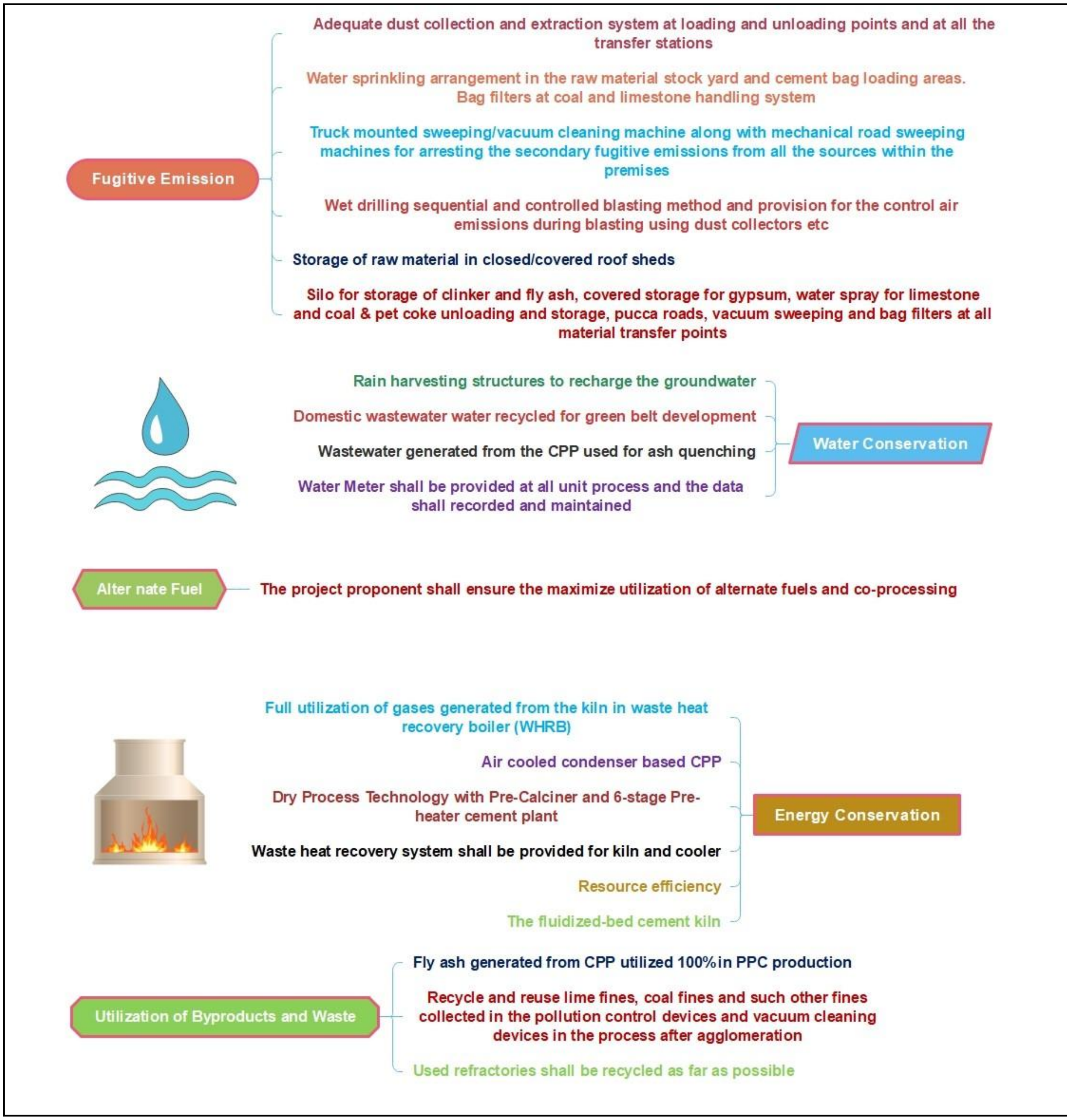


Following are the achievable NOx reductions (in %) with various NOx reduction technologies.

Nox control Technology	Achievable NOx emissions reductions (in %)
Process Modifications	25
Stayed combustion in precalciner	30-45
Conversion to indirect firing with a low NOx burner	20-30
Mid-kiln firing of tires in long kilns	20-40
SNCR	30-70
SCR	80-90

Source:Emission Standards Division, 1994

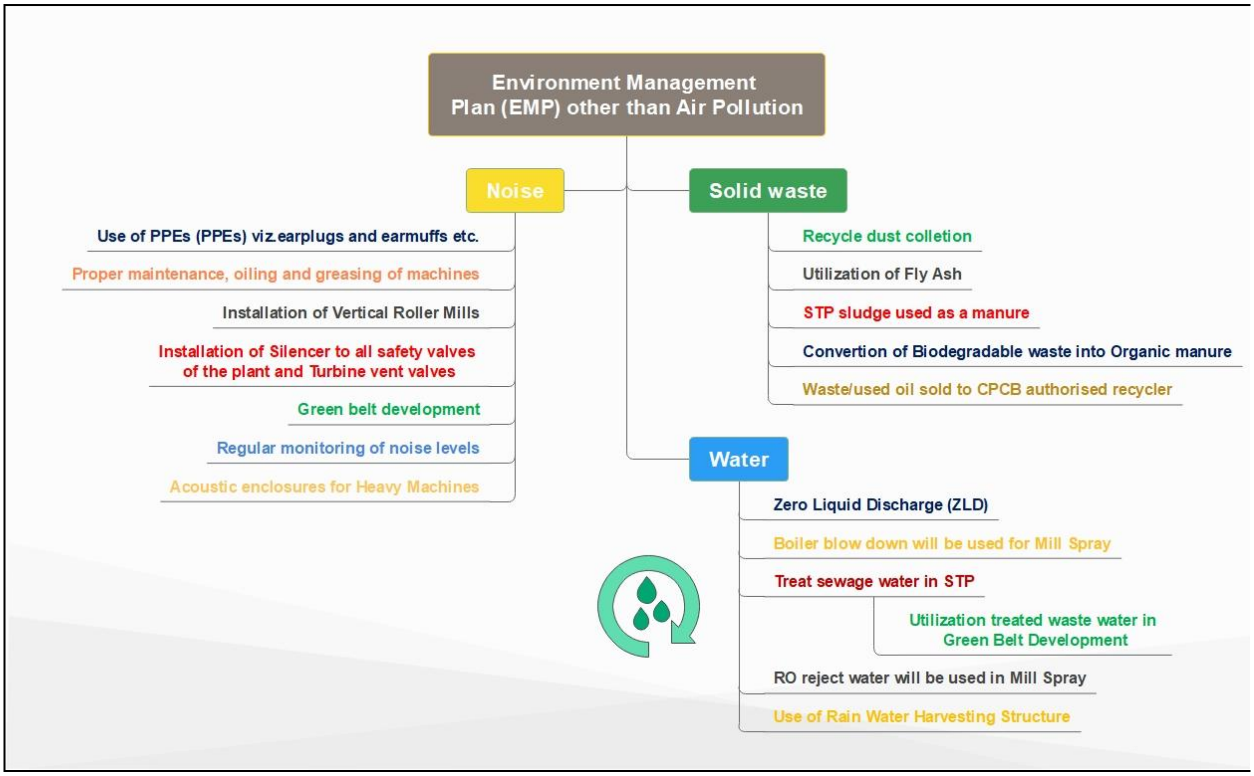



Fugitive Emission
Adequate dust collection and extraction system at loading and unloading points and at all the transfer stations
Water sprinkling arrangement in the raw material stock yard and cement bag loading areas. Bag filters at coal and limestone handling system
Truck mounted sweeping/vacuum cleaning machine along with mechanical road sweeping machines for arresting the secondary fugitive emissions from all the sources within the premises
Wet drilling sequential and controlled blasting method and provision for the control air emissions during blasting using dust collectors etc
Storage of raw material in closed/covered roof sheds
Silo for storage of clinker and fly ash, covered storage for gypsum, water spray for limestone and coal & pet coke unloading and storage, pucca roads, vacuum sweeping and bag filters at all material transfer points
Water Conservation
Rain harvesting structures to recharge the groundwater
Domestic wastewater water recycled for green belt development
Wastewater generated from the CPP used for ash quenching
Water Meter shall be provided at all unit process and the data shall recorded and maintained
Alter nate Fuel
The project proponent shall ensure the maximize utilization of alternate fuels and co-processing
Energy Conservation
Full utilization of gases generated from the kiln in waste heat recovery boiler (WHRB)
Air cooled condenser based CPP
Dry Process Technology with Pre-Calciner and 6-stage Pre-heater cement plant
Waste heat recovery system shall be provided for kiln and cooler
Resource efficiency
The fluidized-bed cement kiln
Utilization of Byproducts and Waste
Fly ash generated from CPP utilized 100% in PPC production
Recycle and reuse lime fines, coal fines and such other fines collected in the pollution control devices and vacuum cleaning devices in the process after agglomeration
Used refractories shall be recycled as far as possible

5.3 Environment Management Plan

The **figure 5.3** described environment management plan for Noise, Water and Solid Waste management.

Figure 5.3: Environment Management Plan other than Air Pollution



5.4 Technologies available to reduced air emission

5.4.1 PM Emission

5.4.1.1 Introduction

Electrostatic precipitators (ESPs) help to remove fine particles from flue gas before passing the gas into the chimney. ESP power supplies are typically composed of rectifier transformers. Rectifier transformers make use of 50 Hz mains frequency and are thyristor controlled to deliver the required corona power into the ESP fields and to accelerate ionized particles to collector plate.

There are several factors that influence ESP collection efficiency, including the generated electric field, migration velocity(ω), effective collection area(A), and volumetric gas flow.

The ESP performance is limited by sparking phenomenon, so the control system is designed to detect it and reduce the voltage to a certain percentage.

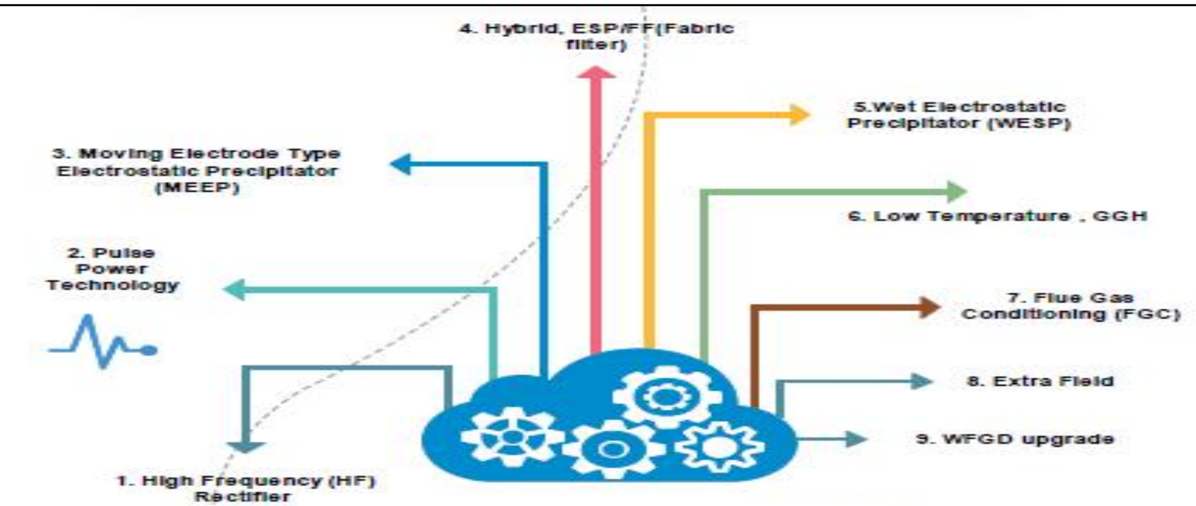
Further, ESP efficiency is depended upon following factors

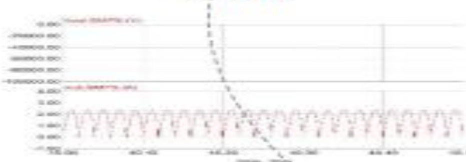
1. Improving uneven velocity distribution of airflow.
2. Overhaul the thermal insulation layer outside the dust collection system regularly to ensure that the thermal insulation materials are in good condition and their thickness meets the standard.
3. Enhance the tightness of the dust collection system and ensure that the wind leakage rate of the whole ESP is less than 3%.
4. Flexibly adjust the material of the electrode plate (collection curtain) according to the chemical composition of flue gas to increase its corrosion resistance and prevent short circuits caused by electrode plate corrosion.
5. Properly adjust the rapping cycle and rapping force of the electrode to improve the corona power and reduce the secondary flying of the dust.
6. Add an extra electric field to increase the capacity and dust collection area of the ESP or increase or broaden the electric field of the electrostatic precipitator. A larger electric field can effectively enhance the dust collecting rate.
7. Adjust the control mode and power supply mode of power supply equipment. The application of high frequency (20 ~ 50KHz) high voltage switching power supply can technically upgrade and improve the efficiency of electrostatic precipitators.

5.4.1.2 Electrostatic Precipitators (ESP) Upgradation Technologies

There are 8 technologies available for up-gradation of existing ESPs is depicted in **figure 5.4**:

Figure 5.4: Technologies available for up-gradation of ESP





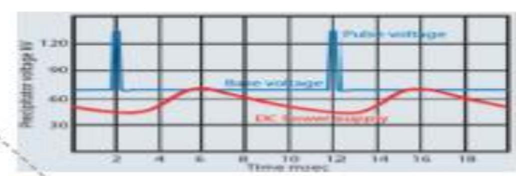
Very low voltage ripple < 1 %
Average voltage ≈ peak voltage
Ripple frequency = 24 kHz

1. High Frequency (HF) Rectifier

This system deploys the concept of high voltage switched mode power supply wherein converter-inverter topology is used to create very high frequency (in Khz) and then converted into DC having negligible ripple voltage.

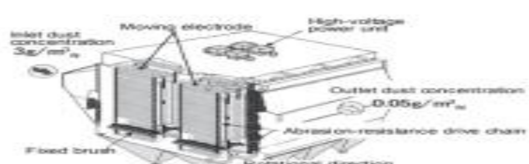
2. Pulse Power Technology

The issue of back corona (associated with high resistivity coal) and lower migration velocity of fine dust particles (radius, a very less) can be addressed by use of pulsed power supply system



Case example of implementation of pulse power technology for upgradation of ESP

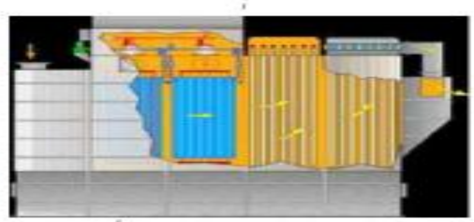
3.MEEP



MEEP, the moving electrode plate collects dust and the rotary brush within the lower hopper removes dust from the electrode surface parts such as the chain and sprocket which move the electrode are exposed to a severely dusty environment.

4. Hybrid, ESP/FF(Fabric filter)

The Air System Hybrid Filter is a combination of ESP and the bag filter. With the installation of Hybrid filter, the ESP collects the majority of the dust including the large particles, while the Fabric filter removes the fine particles. The Hybrid filter therefore ensures optimum particulate removal efficiency with lower operating costs.



5.WESP

Wet ESPs are used in situations for which dry ESPs are not suited, such as when the material to be collected is wet, sticky, flammable, explosive, or has a high resistivity

In wet ESPs, the collectors are either intermittently or continuously washed by a spray of liquid, usually water.

6. Low Temperature , GGH

The Low temperature GGH recovers heat from the untreated flue gas and reheats the treated flue gas for FGD plants without any flue gas leakage from the untreated side and vice versa. This improves ESP performance by decreasing temperature.

7. Flue Gas Conditioning (FGC)

Flue gas conditioning (FGC) is an effective and developed technology used to enhance the performance of Electrostatic Precipitators dealing with high resistivity dust. An ESP equipped with FGC system can work at or even above its design efficiency and collect more fly ash.

8. Extra Field

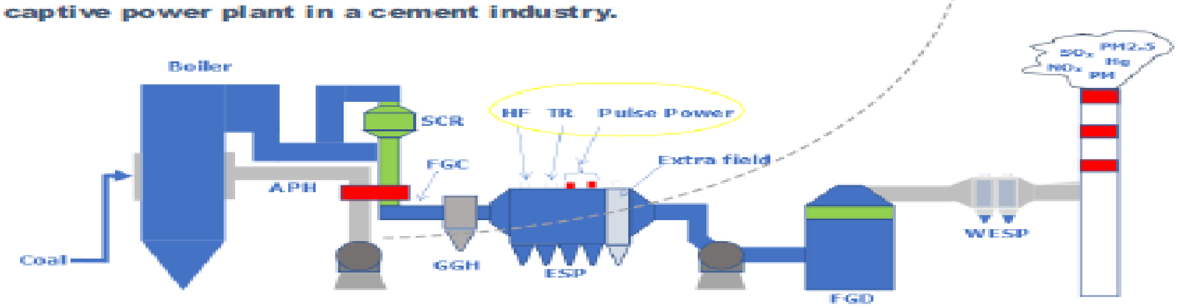
An extra electric field is added to increase the capacity and dust collection area of the ESP, or increase or broaden the electric field of the electrostatic precipitator. A larger electric field can effectively enhance the dust collecting rate.

9. WFGD upgrade

The semi-dry FGD Process is a simple process with high desulfurization efficiency and with no wastewater discharge.

In the Semi-dry system, the Flue Gasses are moistened in an Evaporation Chamber before they are treated in the Reactor. The semi-dry FGD involves the injection of Sorbent (either Hydrated Lime or Sodium bicarbonate) into the Reactor chamber where a particular residence time is provided for Flue Gasses to allow for a reaction. After reacting with the sorbent, Flue Gas Dust is recovered through a Bag Filter which is further used for recirculation in the Reactor chamber.

