LOW-CARBON ALTERNATIVE TECHNOLOGIES IN IRON & STEEL

JEAN-PIERRE BIRAT

20 novembre 2017

IEA, Paris

Menu

This is mostly a summary of a workshop held on 17-02-17 in Brussels , in the framework of the future *ETS Innovation Fund* of the European Commission (DG Climate Action). Therefore, the focus will be on Europe.

- prolegomena
- a historical perspective
- a revival: reformulation of concepts
- conclusions

3

Prolegomena

Prolegomena

- the steel sector is energy-intensive and, therefore (cost optimization), has cut its energy needs by 60% over the last 60 years (best performers)
- the potential remaining to further improve energy efficiency is small (10%) compared to the targets of GHG reduction (80%)
- therefore, only breakthrough technologies will be able to address the challenge of Climate Change
- note that carbon in the steel sector is used for reducing iron ore and not as a fuel: efficiency is much higher (less exergy destruction)!
- the polluter-pay principle, which is applied implicitly in focusing on smokestack or tailpipe emissions, disregards the benefits that steel brings to Society by enabling the whole technological epistemé, and especially low-carbon solutions in other sectors (renewable energy systems, lightweighing of transport systems, etc.)

A historical perspective

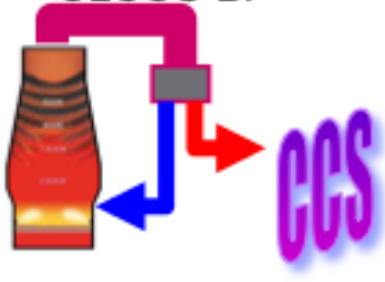
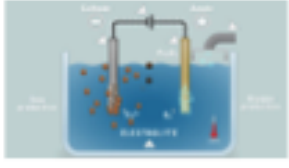
A historical perspective (1)

- the Earth Summit in Rio (1992), the Kyoto Protocol (1995), the Paris agreement (2015): *political time*
- the first papers relative to steel date back to1990 (grey literature) and 1993 (open literature), in Europe and Japan: *technical time*
- the steel sector worked on energy efficiency (generalization of continuous casting, etc.) and built many EAF steel mills (circular economy), thus significantly reducing its emissions : *business time*
- programs to develop breakthrough technologies were launched in the early 2000s, in 2 cooperative programs bringing the whole sector on board:
  - in the EU, ULCOS
  - in the world the CO_2 Breakthrough Program of worldsteel
  - in Japan, COURSE 50 at the end of the decade
  - plus other initiatives, like MIT's

A historical perspective (2)

- ULCOS was active as a unified program from 2004 until the early 2010s, with a series of coordinated programs supported by most of EU steel and partially funded by the EC.
- about 80 process routes were investigated and 4, called the ULCOS solutions, were selected for further development at higher TRLs:
  1. the ULCOS Blast Furnace, with recycling into the BF of the top gas after removing CO_2, to be sent to geological storage (CCS)
  2. the HISARNA smelting reduction process to be used with CCS
  3. the ULCORED process based on natural gas and CCS
  4. electrolysis: low-temperature, ULCOWIN, and high-T, ULCOLYSIS
  5. were also investigated but kept dormant, a direct reduction process based on hydrogen and the use of biomass carbon

