Technology Preparedness for the Steel Industry

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Steel Industry Premise

- Globally, steel industry accounts for 6-7 % of the CO₂ emissions

- Hard to abate sector (BF-BOF route)-Carbon as reductant
  
  Global Best in Class ~1.8 tCO₂e/tcs [WSA]

- Technological interventions for lowering carbon footprint [last two decades]
  - Process optimisation for driving resource efficiencies (Coke rate, Raw material beneficiation)
  - Higher energy efficiency through waste heat recovery (TRT, CDQ)
  - Product improvements for lower lifecycle footprint (Hi Strength Steel)

- Alternatives to carbon as a reductant has low feasibility (commercial, operational)
Steel Industry- Possible Alternatives for Low Carbon Regime

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**GHG Intensity of Materials**

1. **Material Recycling**
   - Scrap aggregation for EAF route, Pelletisation of low grade iron ore, LD Slag utilisation

**Product Intensity of Services**

1. **Prolonged Lifetimes**
   - Anti corrosion, anti rusting technologies

2. **Sharing of assets to reduce consumption: Services**

**Material Intensity of Products**

1. **Design optimisation in end products** - Hi Strength Steel

2. **Material Substitution** - New Materials with lower carbon footprint
Steel Industry - Possible Alternatives for Low Carbon Regime

**Supply Side**

### Energy Efficiency
1. Maximise Waste heat recovery
   - Larger blast furnaces, Top Recovery Turbines, Coke Dry Quenching, Waste heat recovery Boilers etc.

### Fuel Substitution
1. Hydrogen as alternative to Carbon as reductant
2. Higher share of renewable in energy mix

### CCS
1. Affordable and scalable technology for Carbon Capture and storage
   - eg. Hlsarna
2. Develop usage of stored carbon

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Steel Industry- Key Issues

1. Hydrogen as a substitute for Carbon as a reductant
   *Institutional backing to develop technology to produce Hydrogen at economically viable cost*

2. Scalable and affordable technology for Carbon Sequestration
   *Institutional backing to develop economically viable technology*

3. Higher use of renewable in the energy mix [applicable for India]
   *Grid capacity and capability for accommodating large and fluctuating Steel Plant loads*
Thank You
# Lowering CO₂ footprint

## Japan: Steel industry’s voluntary plan

Table 2: Targets of JISF Commitment to a Low Carbon Society.²⁵⁹

<table>
<thead>
<tr>
<th>Phase I</th>
<th>Phase II</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eco-Processes</strong></td>
<td><strong>Eco-Processes</strong></td>
</tr>
<tr>
<td>Reduction target of 5 million t-CO₂ vs BAU *¹</td>
<td>Reduction target of 9 million t-CO₂ vs BAU *¹</td>
</tr>
<tr>
<td><strong>Eco-Products</strong></td>
<td><strong>Eco-Products</strong></td>
</tr>
<tr>
<td>Contribute to reduction of approx. 34 million t-CO₂ (estimated)</td>
<td>Contribute to reduction of approx. 42 million t-CO₂ (estimated)</td>
</tr>
<tr>
<td><strong>Eco-Solutions</strong></td>
<td><strong>Eco-Solutions</strong></td>
</tr>
<tr>
<td>Contribute to reduction of approx. 70 million t-CO₂ (estimated)</td>
<td>Contribute to reduction of approx. 80 million t-CO₂ (estimated)</td>
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</tbody>
</table>

**Innovative Technology Development**

- **COURSE 50** → 30% reduction in CO₂ by 2050

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*¹ BAU: Abbreviation of “Business as Usual”; in these target values, it means the CO₂ emission assuming crude steel production using FY 2005 as the baseline.

*² Preconditioned on creation of infrastructure for CO₂ storage and securing economic rationality for commercial equipment.
1) Development of technologies to reduce CO₂ emissions from blast furnace
   • Technologies to control reactions for reducing iron ore with reducing agents such as hydrogen to decrease coke consumption in BF.
   • Technologies to reform coke oven gas (COG) aiming at amplifying its hydrogen content by utilizing unused waste heat (800°C generated at coke ovens).
   • Technologies to produce high strength and high reactivity coke for reduction with hydrogen.

2) Development of technologies to capture - separate and recover - CO₂ from blast furnace gas
   • Techniques for chemical absorption and physical adsorption to capture CO₂ from blast furnace gas (BFG).
   • Technologies to reduce energy to capture CO₂ through enhanced utilization of unused waste heat from steel plants.

Target: 30% Reduction of CO₂ in Steel Works until 2050
Sunlight can convert iron ore to steel!

Hydrogen essentials

Renewables
- Solar
- Wind
- Wave
- Hydro
- Nuclear
- Geothermal

**Electrolysis of water**

\[ H_2O \rightarrow H_2 + O \]

**Oxygen removal potential**

\[ \begin{align*}
    H_2 & \rightarrow H_2O & 0.5 O_2 \\
    C & \rightarrow CO_2 & 1 O_2
\end{align*} \]

**Reduction gas**

\[ FeOx + xH_2 \rightarrow Fe + xH_2O \]

**Electricity intensive** used only to make oxygen in space

- Electricity needed ≈ 50 kWh / kg \( H_2 \)
- Another 15 kWh for compression of produced \( H_2 \)
  - \( 2 H_2 = 1 C \) (4 kg \( H_2 = 12 \) kg \( C \)) ... 65 kWh x 4
  - 260 kWh = 12 kg \( C \) ... viable when electricity costs Rs 0.50/kWh and Coal Rs 10 / kg

**EAF**

**DRI**

**DRI charge**

**Liquid steel**

**Iron Making Division**

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CO$_2$ emission of technology routes:

- **DR**: 100%
- **BF**: 95%
- **BOF**: 64%
- **EAF**: 68%

The generation of electric energy has the main influence on the CO$_2$ generation beside the basic differences of the two steelmaking technology routes.

