Scenario for near-term implementation of partial capture from blast furnace gases in Swedish steel industry

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Project partners:
Steelmaking

Carbon is used as reducing agent

→ Primary steelmaking has to be decarbonized, while secondary steelmaking is ramped up
How does CCS fit in?

How can CCS contribute to starting mitigation in the near term and in synergy with HDR? What are the techno-economic conditions for this?

Major steel producers in Europe work with hydrogen direct reduction (HDR) to reach close-to-zero CO₂ emissions by Year 2040-2050.
Steel case: design & economics

Entire gas flow into absorber, lower L/G ratio
→ separation rate in absorber <90%;
→ lower specific heat demand

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic plant life time</td>
<td>25 years</td>
</tr>
<tr>
<td>Construction time</td>
<td>2 years</td>
</tr>
<tr>
<td>Plant availability</td>
<td>95%</td>
</tr>
<tr>
<td>Rate of return</td>
<td>7.5%</td>
</tr>
<tr>
<td>Annual maintenance cost</td>
<td>4% of investment cost</td>
</tr>
<tr>
<td>Annual labor cost</td>
<td>821 k€/annum</td>
</tr>
<tr>
<td>Utilities</td>
<td></td>
</tr>
<tr>
<td>MEA make-up</td>
<td>1867 €/m³</td>
</tr>
<tr>
<td>Cooling water</td>
<td>0.022 €/m³</td>
</tr>
<tr>
<td>Electricity</td>
<td>0.030 €/kWh</td>
</tr>
<tr>
<td>Steam</td>
<td>assessed separately</td>
</tr>
</tbody>
</table>

Bottom-up approach in assessing value of excess heat!

Luleå steel mill - CO₂ sources

- Iron production from iron ore pellet 100%
- No rolling mill
- ~ 2 Mt steel slabs p.a.
- ~ 3.4 Mt CO₂ p.a.

Blast furnace gas, 25% CO₂, 1.8 bar

Hot stove flue gas
25% CO₂, atm

CHP plant flue gas
30% CO₂, atm
Emissions reductions and capture cost

- Capturing from blast furnace gas is most economic
  → 20%–38% less CO$_2$ emissions

- Excess heat sources; at constant load:
  - Flare gases
  - Flue gas heat recovery
  - Dry Coke Quenching
  - Dry Slag Granulation

- Partial capture with excess heat costs less than full capture with external energy

Capture cost, no transport & storage

Full capture -76% CO$_2$ site

Back pressure Excess heat Combustion of extra fuel

0 0.5 1 1.5 2 2.5
0 10 20 30 40 50

captured CO$_2$ [Mt/a]
capture cost [€/t CO$_2$ captured]
Capture cost structure

i) Partial capture with excess heat is dominated by CAPEX;

ii) Full capture is dominated by steam cost and is thus more sensitive to changes in energy markets

iii) Production cost for steel slabs increase by 4 – 17%* for investigated cases;


capture cost, no transport & storage
Near-term implementation

Partial capture with excess heat requires a carbon price of 40-60 €/tonne CO₂

Window of opportunity: coming 5-15 years
Later: economic lifetime of partial capture unit (25yrs) would be too short before policies will require close to 100% emission reduction

[now: full chain cost!!]

= capture + transport¹ + storage

¹Assuming ship transport to storage
Transition to low-carbon technologies

i. Accumulated emissions are relevant! Partial capture could de-risk late arrival of HDR

ii. CCS infrastructure could be used in HDR concepts
   - capture remaining fossil & biogenic emissions
   - produce "blue" hydrogen from fossil fuels

iii. Partial capture could evolve
    - co-mitigation with biomass
    - solvent improvement

Integrated steel works with 2Mt steel slabs p.a.
Key findings – steel case

• Integrated steel mills: Partial capture powered by excess heat is more cost-efficient than full capture that relies on external energy

• Near-term implementation in 2020s: possible if policies value carbon at 40-60 €/t CO$_2$

• Window of opportunity for implementation of partial capture, before low-carbon technologies are required to meet CO$_2$ emission targets!

• Partial capture may allow for synergies with other mitigation options (biomass, electrification, etc.)

• Partial capture could be a step toward the transition to low-carbon technologies, such as hydrogen direct reduction (HDR), to enable the low-carbon economies of the future.
Partial Capture: "Some is better than none!"

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