Inside the Cover

Electra

Electra, a clean iron company, has developed novel technology for electrifying ironmaking from iron ore, which if applied globally could eliminate up to 90% of steelmaking CO_2 emissions. Electra's unique patented electrochemical system leverages well-established science, technologies, infrastructure, and markets to accelerate scale-up and adoption by steel producers before 2030. In the first quarter of 2024, Electra commissioned its pilot plant producing 1 m^2 sheets of 99% pure iron at its Boulder, Colo., USA, headquarters. Electra has raised US$85 million from the leading climate-technology investors, including Breakthrough Energy Ventures, Temasek, S2G Ventures, Capricorn Investment Group, Lowercarbon Capital, Valor Equity Partners, BHP, Amazon and Nucor Corp.

Building a decarbonized, sustainable and circular steel industry requires reimagining the entire mine-to-metal supply chain. Uniquely positioned between mining and steelmaking, Electra is transforming industry challenges into market opportunities to produce the most sustainable green steel products for end consumers. Electra's technology addresses two distinct challenges:

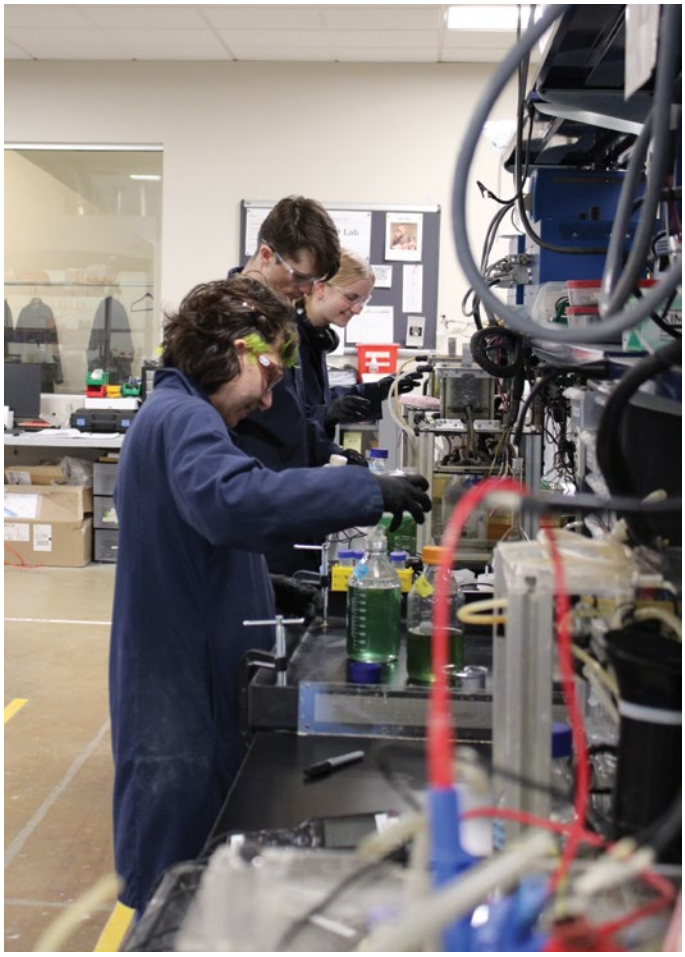
1. Decarbonizing Steelmaking
   - Today, 69% of steel is made at roughly 1,600°C (2,912°F) using a pyrometallurgical process powered by coal that emits about 2 tons of CO_2 for every ton of steel produced.
   - The global iron and steel sector produces 1.9 billion metric tons of crude steel annually. This results in 3.7 gigatons of direct and indirect CO_2 emissions per year, or about 10% of the global total. If the iron and steel sector were

a country, its carbon emissions would rank third in the world behind China and the United States.

- Decarbonizing steelmaking essentially equals decarbonizing ironmaking: Crude steel is 98% iron, and 90% of steelmaking emissions come from refining the iron ore to iron metal.
- The steel sector is currently the largest industrial consumer of coal, which provides roughly 75% of its energy demand. Coal is used to generate heat, and to make coke, which is instrumental in the chemical reactions necessary to produce steel from iron ore.

