Use of Alternative Carbon Sources in Blast Furnace at JSW Steel

The Breakthrough Technology Conference

December 5 -7, 2023 | Intercontinental Abu Dhabi

Basavaraj Bomman
Mohanraj Nagarajan

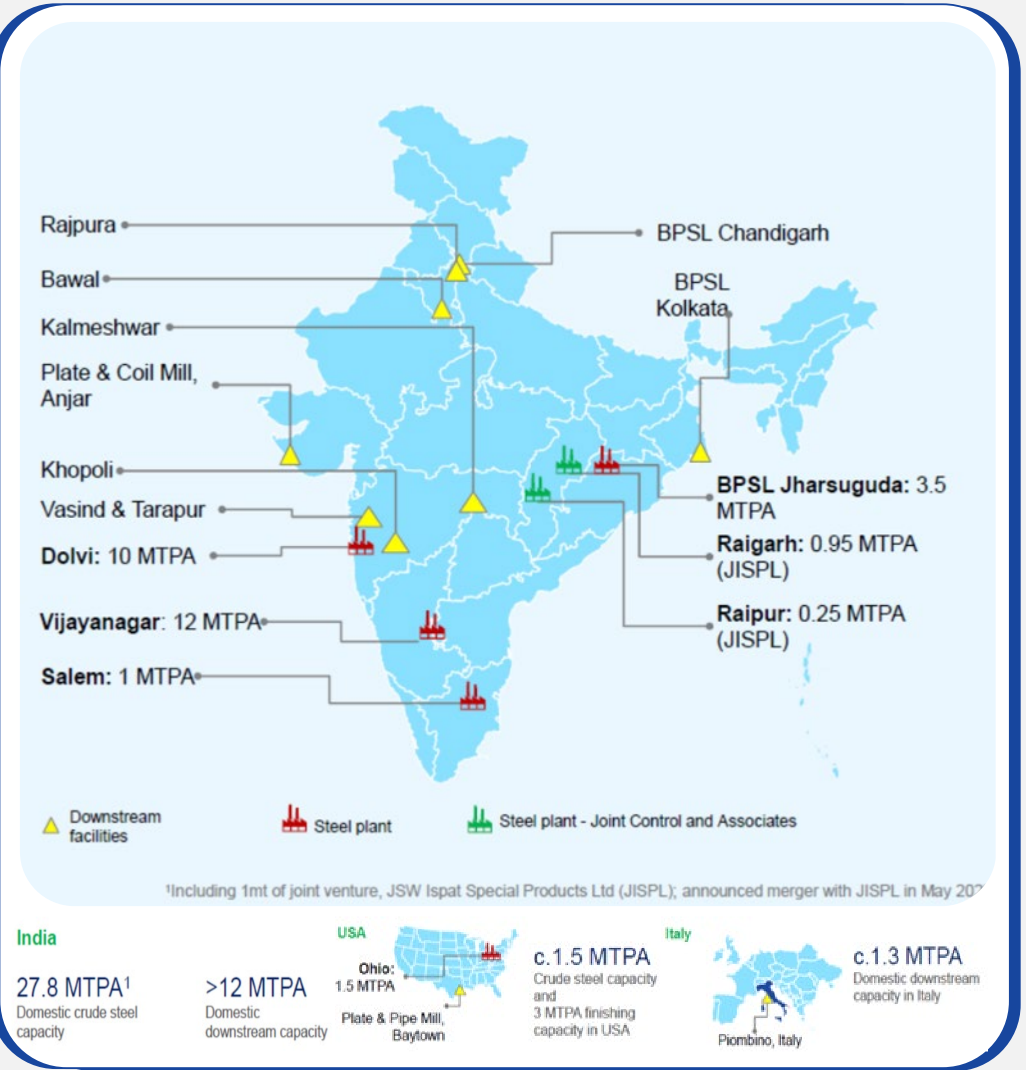
JSW Steel Limited, India

5th Dec 2023

SEED Sustainable Energy Environment and Decarbonization

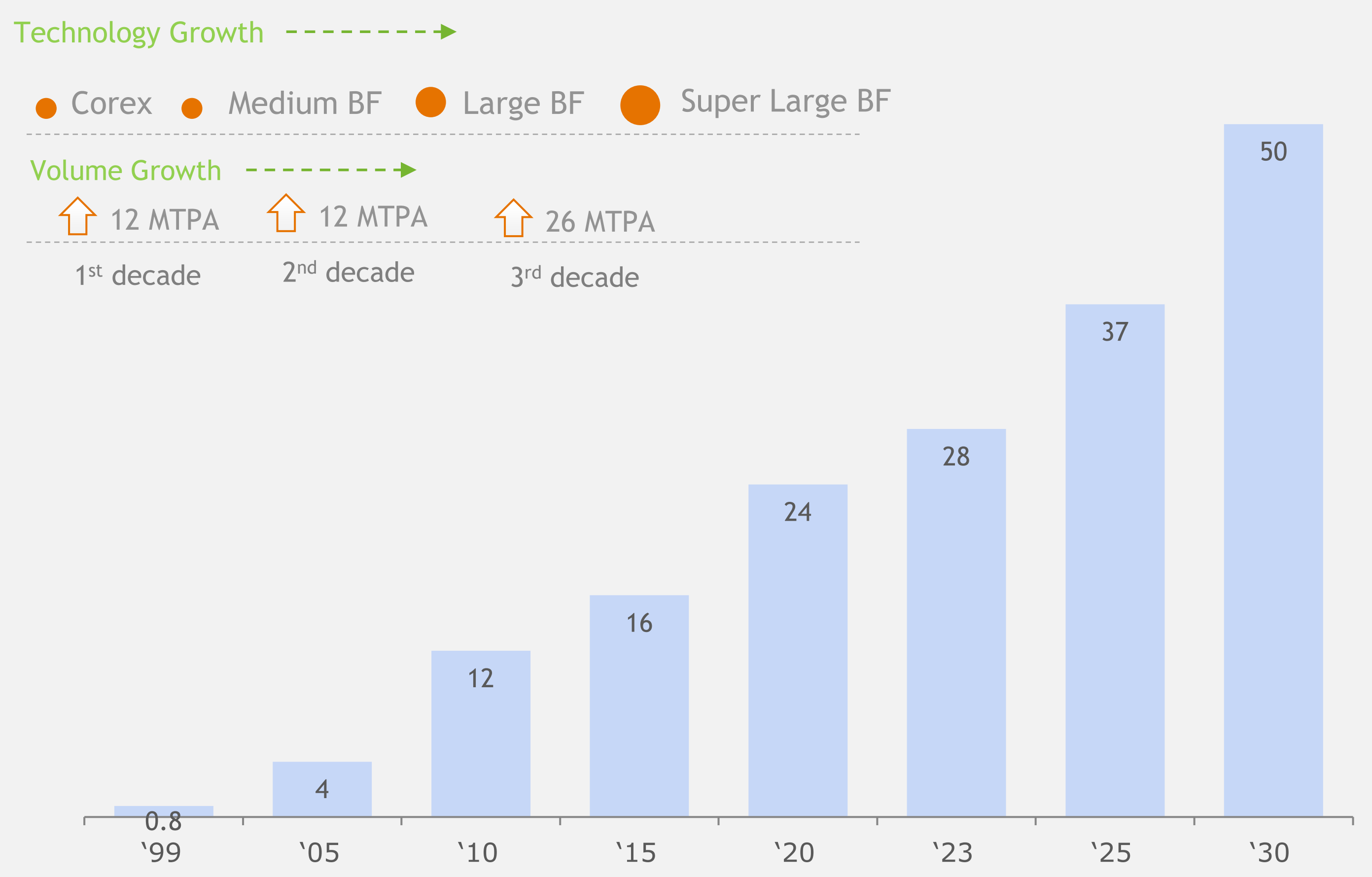
JSW

About JSW Steel



¹Including 1mt of joint venture, JSW Ispat Special Products Ltd (JISPL); announced merger with JISPL in May 20

3 decade of JSW Crude Steel Growth in Million ton



Sustainability at JSW Steel

JSW Steel

ESG Focus Areas

Environment

- Climate change
- Energy
- Resources
- Water resources
- Waste
- Waste Water
- Air emissions
- Biodiversity
- Sustainable mining
- Supply chain sustainability

Social

- Indigenous people
- Cultural heritage
- Employee wellbeing
- Local considerations
- Social sustainability

