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“Hydrogen for Decarbonization of Iron & Steel Sector & Green Pathways”

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Need for Decarbonization of Steel Sector

- Steel making is carbon intensive and considered as **" Hard to Abate"** Sector
- Steel Industry is generating around 1.85 t CO2 / tcs contributing to around 7-9% in the overall global emissions. Average Carbon emission in India is around 2.5% t CO2/Tcs –nearly 10-12% of total emissions .
- India's per capita consumption of steel @ 78Kg is one of the lowest against global average of 228 Kg. Being a developing country, steel demand set to increase.
- Indian Steel production capacity likely to increase to 300 million TPY from existing capacity of 155 million TPY by 2030 and to around 500 million TPY by 2047.
- Presently limited opportunities are available for alternate steel making, although efforts are being made to develop disruptive technologies based on Hydrogen, Electrolysis viz Molten Oxide Electrolysis, Oxygen Decoupled Electrolysis etc
- To limit global warming to a maximum of 2 °C above pre-industrial levels—the goal of the 2015 Paris climate agreement—the steel industry's annual emissions must fall to about 500 million t of CO_2 by 2050 i.e 0.2 T CO_2 / Tcs from present level of 1.85T/Tcs

GHG Emissions- Steel Sector

Scope 1: Direct GHG Emissions

GHG emissions from sources that are owned or controlled by a particular production entity e.g emissions from Coke Ovens, Sinter Plant, BF, BOF etc. in an integrated steel plant.

Scope 2: Indirect GHG Emissions

GHG emissions occur at the facility outside the unit e.g. from the generation of imported energy, defined as electricity and / or heat that is purchased and brought into the organizational boundary of the company

Scope 3: Other Indirect GHG Emissions

GHG emissions as a consequence of the activities of the company, but occur from sources not owned or controlled by the company, e.g. manufacture of steel products , transportation

Focus need to be on adoption of Low Carbon Emission Steel making road map to achieve carbon Neutrality by 2070 based on Scope-1 & 2 emissions

Possible Green Pathways

1. **Improvement in Existing Technologies (CO_2 Reduction Potential: 25-30%)**

   Focus on raw material quality through beneficiation & pelletization, energy efficiency through waste heat recoveries & use of natural /syngas , productivity improvement , process reliability through digitalization, waste management and adoption of best available technologies (BAT), **Hydrogen Injection (upto 70%) in Gas based DRI & Blast Furnaces**, Use of Plastic Waste & CCU

2. **Maximize Scrap based Production (CO_2 Reduction Potential: 10-20%)**

   Maximizing use of Scrap in EAF, IF and BOF. Although, it has high potential to reduce CO_2 emissions but limited availability of Scrap may result in limited reduction of emissions. Use of renewable power in EAF , IF and Integrated steel plants and minimizing Coal based power

3. **Breakthrough Technologies (CO_2 Reduction Potential : Carbon Neutrality)**

   Green Hydrogen based steel making, Carbon Capture Utilization & Storage

   (CCUS), Molten Oxide Electrolysis (MOE) / ODE using renewable power ,

Decarbonisation Pillars for Steel Business

CO_2 Minimization

- Syngas based production
- Resource optimisation
- Pallet feed in blast furnaces
- Zero waste approach

CO_2 Avoidance

- Scrap based production
- Heat recovery from off gases
- Heat recovery from slags
- Use of renewable power
- **Enhancing hydrogen usages / Hydrogen based steel**

Carbon Circularity

- CO_2 to CO
- CO_2 to syngas
- Dry reforming of CO_2

Carbon Capture & Utilization

- Fuels – bioethanol
- Chemicals – methanol
- Biological – crude algae oil (biodiesel/ SAF)