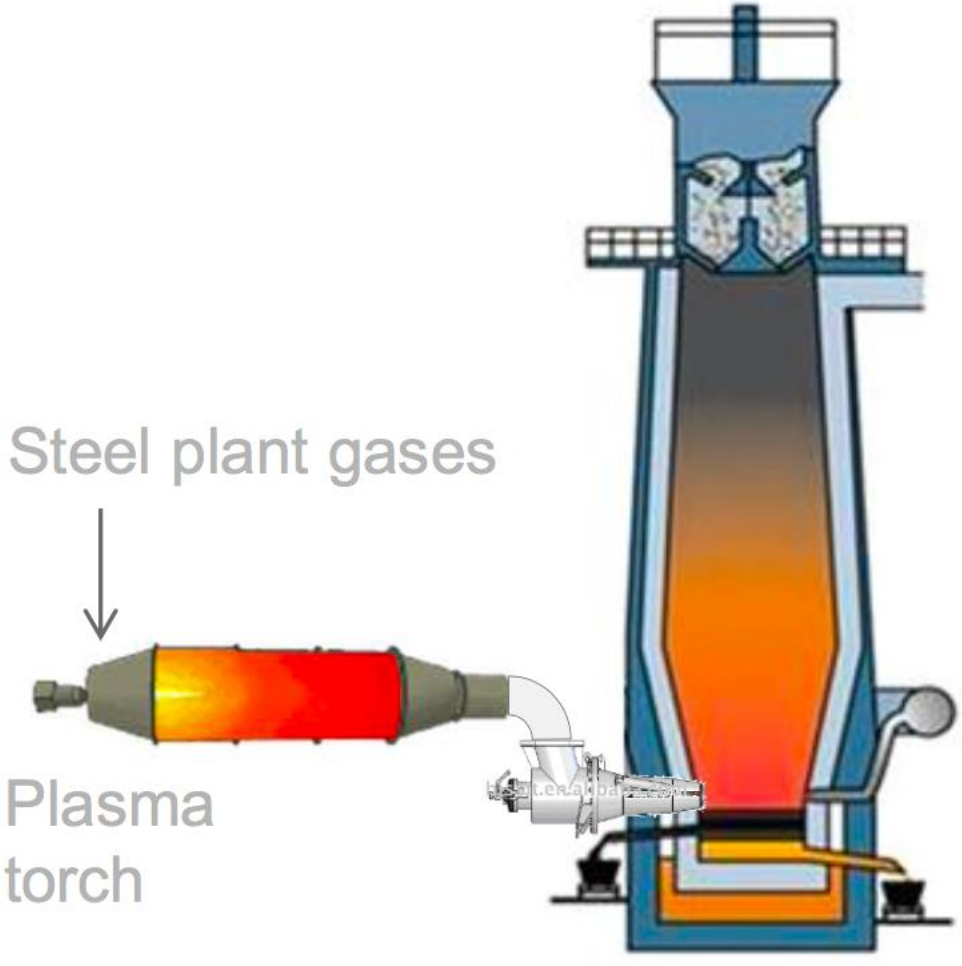
ULCOS solutions

Coal & sustainable biomass		Natural gas	Electricity
Revamped BF	Greenfield	Revamped DR	Greenfield
ULCOS-BF 	HIsarna 	ULCORED 	ULCOWIN ULCOLYSIS 
Pilot tests (1.5 t/h) Demonstrator (Florange) in the freezer	Pilot plant (8 t/h) started up 2010	Pilot plant (1 t/h) under discussion	Laboratory pilot

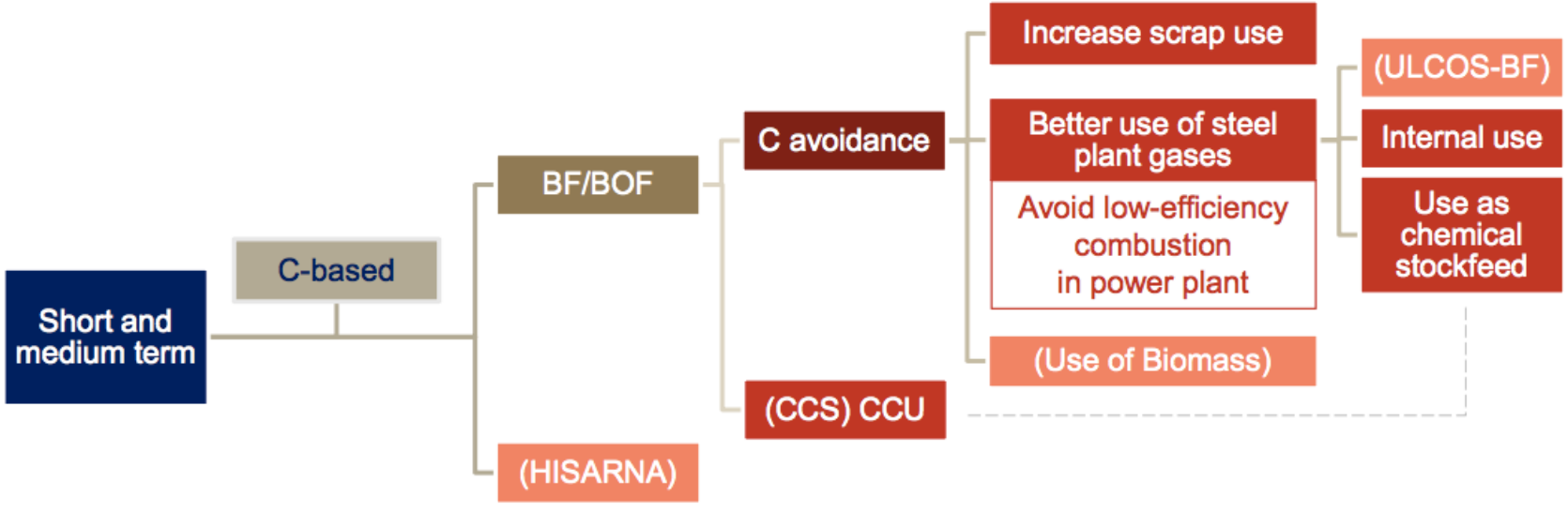
A historical perspective (3)