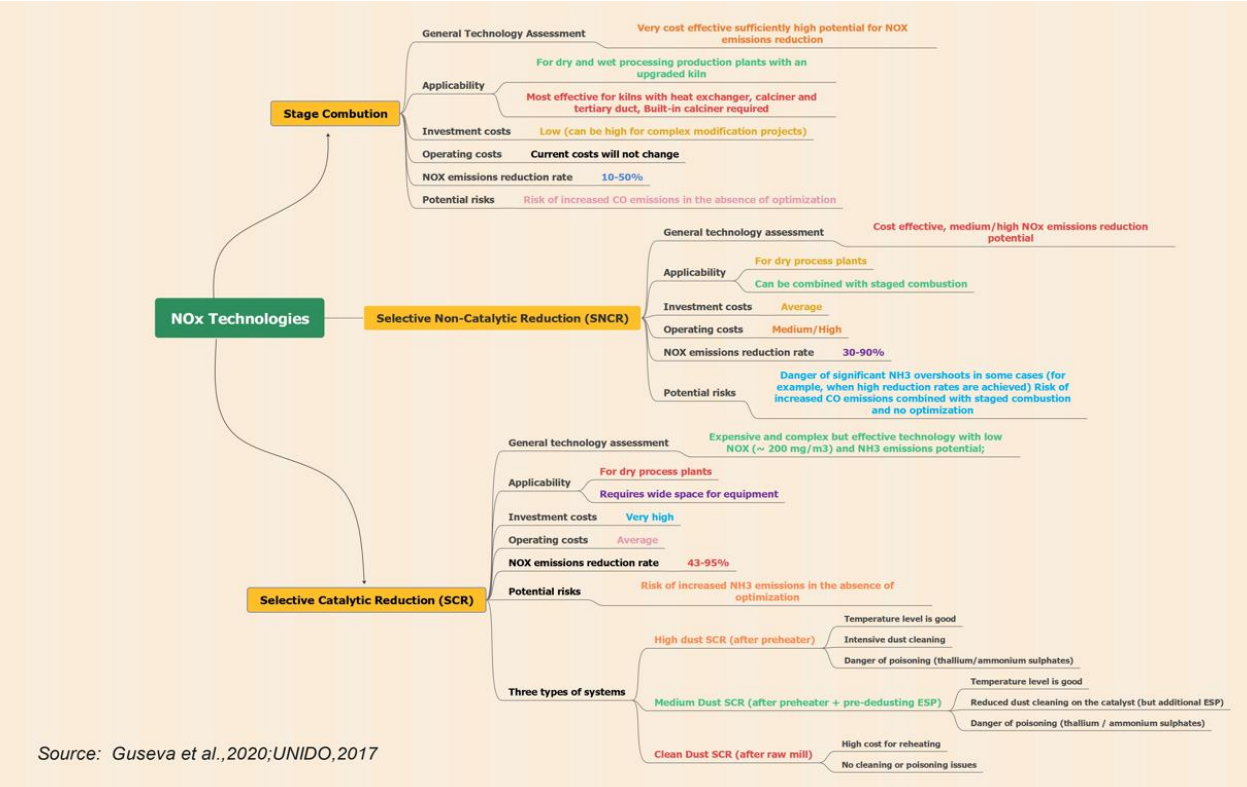
As schematic diagram of combination of various technologies for the captive power plant in a cement industry.



5.4.2 NOx emission

Following are the technologies available for NOx reduction is mentioned in **figure 5.5**:

Figure 5.5: Technologies available for NOx reduction

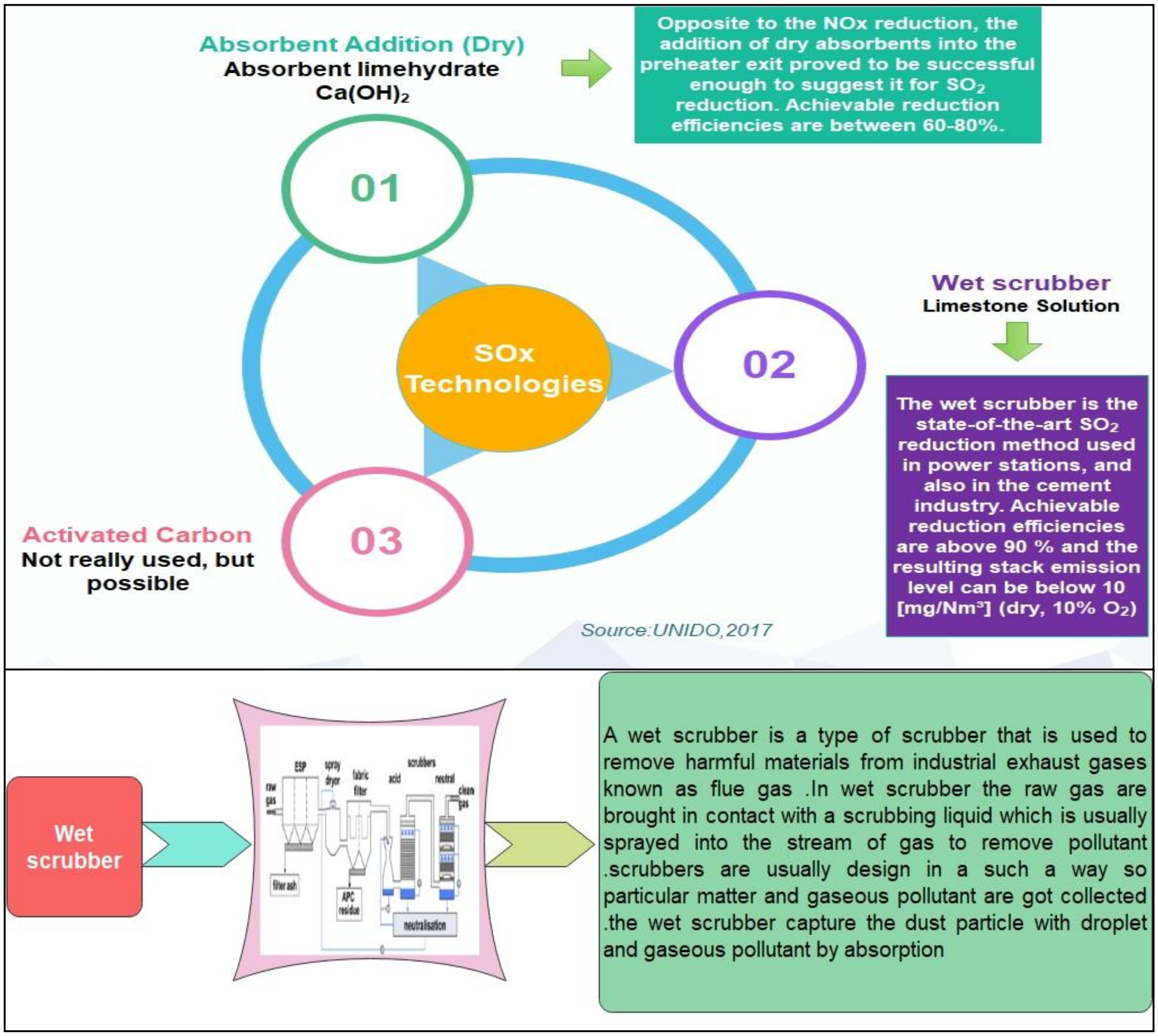


Source: Guseva et al.,2020;UNIDO,2017

5.4.3 SOx Emission

Three different methods used for reducing SOx in cement industry is depicted in **figure 5.6**:

Figure 5.6: Methods used for reducing SOx in cement industry



5.4.4 Other Emission

If CO emissions reach the stack, and no process action helped, they can be reduced by a re-design of the combustion area. e.g., calciner, requiring a significant investment.

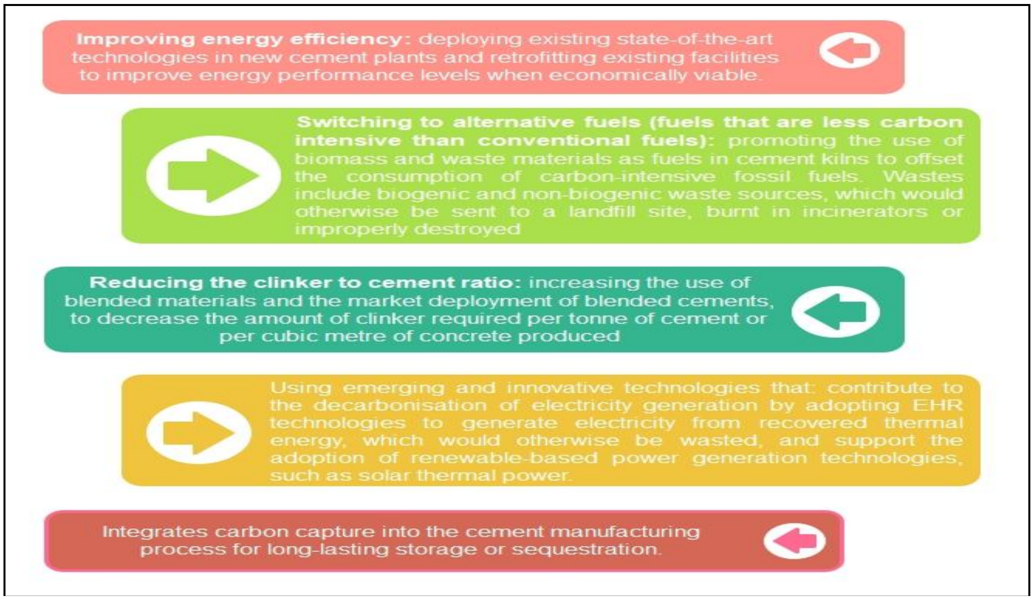
The most modern technology is the installation of an RTO ("regenerative thermal oxidation"), described in the "Organics" section, with the advantage that not only CO, but all organic emissions are eliminated (UNIDO, 2017).

5.5 Moving towards Net Zero Carbon Emissions in Indian Cement Industry

5.5.1 Background

Following roadmap vision pathway has been developed by IEA and WBCSD, 2018:

Figure 5.7: Roadmap vision pathway



Alternative binding materials offer potential opportunities for process CO_2 emissions reductions by using different mixes of raw materials or alternatives compared to PC, although their commercial availability and applicability differ widely.

NCCBM has identified following key levers in the low carbon technology roadmap of Indian cement industry (Mohapatra et al.,2022).

- ✓ Installation of Waste Heat Recovery System
- ✓ Improving Energy Efficiency
- ✓ Substitution of Clinker
- ✓ Alternate Fuel and Raw Materials
- ✓ Newer technologies like Renewable Energy, Novel Cements, Carbon Capture and Storage/Utilization (CCUS)

The low carbon roadmap identified clinker substitution and Carbon Capture & Storage as having the highest potential for reduction in carbon footprint of Indian Cement Industry

(Mohapatra et al.,2022). Further above levers explained in subsequent chapters in this e-guide.

5.5.2 Waste Heat Recovery System

The adoption of waste heat recovery systems in Indian cement manufacturing facilities has been relatively slower compared to its global peers. Out of over 190 large cement plants in the country, only about 20 cement plants have adopted WHR systems. Estimates indicate that the waste heat recovery potential in Indian cement industry is close to 500 MW while the installed capacity till date is only about 275 MW. This indicates the huge opportunity for adoption of waste heat recovery in Indian cement industry.

In case of dry process cement plants, nearly 40% of the total heat input is available as waste heat from the exit gases of the pre-heater and cooler. The quantity of heat from pre-heater exits gases ranges from 180-250 kcal/kg clinker at a temperature range of 300-400°C. In addition, 80-130 kcal/kg clinker heat is available at a temperature range of 200-300°C from the exhaust air of the grate cooler. In some cases, it is observed that although the quantity of thermal energy through pre-heater discharge gases of the grate cooler exhaust is high, the quality of such heat is low. These heats have various applications such as drying of raw material and coal or generation of power.

As raw material drying is important in a cement plant, heat recovery has limited application for plants with higher raw material moisture content. Often drying of other materials such as slag or fly ash requires hot gases from the cooler or pre-heater and, in that case, waste heat recovery potential will be further reduced. Power production utilizing hot gases from the pre-heater and hot air from the cooler requires a heat recovery boiler and a turbine system.

Based on the chosen process and kiln technology, 8-10 kWh/t clinker can be produced from cooler exhaust air and 9-12 kWh/t clinker from the pre-heater gases if the moisture content in the raw material is low and if volume of hot gas/air for drying is less. So in total up to 22 kWh/t clinker or up to 25% of the power consumption of a cement plant can be produced by using WHR technologies without changes in kiln operation. Waste heat recovery technology will result in 0.8 – 1.3 kg CO_2 reduction in emissions.

5.5.3 Improving Energy Efficiency

Broad categories of energy efficiency areas include:

- Installation of sensors/weighing systems

- Smart meters for accurate measurement
- Data acquisition from shop floor to board room
- Real-time data with a transfer rate of milliseconds
- Process data storage for getting business insights with AI technologies
- APC (Advanced Process Control system) Installation
- Remote access for online monitoring

A list of demonstrated technologies on energy efficient equipment/process is prepared by Bureau of energy efficiency and is available at following:
https://www.adeetie.beeindia.gov.in/list-of-energy-efficient-technologies

Some examples from the list are as given in **figure 5.8 to 5.10.**

Figure 5.8 to 5.10: Examples of demonstrated technologies on energy efficient equipment/process

Thermal - Waste Heat Recovery (Low Temperature)

Name Of Technology	About Technology	Potential saving(%)	Sector	Investment (₹ Lakh)	Monetry Saving (₹ Lakh)	Payback (Months)	Equipment Capacity
Heat Exchanger	A heat exchanger is a system used to transfer heat between a source and a working fluid.	8-8.5	Cross-sectoral - Thermal	4	10	6	7000 Kg/h
Hot water generation from cement kiln	The waste heat, which otherwise would escape in atmosphere may be recovered using appropriate heat exchanger to pre-heat water for use in utility or process	30-40	Cement - Thermal	100	20	30	3000 TPD kiln 60 TR VAM system
Low-Grade Waste Heat Recovery System (LGWHRS)	Waste heat even below 100 degree Celsius is recovered by LGWHRS and can be used in the low temperature applications. These heat exchangers are specially designed for low-grade waste heat recovery.	5-7	Cross-sectoral - Thermal	10	10	30	24-36 TPH
Thermo Compression	Utilization of waste flash steam in chiller and process usage	70-80	Cross-sectoral - Thermal	150	20	24	3000TR

Thermal - Waste Heat Recovery (Medium Temperature)

Name Of Technology	About Technology	Potential saving(%)	Sector	Investment (₹ Lakh)	Monetry Saving (₹ Lakh)	Payback (Months)	Equipment Capacity
Air Pre Heater & Drying Bed in furnace	Use of waste flue gas to pre-heat the material and save fuel	5.5-6	Cross-sectoral - Thermal	5	18	12	1.5 TPH
Economiser in boiler/Thermic Fluid Heater Feedback	The use is Economizer is highly recommended to save fuel in thermal application by use of high heat content in flue gas to pre-heat water, which can then be used in utility or process application	4-4.25	Cement - Thermal	3	10	6	4 TPH
Gas-fired Reheating Furnace with WHR System Feedback	A fully automated system ensures better control on temperature of metals in rolling mills, with efficient combustion owing to the use of gas as fuel. In addition, the WHR system will save substantial energy by preheating the metal to the extent possible	16-28	Cross-sectoral - Thermal	19	15	9	2 - 12 TPH

Thermal - Waste Heat Recovery (Medium Temperature)

Name of Technology	About Technology	Potential saving(%)	Sector	Investment (₹ Lakh)	Monetry Saving (₹ Lakh)	Payback (Months)	Equipment Capacity
Waste Heat Recovery System for Coke Drying Quenching (CDQ)	Smelting furnace generates flue gas at high temperature. This flue gas temperature is utilized to heat the atmospheric air that is utilized for coke drying	200-250	Cement Thermal	300	20	18	7 TPH Coke Drying from 15% - 2% W/W
Waste Heat Recovery for power generation	The WHR process is a fuel conservation measure where the heat from waste stream of gases is recovered to generate steam which in turn is used to drive turbine and generate power, instead of using conventional process of burning fuel	230	Cross-sectoral - Thermal	900	10	50	1MW
Waste Heat Recovery Boiler	WHR Boiler is a system which recovers various kinds of waste heat generated from the production process of steel, chemical, cement etc and convert such recovered heat into useful and effective thermal energy	3-3.5	Cross-sectoral - Thermal	3.5	10	12	4 TPH

5.4.4 Substitution of Clinker/Limestone Based Cement/Low Carbon Cement

Bureau of Indian Standards (BIS) which controls the standards for various types of cements produced in the country, has allowed up to 5 % of limestone/slag/ similar material addition in cement.

Presently many cement plants are not adding the filler due to more focus on higher one day strength requirements to maintain competition. The one-day strength does not improve quality of construction as a whole and results in higher specific power consumption and reduces the additives.

Considering the fact that normal household constructions do not require high grade cement, using limestone (up to 20%) in cement can reduce energy consumption and GHG emissions. It is estimated that increasing the addition of limestone in OPC as filler from the existing level by 10% will result in GHG reduction of 25.0 kg CO_2 /MT cement (CII, 2010).

A number of low carbon or carbon-negative cements are currently being developed by some companies that expect to build pilot plants in the near future. The physical properties of these cements appear to be similar to those of OPC and hold equally strong potential for the global and Indian cement industries. These new processes are still at the development stage, but are advancing steadily (IEA and WBCSD, 2013).

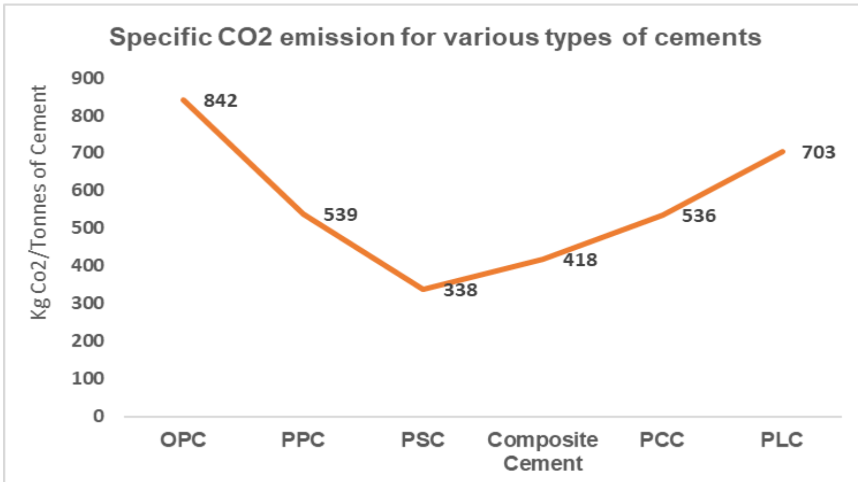
NCB is working on various levers of CO_2 reduction, particularly Clinker Substitution, in order to help cement industry, achieve net zero carbon by 2070 in line with the current global scenario.

Accordingly, NCB has undertaken extensive research for development of low carbon cements like:

- Portland Composite Cement based on fly ash and Limestone
- Portland Limestone Cement
- Composite Cement based on fly ash and slag
- Geopolymer Cement
- Multi component blended cement
- Portland Dolomite Cement

Figure 5.11 depicts specific CO_2 emission for various types of cement.

Figure 5.11: Specific CO_2 emission for various types of cements



Source: (Mohapatra et al.,2022)

Further Readings
1.https://www.lenntech.nl/applications/flue-gas-desulfurization.htm https://www.sciencedirect.com/topics/engineering/flue-gas-desulphurization https://www.micronicsinc.com/filtration-news/flue-gas-desulfurization/ 2. https://iopscience.iop.org/article/10.1088/1757-899X/1083/1/012083/pdf 3.http://www.iipinetwork.org/wp-content/Ietd/content/dry-kilns-multistage-pre-heaters-and-pre-calcination.html. https://www.hindawi.com/journals/ace/2020/5640218/

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Chapter 6: Green Belt Development in Cement Sector

6.1 Introduction

A Green Belt (GB) planted with the right plants can absorb pollution from a variety of sources, including those not removed by air pollution control devices. Plants form a surface capable of absorbing pollutants and forming sinks for pollutants in green belts. To develop a sustainable green belt around any polluted place, it is very important to identify tree species that are capable of biologically monitoring emissions and can endure emissions.

India is a vast country with diverse agro-climates suitable for different plant species. Plant species must be selected for cultivation based on the agroclimatic conditions. In accordance with CPCB (Central Pollution Control Board) guidelines, there are 15 agroclimatic regions, which are further divided into 68 subzones based on annual rainfall, climate, and soil types.