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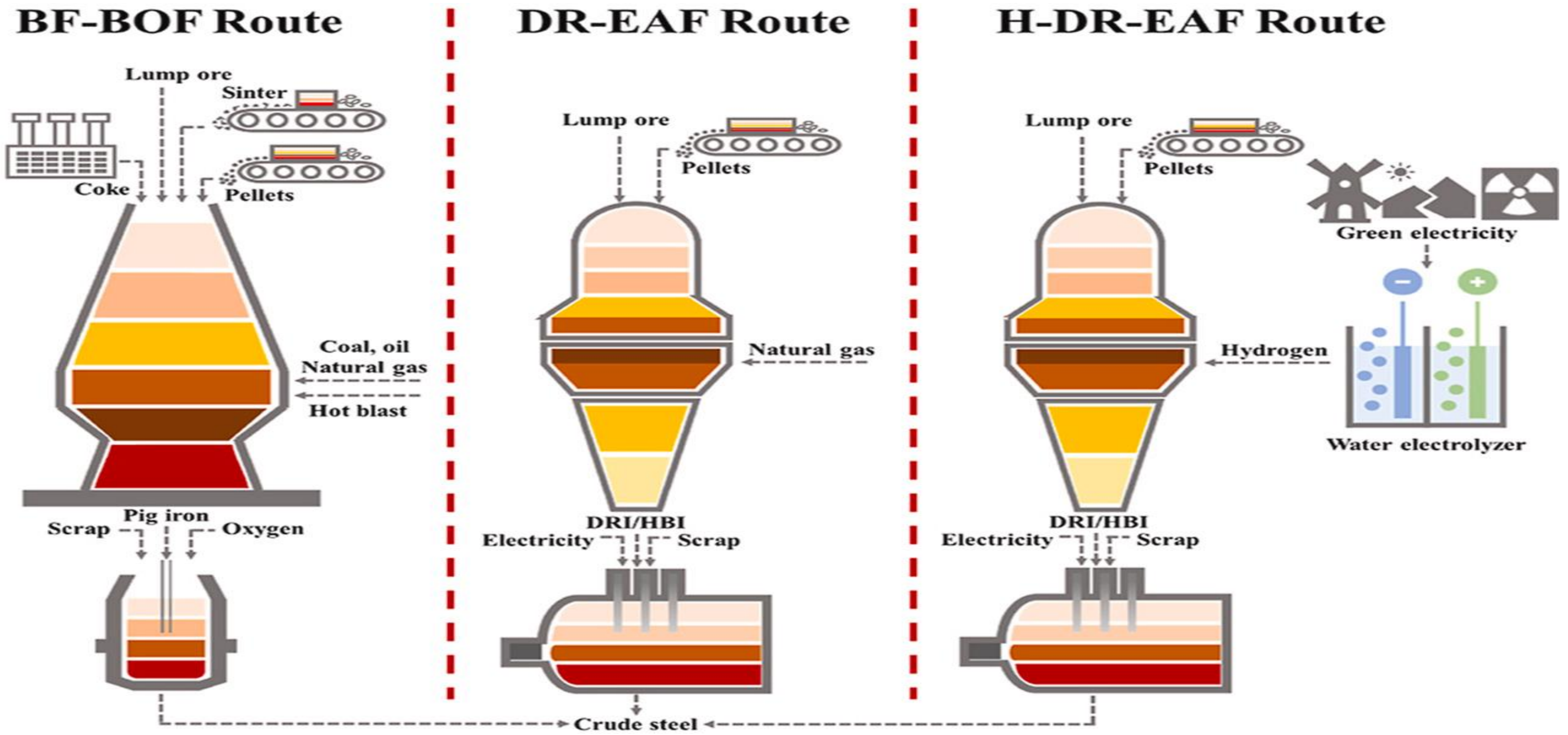
Hydrogen Based Steel Making Vs Conventional Steel making