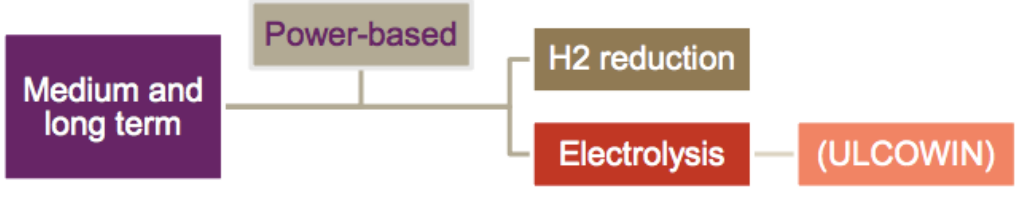
- since ULCOS arrived at the end of its series of projects, it has been continuing as separate programs devoted to the various "solutions"
- a loss in kinetics was due to the 2008 crisis, felt particularly hard in Europe, and to the absence of a realistic support scheme for large-scale demonstration plants (Florange and the NER 300 program)
- solutions had been developed to TRL 4 to 6 or 7
- HISARNA is presently running extended tests in Ijmuiden at TRL 7
- other solutions are explored in various programs called Vallerco or IGAR (plasma torch on a blast furnace tuyere, ArcelorMittal-Dunkirk, France; replacing coke by electricity))
- work on electrolysis has been continuing in Europe (latest: SIDERWIN program (H2020), 2017) and in the US – at lower TRLs than the smelting or direct reduction + CCS projects, because the technological gap is wider

IGAR (BF + Plasma Torch)



A historical perspective (4)





Zero CO2 emission potential
but requires breakthrough in steel production
and availability of green power

A revival? Reformulation of concepts.

Reformulation of concepts (1)