To be used in a Green Belt, a plant should have the following characteristics:

(a) Plant species tolerant to cement dust and pollution.
(b) A fast growth rate that allows the canopy to develop quickly.
(c) Strong branches to ensure they have ability to withstand storms
(d) A large leaf size to enhance pollutant retention.
(e) Dense foliage to trap pollutants more effectively.
(f) A relatively high level of tolerance for insects and diseases,
(g) A high tolerance for soil compaction and nutrient stress
(h) An extended longevity of the GB itself.

Among the above conditions, cement dust tolerance is a mandatory requirement for developing GB in cement plants (CPCB, 2000). APTI measures plant species' tolerance to air pollution.

6.2 APTI definition and its usage

APTI stands for Air Pollution Tolerance Index (APTI) and it reflects a plant's ability to tolerate air pollution. Plants with higher APTI can act as a source of pollution alleviation, whereas plants with lower APTI can be an indicator of air pollution level and are sensitive to air pollution, and their growth is hampered by the presence of pollutants (Singh & Rao, 1983).

APTI is estimated as (Randhi & Reddy, 2012):

$$APTI = \frac{[A(T+P)+(R)]]}{10}$$

where,

A = Ascorbic acid content (mg g− 1) (dry weight),
T = Total chlorophyll content (mg g− 1),
P = leaf extract pH, and R = RWC (%).

Plants which have a higher Air Pollution Tolerance Index (APTI) can be used effectively as 'bio-indicators' of air pollutants and thus, be a tool for effective mitigation.

Accordingly, studies (Randhi and Reddy, 2012) have categorised APTI as follows:

Table 6.1: APTI Index with categories

APTI Index	Categories
<1	Very sensitive
1-16	Sensitive
17-29	Intermediate
30-100	Tolerant

6.3 Plant species sensitive to cement dust

According to studies on plant sensitivity to cement manufacturing processes, higher concentrations of pollutants like NO_x, SO_x, CO_2, CO, and Particulate Matter (cement dust and fly ash) from cement plants hamper plant growth (CPCB 2000, Radhapriya; Gopalakrishnan; Malini; & Ramachandran 2012, Kaur; Bakshi; Bhardwaj; & Verma 2019; Randhi & Reddy, 2012). A cement plant's gaseous emissions contain toxic metals like zinc, copper, lead, fluoride, magnesium, cadmium, nickel, beryllium, among others. A further analysis of the studies indicated that the following plants/shrubs/trees are sensitive to cement dust, as shown in **Table 6.2**.

Table 6.2 Species sensitive to cement dust

Scientific Name	Common Name
Zea mays	Maize
Syzgium cumini	Jamun, Guava Plum
Psidium guajava	Guava
Triticum aestivum	Bread Wheat
Calotropis procera	Rubber bush, Calotrope, Apple of Sodom, giant milkweed
Cassia fistula	Golden Shower Tree, Indian Laburnum, Pudding Pipe Tree
Dalbergia sisso	North Indian Rosewood
Withania somnifera	Ashwagandha, winter cherry
Glycine max	Soyabean
Abelmoschus esculantus	Okra
Brassiza campestris	Field Mustard
Citrus aurantium	Bitter Orange
Delonix regia Raffin	Gulmohar tree

Source: (CPCB 2000, Radhapriya; Gopalakrishnan; Malini; & Ramachandran 2012, Kaur; Bakshi; Bhardwaj; & Verma 2019; Randhi, Reddy 2012)

6.4. Plant species based on Research undertaken in India

Relevant studies (CPCB 2000, Radhapriya; Gopalakrishnan; Malini; & Ramachandran 2012, Kaur; Bakshi; Bhardwaj; & Verma 2019; Randhi & Reddy 2012) have highlighted that those species with a high APTI value are tolerant to cement dust and can be used for GB development close to the cement plants.

Table 6.3: List of plant species tolerant to cement

Location of the research	Species tolerant to cement dust	References
Haridwar, Uttarakhand	Cyperus rotendus (Nut Grass), Cynodon dactylon (Scutch grass, Bermuda grass), Xanthium strumarium (Rough cocklebur),	Kaur, Bakshi, Bhardwaj, & Verma, 2019

	Alternanthera sessilis (Brazilian spinach, sisso spinach, dwarf copperleaf)	
Coimbatore, Tamil Nadu	Polyalthia longifolia (Ashoka, Green Champa), Azadirachta indica (Neem, Indian lilac), Albizia lebbeck (Siris Woman's Tongue, East Indian Walnut), Bougainvillea spp. (Boganvilliea), Murraya paniculata (Orange jasmine), Moringa oleifera (Moringa), Ficus religiosa (Peepal), Aegle marmelos (Bel),Tamarindus indica (Tamarind), Hibiscus rosasinensis (Gurhal), Alstonia scholaris (Dita bark, blackboard tree), Holoptelea integrifolia (Indian Elm, Jungle cork tree)	Radhapriya, Gopalakrishnan, Malini, & Ramachandran, 2012
Kurnool, Amdhra Pradesh	Azadirachta indica (Neem), Eucalyptus obliqua (Messmate), Ficus benghalensis (Banyan), Ficus religiosa (Sacred Fig), Leucaena leucocephala (White lead tree, river tamrind, jumbay), Sapindus emarginatus (Notched Leaf Soapnut), Terminalia catappa (Indian Almond)	Nazaw, Giridhar, & Meerabai, 2019

6.4.1 Species tolerant to cement dust

List of plant species (state wise) tolerant to cement dust according to CPCB are classified in subsequent link :(Read More)

6.5 Criteria for Green Belt design

According to the guidelines of CPCB and MoEF&CC (CPCB, 2000 and MoEF&CC, n.d.) the following criteria should be considered when developing green belt:

1. A total of 1500-2000 trees will be planted per hectare in the cement plant, on the approach roads and on the premises of the township.
2. To create a barrier between the project and the surrounding area, the greenbelt should consist of rows of trees.
3. Depending on the availability of land, a greenbelt with 5m width will be developed on the cement plant premises.
4. 33% of the total plant area is to be used for developing the green belt.
5. A nursery will be established to raise 100,000 saplings every year for plantations.

6. It is proposed to plant medium-height trees (7-10m) and shrubs (5m) in the green belt.
7. A boundary wall will also be planted with creepers to increase its insulation capacity.
8. The greenbelt around the industry wall will be developed keeping in view of the following objectives:
    - Staggered planting of trees in a row.
    - Shorter trees will be planted in the first row and the taller trees in the outer row around the project area.
    - Since tree trunks have little foliage, shrubs are a good option for covering these areas.
    - Sufficient spacing will be maintained between the trees to facilitate effective height of the greenbelt.
    - A greenbelt should be developed using native plants of fast growth with large leaf indexes and a canopy.

The green belt development plan should include at least 1500 trees per hectare. Plantation information must include plant species, planting width, and planning schedule. The green belt shall be developed around the project boundary. In addition, a scheme for greening the roads used for the project shall also be included.

6.6 Conservation of biodiversity and growing urban forests through the Miyawaki technique

Green belts can be developed by creating mini forests. These forests are created using the Miyawaki technique (also known as Potted Seedling Method). Developed by Akira Miyawaki, this method gained popularity over the years. This Japanese technique creates mini forests. Native samples are planted close together, and soil fertility is improved by mulching. It allows sunlight only to reach the top, allowing plants to grow upward, rather than sideways. As a result, plants compete for light, space, and water (Manuel 2020).

Consequently, the plantation becomes 30 times denser, grows ten times faster, and becomes maintenance-free in three years. Plantations can grow in 20-30 years using this unique method. It reduces temperatures, improves air quality, and sequesters CO_2 (Mathur, 2019, Nargi,2019, Sivabalan, Krishnan, and Nithila 2021).

Using this technique, Dalmia Bharat Group established a High-Density plantation in their Kadapa mine to enhance the biodiversity of the neighborhood. Their unique method was coupled with environmentally friendly practices and a hectare of land was developed without pesticides or fertilizers (Dalmia, 2020-2021).

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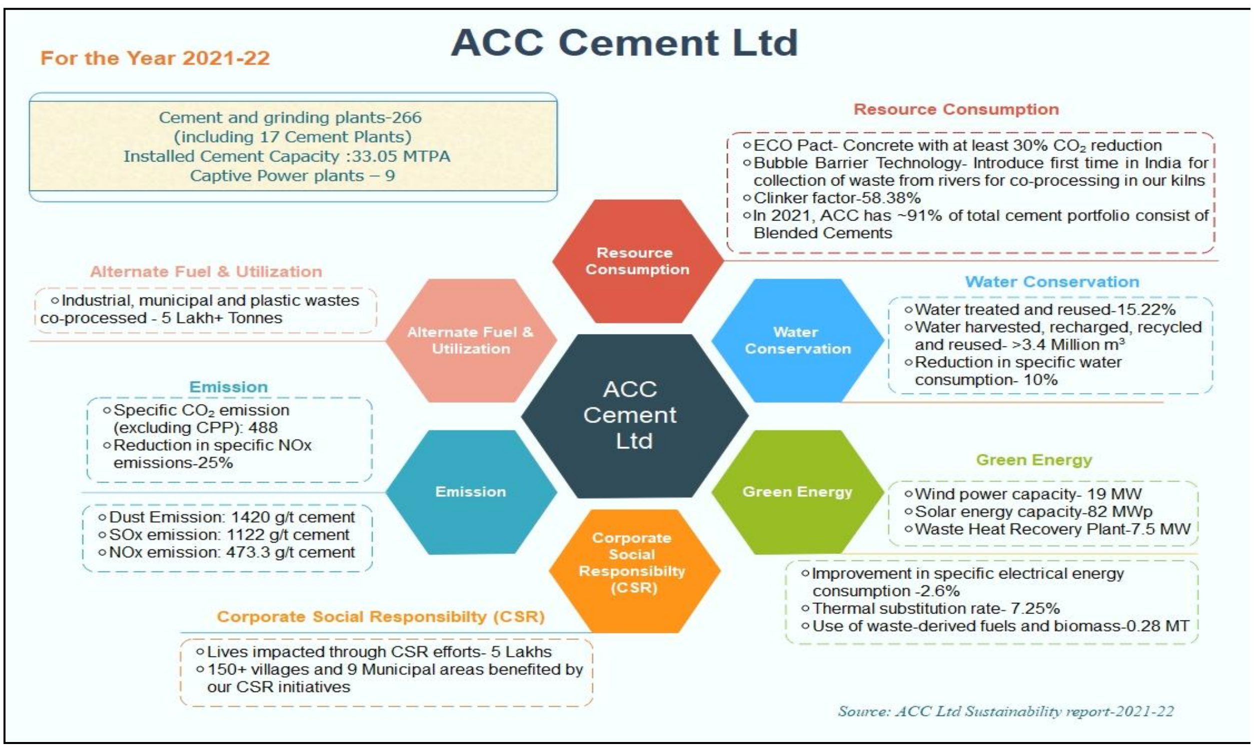
7 Success Stories of Cement

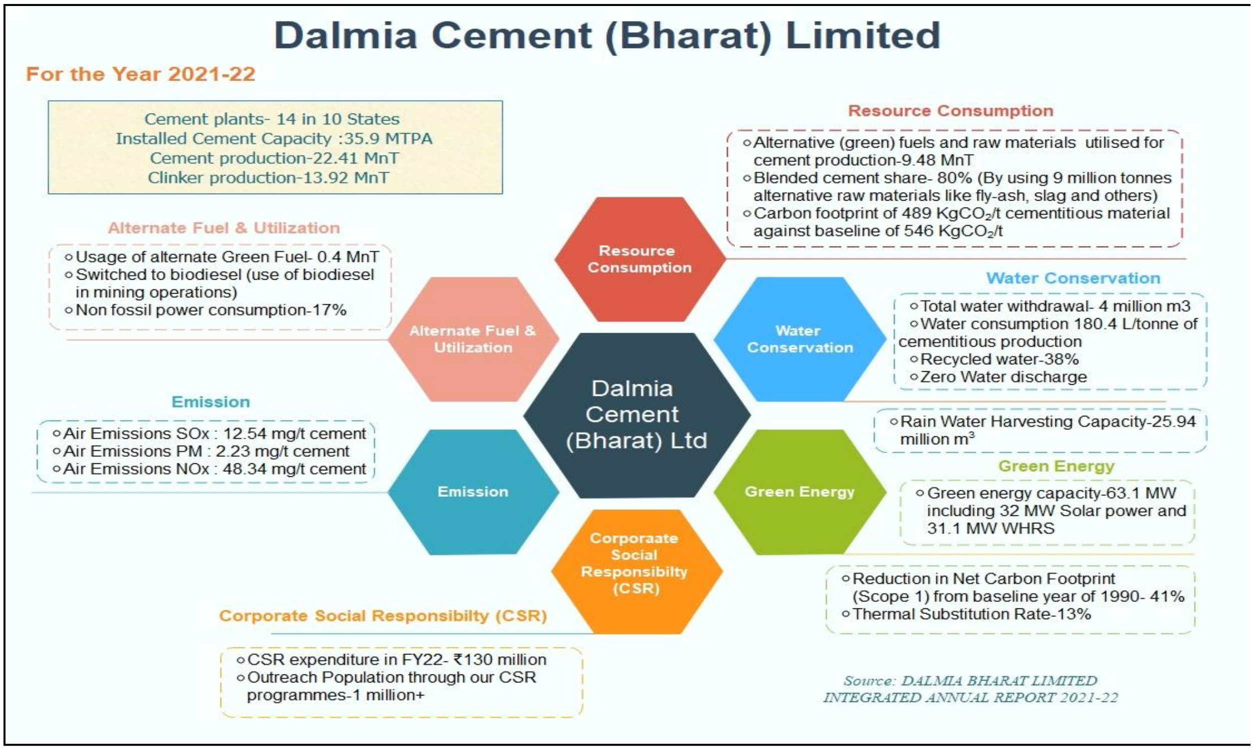
7.1 Achievements in resource reduction, pollution abatement and towards carbon Neutrality

The Indian cement industry is recognized globally as one of the most energy efficient in the world, with relatively large production units and the use of low-carbon, cost-effective technologies (WBCSD, 2018). Achievements in terms of emission reduction, resource conservation, use of alternate fuel & utilization, use of green energy by some of the Indian Cement plants is briefly discussed in this chapter.