Governance

- Business ethics
- Human rights

Aligned to National & International Frameworks

ISO

IFC International Finance Corporation WORLD BANK GROUP *Creating Markets, Creating Opportunities*

OECD

UNITED NATIONS GUIDING PRINCIPLES ON BUSINESS & HUMAN RIGHTS

SUSTAINABLE DEVELOPMENT GOALS

NATIONAL GUIDELINES ON RESPONSIBLE BUSINESS CONDUCT

Driving Sustainability Initiatives Across Platforms

CDP DISCLOSURE INSIGHT ACTION A LIST 2022 CLIMATE

Sustainability CHAMPION worldsteel ASSOCIATION 2023

WE SUPPORT UN GLOBAL COMPACT

TCFD TASK FORCE ON CLIMATE-RELATED FINANCIAL DISCLOSURES

IH2A INDIA HYDROGEN ALLIANCE

CLIMATE GROUP EV100+

wbcsd

Responsible Steel standards & certification

Integrated Reporting

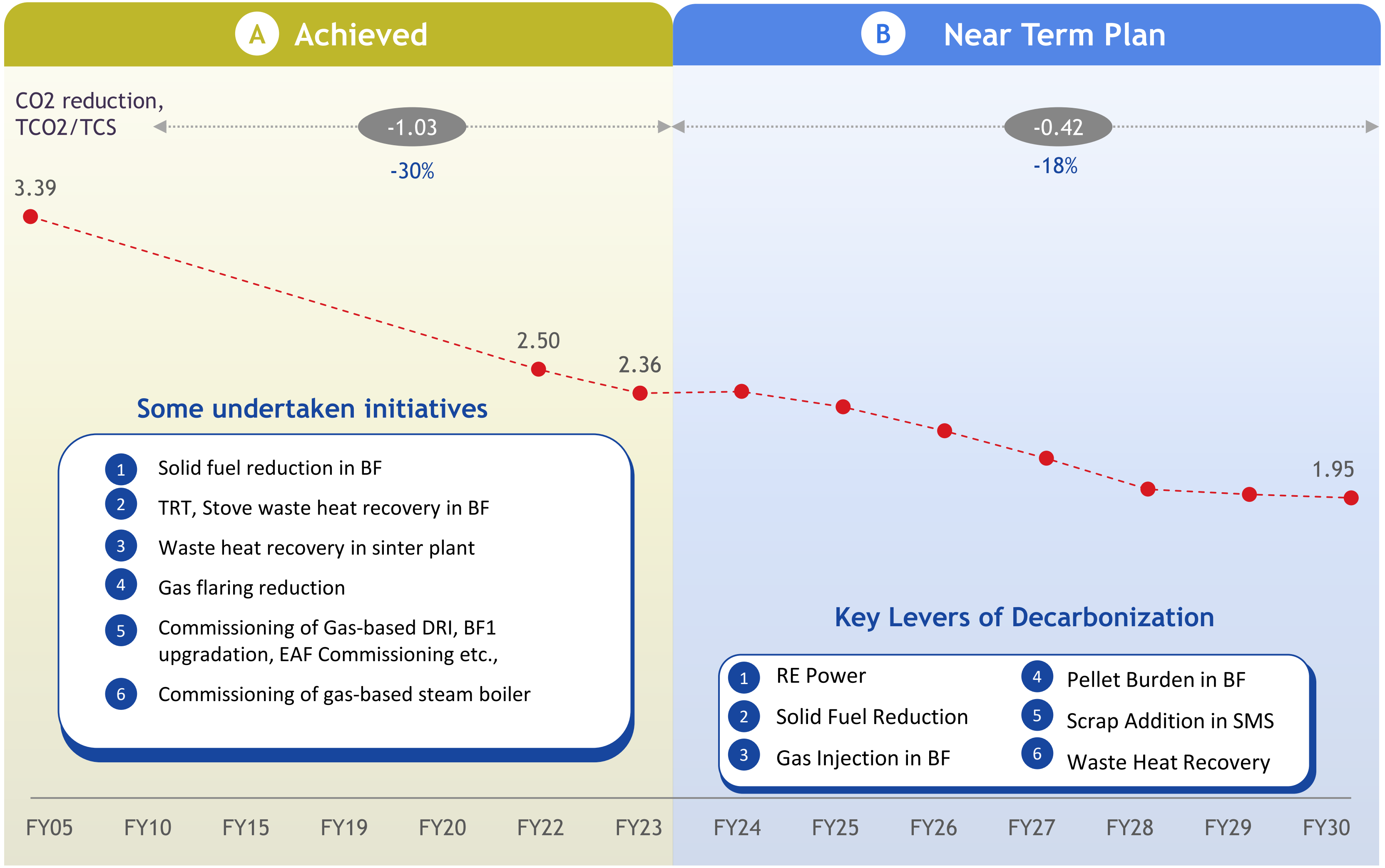
ESG Databook FY 2023

FY 2023

Governance & Oversight By Board-level Business Responsibility And Sustainability Committee