2. The "Iron Ore Challenge"

- Commercial-grade iron ores with low impurities and high iron content (62% or above) are projected to be in short supply by the early 2030s.
- Steelmaking production methods that use hydrogen or natural gas instead of coal to reduce emissions require even higher iron content levels (67% or above).
- This means hydrogen and natural gas production methods aimed at reducing emissions will face even more acute cost increases and supply constraints, likely leading to higher green premiums.



Electra has developed a novel process to electrochemically refine iron ore into clean iron metal at approximately 60°C (140°F) using low-cost intermittent renewable electricity. Electra's clean iron is then converted to green steel using the existing and growing infrastructure of electric arc furnaces.

Instead of heating and smelting the iron ore at high temperatures, Electra's low-temperature iron is made by dissolving the ore in a water-based acidic solution near room temperature. Electricity is used to extract pure iron from the solution while regenerating all chemicals and water used in the process, releasing only pure oxygen into the atmosphere.

Electra's process can intake high-impurity, already-mined, stranded iron ores typically discarded by mines and steelmakers. Mining one ton of commercial-grade iron ores (with iron content >58%) generates about 2 tons of ore waste that cannot be economically processed in traditional steelmaking today. Electra has qualified hematite, goethite and magnetite iron ores with iron content as low as 35% with high levels of silica, alumina and phosphorus impurities. By utilizing high-impurity, already-mined, stranded ores currently unsalable, Electra's clean iron technology extends the life of mines and decreases the need for additional mineral extraction, further decarbonizing the mining industry and improving sustainability. Efficiently and effectively removing and valorizing impurities as co-products creates additional revenue streams while reducing waste and environmental hazards.

Electra's technology can start and stop production quickly due to low operating temperatures and the low thermal mass of the process. Unlike other approaches, this feature allows Electra to leverage increasing supplies of inexpensive, intermittent renewable electricity to lower the operating energy cost. Furthermore, the low-temperature processing reduces the capital cost of the plant.

By using low-cost, high-impurity, already-mined ores that cannot be used in steelmaking today and low-cost intermittent renewable electricity that is increasingly available at scale, electrifying ironmaking is economically feasible for the first time by using Electra's technology.

Focused on commercial adoption by the end of the decade, a technical risk facing Electra is scaling up their bespoke assemblies for use in existing electrowinning equipment. They will be leveraging partnerships with

existing equipment suppliers and engineering, procurement and construction management firms with decades of large-scale electrochemical plant deployment experience to mitigate this risk.

As Electra is scaling its technology to millions of metric tons of iron by the end of the decade, it's also scaling its team. Co-founders Sandeep Nijhawan and Quoc Pham believe that with the right team, you can solve any challenge, and thus have built a company culture that focuses on mentoring the next generation of engineers, chemists and scientists. Electra offers the opportunity to make a significant impact on meaningful problems, while also developing technical and leadership skills.

Electra's innovative process overcomes the three main obstacles faced by prior attempts at hydrometallurgical iron refinement:

- Iron Ore Dissolution Rate — Iron is excruciatingly slow to dissolve in acidic or alkaline solutions. Electra's closed-loop electrochemical process accelerates the ore dissolution rate in a mild acidic solution without permanently consuming water or acid.
- Isolating Iron From Impurities — Low-grade iron ores contain higher levels of impurities, such as silica, phosphorus and alumina, which need to be removed prior to steelmaking. Hydrometallurgical practices for refining other metals treat iron as an impurity and remove it from solution, along with other impurities. Electra's hydrometallurgical refinement step flips the conventional process by keeping the iron dissolved in solution and removing the impurities as solids. Pure iron is electroplated out of the solution and the impurity solids may become co-refined minerals potentially useful to other hard-to-abate industrial sectors.
- Electrochemical Efficiency — Iron is less stable than other commonly used metals. In traditional electrowinning systems, iron is continuously losing or gaining an electron, resulting in electrochemical inefficiency. Subsequent chemical reactions create even more inefficiency and significantly reduce the amount of iron able to be electroplated. Electra's innovative electrochemical process stabilizes the iron and efficiently extracts 99% pure iron metal from solution at 60°C.

Electra was founded in May 2020. Its first 1 m^2 plate of iron was made in December 2023 and has evolved from concept to a pilot plant in only three years. Electra plans to scale up to meet the growing demand for clean iron using its innovative technology. ✦