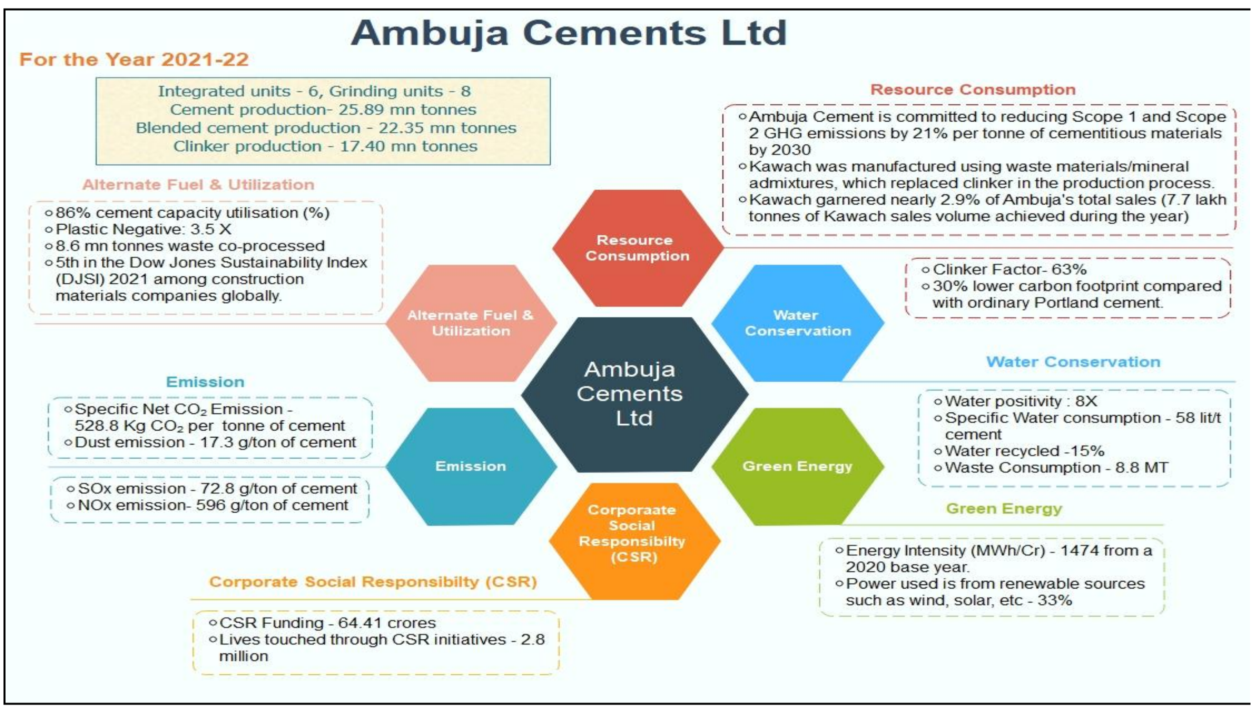
1) ACC Cement Ltd



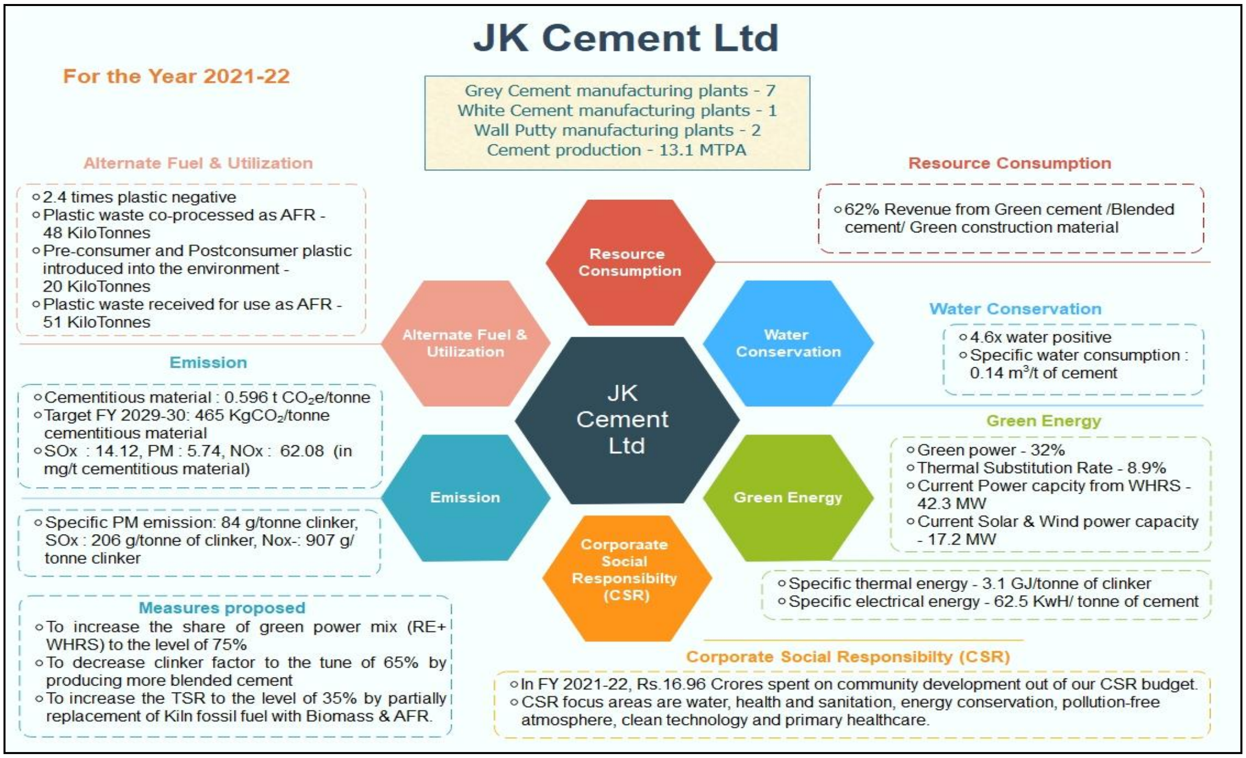
2) Dalmia Cement (Bharat) Limited



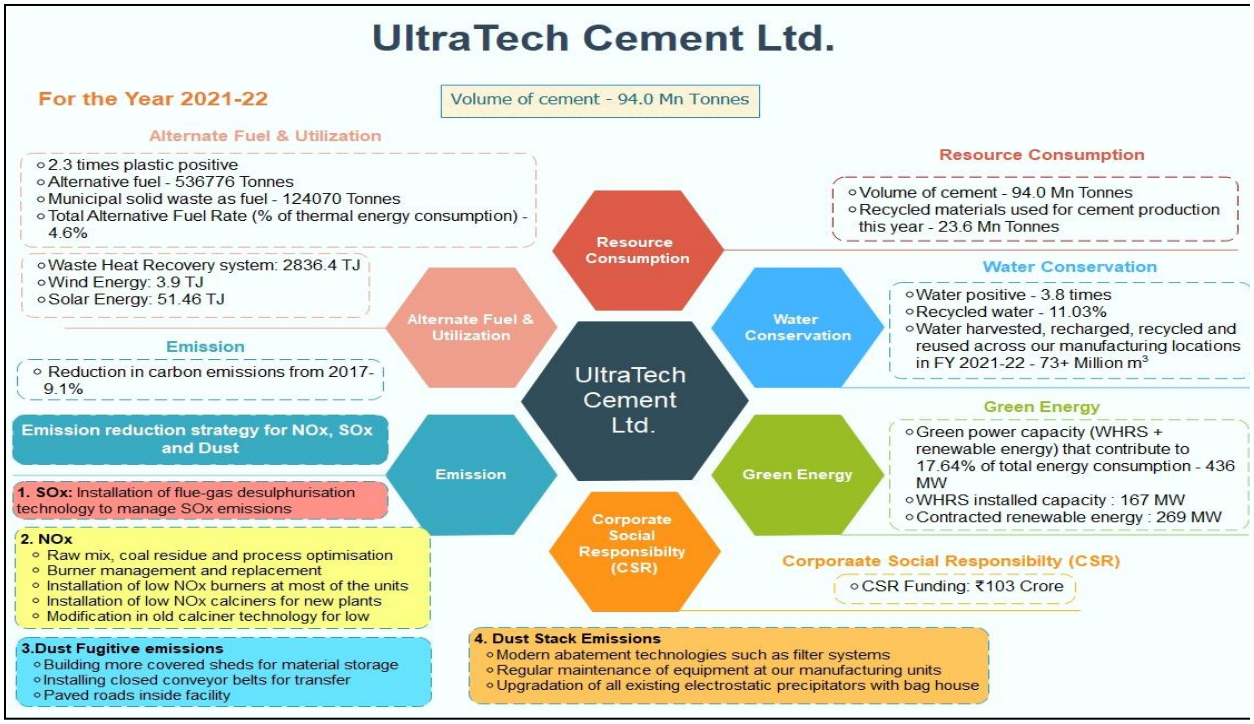
3) Ambuja Cements Ltd



4) JK Cement Ltd



5) UltraTech Cement Ltd



6) Birla Corporation Limited


For the Year 2021-22
Birla Corporation Limited
11 Cement Plants
Total installed capacity of Cement- 20 MN TONS
Cement production 83.22 Lakh Tons
Clinker production 53.40 Lakh Tons
Resource Consumption
Waste fly ash consumed in construction of the plant - 22,000 tons
Cement division capacity utilisation - 90%
Measures taken for conservation of limestone reserves by optimizing (like blending high grade with low grade limestone)
Alternate Fuel & Utilization
Optimization of cement grinding at CCW - CM1
Optimization in Raw Meal Grinding-CCW Raw Mill-2 (Vertical Roller Mill)
Grinding media regradation in CCW and BCW Cement
Water Conservation
Water positive - 1.2X
RWH Capacity - 1,70,000 M^3
reusing treated wastewater for dust suppression and plantation in sustainable way
Use of Air-Cooled Condenser (ACC) technology instead of the water cooled approach- 90% water saving
Emission
The CO_2 emissions marked significant reduction due to consumption of PPC instead of OPC.
To control NOx, SNCR system has been installed in both Satna & Chanderia Plant.
Birla Corporation Limited
Green Energy
Solar Power Plant Capacity - 33.62 MW
WHRS installed capacity : 34.75 MW
Reduction of 68 Million Kg of CO_2 by using Solar and WHRS
Steps in utilization of alternate sources of energy
1 AFR used in kiln in both Satna & Chanderia Plant which includes Carbon Black, Waste mix solids, ETP sludge, Mustard husk, TDI Tar, Industrial waste, Non hazardous waste and replacing fossil fuel in sustainable manner.
2 Liquid waste fuel firing to NCCW calciner.
3 Modification in CCW & NCCW firing system for dosing of carbon black.
4 WHRS system is operating in both Satna & Chanderia Unit for power generation from waste flue gas.
Corporate Social Responsibilty (CSR)
Sourcing renewable energy from captive solar power plant at both Satna & Chanderia.
Sourcing renewable energy from group captive solar power plant at Raebareli
Source: MP Birla Annual Report and Accounts 2021 -22

7.2 Case Studies for implementation of some of energy efficient technologies (NPC, 2018)

Case Study 1: Installation of New High Efficiency SF Cooler in Line-1 with design capacity 2200 TPD at Ramco Cement

Background

The Preheater section was continuously upgraded to 3200 TPD with the same cooler. The cooler efficiency has reduced due to high loading on cooler.

Description of the project

The plant has replaced 3200 TPD conventional grate cooler with FLS cross bar cooler of capacity 3550 TPD. The table shows the operational parameters before and after the cooler upgradation. Productivity increased by 350 TPD of clinker, cooler loss was reduced by 60 kcal/kg clinker, power consumption in cooler section is reduced by 1.35 kWh/T Clinker

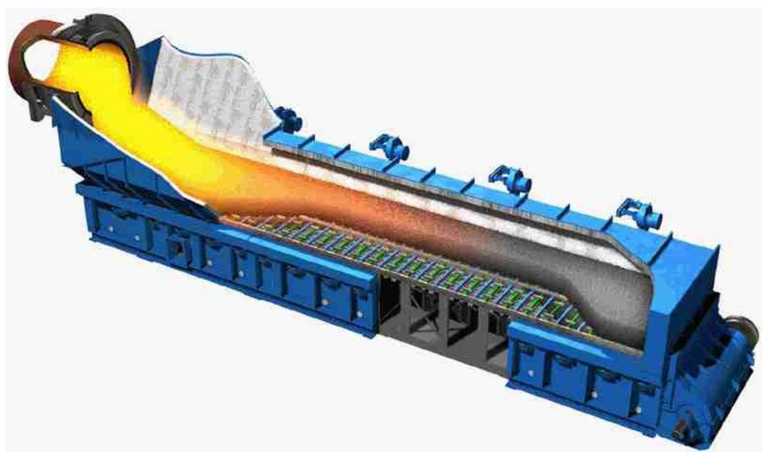
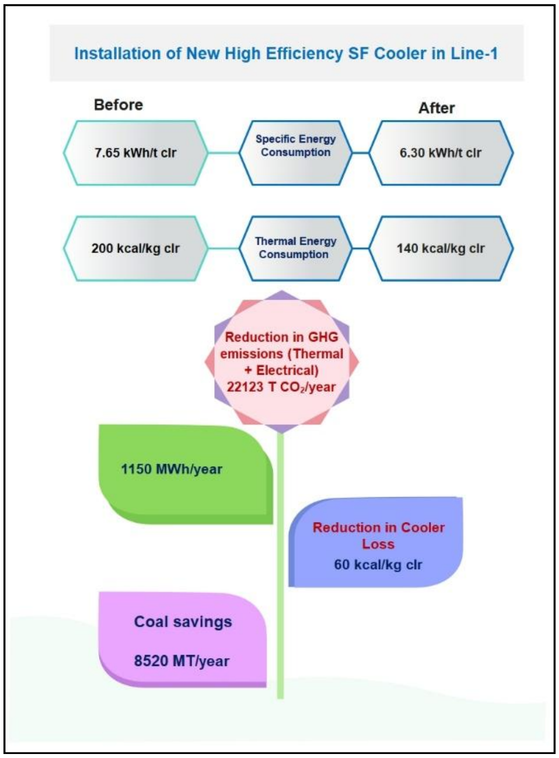


Figure 7.1: New High Efficiency SF Cooler in Line-1

Impact of implementation of the technology is presented in the following **figure 7.2**:

Figure 7.2: Impact of Installation of new high efficiency SF cooler in Line-1



Case Study 2: Installation of Raw Mill-1 Classifier with Energy Efficient Classifier with Vortex Rectifier

Background

The plant had installed Loesche mills for raw material. The raw mill was designed for feed moisture of 5% - 10%. Over a period of time the normal feed moisture increased to more than 10% causing the reduced raw mill output to 205-210 tph from 215-220 tph. During monsoon mill output was further reduced to 190 tph. Hot gas generator (HGG) has to be operated to meet clinker production. Since more heat was required for drying the raw material, the gas volume was to be increased in mill and thereby causing higher product residue. Kiln feed had to be reduced as the Raw mill was unable to support the raw meal requirement. At high residue of raw meal on 212 μm and high quartz %, problems related to clinker burning resulted in high free lime of more than 2.5%.

Description of the project

The plant has replaced the classifier LSKS 52 with LSKS 57 with inbuilt Vortex Rectifier (*first time in India*). Modified louvre and armor ring to maintain uniform gas flow profile inside the mill.

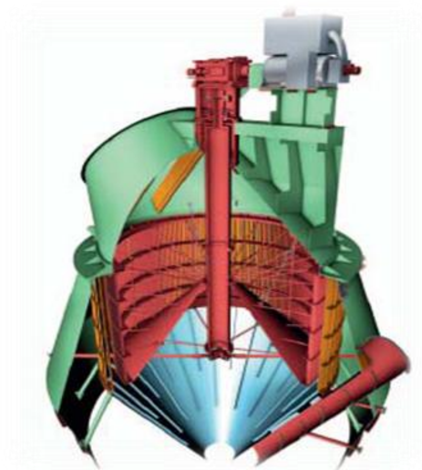


Figure 7.3 Old Classifier without vortex rectifier

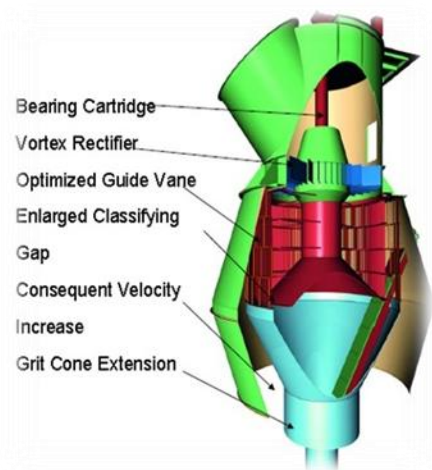
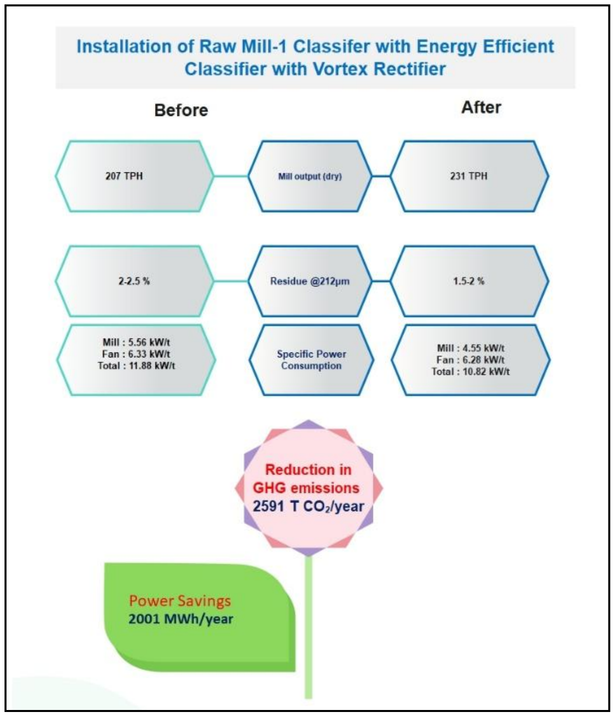


Figure 7.4 New Classifier with vortex rectifier

Impact of implementation of the technology is presented in **figure 7.5**:

Figure 7.5: Impact of installation of raw mill-1 classifer with energy efficient classifier with vortex rectifier



Case Study 3: Installation of Steam Tracer for DG Aux instead of Electrical Heating

Background

The plant has installed with 3 nos. of Diesel Generators (2 x 6 MW and 1 x 4 MW). The DG sets became standby after installation of 2 x 18 MW Coal Based Thermal Power Plant in 2005. During idle time, lube oil and jacket water temperature is to be maintained at 60°C to keep DG in warm up condition. To maintain the lube oil and jacket water temperature at 60°C, the electrical heaters were used.

Description of the project

Since the plant has Coal based Power Plant and plant get low pressure steam from the de-aerator. They have started using this steam to maintain lube oil and jacket water temperatures at 60°C instead of using Electrical Heaters.

	
Figure 7.6 Steam Heating System	**Figure 7.7 Electrical Heating System**

Impact of implementation of the technology is presented in **figure 7.8**:

Figure 7.8: Impact after Installation of steam tracer for DG Aux instead of electrical heating

Case Study 4: Installation of VFD for Line-2 Cement Mill Bag Filer Fan and Pre-heater ID Fan

Background

Cement Mill bag filter fan and Pre-heater ID Fan in Line-2 were running in GRR mode. The speed of these fans can be controlled by varying the resistance in the rotor circuit results in power loss of the motors. The amount of power lost across the GRR depends on the speed at which the fan is operating which in turn depends on the operating step of GRR.

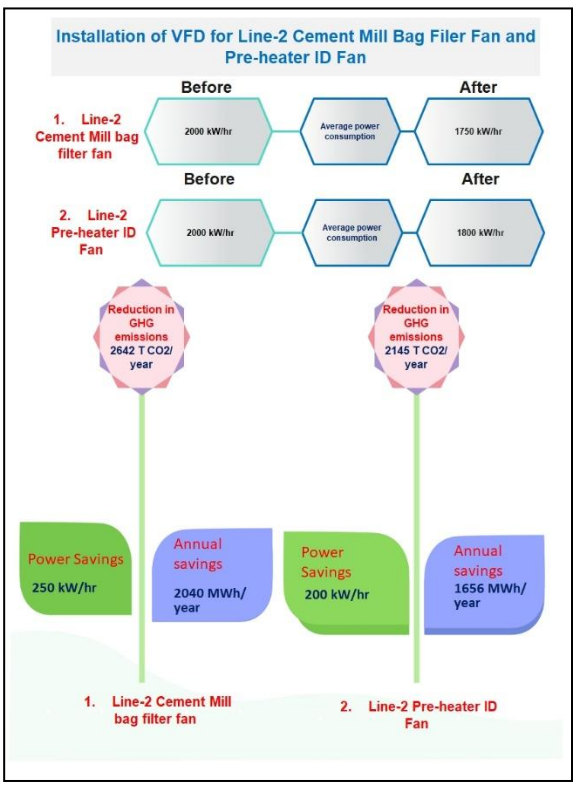
Description of the project

The plant has installed VFD for Line-2 Cement Mill bag filter fan and Pre-heater ID Fan to control the speed and avoid the power loss in the GRR to have optimum control on speed. This has resulted in a significant power savings in the fans power consumption.

	
Figure 7.9 VFD for Line-2 Cement Mill bag filter fan	**Figure 7.10 *VFD* Line-2 Pre-heater ID Fan**

Impact of implementation of the technology is presented in the following **figure 7.11.**

Figure 7.11: Impact of installation of vfd for line-2 cement mill bag filer fan and by installation of vfd for PreHeater ID Fan



Case Study 5: Optimisation of Pressure Drop in Ducts Using CFD in Cement Mill-1 & 2

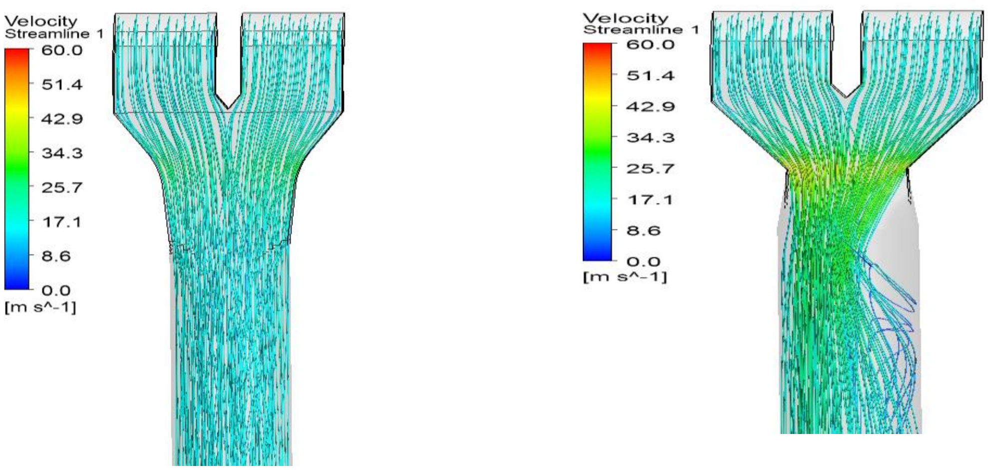
Background

Due to uneven duct area in the Line-1 Cement Mill bag house outlet duct and Line-2 Cement Mill fan outlet duct, there was a high pressure drop in both the ducts due to turbulent flow. This led to high electrical power consumption in Line-1 Cement Mill bag house fan and Line-2 Cement Mill fan.

Description of the project

The plant conducted a CFD analysis of air flow in both the ducts and modified the ducts and reduced the pressure drop. This modification resulted in power savings in Line-1 Cement Mill bag house fan and Line-2 Cement Mill fan.