Carbon Avoidance

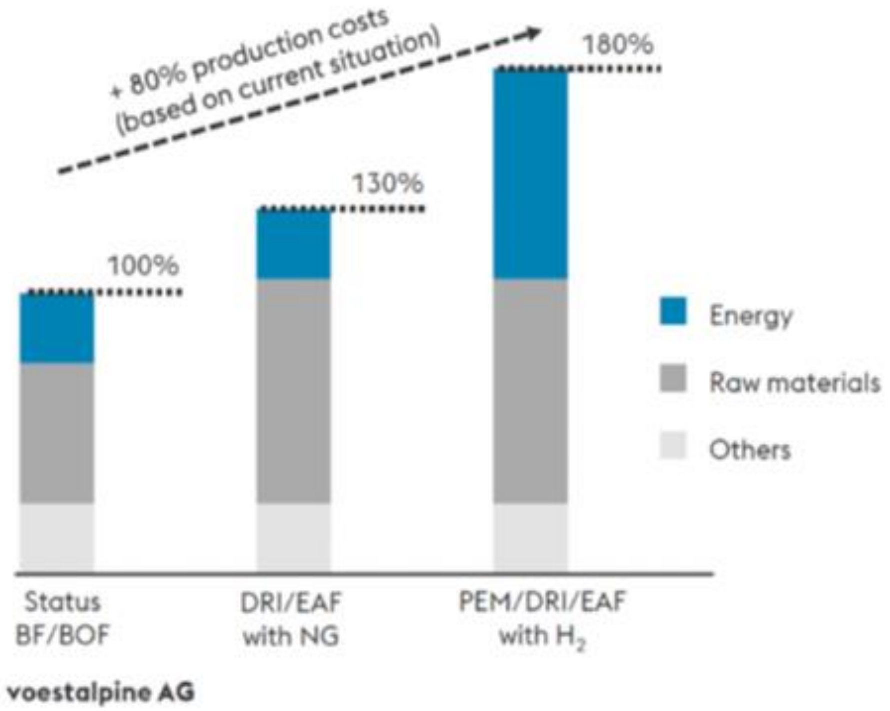


HYDROGEN AND STEEL MAKING-FACTS

- Hydrogen based reduction is endothermic reaction. Requires external source of heat/ energy to carry out reaction
- Direct production of hot metal/ steel not feasible, shall require EAF to produce steel
- Theoretically 54 Kg and practically around 70-80 Kg of Hydrogen is required to produce each tons of steel. Large capacity H_2 generator is a challenge.
- Technically feasible to produce steel from non-carbon energy sources (H_2), but it is an expensive option. 50-55 KWh of energy required per Kg of Hydrogen
- Surging carbon dioxide prices and decreasing hydrogen prices are crucial to ensuring the economic viability (according to cash cost) of pure hydrogen-based steel production

TECHNO-ECONOMIC CONSTRAINTS

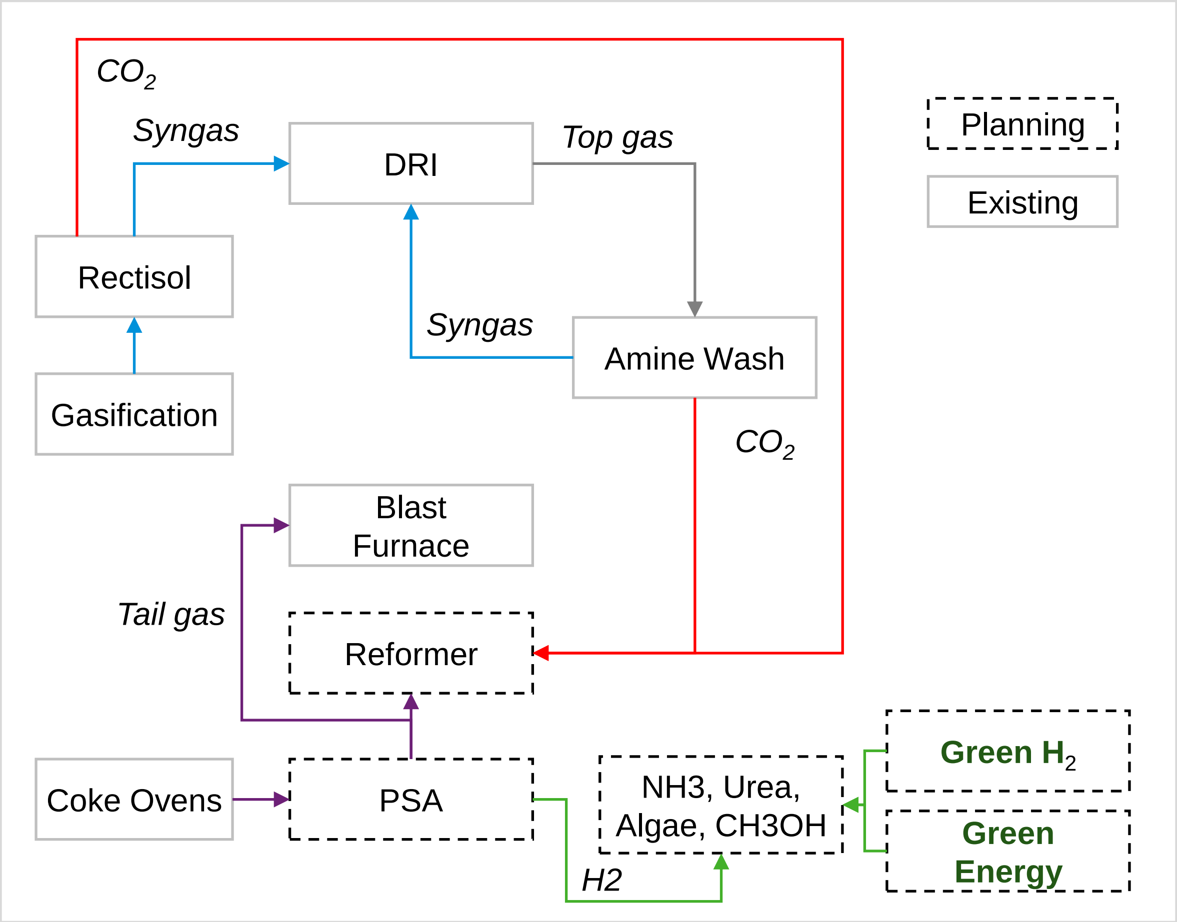
- High Investment made in efficient integrated steel plant ; loss of value due to transition to Hydrogen
- Large Capex and Opex required for transition; Government support may be a necessity
- Hydrogen Based DRI / Steel making : lack of commercially proven technology and not yet competitive, globally difficult to compete
- Competitive energy prices and reduced cost of Hydrogen is essential