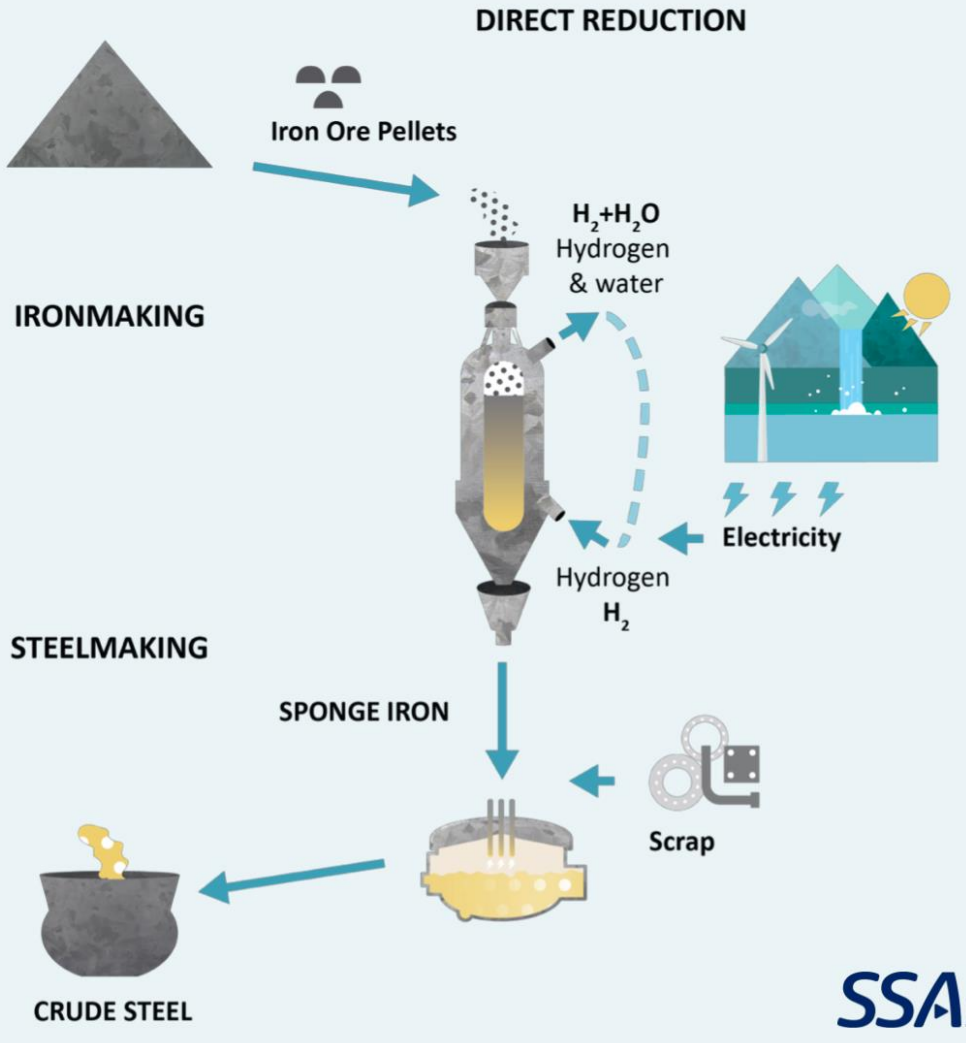
- Direct Reduction based on pure hydrogen rather than natural gas (Carbon Direct Avoidance scheme of EUROFER):
  - HYBRIT project, SSAB, Sweden
  - GrInHy (Green Hydrogen) project, Salzgitter et al., Germany
  - H2Future & SUSTEEL, voestalpine, Austria
  - SALCOS-MACOR, Salzgitter et al., Germany
- Carbon Capture and Usage (CCU)
  - Carbon2Chem, ThyssenKrupp steel, Germany
  - Carbon4PUR, ArcelorMittal, Dechema et al., SPIRE/H2020 Project
  - STEELANOL, ArcelorMittal, Belgium (ethanol), Lanzatech technology

