ΣIDERWIN: A breakthrough technology to decarbonize primary steel production through direct electrification

Online webinar

24th November 2021 15:00-17:00 CET

This document gathers all the questions risen from attendees during the webinar that couldn't be answered during the life event.

QUESTION	ANSWER
Question to Mr Birat: Can the blast furnace CCS route really be described a net-zero pathway? I am thinking of limited capture rates in practice and the large amount of bioenergy needed to get anywhere close to zero.	[Jean-Pierre Birat – IF Steelman] The blast furnace with CCS that I spoke about in my (short) talk, is the so called "ULCOS-BF, with top gas recycling", after removal of CO2 (thus capture), which would then be stored in a deep saline aquifer, for example. See the description of the technology in the published literature or in • ULCOS top gas recycling blast furnace process - (ULCOS TGRBF), J. van der Stel et al., RFCS final report, 2014, EUR 26414 EN. In such a case, virtually all (100 %) of the CO2 can be removed with the proper capture technology (VPSA was used in the experimental trials in Lulea). Now, there remains scope 2 emissions, but if green electricity is used, as should be available in the EU grid by 2050, then it is zero. Storage in saline aquifers would also be 100% efficient, as the studies carried out for the industrialization of the process in Uckange demonstrated. You also speak of biomass in your question. But there is no need for biomass in this kind of process scheme. It would be possible to use biomass, of course, like as a substitute for coal injection, and then the process would deliver negative emissions, provided the biomass is properly labelled as renewable. Finally, other solutions are possible to capture CO2 from the BF top gas, but the ULCOS-BF is the only solution which guarantees net-zero production. Again, this means net-zero in the perimeter of ironmaking. In the downstream area, net-zero would require additional net-zero technologies; however, this restriction also applies to other process-routes, H2-reduction for example. See two paper, in particular: • JP. Birat, JP. Lorrain, Y. de Lassat, The "CO2 tool": CO2 emissions and energy consumption of existing and breakthrough steelmaking routes, La Revue de Métallurgie-CIT, Sept. 2009, 325-336 • Jean-Pierre Birat, Society, Materials and the Environment: the case of Steel, Metals, 2020, 10, 331, 36 pages, doi:10.3390/met10030331 Don't hesitate to continue this conversation with me.

Can you please comment on why use alkaline system instead of acide system, since reduction is theoretically feasible in both?	[Hervé Lavelaine - ArcelorMittal] Alkalinity provides several advantages; it is highly ionically conductive, metals such as Ni and Fe resist to corrosion by passivation, it prevents ferric iron dissolution while favouring ferrous iron solubility thus avoiding chemical looping between the iron valences, it advantageously favour oxygen kinetics at the anode and disfavours hydrogen at the cathode,
What is the working temperature of the cell?	[Hervé Lavelaine - ArcelorMittal] 110 °C
What are you using as an anode material?	[Hervé Lavelaine - ArcelorMittal] Pure Nickel
What is the material of the cathode?	[Sevasti Koutsoupa - NTUA] Stainless steel or carbon
How much of the alkaline solution is needed per kg iron produced?	[Hervé Lavelaine - ArcelorMittal] The alkaline solution is not a chemical reactant, it is not chemically consumed. There are losses due to drag outs and evaporation.
How much of the used electrolyte can be recycled and reused?	[Hervé Lavelaine - ArcelorMittal] The electrolyte is a medium that change the mode of conduction of electricity from electronic in the electrodes and ionic in the electrolyte.
How much of the alkaline solution is required per ton of steel (HRC) or electrowin iron?	[Hervé Lavelaine - ArcelorMittal] The alkaline solution amount is kept constant during the process
What happens with the solution after the electrowinning process? How much of it can be reused in the process? Does it go through some waste treatment process or where is it discharged to?	[Hervé Lavelaine - ArcelorMittal] The electrolyte is moved to supply iron ore in a closed loop.
How abundant is hematite as a raw material?	[Hervé Lavelaine - ArcelorMittal] Hematite at our human scale has no risk of scarcity.
How to deal with larger powder size? I guess it has a problem with suspension homogeneity	[Sevasti Koutsoupa - NTUA] If the iron ore has not the right granularity, it will need grinding and sieving.
How difficult is it to produce the iron ore feedstock in the right granularity?	[Sevasti Koutsoupa - NTUA] If the iron ore has not the right granularity, it will need grinding and sieving.
Was the current density of 1.1 A/cm2 and efficiency of 94 reached in the lab?	[Sevasti Koutsoupa - NTUA] In lab scale current yield has been reached 94% with 1100A/m2 or 0,11 A/cm2.
What is the overpotential? How does the current efficiency of 91% relate to 3.6 MWH/ton Fe?	[Hervé Lavelaine - ArcelorMittal] The energy amount is proportionate to the cell voltage and inversely proportional to the efficiency.
What do these 4kg / 100kg relate to? Per some time frame? Overall during the experiment?	[Mónica Serna-Ruiz – Tecnalia] It is the iron produced in 48 hours of experiment in the lab pilot and SIDERWIN pilot, respectively.
How long time did it take to produce the 100 kg Fe?	[Hervé Lavelaine - ArcelorMittal] Quantity of iron depends on surface extension, in the 3x1 m SIDERWIN pilot it takes 48hours