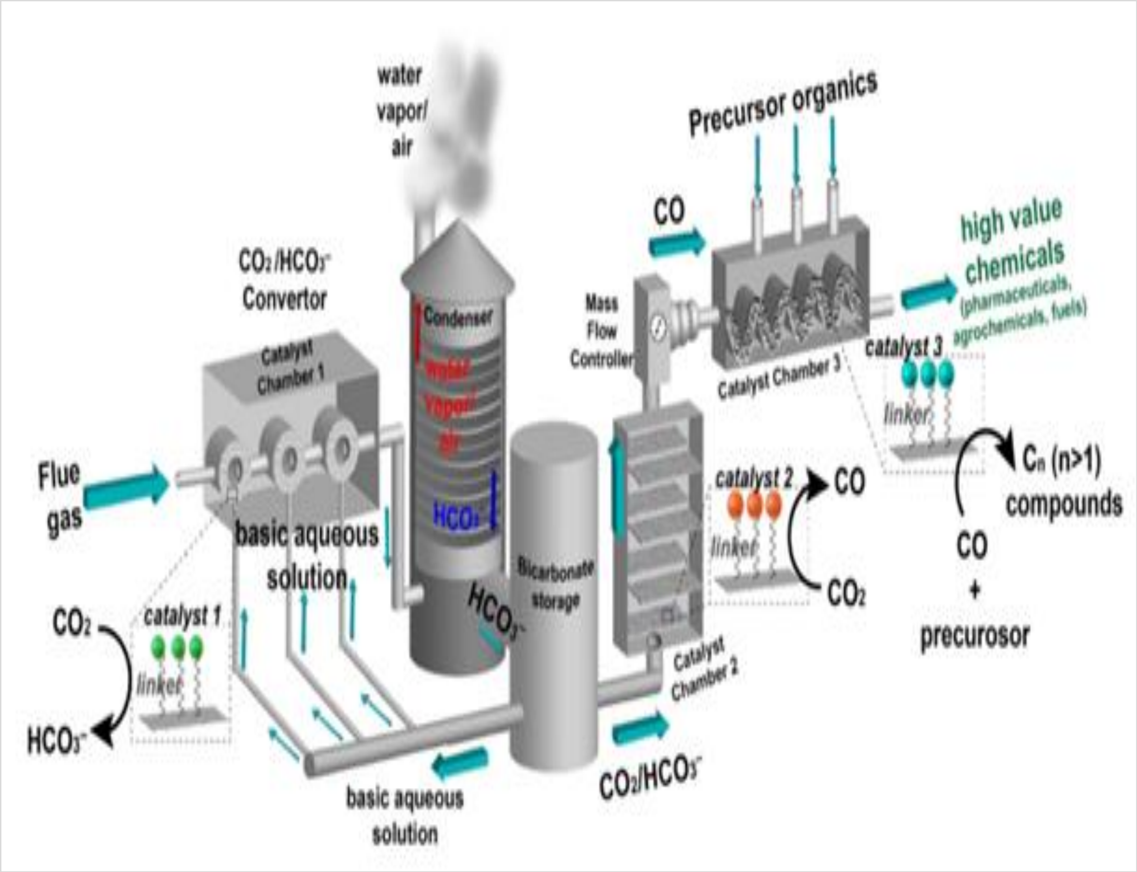
Steel is a globally traded commodity, and with over half the world's production coming out of China, competitive pricing is non-negotiable