HYBRIT: CO_2-emission free ironmaking

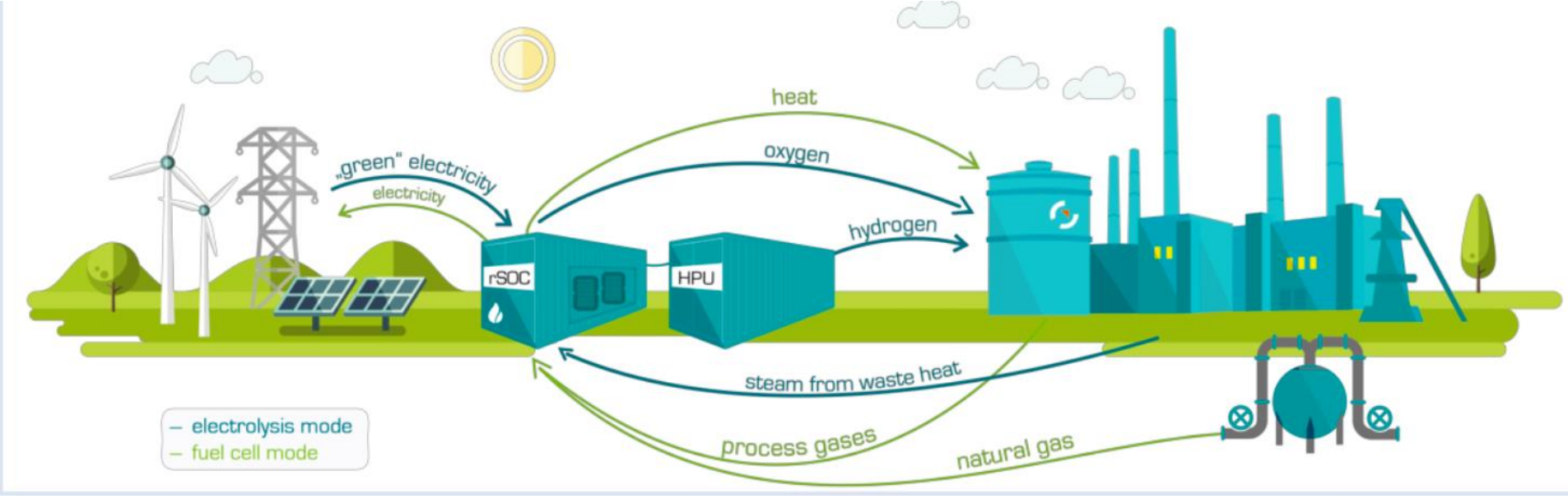
Pre-feasibility study (PFS)
2016-2017

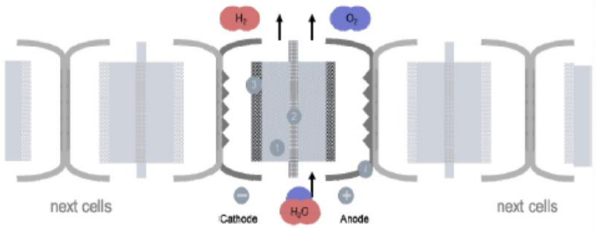
Feasibility study:
pilot plant trials
2018-2024

Demonstration plant trials
2025-2035



GrInHy Green Hydrogen



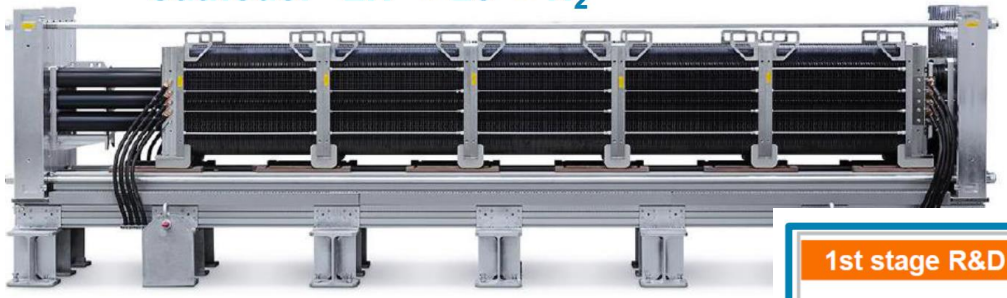


Electrolyzer type	PEM
1 electrolyte	polymer membrane
2 separator	
3 catalyst	platinum + others
4 frame + bipolar plate)	metal sheet