JSW Steel Decarbonisation Roadmap

48% of JSW Carbon reduction journey



Some undertaken initiatives

1. Solid fuel reduction in BF
2. TRT, Stove waste heat recovery in BF
3. Waste heat recovery in sinter plant
4. Gas flaring reduction
5. Commissioning of Gas-based DRI, BF1 upgradation, EAF Commissioning etc.,
6. Commissioning of gas-based steam boiler

Key Levers of Decarbonization

1. RE Power
2. Solid Fuel Reduction
3. Gas Injection in BF
4. Pellet Burden in BF
5. Scrap Addition in SMS
6. Waste Heat Recovery

SEED Sustainable Energy Environment and Decarbonization

Decarbonization Strategy

	FY05 BASEYEAR	FY23 30% REDUCTION	FY30 48% REDUCTION	Path towards Net Zero
Fuel Switch/ reduction		• Solid fuel reduction in BF	 Fuel rate optimization through • Burden-mix optimization • Fe improvement through beneficiation	 Fuel rate optimization through • Green H2 in BF-BOF • Syngas in BF • Green H2 in DRI
Energy recovery		• Heat recovery systems in Sinter Plant • Gas flaring reduction	• Heat recovery across all shops 	 • Top gas recovery in BF • Solid slag heat recovery
Energy & Tech transition		• Gas based DRI commissioning; • BF upgradation; • EAF commissioning	• RE Power (~10 GW) • Continued BF upgradation 	 • Technology transition of end campaign BF • Implementation of CCUS
Circularity			 • Scrap addition in SMS • COG/plastic/biofuel use in BF	 • Scrap based EAF

Energy

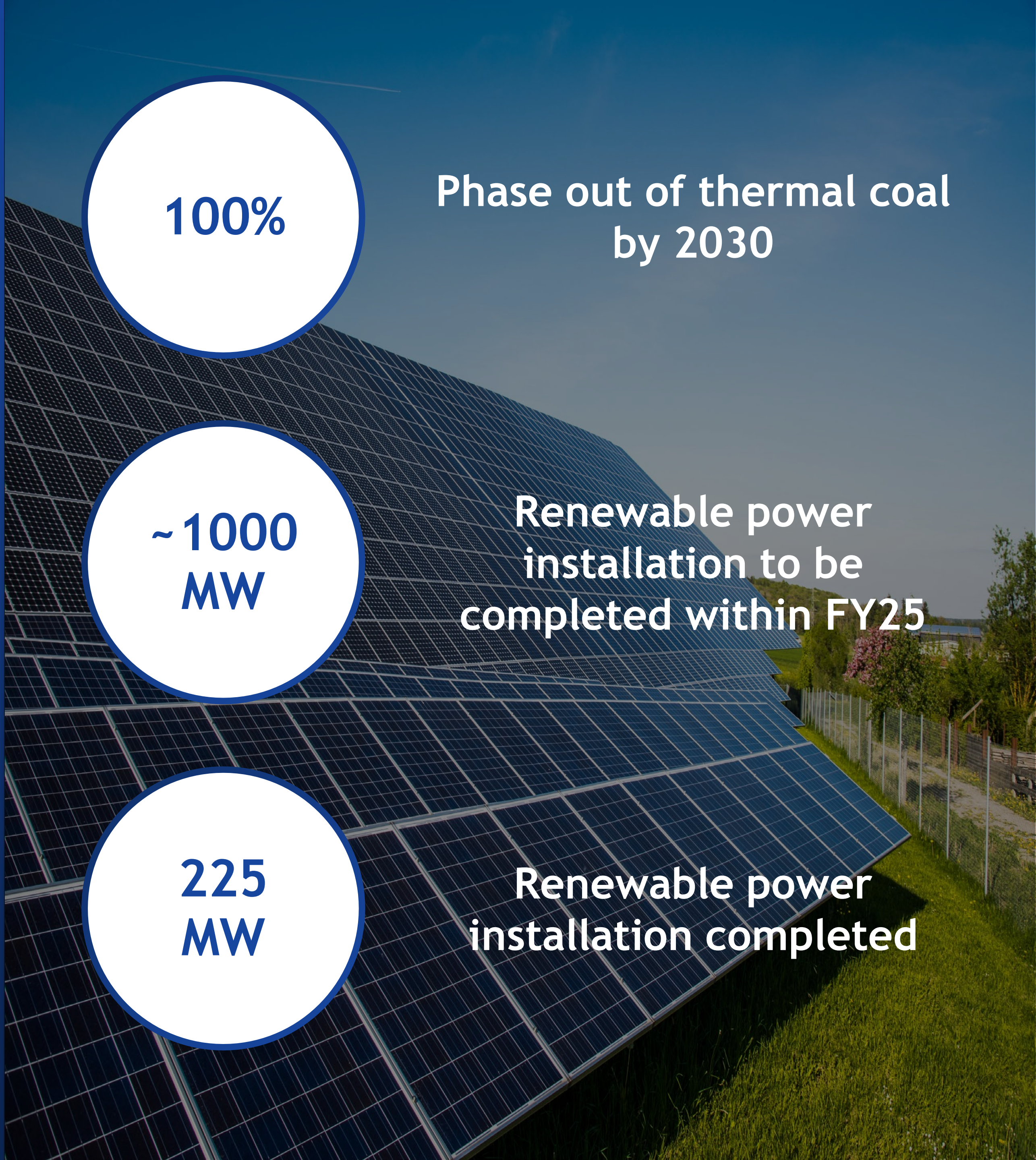
Deploying efficiency, innovation and energy transition