Figure 7.12 Line-1 Cement Mill bag house fan

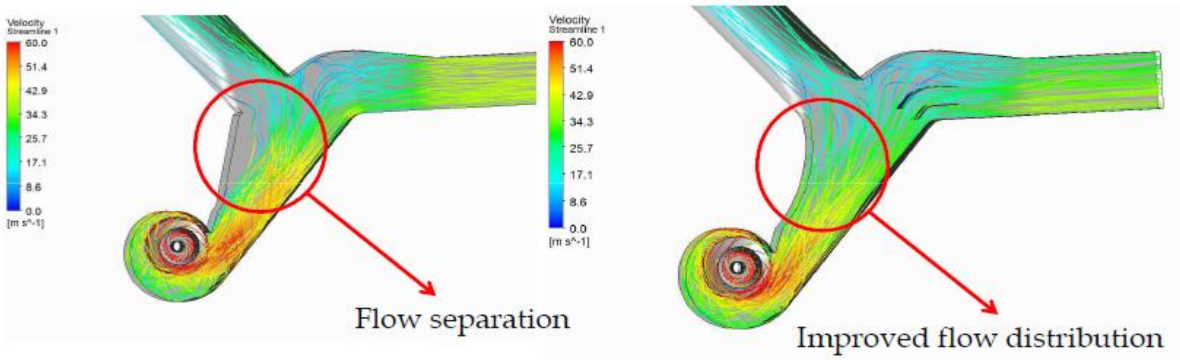


Before Modification **After Modification**

Figure 7.13 Line-2 Cement Mill bag house fan outlet duct

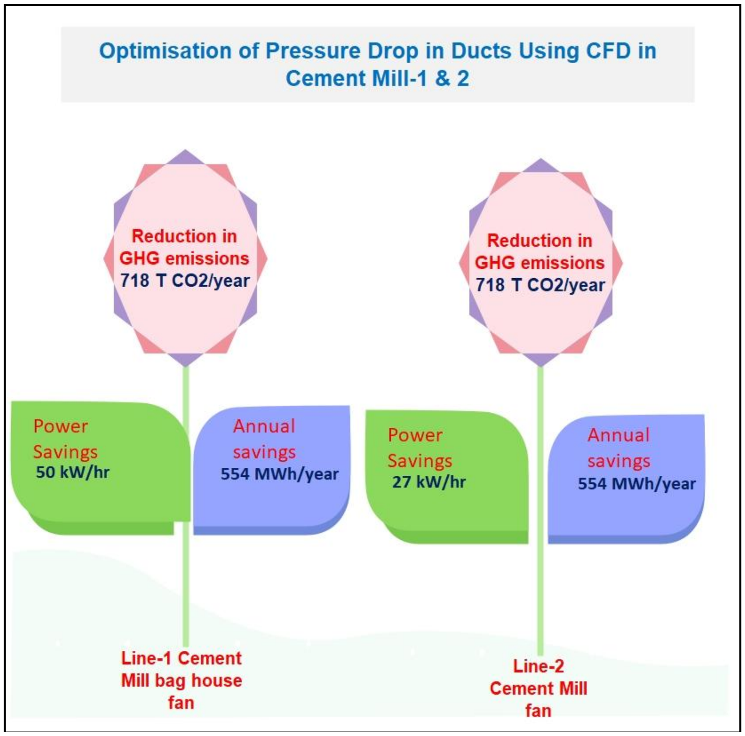
Before Modification

After Modification



Impact of implementation of the technology is presented in **figure 7.14**:

Figure 7.14: Impact of optimisation of pressure drop in ducts using cfd in cement mill-1 & 2



Case Study 6: Modification of Line-2 Raw Mill Fan Inlet Duct

Background

There was a high pressure drop across the Line-2 Raw Mill Fan inlet duct due to small suction area.

Description of the project

The plant has modified fan inlet suction box by increasing its area to reduce pressure drop across fan inlet suction box. This has resulted in Raw Mill Fan power saving of 85 kW.

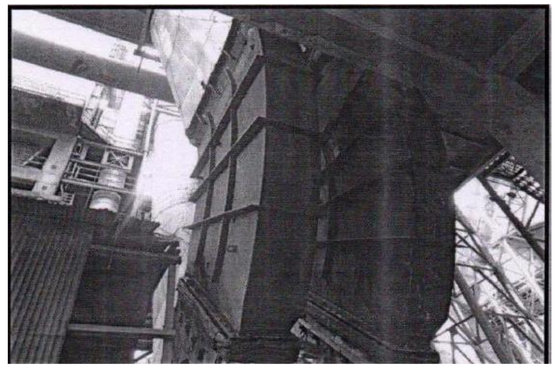
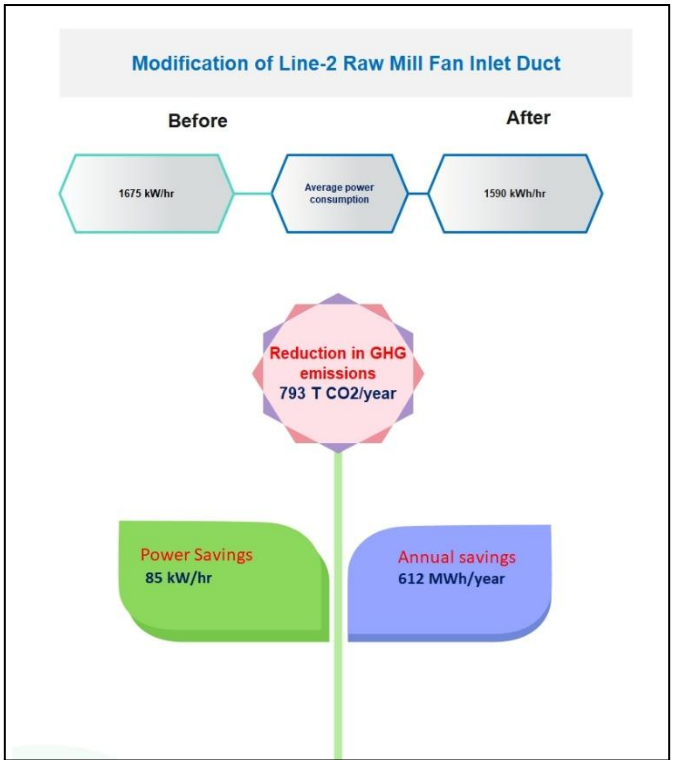


Figure 7.15 Raw Mill Fan Inlet Duct

Impact of implementation of the technology is presented in **figure 7.16**:

Figure 7.16: Impact of modification of line-2 raw mill fan inlet duct



Case Study 7: Installation of Rotary airlock in Line-2 Coal Mill

Background

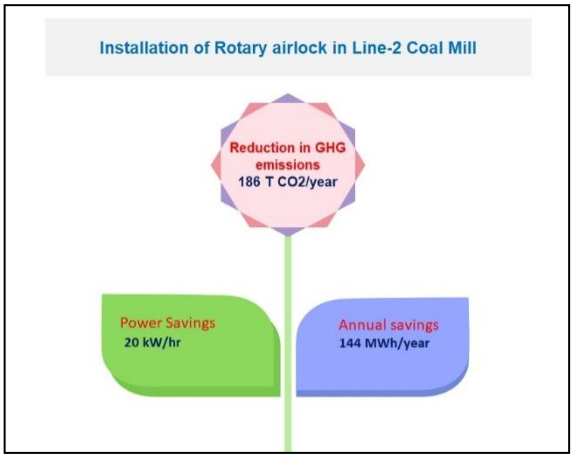
There was false air ingression into the Line-2 Coal Mill inlet which led to the higher power consumption of coal mill Booster fan.

Description of the project

The plant has installed Rotary Airlock in Line-2 Coal Mill inlet to reduce the false air ingression into the mill. This measure has resulted the power saving of 20 kW in booster fan consumption.

Impact of implementation of the technology is presented in **figure 7.17**:

Figure 7.17: Impact of installation of rotary airlock in line-2 coal mill



Case Study 8: Removal of Silencer for Cooler Fans and Arresting Leakages of Cooler

Background

Cooler fans in Line-3 & 4 are having silencers, led to higher pressure drop and hence cooler recuperation efficiency was low and higher power consumption in the cooler section.

Description of the Project

Complete study was conducted and removed all the silencers of all cooler fans and modified the inlet section of the fans. By this measure the pressure drop and the Power consumption of fans has reduced.

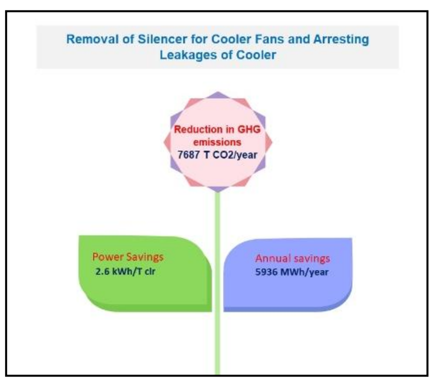
Complete study was conducted and removed all the silencers of all cooler fans and modified the inlet section of the fans. By this measure the pressure drop and the Power consumption of fans has reduced.

Before

After

Impact of implementation of the technology is presented in **figure 7.18**:

Figure 7.18: Impact after removal of silencer for cooler fans and arresting leakages of cooler



Case study 9: Optimization of Coal Handling Plant by Modifying the Belt Feeder Drive Arrangement

Background

The plant was getting the coal from the coal handling plant of quantity 100 TPH only (1200 TPD). The power consumption of line-2 group was 338 kW/hr and the group runs for 12 hours.

Description of the project

The plant optimized the operation of coal handling plant by modifying the belt feeder drive arrangement. With this measure, now the CHP is operating for 7 hours for the same capacity with the reduced power consumption.

Impact of implementation of the technology is presented in the following **Figure 7.19**:

Figure 7.19: Impact after Optimization of Coal Handling Plant by Modifying the Belt Feeder Drive Arrangement

Case Study 10: Utilisation of Alternate Fuels

Background

Vasavadatta Cement is unit of Kesoram Industries Ltd., situated at Sedam, Karnataka. Plant has 4 kilns of capacities 2400TPD, 3600 TPD, 4500 TPD & 4500 TPD.

Description of the project

For increasing the thermal substitution rate to feed different types of alternative fuels Vasavadatta Cement has installed HOTDISC in Kiln-3. The HOTDISC is a safe simple and effective combustion device that maximizes the substitution of fossil fuels by alternative fuels in a controlled manner. The HOTDISC is installed at pyro-processing unit-3 in Sep-2012.

This state of art technology is first of its kind in India, for cement industry to utilize refused delivered waste & tyres in cement rotary kiln as alternative fuel in efficient way with compliance with all environmental regulations. The HOTDISC is supplied by FLSmidth.

The plant is utilizing municipal waste, industrial waste, used tyres of vehicles, etc.

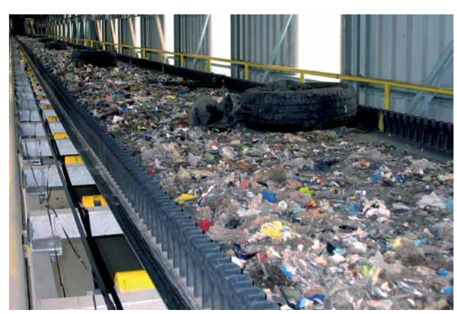
The HOTDISC is a simple combustion device, integrated with pre-heater and pre-calciner systems. The HOTDISC gives the flexibility to burn a wide variety of solid waste in sizes up to 1.2 m – from sludge or grains to whole truck tyres.

Features of HOTDISC Technology

- Combustion of alternative fuels takes place in Oxygen rich atmosphere.
- Variable retention time based on the type of alternative fuel is possible to ensure complete combustion.

Working principle:

As an integrated part of the kiln system, the HOTDISC is added onto the calciner and functions as a moving furnace. When alternative fuel, preheated raw meal and tertiary air are fed into the HOTDISC, it produces combustion gases, partly calcined meal and combustion residues. These are then processed in the calciner along



with the other streams that go into the calciner. The result is calcined meal ready for the kiln and well-controlled emissions.

Benefits of HOTDISC:

- Reduction in Calciner coal firing TPH(TSR>30% based on AF availability)
- Reduction in laterite consumption due to steel wires in tires.
- NOx reduction (PPM) at main stack from based line test: 35%

***AFR feeding rate & other parameters with HOTDISC at Vasavadatta Cement*:**

- Feed rate of shredded tires: 3.5 TPD
- Feed rate of RDF: 10 TPH
- Speed of HOTDISC: 4-5 RPH
- Pre-heater meal diversion towards HOTDISC: 20%

Impact of implementation of the technology is presented in **figure 7.20**.

Figure 7.20: Impact after utilization of alternative fuels

Case Study 11: Logic Modification for Idle Running of Coal Handling Plant Belts

Background

The plant is having coal reclaiming system with series of belt conveyors. Previously when a belt tripped / stopped due to any reason, the CHP belts in the downstream would run continuously. This idle running of belts was approximately 30 min in a day.

Description of the Project

The plant has modified the logic for Line-1 & 2 reclaimer group to avoid the idle running of the CHP belts. As per the modified logic command, the last belt of group should be started within 5 minutes after ON command is given to the group. If not, the entire group will be tripped through interlock protection. Such a way idle running of belts has been avoided.

Impact of implementation of the technology is presented in **table 7.1**:

Table 7.1: Impact of implementation of Optimization of Coal Handling Plant by Modifying the Belt Feeder Drive Arrangement

Description	Units	Before modification	After modification
Average power consumption for Line-1 & 2 @ 30 min idle running	kWh/day	75.7	0
Annual savings	MWh/year	28	
Reduction in GHG emissions	T CO_2/year	36	

Case Study 12: Conversion of Delta Connected Under Loaded LT Motors to Permanently Star Mode

Background

The plant has 70 no's LT motors which are running constantly at low load.

Description of the project

Converted the delta connected and low load running motors to permanently star mode to avoid the power loss.

Impact of implementation of the technology is presented in **table 7.2**:

Table 7.2: Impact after conversion of delta connected under loaded motors to permanently star mode

Description	Units	Before (with delta connection)	After (with star connection)
Annual Energy Consumption	kWh/year	1495000	1065000
Annual Energy Savings	MWh/year	430	
Reduction in GHG emissions	**T CO_2/year**	**557**	

Case Study 13: Optimization of Compressed Air Usage at Packing Plant

Background

In packing plant-2, the compressor installed is of capacity 75 kW (ML-75) and designed for 4 packers. During packer maintenance time (no loading time) or single packer running, the plant operating the same compressor.

Description of the project

The plant has modified the airline and provided one airline from small compressor (UP5-30) which is available in packing plant-2. This modification avoided the running of 75 kW compressor during the maintenance time (no loading time).

Impact of implementation of the technology is presented in **table 7.3**:

Table 7.3: Impact of implementation after optimization of compressed air usage at packing plant

Description	Units	Before modification	After modification
Average power consumption	kW	40	22
Annual power savings	MWh/year	30	

Reduction in GHG emissions	**T CO_2/year**	**39**

Case Study 14: Installation of Waste Heat Recovery System for Power Generation

Background

The India Cements Ltd, Vishnupuram Unit has two rotary kilns. The first kiln (Kiln-1) of 3000 TPD is equipped with two raw Mills of 100 TPH (Ball Mills with closed circuit, central discharge) and two coal Mills of 12 TPH (Ball Mills with closed circuit). The second kiln (Kiln-2) of 4600 TPD is equipped with Vertical Raw Mill of 300 TPH & Vertical Coal Mill of 45 TPH.

Description of the project

Waste Heat Recovery System of capacity 7.7 MW was installed in line 2. The operating load is around 8.6 MW. The hot waste gases coming out from the preheater and clinker cooler are used to produce steam and generate power. This has avoided power requirement from grid/ captive power plant.

Impact of implementation of the technology is presented in the following **Table 7.4**:

Table 7.4: Impact of implementation after installation of waste heat recovery for power generation

Parameter	Unit	Kiln-2	
		PH Boiler	AQC Boiler
Year of Installation	Year	2004	2004
Rated Capacity of Steam Generation	TPH	28.2	14.63
Operating Capacity	TPH	29	14
Net Generation	Units/day	188360	
Kiln Capacity	TPD	4600	
Boiler Inlet temp (design)	°C	360	340
Boiler Inlet temp (operating)	°C	358	329

Boiler outlet temp (design)	°C	210	100
Feed Water Temperature	°C	200	200
Turbine Output (designed)	MW	7.7	
Turbine Output (operating)	MW	8.6	
Average annual generation on design capacity	MWh	60984	
Southern grid emission factor	t CO_2/MWh	0.81	
Reduction in GHG emissions	**t CO_2/year**	**49397**	

Generation Capacity- 7.7 MW

Case Study 15: Installation of IKN's Pendulum Cooler for Upgradation

Background

Jaypee Rewa Plant (JRP) Unit II started as a 4500 TPD SLC kiln with a twin string five stage pre-heater, precalciner and a Folax grate cooler. The capacity was gradually enhanced 5400 TPD with several in house improvements, including modification of pre-heater fans, replacement of cooler fans, increase in pre-calciner volume.

The earlier cooler was conventional cooler and demanding too many maintenance interventions and suffered frequent breakdowns, so the company decided on a complete upgrade of the cooler.

Description of the Project

Jaypee selected IKN's pendulum cooler for up-gradation. An upgrade with IKN pendulum cooler resulted In Improved productivity, enhanced run time and lowered thermal and electrical energy consumption.

Impact of implementation of the technology is presented in table 7.5 shows the operational parameters before and after the IKN upgrade. A significant improvement was achieved in the run days after the upgrade. Specific heat consumption was Reduced by 15-20 kcal/kg of clinker, productivity increased by approximately 200 TPD. The Power in cooler section was also lowered by approximately 0.59 kWh/MT. The upgrade has resulted in improved productivity and run time and reduced thermal and electrical energy consumption.