PEM reactions

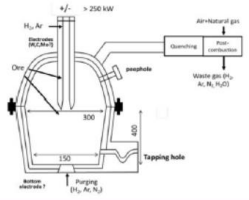
Anode: $H_2O = 2H^+ + 0{,}5O_2 + 2e^-$

Cathode: $2H^+ + 2e^- = H_2$



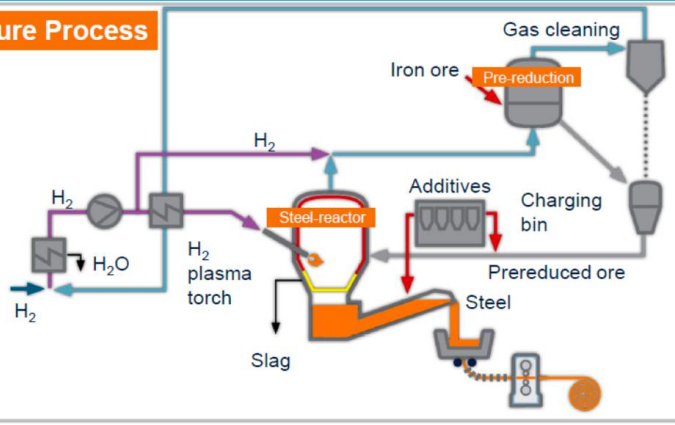
H2FUTURE & SUSTEEL

1st stage R&D



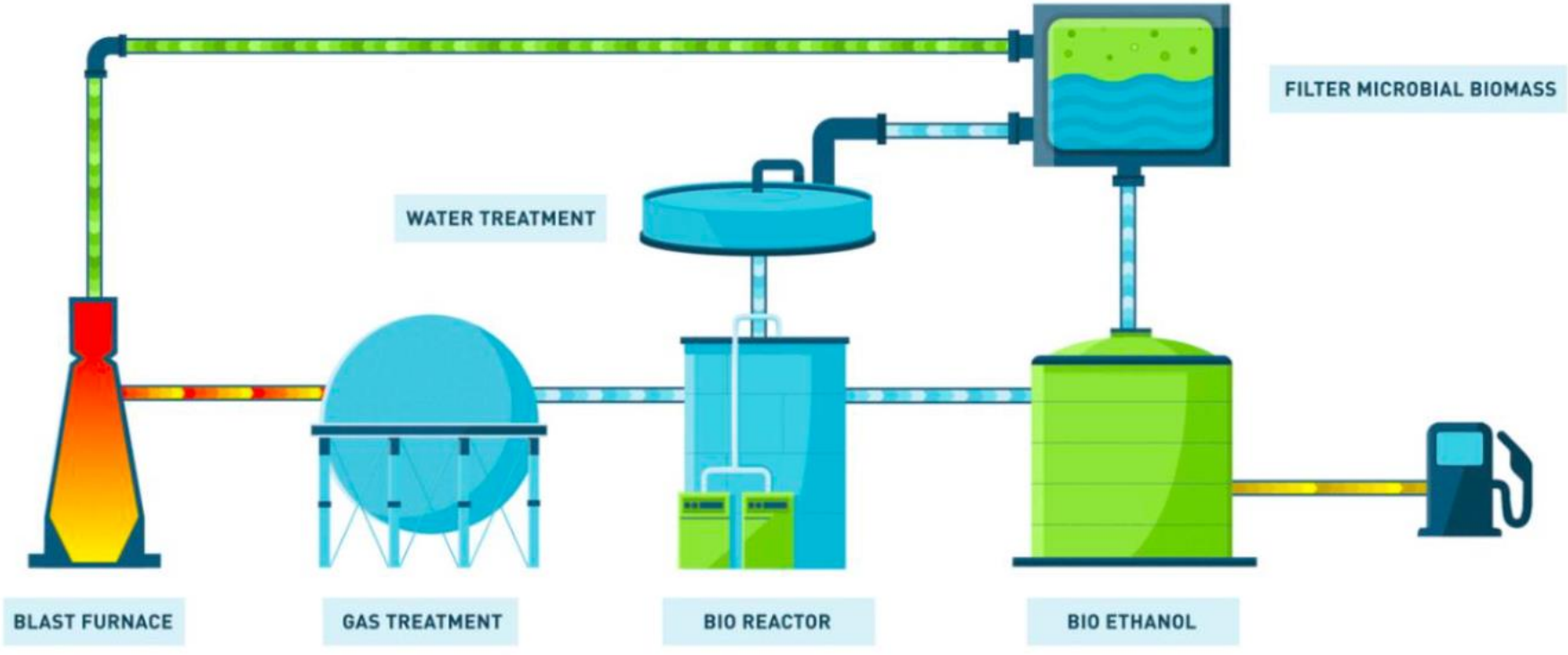
- Labscale facility
- Input: Ore or DRI
- Output steel: ~20 kg
- Energy: ~250 kW

Future Process



- **Goal**
  Reduction of iron oxide with hydrogen in fluidized bed cascades
- **Second stage**
  Melting of pre-reduced iron ore in steel-reactor within a hydrogen plasma directly to liquid steel