Strategy

- PAT (Perform, Achieve & Trade) compliance and transition to RE

Key Interventions

- Usage of Renewable energy in operations
- Extend installation of waste gas recovery and waste gas recirculation system
- Better demand and supply management
- Participation in StepUp Program (World Steel Association)
- Adopted energy-efficient systems and streamlined practices across operations



100% — Phase out of thermal coal by 2030

~1000 MW — Renewable power installation to be completed within FY25

225 MW — Renewable power installation completed

SEED
Sustainable Energy Environment and Decarbonization

RE: Renewable Energy

Green Hydrogen

25 MW Electrolyzer, Operates from Green Energy

SEED
Sustainable Energy Environment and Decarbonization

Green Hydrogen

~3500 TPA Green hydrogen Generation for DRI unit

Carbon capture

Exploring and adopting latest technologies for decarbonisation

Collaborating with leaders

- Agreement with Royal Dutch Shell[1] to evaluate and develop options to improve energy efficiencies, optimise carbon products demand, and explore decarbonisation technologies
- Collaborated with Larsen and Toubro to evaluate various CCUS technologies

Front ending the call for India's hydrogen economy

- JSW Steel is a member of the India H2 Alliance
- Scoping to pilot hydrogen-based pilot project at Vijayanagar

1 Through its subsidiary Shell India Markets Private Limited


100 TPD CCU plant at Salav Works

Carbon capture

Implemented carbon capture and utilisation (CCU) technology at JSW Salav Works.

Key benefits

- CO2 purity level of up to 99.5%.
- Scalable across the energy system and enables emission reduction

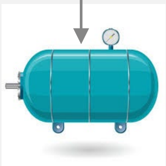
The CCU process

JSW Steel Salav DRI

CO & H_2 are passed through iron ore pellets & lump ore to facilitate the reduction process

Waste gas recovery

Carbon-rich waste gas is recovered and sent to absorber which treats it counter current with g.v. solution forming **rich solution.**



HP & LP regenerators

Rich Solution is treated in the Regenerators separating G.V. Solution and Carbon Dioxide which is then passed on for further processing

CCUS

Carbon capture and storage

CO_2 is then captured, stored and transported for its usage in the food & beverages industry

99.5%
Purity of CO_2

100 TPD
Production capacity

Driving decarbonization agenda at Vijayanagar and Dolvi Plants with SEED

400+
participants involved in driving execution

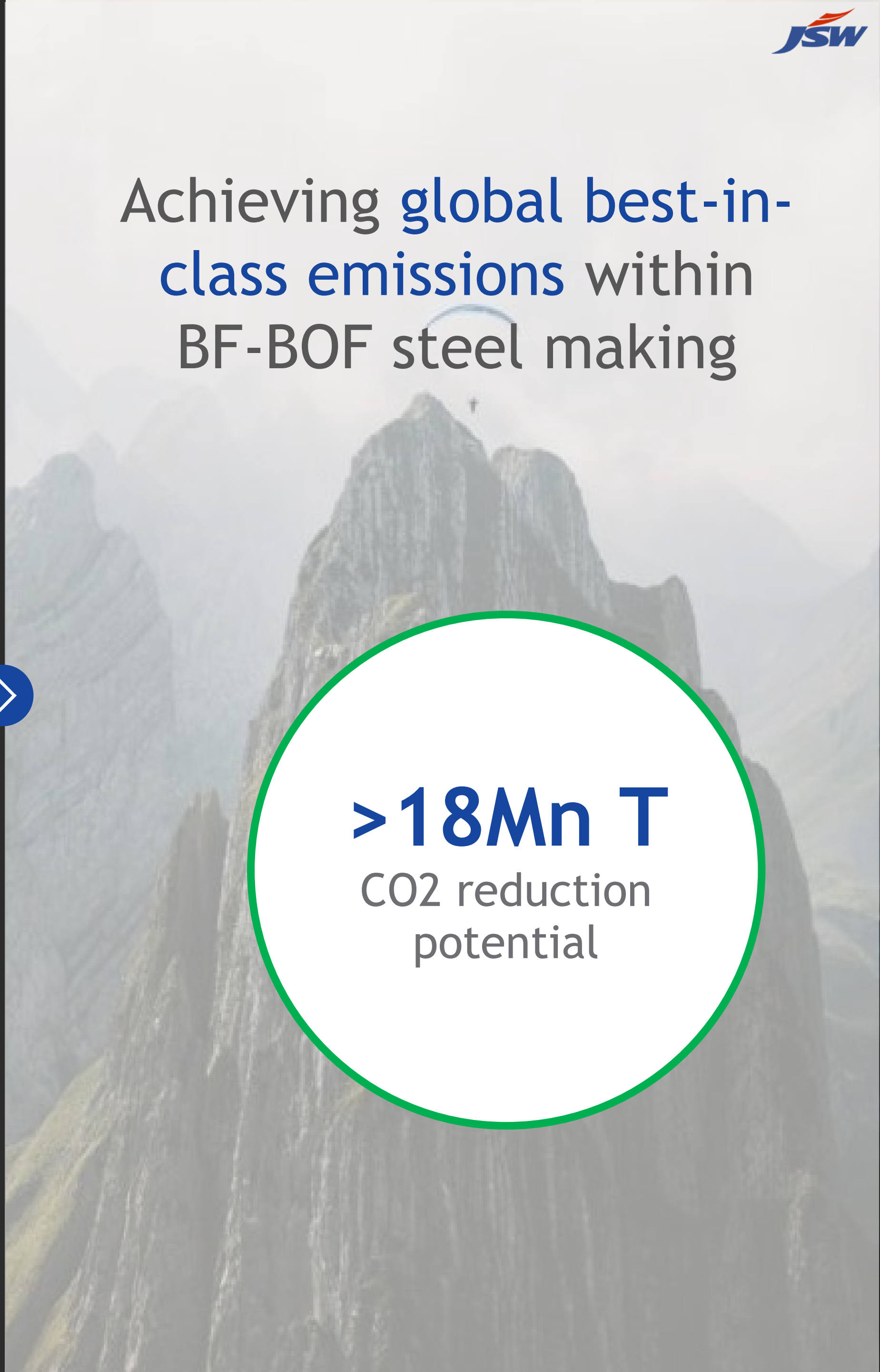
200+
Initiatives identified with granular shop level climate action plans