Carbon circularity in Syn Gas & BF-JSP

Carbon Circularity



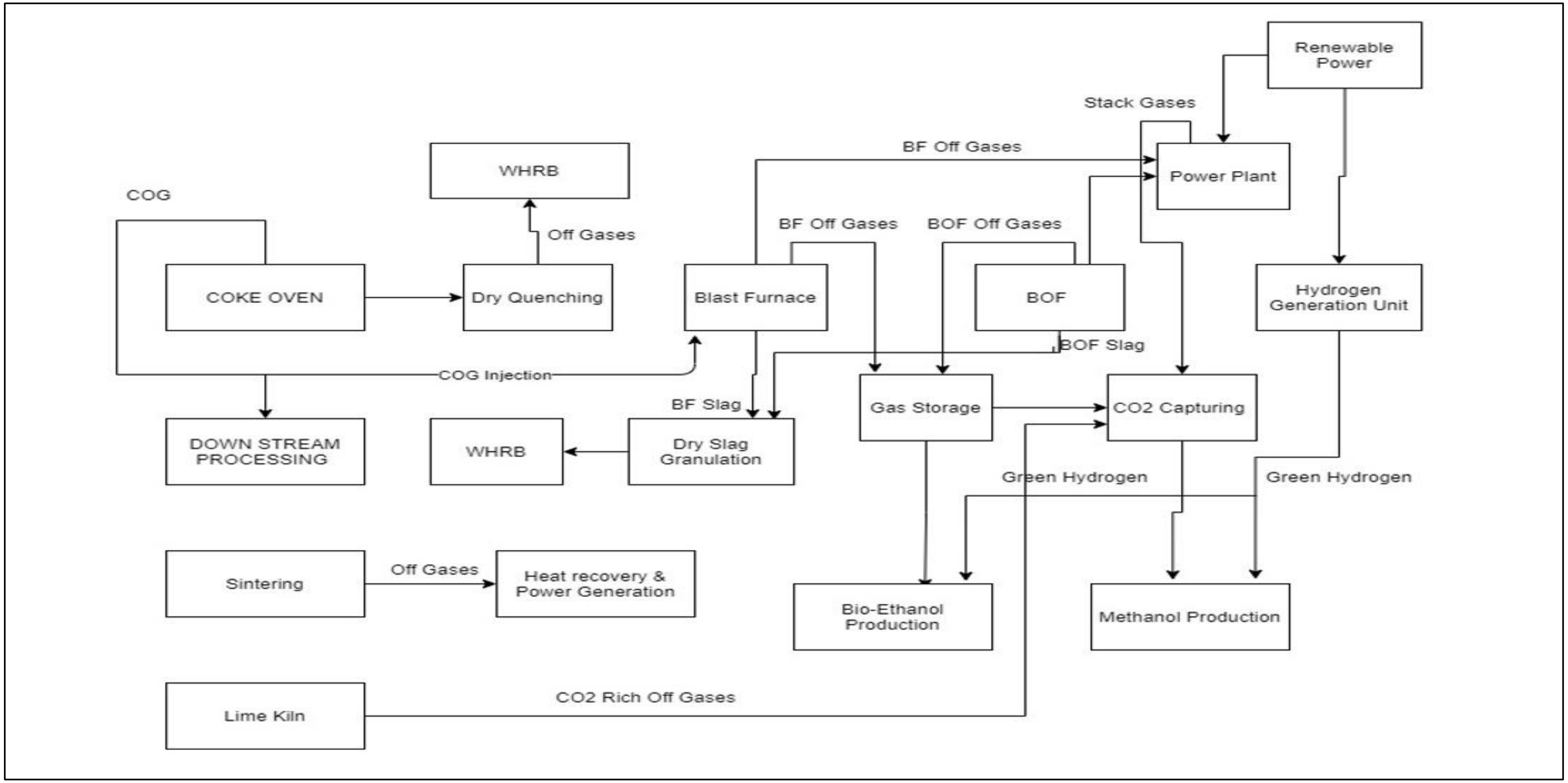
Carbon Recycling & Re-use



Triple Module CO_2 treatment system for Carbon Circularity

Road Map for CCUS and Heat Recoveries in BF-BOF

Carbon Circularity



Energy Saving Technologies (BAT)

Energy Saving Technologies	Energy Flow	Applications	Energy Saving Potential
Top Pressure Recovery Turbine(TRT)	BF Gas	BFG Pressure reduction	Electricity generation @30Kwh/thm
BFG dry dedusting &heat recovery	BF Gas	BF Gas Scrubbing	Increase of 30% in TRT power generation and increase of lower heating value (LHV) by 5-8%
LD Gas dry-dedusting &recovery	LD gas	LD Gas scrubbing	Increased Steam Generation and lower heating value by appx 5%
High Temperature Air Combustion	BFG, LDG, COG	Reheating Furnace and hot blast stoves	20-30% increase in thermal efficiency
Coke Dry Quenching	Coke	Coke quenching	Electricity generation@95-105Kwh/T(Coke)
Pulverized Coal Injection	Coal	Blast Furnaces	Reduction of 10Kg/thm of Coke for appx 15Kg/thm of PCI
Use of VFD and energy Management system	Electricity	Entire Plant	Upto 10-15% reduction in energy consumption
Dry reforming of Methane of COG	COG	Coke Oven	Methane in COG to be converted into Syn gas and used in BF. Saving of PCI & Coke.

Promoting Efficiency in BF-BOF

Parameters	Present Consumption	Target-2047	Likely Technology Intervention
Specific Energy, Gcal/tcs	5.6-6.7	<5	Iron Ore Grade Improvement, Pellets feed TRT,CDQ, Waste Heat Recovery, COG/NG injection, Renewable Power, Dry Slag Granulation (DSG), Organic binders