Could the oxygen be a valuable by-product?	[Hervé Lavelaine - ArcelorMittal] It is a conspicuous aspect of the process to collect the oxygen gas produced
If you produce oxygen at this high concentration, what is the risk of corrosion or even explosion?	[Hervé Lavelaine - ArcelorMittal] The oxygen is explosive if mixed with hydrogen, then it is important to prevent hydrogen production
How to prevent oxygen and reduced Iron interact directly to form iron oxide again? How sensitive is that?	[Sevasti Koutsoupa - NTUA] The deposited iron cannot react with the oxygen produced in the anode.
How do you get the iron out of the cells? Is this done in batches or continuous mode?	[Hervé Lavelaine - ArcelorMittal] The process has a batch mode of operation, iron is "demolded" as a plate from its graphite substrate
Do you couple electrochemical calculations with the flow/bubble calculations in the CFD model?	[Thierry Conte – CFD-Numerics] The location of bubble generation is independent to electrochemical conditions. Then, bubble/CFD is modelled by considering that the bubbles are generated at the tip of the anode
What is the timeline to have this technology available industrially? And what are your thoughts on the current electrolytic iron available on the market? (allied metals, etc.)	[Hervé Lavelaine - ArcelorMittal] It took 18 years from TRL 0 to TRL6, assuming a change of scale of effort, it will probably take 9 years to reach TRL9, the final industrial size.
How large is the cell now at TRL5?	[Hervé Lavelaine - ArcelorMittal] The cell itself is 3x1m
What would the footprint of a plant be compared to integrated or electric mill?	[Anna Kounina – Quantis] I don't understand the question. In the analysis, we compare steel production through the BF / BOF route with a SIDERWIN full scale projected scenario.
How does the footprint of a fully upscaled TRL9 SIDERWIN plant compare to a conventional iron production technology (integrated steel plant)?	[Anna Kounina – Quantis] This is what we are assessing: a full scale SIDERWIN plant compared with the BF / BOF route plant. ArcelorMittal modelled a full scale SIDERWIN plant CAPex and OPex in deliverable D7.3, that we are using as a basis for the environmental assessment.
What can be said at this stage relative to the flexibility of the process using variable renewables?	[Hervé Lavelaine - ArcelorMittal] The process is very tolerant to power shutdown. It can resume on a passivated surface
What are the major obstacles for further upscaling?	[Hervé Lavelaine - ArcelorMittal] Knowledge is the only limit, from electrochemical mechanisms to large scale industrial flow sheet
How does the total energy input compare to the energy used in a blast furnace?	[Hervé Lavelaine - ArcelorMittal] Electricity provides an advantage that can lower the energy need by one third
The current focus is on DRI. How can Siderwin be fast enough?	[Hervé Lavelaine - ArcelorMittal] By developing knowledge and engineering applications
DRI offers more options for importing the required H2 from optimal locations of production. How can the necessary electricity be delivered in Europe?	[Hervé Lavelaine - ArcelorMittal] Siderwin is assumed to be supplied from the European grid, being no dependent on location