15
Climate action centers set up for agile implementation

40
Initiatives implemented in the program so far

SEED EM
Launched customized digital tool to monitor CO_2 emissions

35+
Champions being trained on through EdTech programs



Achieving global best-in-class emissions within BF-BOF steel making

>18Mn T
CO_2 reduction potential

Note: CO_2 reduction potential calculated on current production levels

200+ initiatives being actively driven across multiple themes

Select initiatives showcased

Fuel consumption reduction
- Oxyfuel burner, burner fuel-flow throttling
- Furnace coating in RHFs at HSM, LP Mills
- Increased % hot charging in HSM and LP Mills

Power consumption reduction
- Installation of VFDs
- Optimizing compressor operations and arresting leakages

Waste Heat recovery
- Multiple Waste Heat Recovery System projects being explored across the plant

Circularity
- ☆ Establish waste plastic injection in BF
- Use alternate fluxes, KR slag, LD slag in agglo. and iron making

Alternate fuels
- Establish green H2 injection in DRI through pilots
- ☆ Establish COG injection in BFs
- ☆ Establish Super Sinter trials in SP with COG/NG/H2
- ☆ Charcoal Trial in Sinter Plant

Digital & Analytics
- Optimized hot stove operations in BF
- Improve HMSi prediction accuracy for reducing fuel rate

Renewable energy
- Deploy renewable energy

Scrap charging
- Exploring avenues to increase scrap charging in SMS

SEED Sustainable Energy Environment and Decarbonization

☆ For discussion today

Background of Waste Plastic in India

9.4 Million Ton (MT) of waste plastic generated every year in India[1]

- ~60% of this waste is recycled
- ~40% (3.8 MT) causes water/ land pollution wherever it is dumped

Indian steel production is ~ 120 MTPA; expected to increase by 4X by 2050

Potential to inject waste plastic in BF to tackle the challenge of plastic disposal while promoting the principles of a circular economy

1. Source: UNIDO Report- Recycling of Plastics in Indian perspective by Dr. Smita Mohanty, Central Pollution Control Board (CPCB)

SEED Sustainable Energy Environment and Decarbonization

Waste plastic injection in BF can lead to reduction in CO_2 emissions

JSW

Waste plastic has higher H2 content and can replace coke in the blast furnace leading to CO_2 reduction

Methodology
- Waste plastic injected in BF via tuyeres

Working principle
- Higher H2% and CV in plastic reduces CO_2 emissions by replacing coke in BF

Challenges
- Consistent size, quality and availability are a challenge

14.5 Kg/thm

savings in CO_2 emissions @ 50 kg/ thm plastic injection in BF[1]

Waste plastic injection trials conducted in Vijayanagar

Objective of the trials was to **demonstrate successful plastic injection by conducting multiple trials** by injecting plastic :

- **In various form factors** (plastic chips, granules)
- **Via multiple injection setups** (conventional lance, coaxial lance, with or without PCI, etc.)

Waste plastic injection in BF is a one of the initiatives being pursued as part of SEED, JSW Steel's flagship decarbonization program

SEED Sustainable Energy Environment and Decarbonization

1. Assumptions: Waste plastic composition taken as 78% C, 12% H2, subject to change based on plastic availability, Replacement ratio of 0.95 for waste plastic and coke

Multiple trials conducted over the past year leveraging key learnings to make adjustments to plastic form factor and injection mechanism

Fibrous plastic chips

1st Set of trials
Sep 2022

- 20kg fibrous plastic chips made from PP[1] (<5mm) collected from Municipal Solid waste plant
- Hopper choking observed when using fibrous chips which hampered plastic injection

Plastic granules

2nd set of trials
Nov 2022 – Apr 2023

- Type of plastic changed from PP fibrous chips to PE granules (3mm) to facilitate smooth discharge
- 1 kg trial injection done successfully with existing injection system in BF2
- However, injection of 30kg via conventional lance led to melting of plastic in lance leading to choking

Coaxial injection

3rd set of trials
May 2023 – Jul 2023

- Type of injection mechanism changed to a coaxial lance to regulate temperature inside the lance
- 300 kg plastic granules (3-5 mm) successfully injected via a coaxial lance in BF3
- In later trials, plastic was injected with PCI using a similar injection mechanism

1. PP Composition by weight: 85.75% Carbon, 14.15% Hydrogen, 0.1% Ash
2. PE Composition by weight: 85.60% Carbon,14.21% Hydrogen and 0.19% Ash

1st set of trials| ~20kgs Fibrous type plastic chips <5mm collected from Municipal Solid Waste Plant

Hopper pressurized & trial taken in open atmosphere; Hopper choking observed

SEED
Sustainable Energy Environment and Decarbonization

2nd set of trials| 1kg trial injection done successfully in BF2 with plastic granules

2nd set of trials| 30kg trial injection attempted but melting of plastic in lance led to fusing & hosepipe choking observed

3rd set of trials | Successfully demonstrated injection of waste plastic in large quantities

Plastic granules used for injection

Injection setup in blast furnace

Injection lance set-up through tuyeres

- Trial successfully conducted in BF3 at JSW Vijayanagar plant
- 300 kg plastic injected
- 3-5mm plastic granules injected with in-house modified lance

Way forward: We are in discussion with the Municipal Corporation of Bellary to source waste plastic which will then be segregated and granulated such that it satisfies our required quality, form factor and replacement ratio requirements for injection

SEED Sustainable Energy Environment and Decarbonization

COG Injection in Blast Furnace

Objective

Through COG injection, we aim to reduce consumption of coke, which will effectively decrease both emissions and costs at Blast Furnace

SEED Sustainable Energy Environment and Decarbonization

1. Source: UNIDO Report- Recycling of Plastics in Indian perspective by Dr. Smita Mohanty, Central Pollution Control Board (CPCB)

