

# SIDERWIN Concluding Webinar 2023

## Agenda

Time	Topic	Speaker
15.00-15.10	Welcome and introduction to the Webinar.	José Ignacio Barbero (TECNALIA)
15.10-15.20	SIDERWIN Project General Overview.	Valentine Weber-Zollinger (ArcelorMittal)
15.20-15.35	The decarbonization strategy of ArcelorMittal – how and why is iron electrowinning a promising for the future of steel?	Jean-Paul Allemand (ArcelorMittal)
15.35-15.45	Iron Electrowinning – Lessons learned.	Daniela V. Lopes (Uni. Aveiro)
15.45-15.55	Alternative feeding materials. Current status and future perspectives.	Dimitrios Panias (NTUA)
15.55-16.15	Iron production by electrolysis at pilot scale.	Thierry Conte (CFD Numerics) Salah Touhami (ArcelorMittal)
16.15-16.30	The flexible potential of SIDERWIN process for the future European power system.	Morgan Barberousse (EDF)
16.30-16.50	What is the environmental impact and cost of steel decarbonization with SIDERWIN?	Roland Kahmann (RECOY)
16.50-17.00	Conclusions and Perspectives.	Valentine Weber-Zollinger (ArcelorMittal)
17.00-17.15	Questions & Answers (Final Round).	José Ignacio Barbero (TECNALIA)

## Questions asked by attendees during the SIDERWIN concluding webinar 2023

1. How far is the research on Carbon Capture and Storage (CCS)?
ArcelorMittal (AM) research is experimenting pilot units for CO <sub>2</sub> capture and separation. And in the frame of X Carb, innovative and disruptive technologies are funded to support AM in its journey towards decarbonization, such as Lanzatech for CO <sub>2</sub> capture and transformation in bio-ethanol.
2. Recently, ArcelorMittal has invested in Boston Metal (BM). This means it is now engaged in both electrolytic technologies (high temperature and alkaline) as well as in H <sub>2</sub> based Direct Reduced Iron (DRI). Does this mean ArcelorMittal regards all those technologies as complementing each other rather than expecting one to become superior over the others? Which features come to mind that suggest complementary roles of the technologies in question?
3. According to recent news, ArcelorMittal has also invested into Boston Metal, which develops a different type of Electrolysis process. Can you comment on how the two processes SIDERWIN and Boston Metal fit into ArcelorMittal's strategy?
Boston Metal is developing a Molten Oxide Electrolysis (MOE) at high temperature, while internally ArcelorMittal is developing a low temperature Electrolysis in solid state. Both are at similar TRL level and have complementary strengths. AM footprint and local contexts are so wide that both solutions will play a role. AM wants to become leader in electrowinning of iron - as one of the most promising solutions to reach carbon neutrality in 2050 - reason why both MOE from BM and SIDERWIN fit both perfectly in AM strategy.
4. How does it come that SIDERWIN is expected to operate flexibly, while Boston Metal says that their technology cannot be operated flexibly? What is the main difference between the two technologies?
As mentioned above, Boston Metal's MOE and SIDERWIN will operate at different steelmaking process steps, and the integration in AM processing route will be done accordingly, related to local context - availability and price of energy sources, supply of iron ore... - and strengths of each technology.
5. How is SIDERWIN similar/different compared to Boston Metals and Electra?
See questions 3 and 4. Electra develops a technology at low temperature 60 °C in acidic media.
6. Is there any share of the 3 technologies for the future of steelmaking?
As mentioned in the roadmap towards carbon neutral, ArcelorMittal bets on the 3 process routes: direct reduced iron on electric arc furnace (DRI-EAF), smart carbon blast furnace (BF) and iron electrolysis. Some projects are already in the pipe (DRI-EAF, Gijon and Sestao; EAF-DRI, Hamilton; H <sub>2</sub> DRI pilot, Hamburg...) for 2030.
7. Do you see any corrosion/destruction of the Teflon cell during or after the experiment?
No, the Teflon does not suffer corrosion or destruction.