STEELANOL

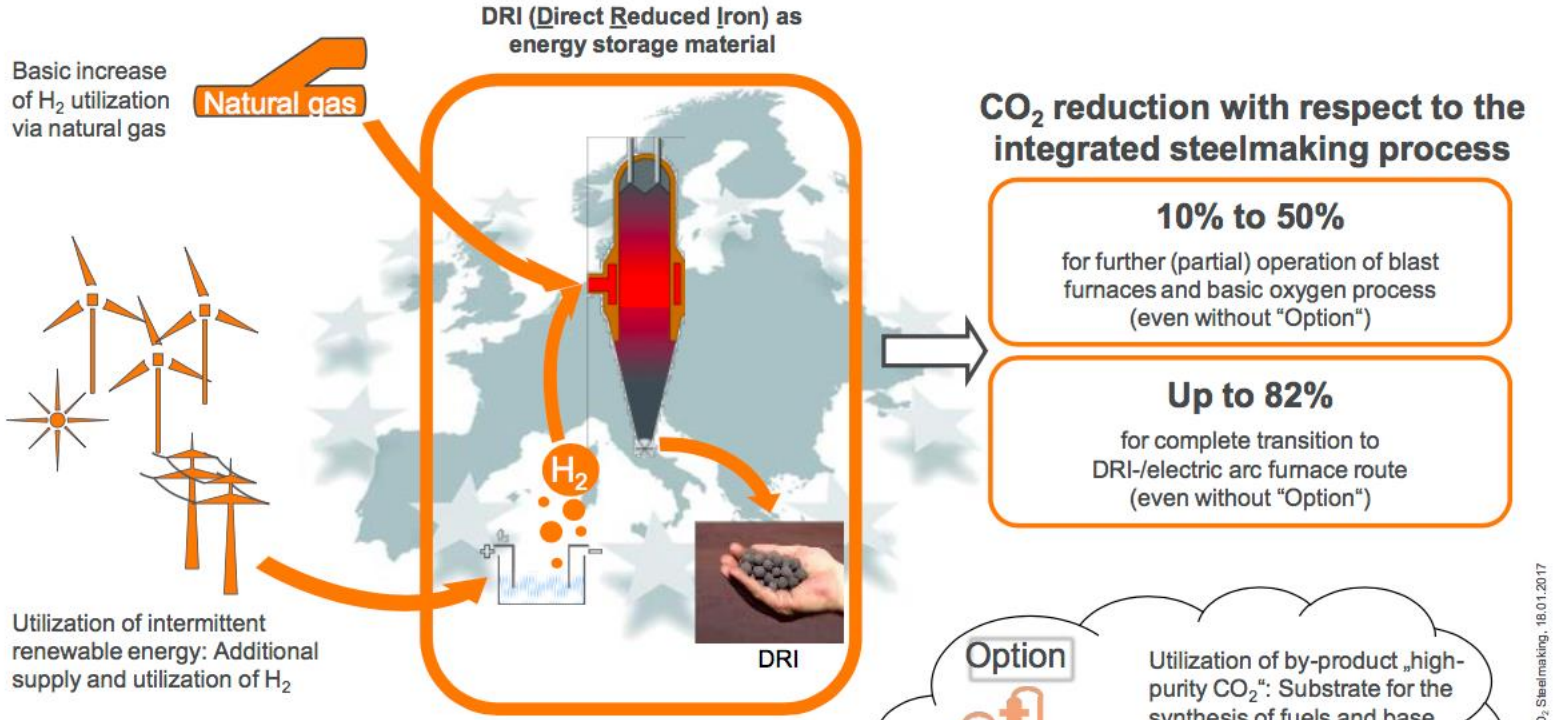

FILTER MICROBIAL BIOMASS
WATER TREATMENT
BLAST FURNACE
GAS TREATMENT
BIO REACTOR
BIO ETHANOL

SALCOS

SALCOS – SAlzgitter Low CO_2 Steelmaking

Fraunhofer SALZGITTER AG Stahl und Technologie

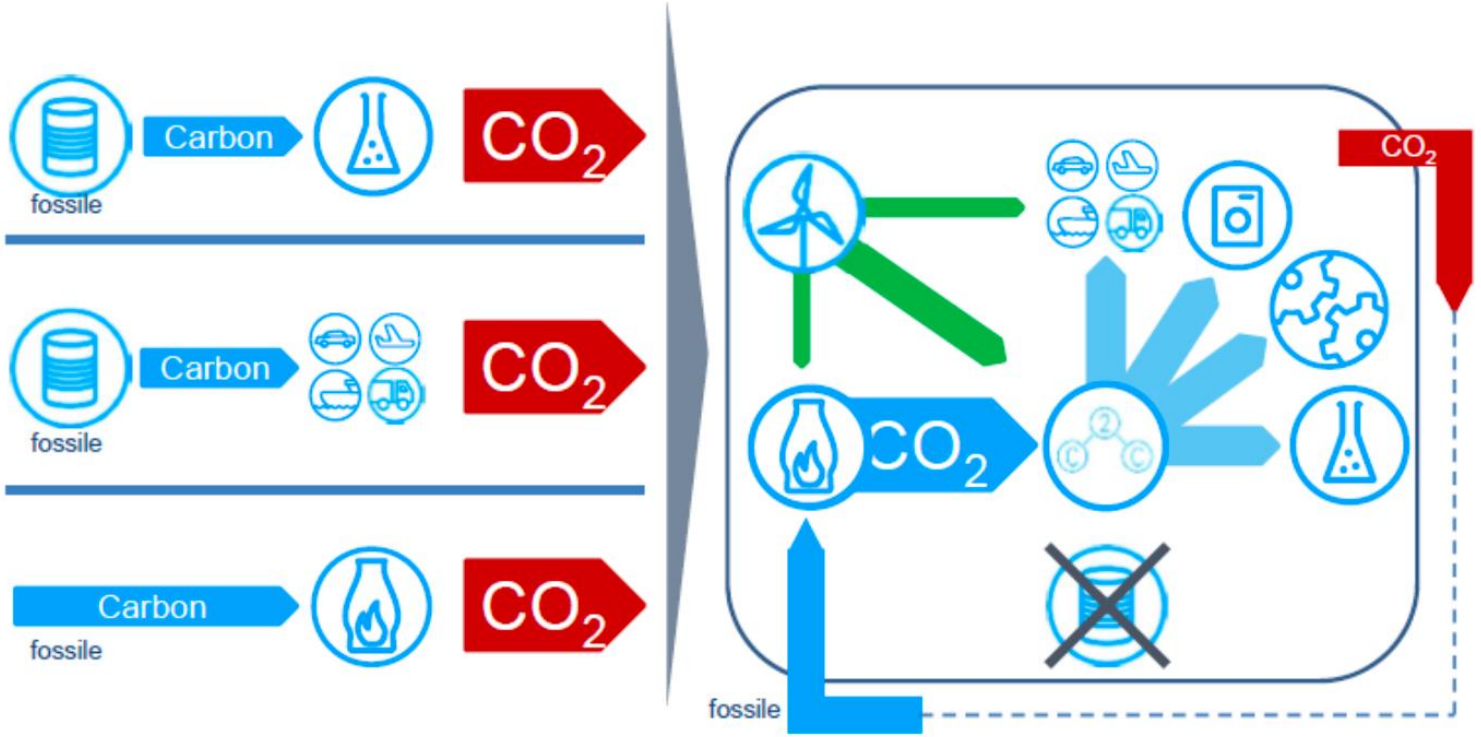
A Distinct Example of CDA (Carbon Direct Avoidance)



Reference: Fraunhofer-Gesellschaft/ SZAG

Carbon2Chem

Schematic concept of transformation by Carbon2Chem®:
Cross-industry utilization of CO_2 as a valuable raw material



Reformulation of concepts (2)

- electrolysis (SIDERWIN) brings two concepts together: direct use of electricity and demand-side management of an electricity grid with intermittent feed from renewables
- a number of these conceptual proposals aims at creating an industrial synergy between steel, electricity generation & the chemical industry

Conclusions

Conclusions

- the steel sector has been reducing its emissions since before reductions were being monitored, by managing its energy efficiency and increasing its use of scrap (recycling)
- the sector understood very early that breakthrough solutions would be needed, identified the most promising ones & started developing them to fairly high TRLs
- it is a 20-30 year endeavor, which started up briskly, slowed down due to the economic crisis and now is picking up speed again.
- a large number of options are being explored in parallel, which might be fitting in such a large a complex industrial sector as steel
- steel is not simply energy-intense and GES intensive: it is also an enabler of low-carbon technologies in the whole technological epistemé. This ought, somehow, to be counted in favor of steel! Let's have a broad enough vision!!

MERCI !

JEAN-PIERRE BIRAT

20 novembre 2017

IEA, Paris