COG Injection | COG chemistry analysis for injection

COG Chemistry for injection

Coke oven gas composition

	Carbon Dioxide (Vol %)	Oxygen (Vol %)	Hydrocarbons (ethane etc.) (Vol %)	Carbon Monoxide (Vol %)	Hydrogen (Vol %)	Methane (Vol %)	Nitrogen (Vol %)	Calorific value (Kcal/Nm3)
CO3	2.37	0.98	3.74	7.27	55.56	25.22	4.87	4,454.42
CO4	2.31	1.29	3.38	7.04	56.15	25.24	4.59	4,404.33

Summary of other chemical constituents in COG

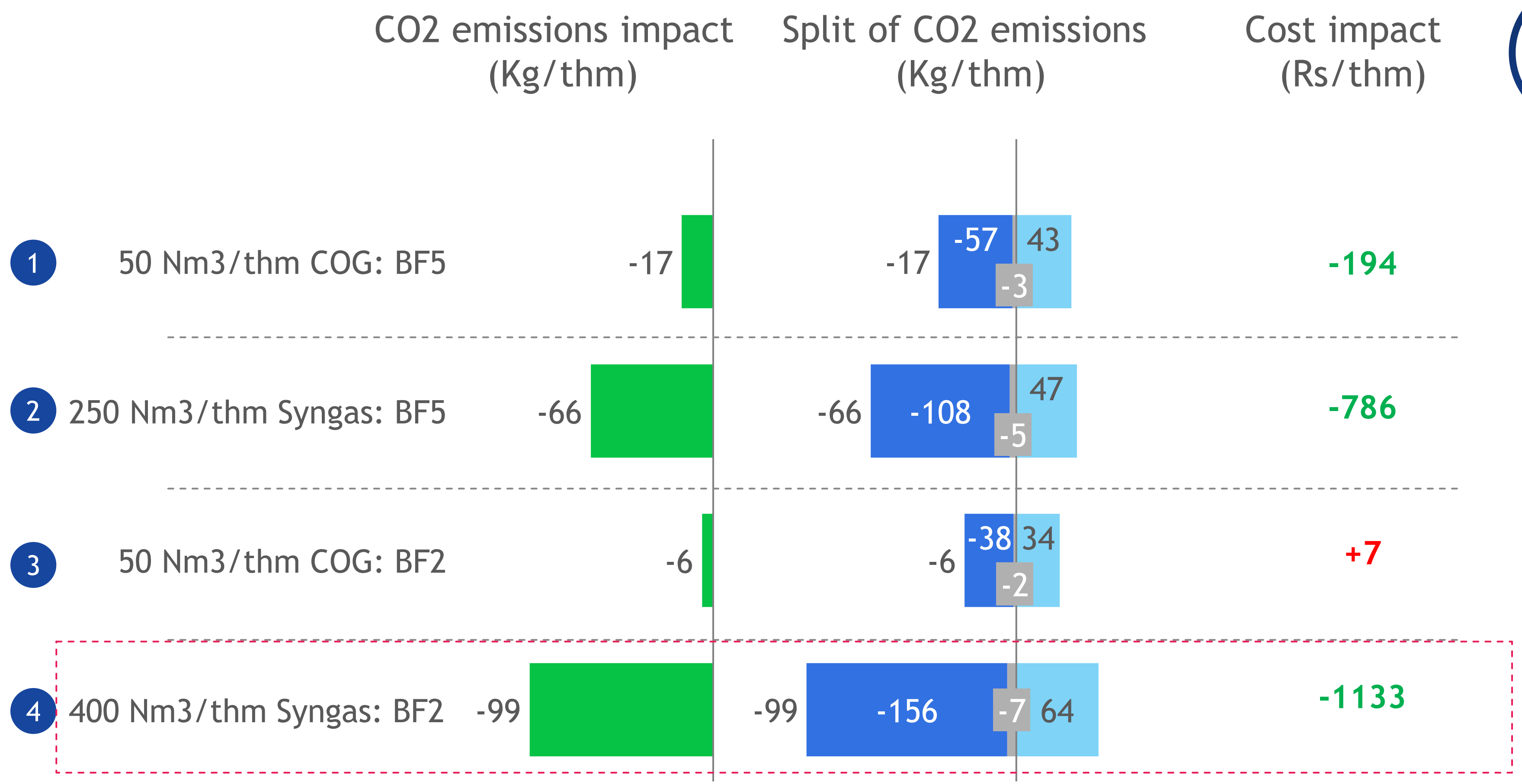
	Ammonia (g/Nm3)	Hydrogen sulfide (g/Nm3)	Naphthalene g/NM3	Tar & dust, g/NM3	Tar fog, g/NM3
CO3	0.11	0.25	0.30	Traces	Traces
CO4	0.12	0.17	0.27	Traces	Traces

Highlights

- For COG injection in BF, target COG chemistry required is:
  - H2S < 0.3 g/Nm3
  - Naphthalene < 0.5 g/Nm3
  - BTX < 10 g/Nm3

SEED Sustainable Energy Environment and Decarbonization

COG & Syngas | CO2 impact varies from -17 to -99 Kg/thm depending on furnace and type of gas being injected



Key drivers of CO2 emissions

Scope 1:
- − Lower coke rate

Scope 2:
- + Increased energy input in the form of COG/Syngas
- − Reduced steam consumption
- − Lower net electricity consumption
- − Export of high CV BF gas