8. At 110 °C with 18 M NaOH what is the current efficiency? With pure hematite is it better to work at 70 °C or at 110 °C?
Previous results have shown about ~87% of Faradaic efficiency at 18 M NaOH and 110 °C (0.033 A/cm <sup>2</sup> , 100 rpm) for iron deposits on Ni substrate from Fe <sub>2</sub> O <sub>3</sub> suspensions (100 g/L). Higher efficiencies (~95%) were obtained when temperatures were about 70-80 °C in the experimental conditions tried.
9. What types of ores are not suitable for this process?
The suitability of the ore to be fed into the SIDERWIN plant depends on the efficiency of the pre-treatment route.
10. How is the cost comparison with regard to DRI?
SIDERWIN and H <sub>2</sub> -DRI are cost competitive.
11. With the non-conductive impurities, how much was the current efficiency?
Depending on the impurity and its concentration, and also depending on the experimental conditions used for bulk or suspensions modes, the faradaic efficiencies can vary from 70-20% (-Al case), 55-20% (-Mg case) and 0% in the case of -Ti impurity.
12. How long you run your experiments? % yield achieved?
It depends on the experiment. During the optimization of the experimental conditions, like temperature or alkali concentration, shorter times were used (1-2h). For the evaluation of the interruption cycles tests, about 15h were tested with 1 or 5 h of interruption in between. During the impurities impacts tests, 6-7h were tried. The yields vary depending on the experiment and conditions tested. These values are all reported in the slides of the webinar presentation.
13. How much sodium hydroxide (NaOH) is needed to produce 1 kg of iron?
14. Can you estimate the use of alkaline agent per kg of product?
There is no consumption of NaOH in the electrolyte (50 wt.% NaOH) which is totally recirculated in the electrolysis cell.
15. Which is the power consumption per ton of iron?
At pilot scale and in stable conditions: 2.7 MWh/t product.
16. Is the process tolerant of silica in the feed ore?
17. What about the presence of gangue on raw materials?
Regardless of the type of non-conductive species added to the iron oxide feedstock, it will always cause problems during iron deposition. The process may tolerate a very few percentages of silica content in a short period of time, but it will eventually block the surface of the iron deposits through deposition time. Silica reacts with the Na <sup>+</sup> cations from the electrolyte (NaOH) by forming sodium silicates which will block the surface of the iron deposits and prevent further deposition with time. The gangue will be very problematic since it contains several non-conductive impurities simultaneously. However, in both cases a pre-treatment can be beneficial to eliminate or decrease as much as possible the concentration of the contaminants presents in the initial raw material.

18. How about starting with extractive processes that reduce the volume of titanium and magnesium? Both metals may be worth to be gained before iron.
The pre-treatment of bauxite residue (BR) to remove the “problematic” metals like Ti is a research work that we are performing now. But calcium titanates are not easily soluble compounds, which is an additional difficulty.
19. How are impurities removed from the Fe metal produced by the process?
Normally, in the case of iron ore electrolysis we do not have metallic impurities on the Fe deposition. In the case of alternative raw materials, there are impurities on the Fe deposit, which constitutes a serious drawback. Therefore, a pre-treatment for the removal of such metals from alternative raw materials before iron electrolysis is the approach we are currently studying.
20. How about EAF dust? Does it apply?
Although the EAF dust contains a high amount of iron, it is in the form of zinc ferrates, which can probably create some problems during the electrodeposition. On the other hand, the presence of Zn is positive because it creates very high overpotentials on hydrogen evolution favouring the Fe deposition. So, although I have never tested it, I think that it probably has potential. However, my feeling is that the current efficiencies achieved will be extremely low making the electrolysis completely uneconomic.
21. What's the source of H <sub>2</sub> bubbles? Do they come from the electrolyte fluid or some impurities in the input material?
The hydrogen bubbles come from the secondary reaction that happens in the electrolytic cell: the electrolysis of water.
22. How long does it take to get 10 kg of reduced iron deposit?
23. How much time is required to produce an iron plate with the current pilot plant?
It takes less than 20 hours for around 10 kg/m <sup>2</sup> (at 1000 A/m <sup>2</sup> ).
24. How do you manage the balance of fresh oxide in and reacted oxide out? What % of iron oxide converts to Fe?
25. What % of the Fe in feedstock is recovered as metallic iron?
26. What is the purity of the Fe metal from SIDERWIN electrowinning process? What are impurities?
The electrolyte is prepared at the beginning of each trial with fresh oxides and intermediate feedings are done if necessary. The products from the pilot trials had more than 96% of metallic iron.
27. How much of the electrolyte is lost vs. recirculated?
There is no loss of the electrolyte which is totally recirculated in the electrolysis cell.

28. Was the energy requirements of the production of the electrolyte also considered and if so, how much is it?

For the assessment of the future European power system, with the contribution of SIDERWIN as an electricity intensive process but also as an important flexibility source, we have chosen a conservative approach by considering only the flexibility of the electrolyser.