Table 7.5: Impact after installation of IKN's pendulum cooler for upgradation

Parameters	Before	After
Production **rate** (TPD)	5550	5750
Tertiary air Temp(°C)	760	930
Specific Heat **Consumption** (kcal/kg clk)	710	690
Power in cooler section (kWh/MT clk)	4.47	3.88
Cooler vent air temp (°C)	220	200
Clinker temp (°C)	152	132

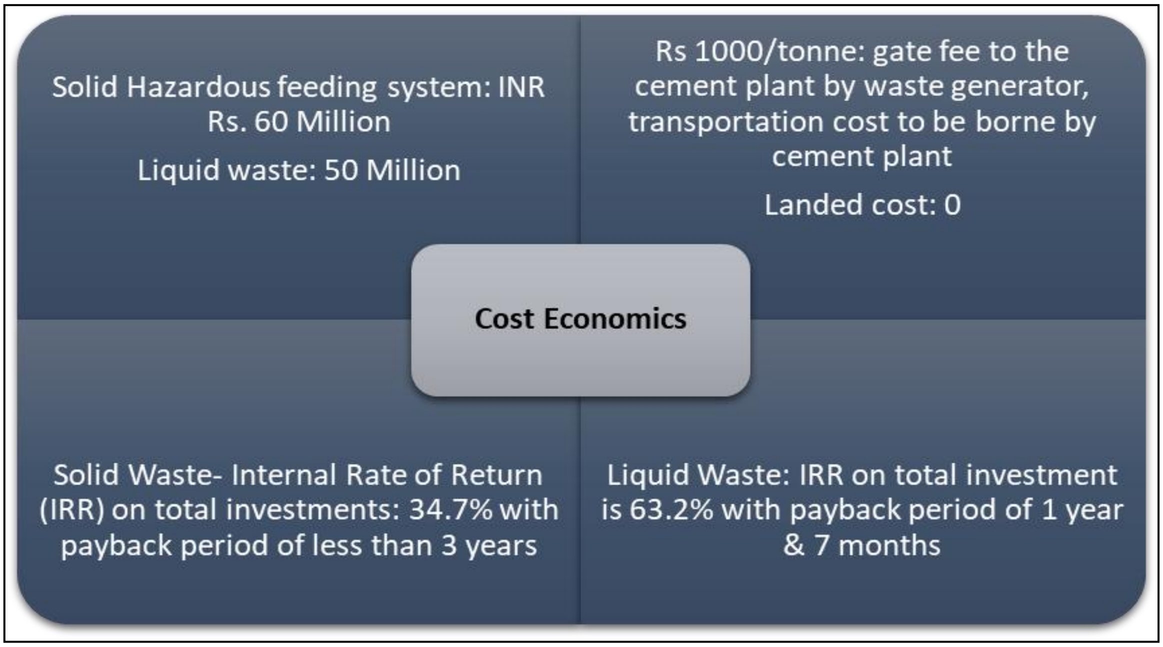
Case Study 16: Co-processing of RDF

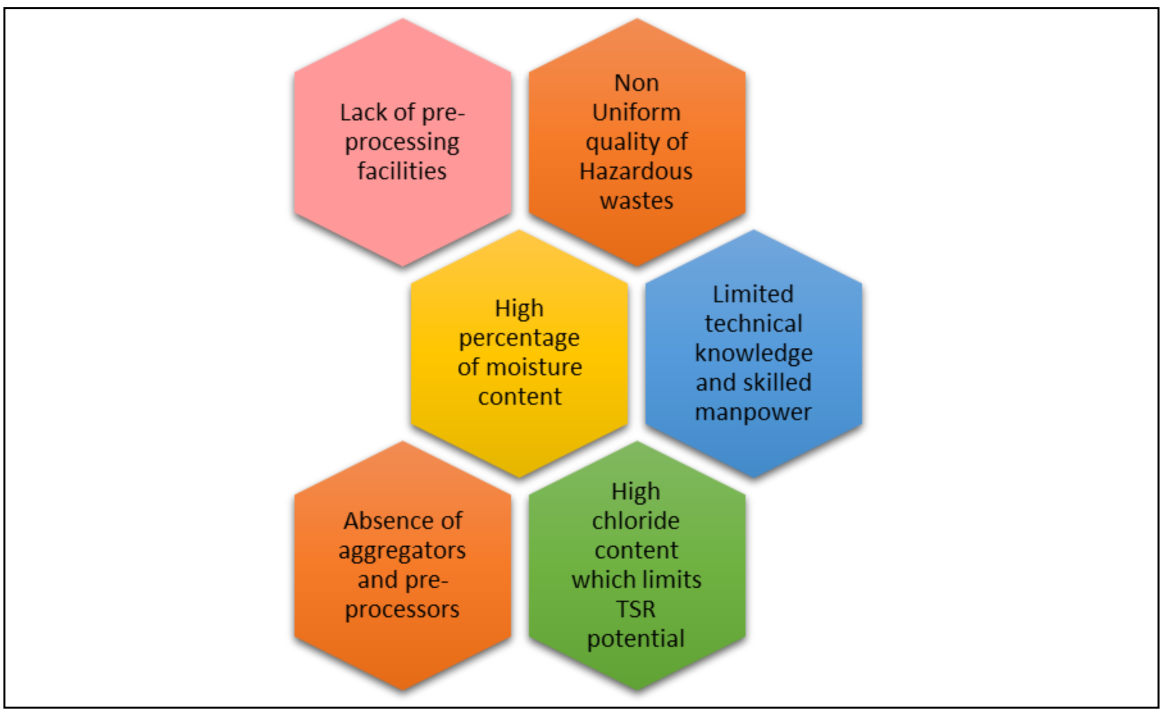
Case Study on utilising RDF in a cement plant- based on techno-economic feasibility study

The plant can use about 45,000 types of RDF within 200kms of the cement plant periphery

- Poor quality of MSW- combustible paper and plastic is picked out by recyclers/ rag pickers
- High moisture content in MSW
- High chloride percentage in RDF restricts the percentage substitution
- Heavy metal content needs to be analyzed
- MSW to cement grade RDF conversion plants

Case Study 17: Utilization of Hazardous Waste in a 4500 TPD plant-based on a techno-economic feasibility study





Case Study 18: Consumption of Green Fuel Dalmiapuram plant of Dalmia Cement

Dalmia Cement

- Increase green fuel consumption at Dalmiapuram
- Use of green fuel reduces dependence on fossil fuels while being more sustainable.
- Thermal Substitution Rate (TSR) from 3% to 8%. After Stabilization TSR achieved to 12%
- Homogenized green fuel feeding with the help of the pre-processing unit, enabled the plant to achieve a TSR of up to 20%.
  In FY 22, ·improve the TSR to 30% at 4,200 tonnes per day

Modification in Plant

DALMIAPURAM, TAMIL NADU

- Increase of ATS extractor operating capacity from 19-25 TPH (tonnes per hour)
- Increase of transportation belt capacity from 20-25 TPH (tonnes per hour
- Modification of green fuel feeding chute and replacement of bent portion with temperature-resistant arco plate
- The remaining feed chute was replaced with SiC bricks to avoid erosion
- Utilization of used ESP sheets as deck plate to avoid material accumulation

Source: Dalmia Cement Annual report-2021-22

Chapter 8 Emergency Preparedness Plan

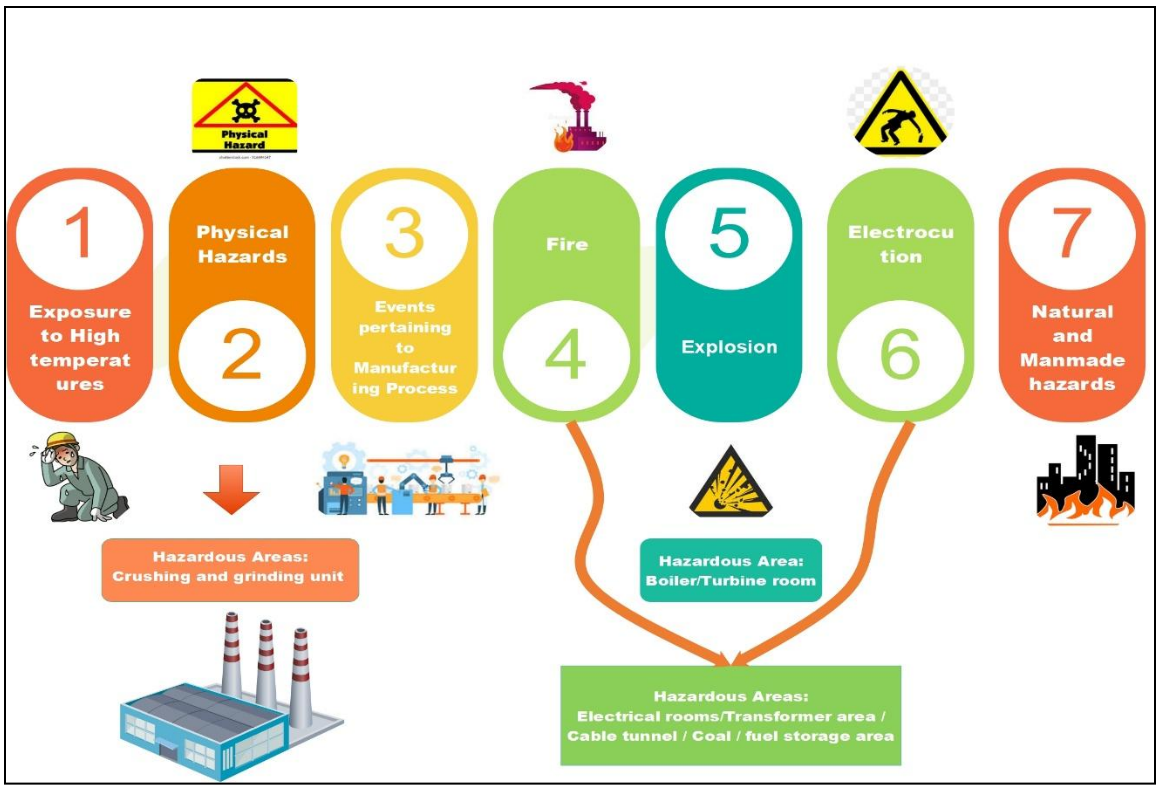
8.1 Risk Assessment and Damage Control

Risk assessment is the determination of quantitative or qualitative value of risk related to a concrete situation and a recognized threat.

Activities requiring assessment of risk due to occurrence of most probable instances of hazard and accident are both onsite and off-site.

8.2 Hazard Identification & Risk Assessment (HIRA) for Integrated Cement Project

The cement manufacturing industry is labor intensive and uses large scale and potentially hazardous manufacturing processes. The industry experiences accident rates that are high compared with some other manufacturing industries. Cement industries experiences risk of a number of hazards inherent to the cement production process. Following hazards may occur:



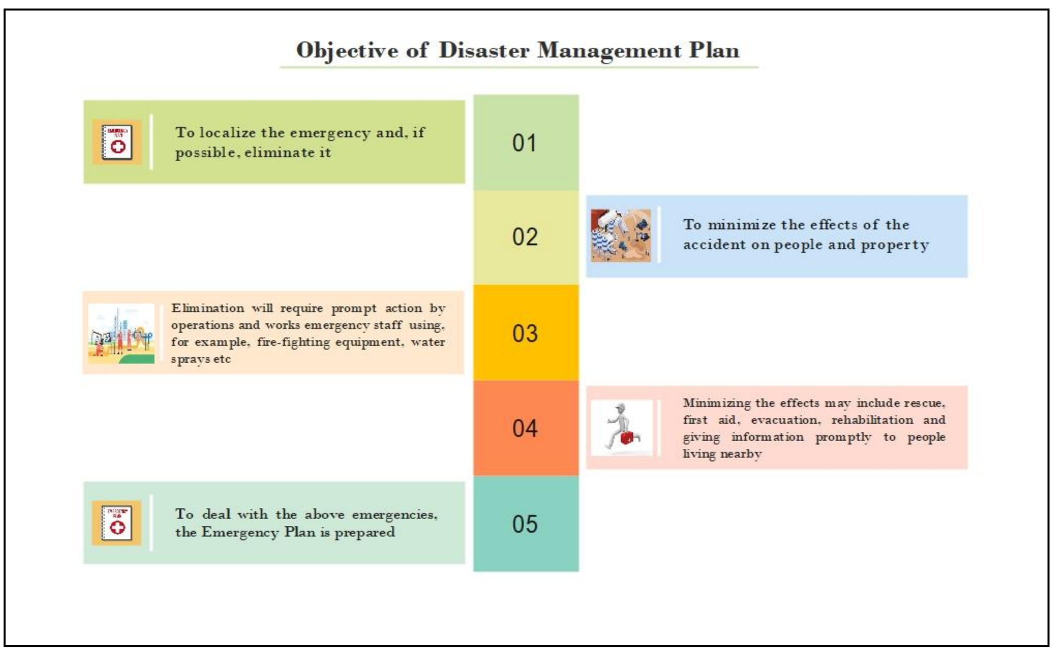
For Further Reading→ Click Here

8.3 Disaster Management Plan

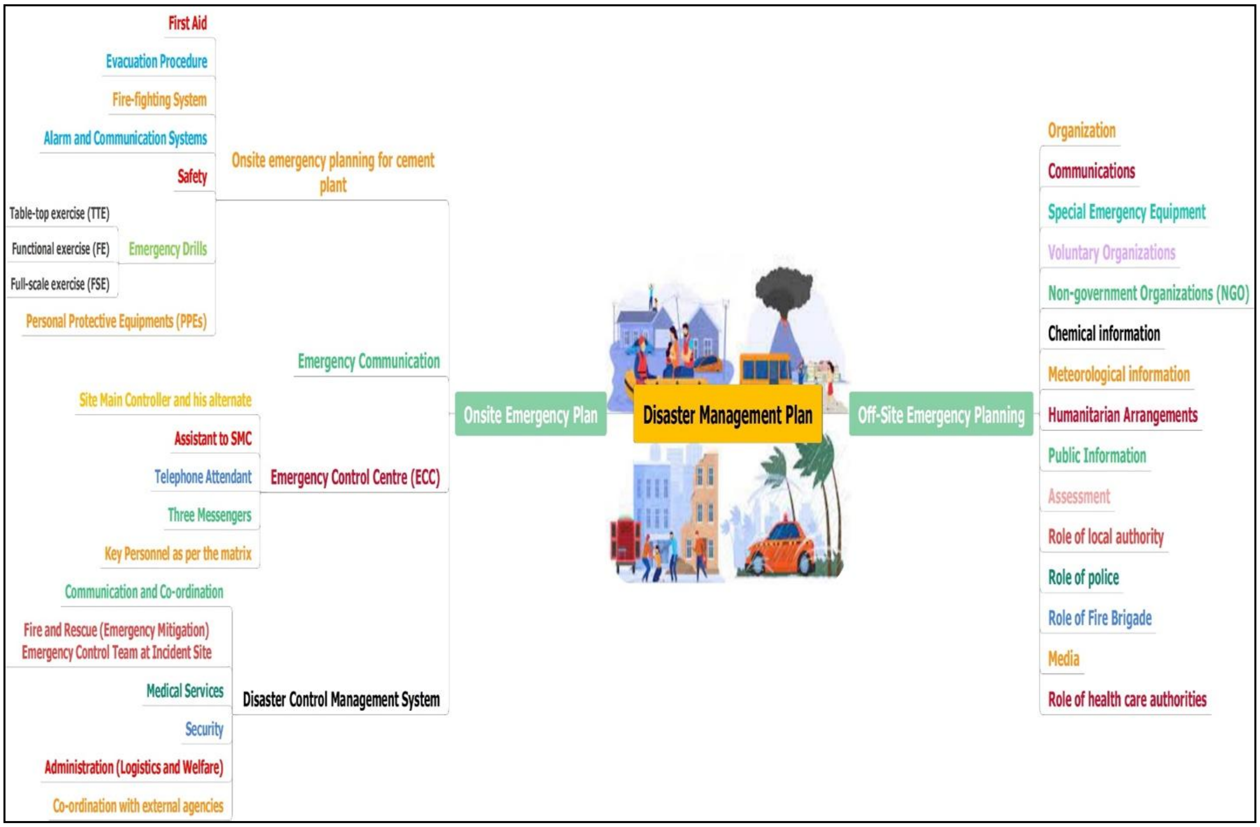
A major emergency in a work is one, which has the potential to cause serious injury or loss of life. It may cause extensive damage to property and serious disruption both inside and outside the work. It would normally require the assistance of emergency services to handle it effectively.

Scope and Objective

The aim of hazard control and disaster management is concerned with preventing accidents through good design, operation, maintenance, and inspection, by which it is possible to reduce the risk of an accident, but it is not possible to eliminate it. Since absolute safety is not achievable; an essential part of major hazard control must also include mitigating the effects of a major accident. An important element of mitigation is emergency planning, i.e. recognizing accidents as soon as possible, assessing the consequences of such accidents and deciding on the emergency procedures, both on-site and off-site, that would need to be implemented in the event of an emergency.



Mind map for Disaster Management Plan are as follows:


Disaster Management Plan
Onsite Emergency Plan
Onsite emergency planning for cement plant
First Aid
Evacuation Procedure
Fire-fighting System
Alarm and Communication Systems
Safety
Emergency Drills
Table-top exercise (TTE)
Functional exercise (FE)
Full-scale exercise (FSE)
Personal Protective Equipments (PPEs)
Emergency Communication
Emergency Control Centre (ECC)
Site Main Controller and his alternate
Assistant to SMC
Telephone Attendant
Three Messengers
Key Personnel as per the matrix
Disaster Control Management System
Communication and Co-ordination
Fire and Rescue (Emergency Mitigation) Emergency Control Team at Incident Site
Medical Services
Security
Administration (Logistics and Welfare)
Co-ordination with external agencies
Off-Site Emergency Planning
Organization
Communications
Special Emergency Equipment
Voluntary Organizations
Non-government Organizations (NGO)
Chemical information
Meteorological information
Humanitarian Arrangements
Public Information
Assessment
Role of local authority
Role of police
Role of Fire Brigade
Media
Role of health care authorities

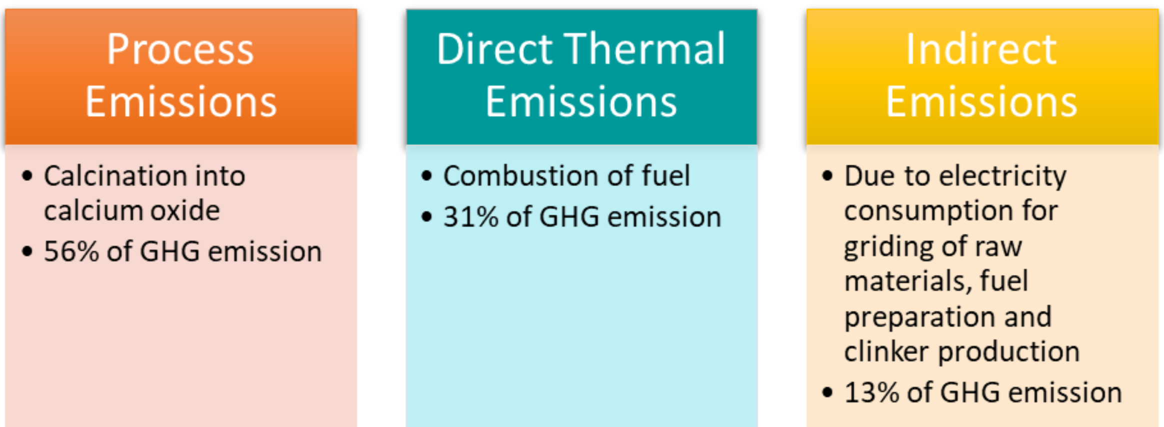
Chapter 9 Towards achieving carbon neutrality

9.1 Background

In the period 2010-2017, direct CO_2 emissions from cement have declined by 5%, ranging from 32 to 588 grams/ton (WBCSD, 2018). This has been possible through adoption of Low Carbon Technology Roadmap strategy (WBCSD, 2018).

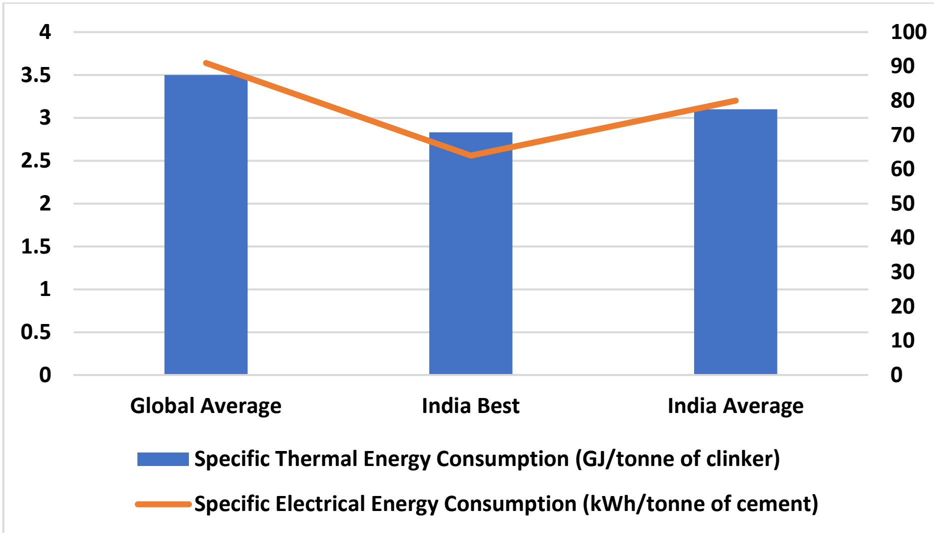
Higher clinker content leads to more consumption of limestone, thereby increasing the GHG emissions. Various sources of GHG emissions in a cement industry is depicted in **Figure 9.1**:

Figure 9.1: Sources of GHG emissions in cement industry



It is inferred from figure 9.1 that 44% (31% Direct and 13% Indirect) of GHG emissions is from thermal and electrical energy consumption in cement industry. Performance of Indian Cement Industry in terms of thermal and electrical energy consumption as of 2017 is depicted in **Figure 9.2**:

Figure 9.2: Performance of Indian cement industry in energy efficiency



Source: (Bhardwaj et. al, 2020)

Importance of Decarbonisation

In response to the ambition of the 2015 Paris Agreement, many governments and business leaders have set targets and made commitments to reduce carbon emissions. Decarbonisation has become a global imperative and a priority for governments, companies, and society at large, because it plays a very important role in limiting global warming.

