Greening steel production – technologies and policies

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Greening High-Temperature Manufacturing: Toward an RD&D Agenda
Outline

• US steel production 2019
• Alternatives to coal
• The challenge
• Technologies
  - Hydrogen Direct Reduction
  - Electrolysis
  - Plasmasmelting
• Conclusions
US steel production 2019

88 million tons

- coal based (coal & iron ore)
- natural gas based (natural gas & iron ore)
- scrap based (scrap & electricity)

Sources: Worldsteel Steel in Figures, 2019, Midrex 2019.
Steel sector’s CO₂ emissions – it’s not only about heat, it is also about chemical reactions

<table>
<thead>
<tr>
<th>Steelmaking Type</th>
<th>Chemical Equation</th>
<th>Reaction Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal based steelmaking</td>
<td>( Fe_2O_3 + C \rightarrow Fe + CO_2 )</td>
<td>Iron Ore + Carbon → Iron + Carbon Dioxide</td>
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<tr>
<td>Hydrogen based steelmaking</td>
<td>( Fe_2O_3 + H_2 \rightarrow Fe + H_2O )</td>
<td>Iron Ore + Hydrogen → Iron + Water</td>
</tr>
<tr>
<td>Electricity based steelmaking</td>
<td>( Fe_2O_3 + e^- \rightarrow Fe + O_2 )</td>
<td>Iron Ore + Electricity → Iron + Oxygen</td>
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<tr>
<td>Coal based steelmaking + carbon capture</td>
<td>( Fe_2O_3 + C \rightarrow Fe + (CO_2) )</td>
<td>Iron Ore + Carbon → Iron + Carbon Dioxide</td>
</tr>
</tbody>
</table>
Coal based steel production site (example)

- Sinter Plant
- Coke Oven
- Blast Furnace
- Steelmaking
- Rolling/Finishing

- Hydrogen Direct Reduction
- Electrolysis
- Plasmasmelting
- (Carbon capture)
- demand reduction

Gas-based direct reduction

- commercial, 82 Mt globally in 2019
- can be switched to hydrogen with minor changes (flexible use as well)
- in Europe: HYBRIT (Pilot), SALCOS (Pilot), ThyssenKrupp, Dillinger, ArcelorMittal (grey hydrogen)
- in Asia: HBIS Group 0.6 Mt plant ordered Nov 2020; Baosteel Carbon Neutrality Goal 2050 (?)
Electricity based steelmaking at ArcelorMittal (Siderwin)

Plasmasmelting Reduction

Electric Arc Furnace

Hydrogen Plasma Smelting Reduction

Upscaling from 100 g to 50 kg batch process

Conclusions

• Hydrogen direct reduction for close to zero emissions steelmaking is (almost) commercially available

• Steelmaking plants that use natural gas can be run with hydrogen as well (with minor adjustments)

• Other low CO$_2$ steelmaking technologies are at early stage of development.

• Carbon capture as a low-CO$_2$ technologies may be reserved for sectors harder to abate (air transport, chemicals) or to achieve negative emissions to compensation agriculture and land-use

• Material efficiency!

• Major barriers: operational costs & availability of low-CO$_2$ hydrogen

• Policies that adress operational costs: e.g. lead markets, quotas, carbon contracts for difference, carbon border adjustments
Thanks for listening!

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Back up
Coal based steelmaking: 72%
Natural gas based steelmaking: 4%
Scrap based steelmaking (Recycling): 24%

Total 1.7 billion ton steel (2017)

Sources: Worldsteel, Midrex (neglecting coal based steelmaking in rotary kilns (15 Mio t, 2017))
What is going to happen - Primary steel production (2000-2015) & Forecast (2020-2050)


Marlene Arens - Lund University
What should happen?

If blast furnaces were relined only until 2030...
(assuming campaigns of 20 years)

source: Plantfacts Database (The database lacks several 100 Mts for China)