Actually, the current electricity consumption of the pilot for the preparation step, essentially for heating the electrolyte, may not represent the real demand of the future industrial process because of the energy efficiency and heat recovery opportunities that could offer an industrial scale.

But then, to validate the entire ability of the SIDERWIN process to operate in an on-demand mode, we have simulated interruptions for each step of a production cycle, including the preparation of the electrolyte, especially to observe the responsiveness of the electric heating elements and the thermal behaviour of the pilot during an interruption.

29. The presentation from EDF suggests SIDERWIN capacities will be isolated. But they will much more likely be part of a large grid, so there is no need that the consumption profile exactly matches the production profile of additional capacities on this grid. And I'm confused: how can you be part of the profitable flexibility market if you only have a very flat consumption profile? Thank you

In our model, we have considered SIDERWIN capacities that are not isolated but obviously connected to the grid of the countries in which the SIDERWIN plants have been located. And in the model, the grid connexions (and the predictive evolutions) between the different European countries, have also been considered.

Even if the SIDERWIN plants are connected to the grid, SIDERWIN is an electricity intensive process, so at a large scale its development could represent a very important electricity demand in Europe up to 43 GW (ambitious scenario considering the total replacement of the current blast furnaces in Europe with the SIDERWIN technology), and with a very flat profile.

The use of additional intermittent electricity production means that, at this level, it will increase the occurrence and intensity of the imbalance episodes for the system. That is why it is important for the assessment to prioritize the electricity production means with a similar flat profile as much as possible.

To answer your second question, the flat but responsive electricity consumers are excellent competitors in the flexibility market. Nowadays, the industrial processes based on electrolysis, such as the aluminium or chlor-alkali industries, already benefit from this market opportunity. Their contribution consists in interrupting or modulating their power demand, when there is not enough electricity available on the grid, especially during the peak periods in winter.

30. What are the main drivers for the scope 3 emissions (i.e., the main contributors to scope 3 emissions)?

Those will be the emissions caused by the production, transportation of input raw materials such as titanium.

31. What assumptions are used to model the electricity consumption to regenerate the alkaline solution?

The electricity mix used for the 2050 projections has been presented in the slides. The amount of electricity has been calculated and explained in D6.3, which is unfortunately not publicly available.

32. Will the final life cycle inventories developed in this project be published?
No, the final inventory is confidential and is not included in the public deliverable.
33. The article by Barberousse is not found on google nor on the SIDERWIN website. Is it possible to get an exact reference?
The paper was presented at the European Council for an Energy Efficient Economy (ecee 2020), and its title was "Electrification of primary steel production based on SIDERWIN process: simulation on the European power system in 2050". It appears in the <i>Documents/Papers and posters/Papers in conferences</i> section of the Siderwin website. Here is the direct link: <a href="https://www.ecee.org/library/conference_proceedings/ecee_Industrial_Summer_Study/2020/6-deep-decarbonisation-of-industry/electrification-of-primary-steel-production-based-on-iderwin-process-simulation-on-the-european-power-system-in-2050/">https://www.ecee.org/library/conference_proceedings/ecee_Industrial_Summer_Study/2020/6-deep-decarbonisation-of-industry/electrification-of-primary-steel-production-based-on-iderwin-process-simulation-on-the-european-power-system-in-2050/</a>
34. The flexibility value of SIDERWIN would be higher in a system dominated by variable renewables?
Of course, because the development of renewables as photovoltaic and wind turbines will introduce more intermittency in the power system, so the demand for flexibility will increase.
35. What would be the typical production volume for a SIDERWIN plant?
The first pilot plant is expected to be between 40 and 100 kt per year. The next step will be a Mt scale plant.
36. Which is the relative cost of SIDERWIN compared to Blast Furnace technology?
Both technologies are not at the same level of maturity, it is thus hard to give precise figures. Nevertheless, first calculations are showing that SIDERWIN will be soon cost-competitive in a context of CO <sub>2</sub> taxes.
37. What different Fe-grades of iron ore were tested? Can it use <60% Fe iron ore? Or only DR-grade?
Synthetic hematites were tested at the pilot. Different iron sources from residues of other industries have been tested at lab scale, showing promising potential as alternative feeding materials.
38. How quickly do you think electrowinning will be adopted?
39. When do you expect SIDERWIN to be available at industrial scale?
40. What is the productivity achievable by SIDERWIN Mt (Fe)/h at expectable industrial scale?
A small pilot plant is expected by 2027 and a Mt-scale plant by 2030.