Voestalpine Steel Division
28 | 28.04.2015 | Challenges for resource intensive processes
<table>
<thead>
<tr>
<th></th>
<th>Hot Metal based on Coke + PCI</th>
<th>DRI based on Natural gas</th>
<th>DRI based on Coke Oven gas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coke - C</td>
<td>CH₄</td>
<td>55% H₂, 25% CH₄</td>
</tr>
<tr>
<td></td>
<td>PCI ~ 4-5 % H₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reducing molecules</td>
<td>90:10</td>
<td>35:65</td>
<td>20:80</td>
</tr>
<tr>
<td>C:H₂ ratio</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂ footprint, t / t</td>
<td>1.80</td>
<td>0.42</td>
<td>0.30</td>
</tr>
<tr>
<td>Melting energy</td>
<td>already molten</td>
<td>Electricity</td>
<td>Electricity or “BOF excess”</td>
</tr>
<tr>
<td>Examples – exact and similar ideas</td>
<td></td>
<td>std NG based DR→EAF</td>
<td>Dolvi Hazira Poland ?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VA – mixing with BF-BOF approach</td>
<td>Posco – Finex excess DRI</td>
</tr>
</tbody>
</table>
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**Concept of Iron Ore Hydrogen Reduction**

- **Conventional BF**
  - 60% CO Indirect Reduction: Exothermic reaction
    \[ \text{FeO} + \text{CO} \rightarrow \text{Fe} + \text{CO}_2 + 413.6 \text{kcal/kmol} \]
  - 10% H₂ Indirect Reduction: Endothermic reaction
    \[ \text{FeO} + \text{H}_2 \rightarrow \text{Fe} + \text{H}_2\text{O} - 570.2 \text{kcal/kmol} \]
  - 30% Carbon Direct Reduction: Large Endothermic reaction
    \[ \text{FeO} + \text{C} \rightarrow \text{Fe} + \text{CO} - 3708.4 \text{kcal/kmol} \]

**COURSE50 BF**

- 60% Carbon Consumption (Target Level)

**H₂ reductant**

We develop technologies to control reactions for reducing iron ore by use of H₂ reductant to decrease carbon consumption in BF.
Variations of BF process

simulations of lowering CO\textsubscript{2} footprint

ULCOS concept

JFE simulation

a) Conventional BF

b) Oxygen BF with top gas recycling

c) Advanced oxygen BF

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UCG with Carbon Capture and Storage (UCG-CCS)

Carbon capture and storage (CCS) aims to reduce net greenhouse gas emissions, chiefly CO₂, through storage of gas underground.

Storage Targets

- Saline Aquifers
- Depleted Oil & Gas fields (w/ or w/o EOR and EGR)
- Unmineable Coal Seams (w/ or w/o ECBM)
A simpler hydrogen based CO$_2$ footprint reduction?

- BF Coke: 300 kg/thm
  - PCI: 220

- Coke Ovens
  - Coking coal: 450 kg/thm

- DR shaft
  - COG: 135 Nm$^3$/thm

- HM 1 t @ 2.1 t CO$_2$/t
- DRI 0.25 t @ 0.3 t CO$_2$/t

Iron 1.25 t @ 1.92 t CO$_2$/t

9 % reduction in CO$_2$ footprint per t of iron
Using the underground to greener steelmaking

Footprint.. CO₂

Case 1
DRI - 1.2
EAF - 0.7 power from syn gas
Overall
~2.0 t CO₂ / tcs (100% ore based)

Case 2
DRI - 1.2
EAF - 0.1 power from renewables
Overall
~1.3 t CO₂ / tcs (100% ore based)

Case 3
Sequestration of CO₂ from both DRI and power generation
Overall
~0.4 t CO₂ / tcs (100% ore based)
.. the **iron** ahead: *summary*

- **India** – a lot more liquid iron production is imminent
  - the BF will dominate by far

- **Leverage technology** to address chronic issues
  - eg. coal moisture, adverse ore characteristics

- **The BF will get bigger** – need to prepare far more:
  - visualization, understanding, additional controls

- **Leverage precious hydrogen to maximize footprint reduction**
  - make more iron with it
### SUSTAINABILITY INDICATORS 2003 - 2016

#### Environmental performance

<table>
<thead>
<tr>
<th></th>
<th>Greenhouse gas emissions (tonnes CO₂/tonne crude steel cast)</th>
<th>Energy Intensity (GJ/tonne crude steel cast)</th>
<th>Material efficiency (% of materials converted to products &amp; byproducts)</th>
<th>Environmental management systems (EMS) (% of employees &amp; contractors working in EMS-registered production facilities)</th>
</tr>
</thead>
</table>