While progress is being made at global, national, sector and local levels, recent estimates suggest we are not on track to meet the Paris targets, and more must be done.

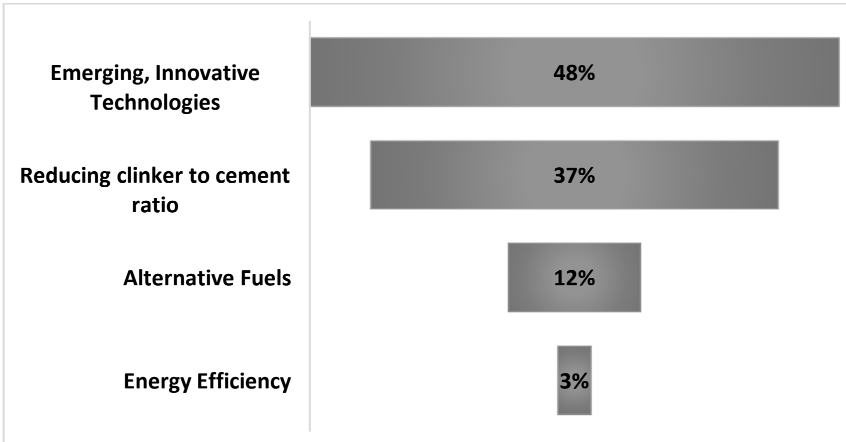
9.2 Decarbonization Techniques

If the climate targets (COP-26 commitments, PIB 2021) are to be met, decarbonization of cement i.e. reducing direct CO_2 emissions must be achieved. It is also indicated that about 75% of direct CO_2 emissions can be reduced through adoption of low carbon technology strategy. However, for capturing 20-25% of the residual CO_2, carbon capture, use, and storage in the cement industry must be implemented.

Among emerging technologies, carbon capture and storage, and renewable energy technologies have the greatest decarbonisation potential. However, the cement industry

in India has yet to demonstrate a commercial capture technology, but over the past decade, much progress has been made. (Bhardwaj et. al, 2020).
The different categories of decarbonisation techniques are illustrated in **Figure 9.3**:

Figure 9.3: Decarbonisation potential of different techniques



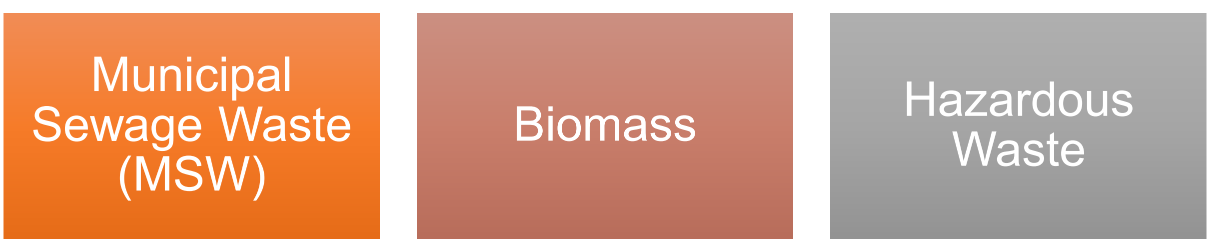
Source: Bhardwaj et.al, 2020

9.2.1 Alternative Fuels

Alternative fuels generally includes Municipal Solid Waste, Biomass and Hazardous waste etc. As a result of the use of alternative fuels in the Indian cement industry, emissions have been further reduced. (Bhardwaj et al., 2020).

Various options for alternative fuels are depicted in **Figure 9.4**

Figure 9.4: Alternatives fuel potential

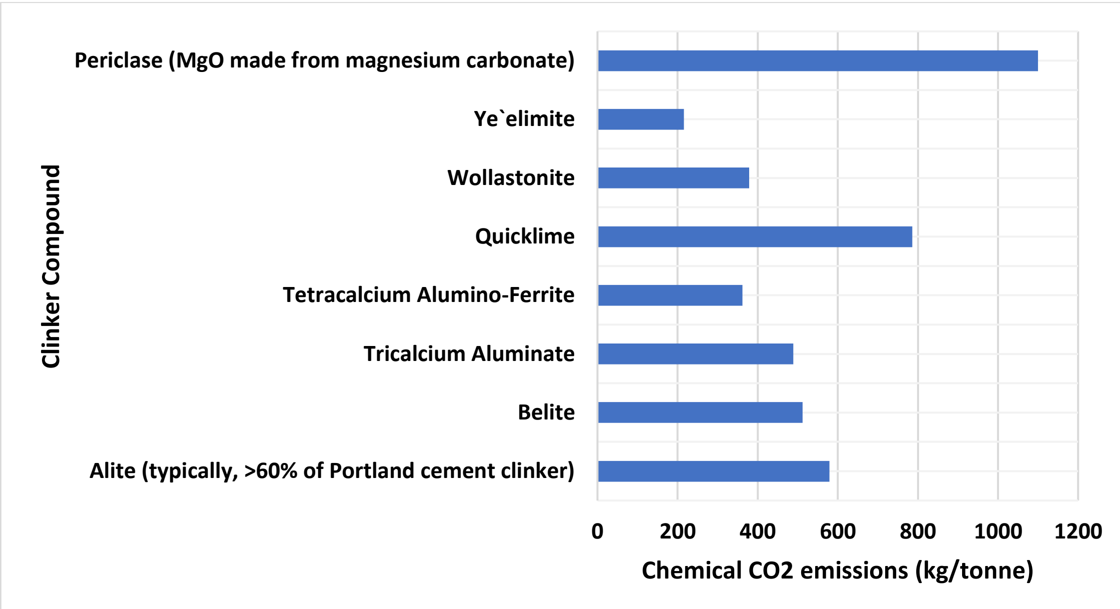


Source:Bhardwaj et. al, 2020

The Thermal Substitution Rate (TSR), helps to determine the amount of fuel used by the cement industry. TSR is the percentage of alternative fuel which can replace/ substitute fossil fuel (Bhardwaj et.al, 2020).

Typically, RDF can replace up to 15-20% of primary fossil fuels used in cement plants. However, the current thermal substitution rate (TSR) or the rate of co-processing wastes in India ranges between 0.5-1%, while in some developed countries, this figure is as high as around 60%. There are some cement plants in Europe where more than 80% of the conventional fuel is being replaced with RDF (Bhardwaj, R. 2016).Figure 9.5 indicates the clinker compound and chemical CO_2 emissions (kg/tonne)

Figure 9.5 Clinker Compound and chemical CO_2 emissions (kg/tonne)



Source:UNEP, Scrivener et.al, 2017

9.2.2 Reducing Clinker to Cement Ratio

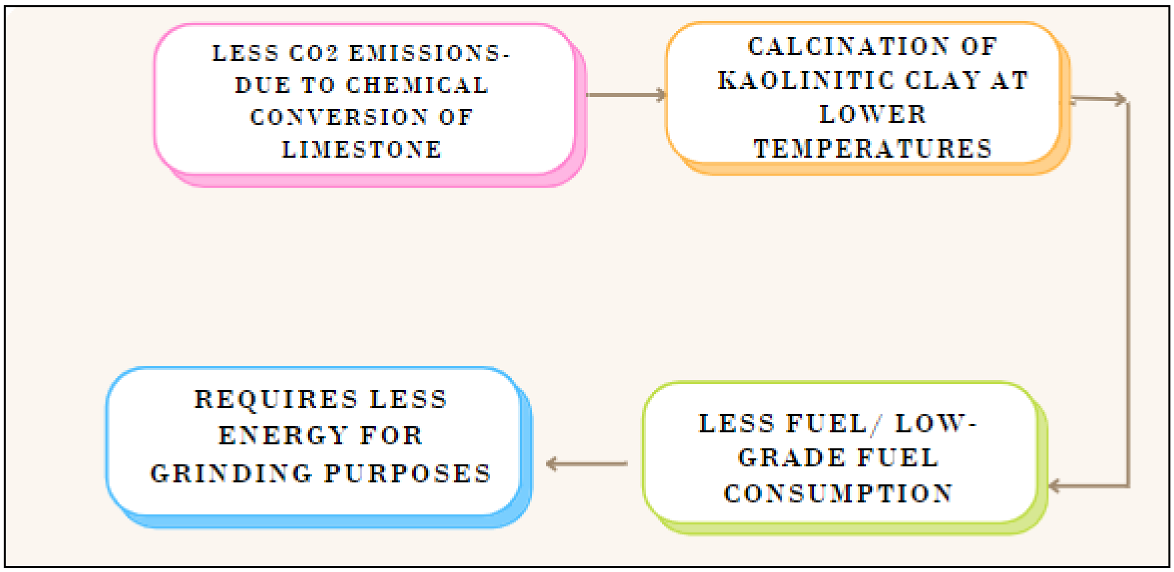
Higher clinker content leads to more consumption of limestone, thereby increasing the GHG emissions. Research has contributed to the development of low clinker cements, which are viable alternatives. Some of these are mentioned below:

A. Limestone Calcined Clay Cement (LC^3)

LC^3 is a blend of clinker, low-grade limestone, calcined clay, and gypsum. In the production of LC^3, clay (kaolinitic clay) is calcined at 700°C - 850°C, in the rotary kilns. 50% clinker is used in the production of LC^3 (Bhardwaj et.al, 2020).

In India, calcined clay and low-grade limestone are readily available to produce LC3. The production of LC^3 cement does not require any additional sophisticated equipment. Old rotary kilns used in wet processing; kilns already used for calcination can be used for calcination of clays. The physical and mechanical properties of concrete produced with LC^3 are similar to those of concrete produced with OPC (Bhardwaj et.al, 2020). Figure 9.6 illustrates the impact of calcinated clay cement.

Figure 9.6: Impact of calcinated clay cement

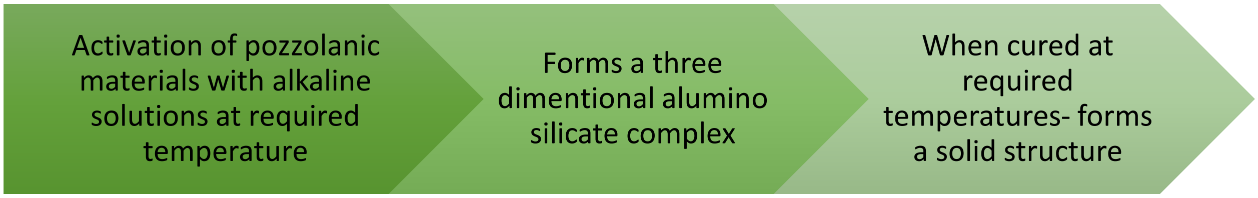


Source: Bhardwaj et.al, 2020

B. Geopolymer Cement and Concrete

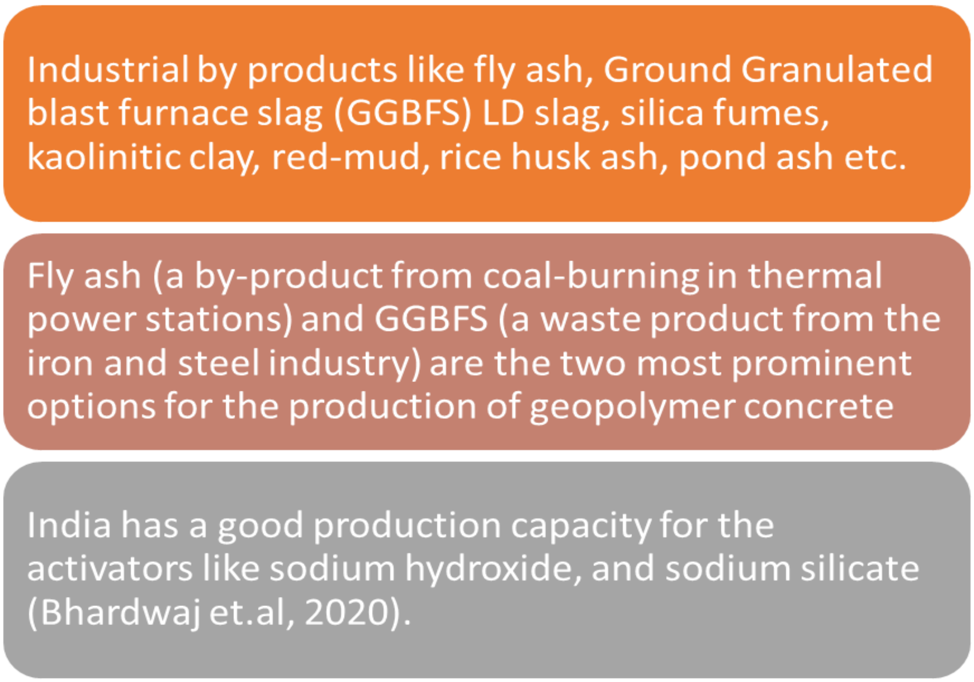
The activation of pozzolanic materials (rich in silica, and alumina), with alkaline solutions like sodium hydroxide, and sodium silicate etc. at required temperatures. Pozzolanic materials when reacted with alkaline solutions, form a three-dimensional alumino silicate complex, which when cured at required temperatures forms a solid structure, which exhibits properties like ordinary Portland cement, and can be used as a building material (Bhardwaj et al., 2020).

Figure 9.7 process of formation of solid structure



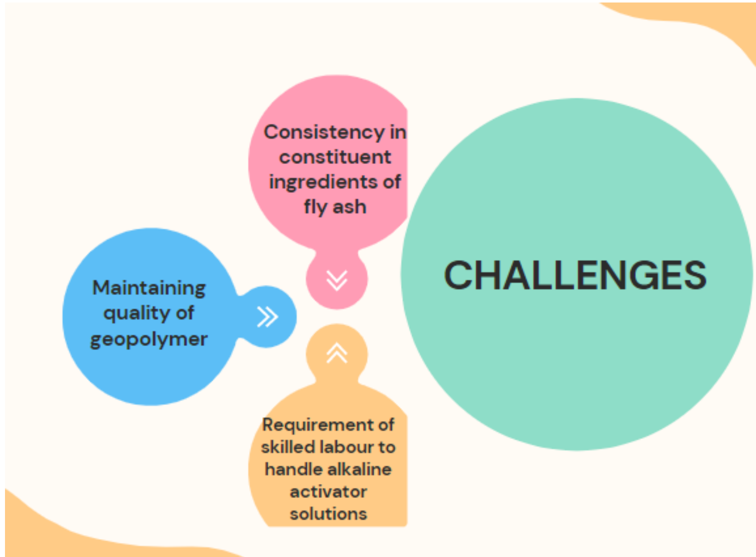
Source: Bhardwaj et.al, 2020

Following are the Industrial by-products



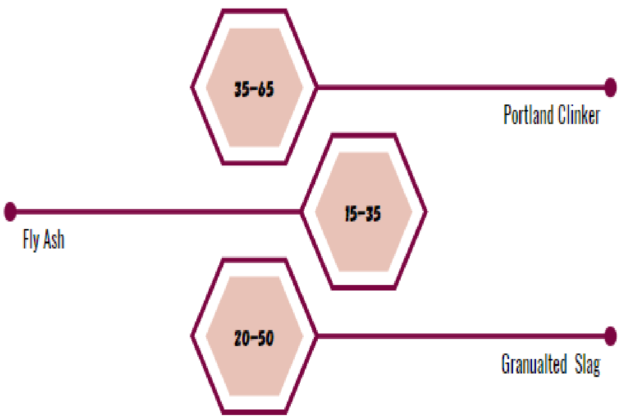
Following are the challenges in production of geopolymer cement/concrete

Figure 9.8: Challenges in production of geopolymer cement/concrete



Source: Bhardwaj et.al, 2020

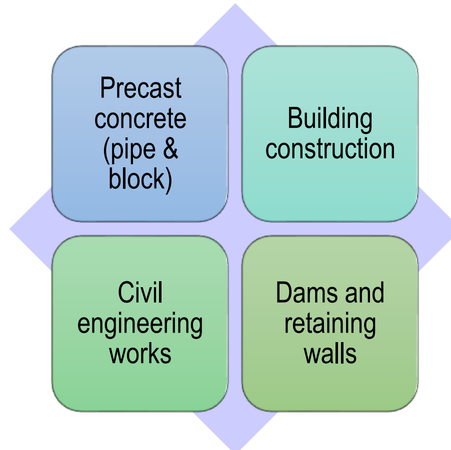
C. Composite cement

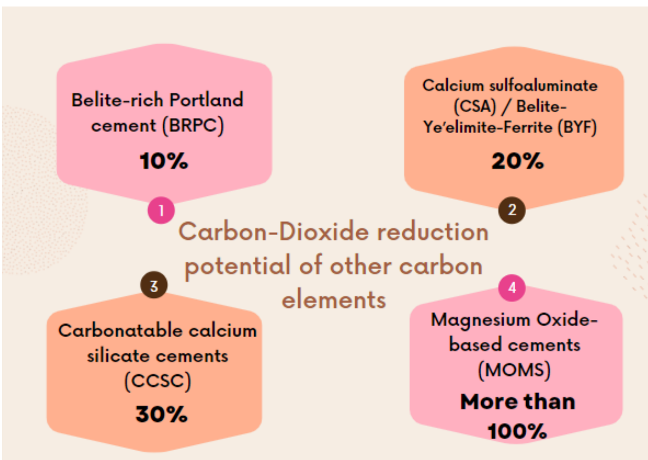


Composite cement is produced by a blend of Portland clinker, fly ash and slag. The proportion (percentage by weight) of the material is illustrated in **Figure 9.9**:

Due to reduced clinker demand, the CO_2 reduction potential is 56% (Bhardwaj et.al, 2020).