Specific Water Consumption, M^3/tfs	3.3-4.5	<2.5	Dry Disposal of Tailings, CDQ, DSG, Dry Dedusting of BOF and LD gas, COC improvement,
GHG Emission, T of CO_2/tcs	2.3-2.8	<1.5	CCU, Heat Recoveries and Power Generation, CDQ, 60-70% pellets feed, Maximizing Scrap in BOF, NG/Hydrogen/ COG injection, Increasing PCI, Hot blast temperature
Coke Rate, Kg/Thm	350-450	275-300	Pellets Feed, Iron Ore grade improvement, Micro pelletization for waste dust/sludge, NG/COG/Plastic/Oil injection,
Pulverized Coal Injection, PCI, Kg/thm	75-180	>200	Pellets feed, Iron Ore Grade Improvement, Sinter quality,

Promoting Efficiency in BF-BOF

Parameters	Present Consumption	Target-2047	Likely Technology Intervention
Blast Furnace Productivity, T/M^3/day	1.6-2.5	3-3.5	Iron Ore Grade Improvement, Pellets feed, Coal & Coke quality, Sintering quality
Slag Rate, Kg/thm	350-450	<300	Iron Ore Grade Improvement, Pellets feed, Coal & Coke quality, Sintering quality
Effluent Discharge		Zero Discharge	CDQ, DSG, Dry Dedusting of BOF and LD gas, Nano Technology for Cyanide treatment, Advanced waste water treatment
Dust Emission	MOEF&CC norms	MoEF&CC norms	Dry Filters, ESP, Vacuum Extraction system
Solid Waste Utilization, %	60-80	Zero Waste	Micro pellets, Composite pellets, briquetting, Integrated Slag management for use in Cement, Road and Fertilizers
Employee Productivity, Tonnes of steel/per man/year	400-800	>1500	Digitalization, Supervisory Process Control, (Industry 4.0)

Innovation is key to success.

De-carbonization strategy may influence future growth of the steel Industry. Hydrogen can be an option but requires large R&D to address technological challenges and minimize cost of production

Thank you