Will there be one winning all technology or is it more likely that H2-DRI, Electrowinning and the Boston Metal type of high temperature electrolysis will complement each other according to specific strengths, weaknesses and local conditions?	[Hervé Lavelaine - ArcelorMittal] The basic problem of steel production is the energy barrier, then the most important criteria is energy efficiency.
To what extent do you plan with nuclear new-builts in Europe for your scenario? Are they also positioned outside France?	[Hervé Lavelaine - ArcelorMittal] Siderwin is electrical and accepts any source of electricity
What are your assumptions for the electricity demand for Siderwin per ton of steel produced in 2050?	[Hervé Lavelaine - ArcelorMittal] Our estimate is 4000 kWh/t
Induction arc furnaces are already used in industry, and not proving to be actually more efficient than EAFs. But the question is - in what sense are induction AF linked to Siderwin or part of it?	[Hervé Lavelaine - ArcelorMittal] Induction furnace doesn't involve CO2 emission like EAF
If as shown during the previous presentation Siderwin plants do not work at times of "dark doldrums" with too low wind and solar.... this would improve its carbon performance, it seems. Is this part of your assessment?	[Hervé Lavelaine - ArcelorMittal] Flexibility is firstly used to access cheap electricity and secondly to help balance variable energy sources
How much are the scope 3 emissions from the production of the alkaline solution per ton steel produced with Siderwin?	[Anna Kounina - Quantis] The final answer will be provided in the final version of deliverable 7.4, when the amount of all inputs will be upscaled and finalized. Deliverable 7.3 will provide the updated inventory for the LCA and techno-economic analysis, which should be available in Q1 2022.
How is it economically comparable of this technique to hydrogen direct reduction of iron oxide?	[Hervé Lavelaine - ArcelorMittal] The comparison is under study
How could the project be accelerated to get to net zero sooner?	[Anna Kounina - Quantis] The project provides a substantial reduction potential for steel production, however it does not allow to get to a net zero steel, as some inputs cannot be reduced (e.g. iron ore extraction, plant infrastructure, etc.). On the other hand, this technology would serve the European Union objective to achieve net zero emissions in 2050, through both reduction (e.g. SIDERWIN technology for steel) and compensation measures (e.g. land use change, carbon sequestration).
Is the flexibility of the process fully taken in account in the assessment of scope 2 emissions?	[Anna Kounina] Yes, indeed, the flexibility is taken into account through the considered grid mix, which has been modelled by EDF. We integrated several grid mix scenarios, among which one that takes into account the flexibility offered by SIDERWIN.

What could be the advantages/limitations of a higher cell temperature?	[Hervé Lavelaine - ArcelorMittal] Advantage: quick and short process. Disadvantage: it relies on material properties that probably don't exist.
Do you think Siderwin will/should dominate over other low carbon steel making processes, notably H-DRI, or will there be room for both, and what would be the criteria or the domains in which each process would/should be preferred?	[Hervé Lavelaine - ArcelorMittal] The important is to find the most energy efficient solution.
What are the next steps? Is there a successor project on the way? What would be the size?	[Hervé Lavelaine - ArcelorMittal] The next step would be a small plant that includes all the steps from iron ore to final semi-finished steel product as Hot Roll Coil.
How does the total energy input compare to the energy used in a blast furnace?	[Hervé Lavelaine] Siderwin is estimated to consume one third less energy than blast furnace.
(1) How to improve the yield of this process? (2) What about acid experiments? Did it give lower efficiency? (3) Is it possible to produce directly the reduced iron to be iron powder? What about post processing method to use?	[Hervé Lavelaine - ArcelorMittal] The last source of energy improvement is catalysis of oxygen production. Acid route is not practicable due to looping of multivalent ionic species of iron. Powder is reactive and difficult to handle, we prefer compact pieces of iron.
What do you think, around when can Siderwin become mature such that it can be implemented in industry?	[Hervé Lavelaine - ArcelorMittal] If SIDERWIN fulfils is expectation, ten years is minimal to operate a small representative plant.
Is the Siderwin technology comparable to the technology developed by Boston metal in the US?	[Hervé Lavelaine - ArcelorMittal] They are both electricity based. Siderwin is slower but operates with existing and available materials.
How does the Siderwin technology relate to plans by many steel corporations to use direct reduction with hydrogen? Is it more efficient? (I am expecting that the technological readiness level is much lower.)"	[Hervé Lavelaine - ArcelorMittal] Today, its Readiness is too low to be incorporate in investment plans.

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