Carbon Dioxide Capture and Storage in the Iron and Steel Sector

Tim Dixon and Stanley Santos
IEA Greenhouse Gas R&D Programme
Cheltenham, UK

The Necessity of CCS: Looking Beyond Fossil Power
COP-18
Doha
3 December 2012
Iron and Steel in Europe –
22 Sites with > 2 Mt/y CO₂ Emissions (2008)

Amount of CO₂ capture per site could be greater than what we get from coal fired power plant.

Data from C. Beauman – EBRD
Challenges to CCS deployment in the Iron and Steel sector

Syntesis Report:

Assessing the Potential of Implementing CO₂ Capture in an Integrated Steel Mill

Volume I: Estimating the Cost of Steel Production from an Integrated Steel Mill (Base Case)

Project Partners:

Project Management, Implementation and Delivery:

Issued by:

IEA Greenhouse Gas R&D Programme
Cheltenham, UK

January 2012
An integrated steel mill is composed by numerous facilities - from iron ore to steel products.

1. heavy plate mill
2. coking plant batts
3. casting line + hot strip rolling or continuous casting line
4. blast furnaces
5. BOF

- ores
- coal
- sinter plant
- hot metal
- scrap + additives
- crude steel
- slab
- heavy plate finishing shop
- hot strip finishing shop
- pickling
- coating line
- hot strip
- coated / organic coated sheets
- uncoated sheets
- electrolytic coated sheets
- skin pass rolling
- batch annealing
- continuous annealing
- cold rolling finishing shop
- hot-dip coating line
- zinc
- zinc oxalate
- zinc
- heavy plate
- hot strip
- coated / organic coated sheets
- uncoated sheets
- electrolytic coated sheets
First Challenge...

- **There is no steel mill in this world which is alike...**
  - Steel is produced with different processes
  - Steel is produced with different types of finished or semi-finished products
  - Steel is produced with different grades
ThyssenKrupp Steel Europe – main CO₂ emitters (schematically) up to 20 Mt CO₂ p.a.
2nd and 3rd Challenges...

- **Emissions from integrated steel mills come from multiple sources.**
- **The source of CO\textsubscript{2} may not be the emitter of the CO\textsubscript{2}.**
  - Strongly dependent on how you define *boundary limit*
  - In addition to the direct use of fossil fuels, the emissions is also strongly dependent on the use of by-product gases
4th Challenge...

BF technology is already near the theoretical limit of efficiency

source: VDEh, Germany.
Essentials for CCS deployment

- Accounting of CO$_2$ Emissions is an essential activity for Deployment of CO$_2$ Capture Technology in the Iron and Steel Sector.
- Accounting of CO$_2$ Emissions should be based on a globally consistent methodology that will allow production normalised CO$_2$ emission comparable between regions.
- These would result in better benchmarking – therefore providing a meaningful number for the CO$_2$ avoidance cost.
UNDERSTANDING THE COST OF INCORPORATING CO₂ CAPTURE IN AN INTEGRATED STEEL MILL
# Acknowledgement

<table>
<thead>
<tr>
<th>PROJECT PARTNERS</th>
<th>PROJECT DELIVERY</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Swedish Energy Agency logo]</td>
<td>[swereaMEFOS logo]</td>
</tr>
<tr>
<td>swereaMEFOS</td>
<td>TATA STEEL</td>
</tr>
<tr>
<td>SSAB</td>
<td>SINTEF</td>
</tr>
<tr>
<td>LKAB</td>
<td></td>
</tr>
</tbody>
</table>

Total value of the Project: ~4.4 million SKr  
IEA GHG Contribution: ~1.2 million SKr
Objectives of the Study

- To specify a “REFERENCE” steel mill typical to Western European configuration and evaluate the techno-economic performance of the integrated steel mill with and without CO$_2$ capture.

- To determine the techno-economic performance, CO$_2$ emissions and avoidance cost of the following cases:
  - An integrated steel mill typical to Western Europe as the base case.
  - An end of pipe CO$_2$ capture using conventional MEA at two different levels of CO$_2$ capture rate
  - An Oxygen Blast Furnace (OBF) and using MDEA for CO$_2$ capture.
Cost of Steel Production – Breakdown without CO2 capture

- Break Even Price: $575.23
- Capital Cost: $135
- Fuel & Reductant: $118
- Iron Ore (Fines, Lumps & Pellets): $120
- Purchased Scrap & FerroAlloys: $53
- Fluxes: $11
- Other Raw Mat'l & Consummables: $12
- Labour: $70
- Maintenance & Other O&M: $55

55% of the Cost is related to Raw Materials, Energy and Reductant.
Oxy-Blast Furnace Operation

(Picture of OBF courtesy of Tata Steel)

Raw Materials
- Coke 253 kg
- Sinter 1096 kg (70%)
- Pellets 353 kg (22%)
- Lump 125 kg (8%)
- Limestone 6 kg
- Quartzite 3 kg