The applications of composite cement are given in **Figure 9.10** →





The CO_2 reduction potential of low carbon elements is given in **Figure 9.11:**

Cements made from 'Alternative Clinkers', which are other low carbon cements and thus viable alternatives for emission reduction are listed below (UNEP, Scrivener et.al, 2017):

Figure 9.12: CO_2 reduction potential of other carbon elements (Bhardwaj et.al, 2020)

Belite-rich Portland cement clinkers

- Uses less limestone in clinker raw material mix, CO_2 generation is reduced
- 10% emission reduction
- Barrier: Gain strength slower than OPC- suited for niche markets, where strength gain after few days is not critical

Belitic clinkers containing ye`elimite (Calcium solfoaluminate- CSA)

- Can be made in conventional Portland cement plants- requires changes in proportions of raw material
- CO_2 emission decrease as the ye`elimite content increases
- Barrier: Higher ye`elimite content requires expensive aluminium-rich raw materials- thus significant costs

Hydraulic calcium silicate clinkers

- Complex manufacturing process- more processing ateps than required for OPC production
- Still under development at laboratories- no reliable estimates for efficiency

Magnesium-based cements

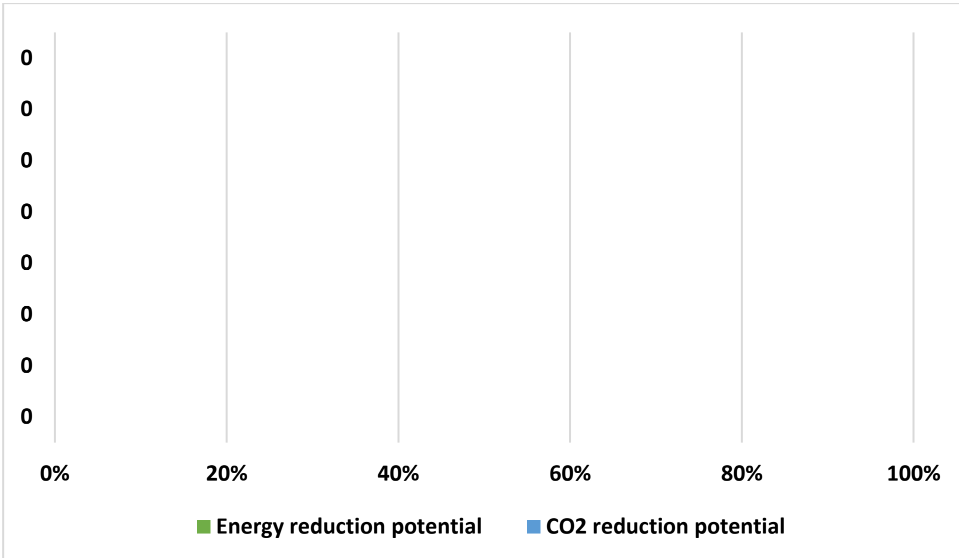
- CO_2 emissions are extremely high, thus unsustainable at present
- Carbonation-curing approach can be adopted, with even greater benefits for net CO_2 capture

Carbonation hardening cements

- Manufacture of concrete products by carbonation
- Development of Calcium silicate clinkers (CCSC) made specifically for carbonation curing
- Clinkers comprising low-lime calcium silicate minerals like wollastonite can be made in conventional cement kilns using limestone and silica that are not expensive
- Low CO_2 emissions and reduced energy costs
- Unreactive to harden by hydration- can only be cured rapidly in an atmosphere of almost pure CO_2 with controlled relative humidity below 100%
- Barrier: Does not protect steel against corrosion, thus best suited for reinforced precast cement based products market
- High calcium industrial wastes with poor cementitious properties, including steel slags
- Using the Uncarbonated calcium in these wastes is to substitute them for raw material components in the kiln feed for making Portland cement

Figure **9.13** illustrates the energy and CO_2 reduction potential for some low carbon elements.

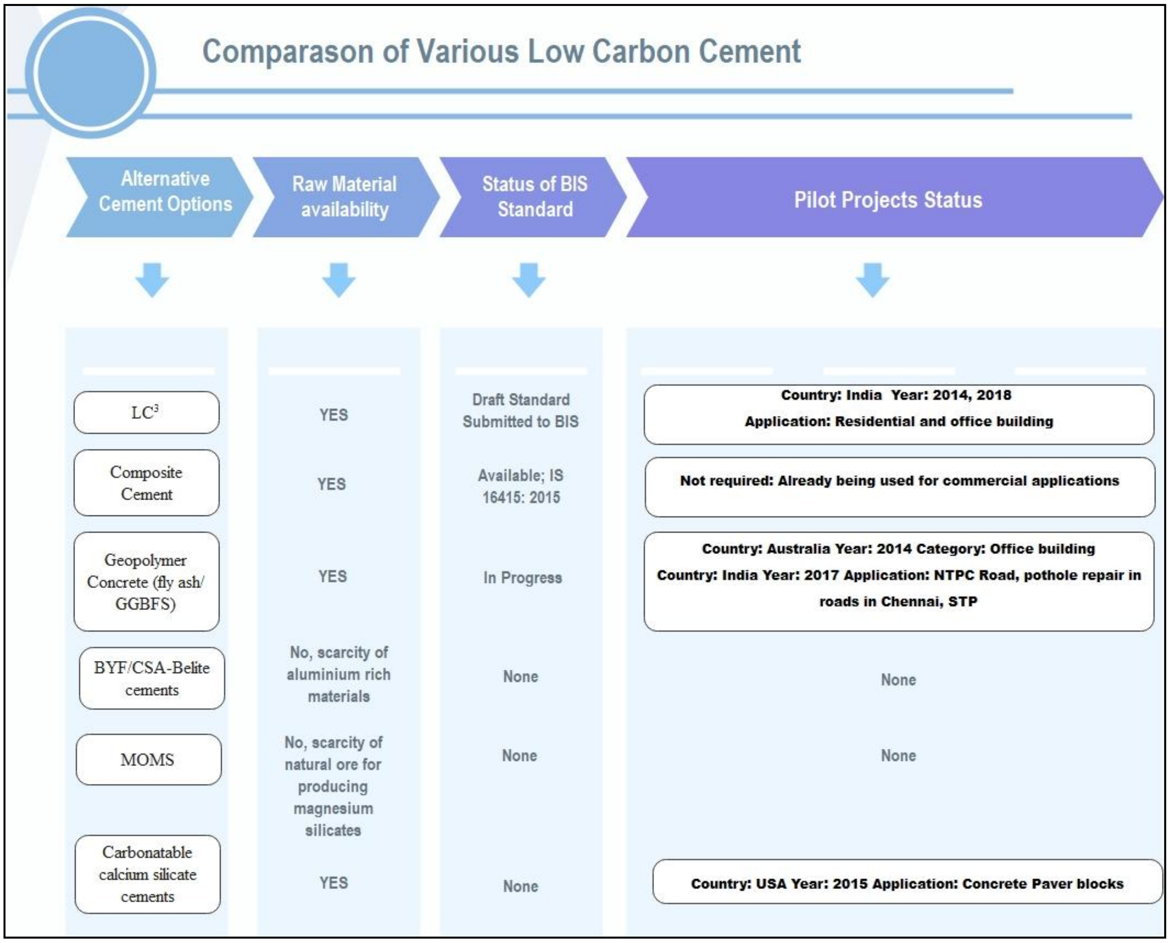
Figure 9.13: Energy and CO_2 reduction potential for various low carbon elements



Source: Bhardwaj, et.al 2020

A comparative assessment of various law carbon cements is illustrated in **Figure 9.14**:

Figure 9.14: Comparative assessment of low carbon alternatives (Bhardwaj, et.al, 2020)



9.3 Carbon Capture, Use and Storage (CCUS)

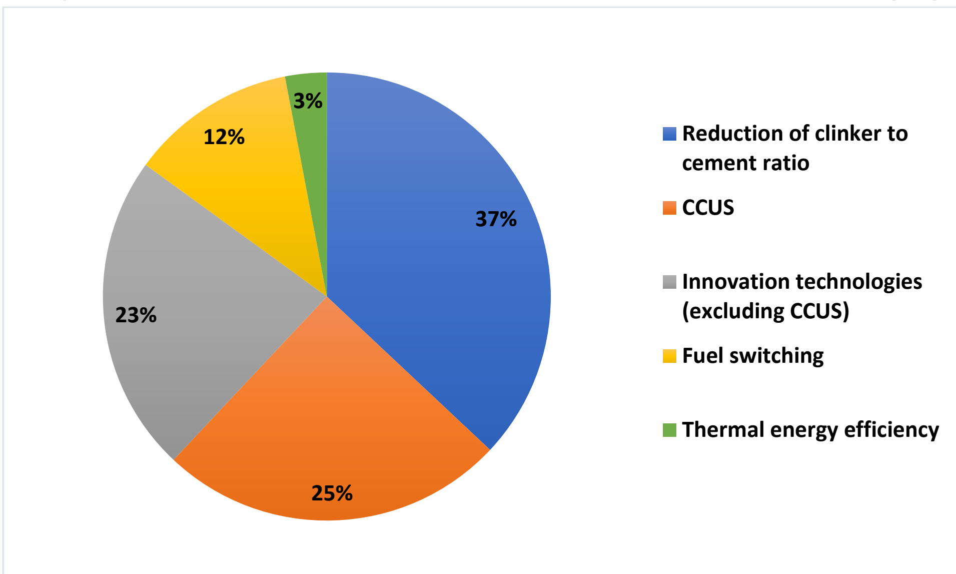
CCUS (Carbon Capture, Utilization, and Storage) is a technology that can help reduce greenhouse gas emissions and boost energy efficiency. In order to meet global emission targets by 2030, carbon capture capacity must increase by more than 20 times (Bhardwaj et. al, 2020).

In the case of the cement industry, CO_2 capture can be accomplished using post-combustion and oxyfuel combustion technologies. Pre-combustion capture technologies would have limited mitigation potential in the cement sector, as they could deal only with the energy-related CO_2 emissions. They might be of use in new cement plants integrated with gasification technologies to produce syngas or H_2 fuel (Plaza, M.G. et.al 2020).

A third type of CO_2 capture technology with great promise to be implemented in the cement sector is direct capture (Plaza, M.G. et.al 2020).

CCUS helps prevent CO_2 from being released into the atmosphere by capturing it, using it, or injecting it in geological formations for storing it permanently. CCUS will play a key role in achieving carbon neutrality by 2050. It helps achieve deep levels of decarbonisation. The high process emissions in cement sector mandates the deployment of CCUS technologies. However, at present, CCUS facilities are not yet operational in the cement sector at a large scale, CCUS facilities are operational in the power and industrial sectors, with a total annual capacity close to 40Mt CO_2 (Plaza, M.G. et.al 2020). Figure below gives the percentage of global CO_2 emissions reductions by 2050:

Figure 9.15: Cumulative Direct CO_2 emissions reduction (Gt)



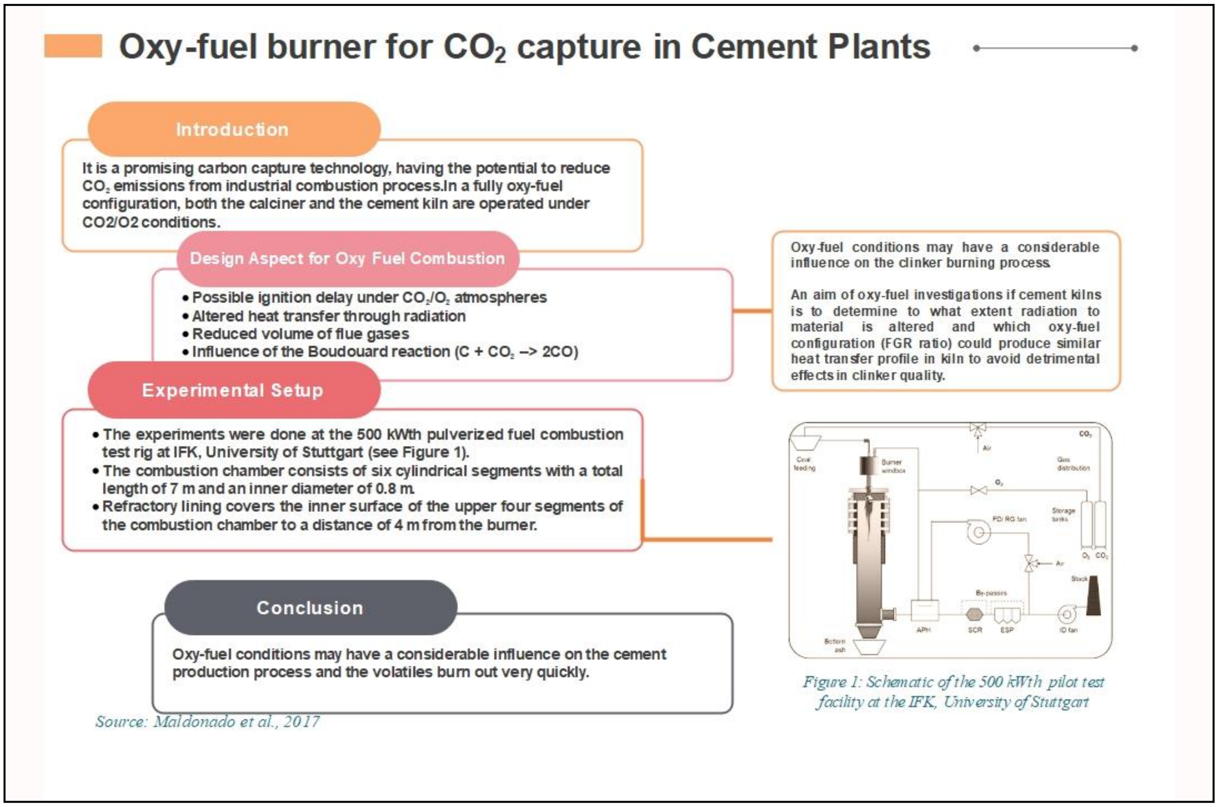
Source: Adapted from: Plaza, M.G. et.al 2020

9.4 Oxy -Fuel Combustion

It is a promising carbon capture technology, having potential to reduce CO_2 emission from industrial combustion process. The details process of oxy-fuel burner for CO_2 capture in cement plants is depicted in figure 9.16.

Figure 9.16 illustrates the process of oxy-fuel burner for CO_2 capture in cement plants

Figure 9.16: Oxy-fuel burner for CO_2 capture in cement plants



Source: Carrasco-Maldonado et al., 2017; Shukla, A.K. et.al 2020

Decarbonisation projects across the world:

Figure 9.17: Various decarbonization projects across the world

Various Decarbonisation Projects across the world

Project ACCSESS

Carbon Capture Unit is in Germany and Transport CO_2 from sites in Mainland Europe and Norway

1) A pilot carbon capture project of Heidelberg Cement in Eastern Europe
2) A consortium of 18 industry partners and research organizations is developing CCUS to link emissions from mainland Europe to storage fields in the Nordic region.
3) An enzyme-based capture unit at Górażdże plant reduce costs in the capture process and allow a broader use of the waste heat, control of secondary emissions
4) Carbon capture unit optimally integrated at the Hanover plant in Germany for transporting CO_2 from sites in mainland Europe to Norway
5) A joint project by Equinor, Shell, and Total Energies involves the transfer of the Hannover cement plant and the Gorade cement plant to the Northern Lights storage facility in Norway
6) The ANRAV CCUS project will capture carbon emissions at the Bulgarian cement plant of Heidelberg Cement's subsidiary Devnya Cement through a pipeline system with offshore permanent storage.
7) Tentative Budget for the Project: ~ € 15 million.

Methanex

Decarbonisation Facility in New Zealand

1) As part of this multimillion-dollar investment, the distillation columns at the facility will be upgraded over the next 12 months.
2) The efficiency improvements provide an economic payback within two years.
3) Once completed, this project has the potential to reduce the site's carbon emissions by over 50,000 tons per year, the equivalent of taking 20,000 cars off the road

Project of BASF and GS E&C

Modular solutions for carbon capture across Globe

1) As a result of BASF's OASE blue process technology, CO_2 will be captured from flue gases more sustainably and more cost effectively
2) As a comprehensive one-stop carbon neutrality solutions provider, GS E&C offers engineering services, carbon capture, project financing, storage, and utilization services to CO_2 emitters

Project of KBR and Giammarco-Vetrocoke

For providing licenses of its carbon capture technology globally

1) In today's petrochemical, blue ammonia, and refining industries, carbon capture is a proven technology that is energy efficient, flexible, and can be incorporated across the value chain.

Air Liquide, Chevron, Keppel and PetroChina

Carbon-capture consortium in Singapore

1) The consortium intends to research, test, and develop technological, logistical, and operational solutions for CCUS in Singapore
2) CO_2 could then be utilized to make useful products, such as plastics, fuels, and cement, and/or transported through either pipelines or ships

Reference:

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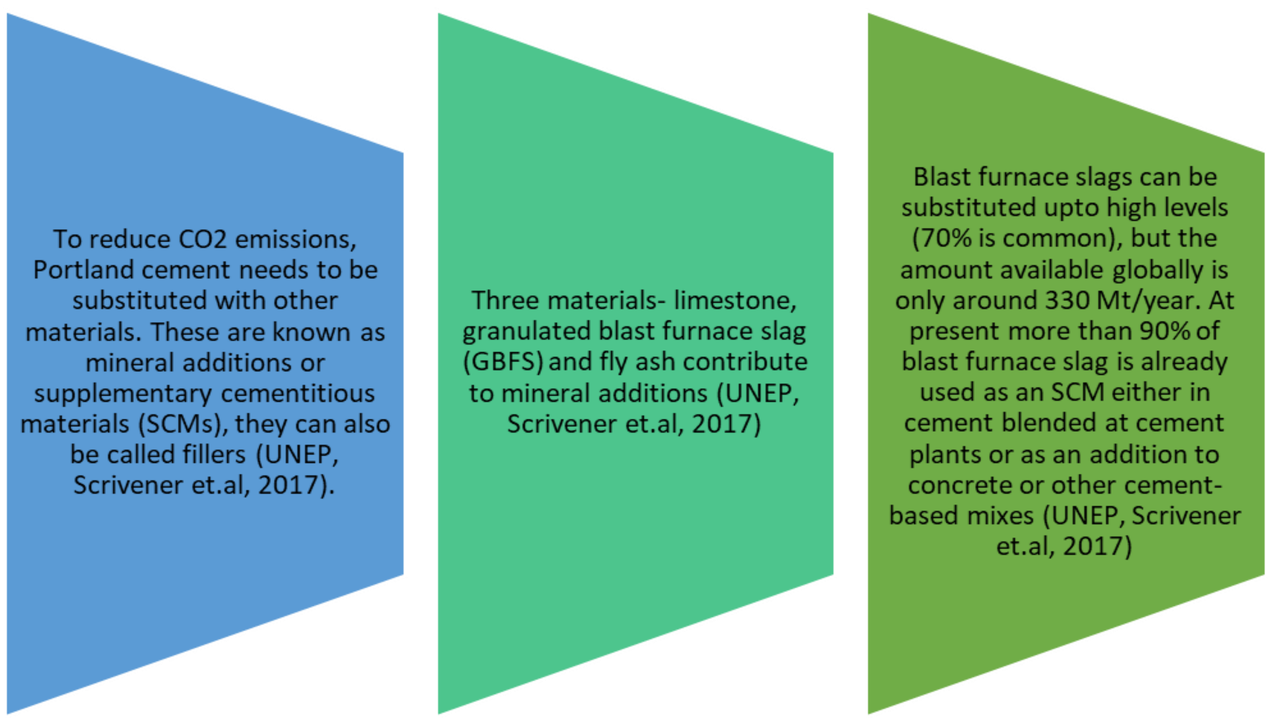
https://www.chemengonline.com/air-liquide-chevron-keppel-and-petrochina-form-carbon-capture-consortium-in-singapore/

9.5 Extending Clinker Substitution with Mineral Additions/Supplementary Cementitious Materials

Extending Clinker Substitution with Mineral Additions/Supplementary Cementitious Materials is depicted in in **figure 9.18**:

Figure 9.18: Extending Clinker Substitution with Mineral Additions/Supplementary Cementitious Materials



Source: UNEP; Scrivener et.al, 2017;

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List of Annexures:

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