Steel, CO$_2$ mitigation, CCS and **ULCOS**

**Ultra-Low CO$_2$ Steelmaking**

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Steel & CO₂

• Steel produces about 5% of the world anthropogenic CO₂ emissions (3-8%)
• 70% of steel is produced, today, in integrated steel mills, 30% in EAF mills (recycled steel=scrap, circular economy)
• Integrated mills (IM) use coal (coke) as a reducing agent and transform it into CO₂, when it scavenges metallic iron from iron ore in a Blast Furnace. "Ironmaking" accounts for roughly 80% of emissions in an IM and is thus “the” process that needs to be made carbon-lean.
• Steel simply cannot use technologies developed by other sectors: it had to develop its own solutions.
• Thus, to investigate, select and eventually develop them from scratch, the steel sector in Europe launched a common initiative called ULCOS.
The ULCOS approach

• the ULCOS approach was developed in the early 2000s and implemented in a major EU program in 2004:
  – from a broad panel of potential production routes (80), select those which can deliver a credible cut in emissions of 50% or more
  – carry out this selection process inside the ULCOS consortium
  – choose the most realistic solutions and scale them up within the same consortium
  – the scale up process is now called ULCOS II

• ULCOS has been the largest and most comprehensive effort in the Steel sector all over the world to identify and practically develop carbon-lean production routes. The 80 routes have been studied in great detail, to the level of other publications in the field.
Consortium

ArcelorMittal

Energy, Oxygen

Lhoist

STATOIL

INCAR

Instituto Nacional del Carbón

TATA

MAN Ferrostaal

LKAB

VAI

saarstahl

voestalpine

Rautaruukki

SSAB

Europlasma

SMES

Metalys

NTNU

Universities

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The 4 short-listed **ulcos** process routes

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ULCOS-BF (TGR + CCS)

CO₂ emissions of the steel plant: - 60%

Full CCS demonstrator, filed as an NER-300 proposal

Underground storage of CO₂
0.8 t/t_{steel}

-100 kg coke/t_{steel}
Hlsarna, smelting reduction

Iron ore
Oxygen
CCF cyclone (CORUS)
Oxygen
Coal
Smelter (HIsmelt)
iron

CCS

Ijmuiden pilot Strated up in 5/2011

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Hlsarna, smelting reduction
ULCOWIN

- alkaline electrolyte with dispersed hematite particles
- 3.5 kg samples of pure iron
- targets: 3 MWh/t, 90% Faradic yield
- 0.1 A/m², 1.8 V (target: 1.6)
- electrode materials identified
- inert anode
ULCOLYSIS

1550°C
Performance of ULCOS routes

Energy consumption (GJ/t HRC)

- 10-20% reduction vs. benchmark BF

CO2 emissions (tCO2/t HRC)

- > 50% reduction vs. benchmark BF

Operating cost (index/t HRC)

- still a "regret" solution vs. benchmark BF

Cost of avoided CO2 (index/t HRC)

- Cost of avoided CO2 = 1/2 end-of-pipe CCS

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CCS in ULCOS is an original process...

- CCS applied to Steel production cuts CO₂ emissions (> 50%) but also energy input (-25% coke consumption for ULCOS-BF)
- CSC also improves productivity (20-30% for ULCOS-BF)
- … and cuts CO₂ abatement cost by half compared to an end-of-pipe solution
- in the steel case, the CAPTURE part of CCS is an original concept (in-process capture), which does not have much in common with power-plant solutions; the STORAGE part might also be substantially different
- in the Steel sector, CCS will not be a bridging technology… at least for the next 50/100 years
The future…

- ULCOS-BF demonstrator to be built and started up **within 5 years**
- the demonstrator has to operate for at least 10 years (NER-300)
- **industrial deployment**, based on "technological realism" (feasibility), might start in the 2020s
- … but, beyond these technological issues, **there remains many political and economic issues**, which will have to be tackled at the appropriate geopolitical scale
- parallel to ULCOS-BF, we have been developing a **line of ULCOS solutions**, targeted at the world more than at Europe, which ought to reach maturity with a delay (5 to 20 years) compared to ULCOS-BF
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