OBF Screen
- Undersize 21 kg

PCI Coal 152 kg

Oxygen 253 Nm3

Nitrogen 5 Nm3

BF Slag

Air 332 Nm3

Natural Gas 18 Nm3

Flue Gas 352 Nm3

Top Gas Cleaning
- OBF Top Gas 1385 Nm3
- BF Dust 15 kg
- BF Sludge 4 kg

CO₂ Capture & Compression Plant
- Carbon Dioxide 867 kg

OBF Process Gas
- 938 Nm3

OBF PG to Steel Works
- 171 Nm3

BF Dust

BF Sludge

Steam 2.0 GJ

Flue Gas

OBF Process Gas Fired Heaters
- 563 Nm3
- 205 Nm3
- 205 Nm3

OBF Screen Undersize
- 21 kg

Hot Metal
- 1000 kg
- 1470°C

Limestone 6 kg

Quartzite 3 kg

Coke 253 kg

Sinter 1096 kg (70%)

Pellets 353 kg (22%)

Lump 125 kg (8%)

Air 15 kg

4 kg

Nitrogen 5 Nm3

Oxygen 253 Nm3

Nitrogen 5 Nm3

BF Sludge

BF Slag 235 kg

Oxy-Blast Furnace Operation

DRI: 11%

FT: 2140°C

TGT: 170°C

HM Si: 0.5%

HM C: 4.7%

Coke 253 kg

Sinter 1096 kg (70%)

Pellets 353 kg (22%)

Lump 125 kg (8%)

Limestone 6 kg

Quartzite 3 kg

Oxygen 253 Nm3

Nitrogen 5 Nm3

Oxy-Blast Furnace Operation

DRI: 11%

FT: 2140°C

TGT: 170°C

HM Si: 0.5%

HM C: 4.7%
Impact of the OBF/MDEA CO2 Capture Plant to the Breakeven Cost of HRC Production

Break- even Cost of HRC Production for OBF @ $630/t increase of $55/t over reference plant without capture

- **Capital Cost**  
  *increased by 18.8%*

- **Fuel and Reductant Cost**  
  *increased by 17.3%*
  - Coking Coal Cost – decreased by ~24%
  - Natural Gas Cost – increased by ~495%

- **Iron Burden Cost**  
  *increased by 1.0%*
  - Iron Ore (Fines, Lumps and Pellets), Purchased Scrap & Ferroalloys

- **Fluxes Cost**  
  *decreased by 9.4%*
  - Significant reduction of limestone and quartzite consumption

- **Other Consumable Cost**  
  *increased by 15.7%*
  - Increased in cost of raw water consumption
  - Additional cost due to Chemicals & Consumables used by SGP.
  - Additional cost due to MDEA/Pz Solvent Make Up

- **Labour Cost**  
  *increased by 1.4%*

- **Maintenance and Other OPEX**  
  *increased by 10.4%*
Summary of Results
(Sensitivity to Coke Price)

It should be noted that Steel Mill used a significant variety of coking coal depending on market price (low to high quality coking coal)

COKE is a tradable commodity

CO₂ Avoidance Cost (US$/t)

Price of Coking Coal

OBF Base Case
CO₂ Avoidance Cost = ~$56.4/t

+ $92/t Coke

OBF/MDEA Case
EOP-L1 Case
What We Have Learned from this Study

• Recognising the different limitations for this study allows us to identify where the gaps in information are and what we need to evaluate in future studies.

• What are these limitations…
  • Availability of a reliable cost data
  • Limited budget for this study didn’t allow us to optimise certain aspects of the different processes evaluated.
What We Have Learned from this Study...

**Technical Aspects...**

- Helped us understand the dynamics of the integrated steel mill – especially interaction of various processes with respect to CO\textsubscript{2} emissions.
- Identified the uncertainties with respect to the operation of the oxy-blast furnace.
  - Need to verify and validate coke reduction potential of the oxy-blast furnace.
  - This study presented a reduction of 24% of coke requirements for the Blast Furnace.
What We Have Learned from this Study…

- **Stakeholders discussion**
  - 1\textsuperscript{st} Workshop – November 2011
  - Review Meeting – April 2012
  - Planned 2\textsuperscript{nd} Workshop – April/May 2013

- **ULCOS Data Comparison**
Conclusions

• **CCS** has and **important** role to play in **emissions mitigation** in the 2°C policy scenario

• **Industrial sector** is expected to contribute **40% of the overall CCS emissions reduction by 2035**, with Iron and Steel having a big role to play in this sector

• The **strategy** for the Iron and Steel Sector has **to also look at efficiency improvements and fuel switching**

• **Much needs to be done** in terms of **benchmarking emissions and costs**, identifying the **best options** and in **optimising process performance**

• **Cost competitiveness** is a **significant challenge** to the Iron and Steel industry

• **Demonstration of integrated CCS** with large scale storage ~**10 Mt/y** would be a **key milestone**
Thank You

stanley.santos@ieaghhg.org