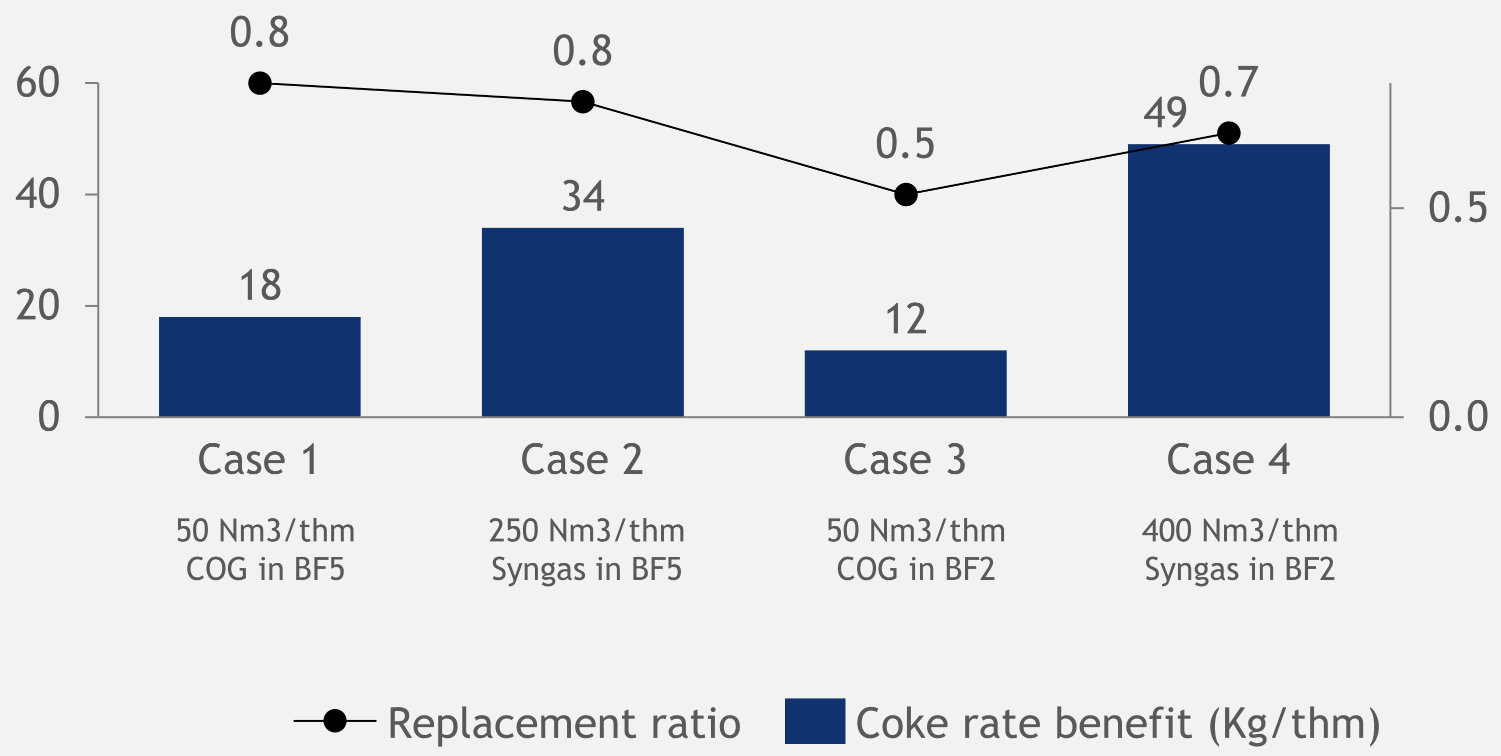
COG volume requirement of ~28,000 Nm3/hr in line with excess COG capacity available

Syngas injection not yet implemented on large scale in any steel plant globally

Scope 1 Scope 2 Upstream

Sustainable Energy Environment and Decarbonization

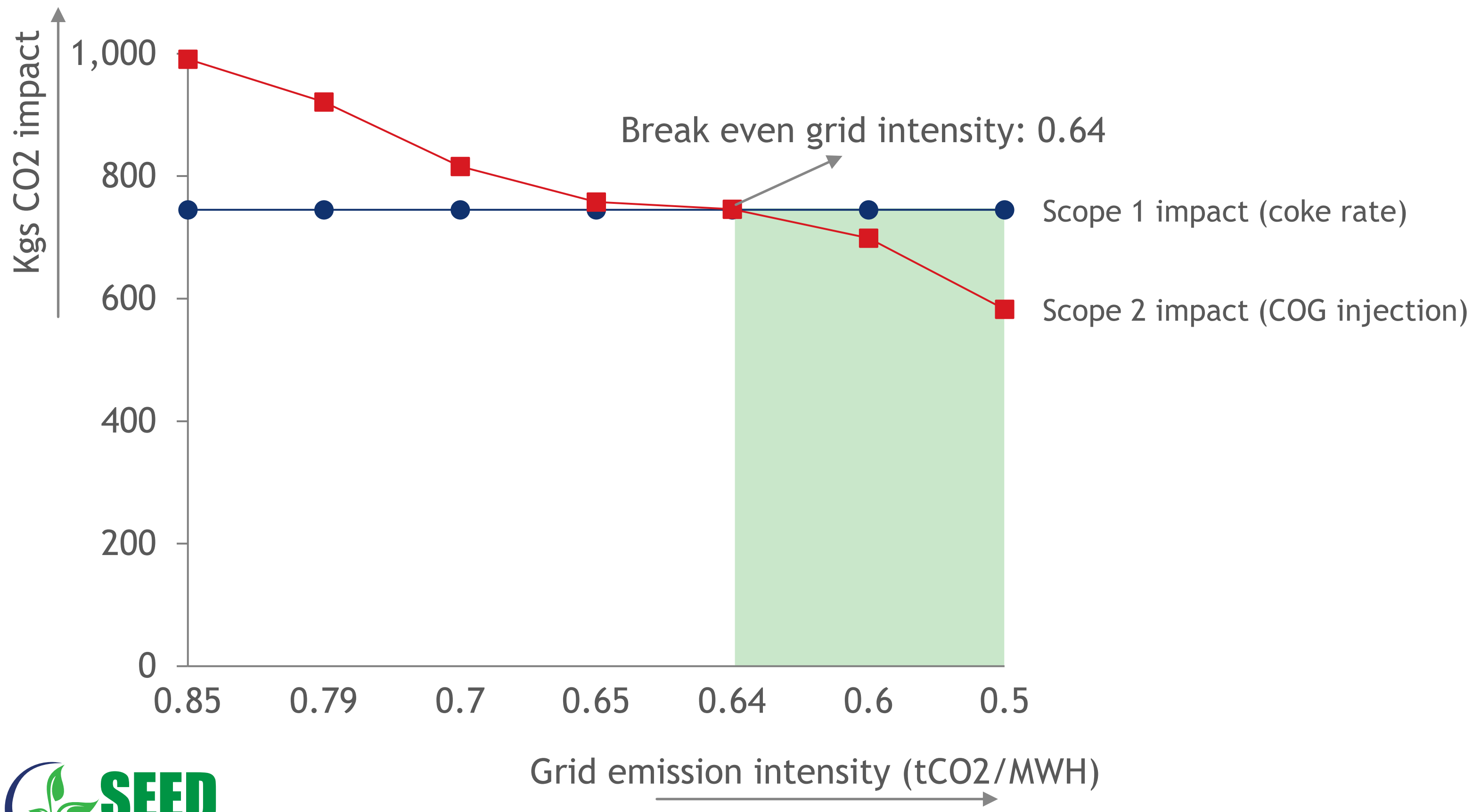
Replacement ratio for Syngas better than COG in BF2; At par in BF5



SEED
Sustainable Energy Environment and Decarbonization

Scope 2 | Exporting COG as source of energy vs consuming as feedstock more beneficial due to higher grid emissions intensity in India

Illustrative example of emissions tradeoff between Coke reduction and COG injection (case 1)



Key highlights

- Scope 1 emissions not dependent on grid emission intensity
- Scope 2 emissions reduce as grid becomes cleaner
- Grid emission intensity of EU: ~0.5 tCO_2/MWH vs 0.79 tCO_2/MWH for India
- As grid becomes cleaner, CO_2 reduction potential of COG injection increases

Charcoal & COG usage in Sinter Plant

Objective

To improve the Sinter Properties and development of alternate Fuel for Sinter plant

SEED
Sustainable Energy Environment and Decarbonization

1. Source: UNIDO Report- Recycling of Plastics in Indian perspective by Dr. Smita Mohanty, Central Pollution Control Board (CPCB)

Charcoal | Use of charcoal in solid fuel mixture helps improve productivity and tumbler index

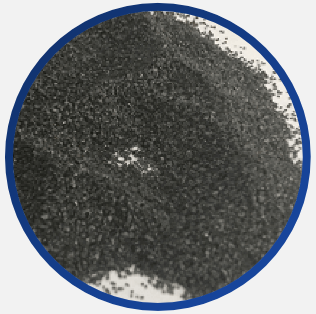
Improvement in Productivity

Charcoal content in solid fuel *(%)*	0%	22%	45%	64%	84%
Sintering time (BTT achieved) *(mins)*	23.1	21.6	23.7	25.2	27.4

Improvement in Tumbler Index

Charcoal content in solid fuel *(%)*	0%	22%	45%	64%	84%
Sintering time (BTT achieved) *(mins)*	64.0	64.9	63.9	62.1	61.1

Charcoal can make up to 20-25% of total solid fuel mixture



Benefits

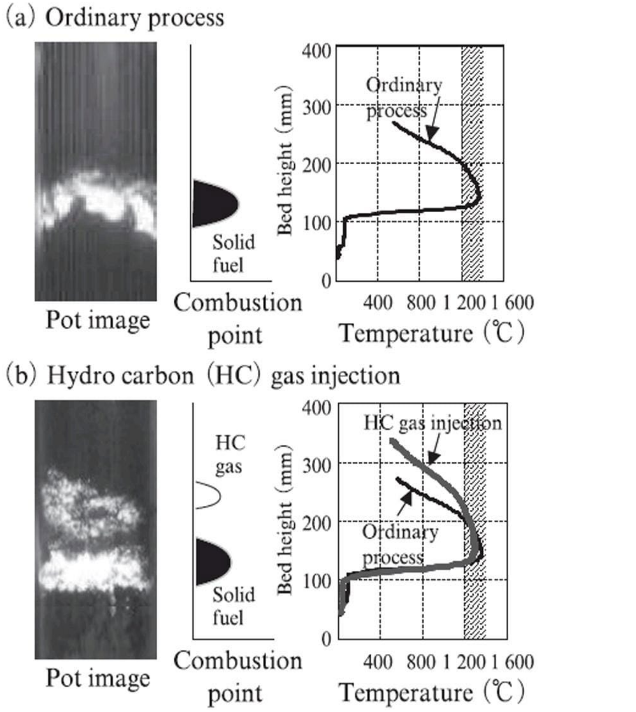
- ~8% improvement in productivity
- ~1.4% improvement in tumbler index
- ~15 kg CO_2/ts reduction in CO_2 emissions
- Reduced CO, SO_2, NOx emissions

SEED Sustainable Energy Environment and Decarbonization

Note:
1. Charcoal with low VM must be used
2. Increased use of charcoal results in higher requirement of water in green mix

COG Injection| Use of hydrogen bearing gas fuel to reduce the coke consumption by ~2.5kg/t of sinter and improve sinter quality

Super-sinter involves blowing of hydrogen bearing fuel in sintering process as partial replacement for coke breeze



Schematic diagram of heat pattern and ignition behavior with hydrocarbon gas injection technology

Diff. in combustion temperature of fuel gas and coke breeze enables sustaining favorable temp (1200-1400 deg. C) for longer duration

The technology has potential to:

- Decrease coke consumption by ~2.5kg/ts
- Improve TI by 1%[1]
- Improve RI by 4%[1]

Impact on carbon emissions

2.5 kg/ts

Reduction in coke cons.

7-8 kg of CO2/ts

Reduction in CO2 per ton of sinter; accounts to **6-7 kg CO2 per tcs**

1. Impact estimated basis implementation in JFE Steel (Japan)

Summary of JSW De-carbonisation initative

2030

Emissions reduction

- Demand reduction through material efficiency
- Technology performance improvement with conventional routes
- Internal monitoring & planning by CAG[1]
- Risk assessment and mitigation via TCFD[2] alignment

Other enablers

- Adoption of BAT
- Iron ore beneficiation for efficiency
- Reduction in coke rate
- Reducing coke utilisation and increasing PCI[3] and NG[4] in BFs[5]
- Increased usage of RE
- Exploring technology such as CCUS[6]
- Increased usage of scrap
- Creation of carbon sinks
- Efficient logistics through pipe conveyor

2030-2050

Deep decarbonisation

- Scaled deployment of CCUS
- Carbon Avoidance – Use of hydrogen for reduction of iron

(to continue post 2050)

2050-2070

Offsetting and other interventions

- Direct electrolysis of iron ore
- Development of green cover to act as carbon sink

SEED Sustainable Energy Environment and Decarbonization

[1]CAG: Climate Action Group [2]TCFD: Task Force on Climate-related Financial Disclosures [3]PCI: Pulverised Coal Injection [4]NG: Natural Gas [5]BF: Blast Furnace. [6]Carbon Capture and Storage

THANK YOU