ROSIE—Revolutionizing Ore to Steel to Impact Emissions

PROJECT DESCRIPTIONS

Argonne National Laboratory – Lemont, IL

High Efficiency, Solid State Microwave-Powered Hydrogen Plasmas for Use in Direct Reduction of Taconite Ore and Ore Concentrates in a Rotary Kiln Furnace - $3,066,221

Argonne National Laboratory is developing a microwave-powered hydrogen plasma rotary kiln process for reducing iron ore that would eliminate carbon dioxide emissions from the ironmaking process. The proposed technology eliminates the coke used in traditional blast furnaces and removes the energy-intensive step of pelletizing iron ore. The approach takes advantage of the fact that atomic, ionic, and vibrationally excited species of hydrogen plasma reduce ore more effectively than molecular hydrogen. Argonne's method has the potential to reduce carbon dioxide emissions arising from ironmaking by 35% compared to the blast furnace process when using today's grid and by 88% when using a future low-carbon grid, while also reducing the cost of making hot rolled steel.

Blue Origin – Los Angeles, CA

Ouroboros: A Novel Reactor for Zero Emission Electrolytic Reduction of Iron - $1,109,422

Blue Origin is developing an "Ouroboros" system that produces high-purity ferro-silicate pig iron from low-quality iron ores using molten oxide electrolysis (MOE) with zero direct process greenhouse gas emissions. Blue Origin will leverage MOE expertise developed for lunar applications including novel, efficient indirect heating methods. An integrated system could excavate, beneficiate, and extract iron product in mine-tailings facilities using only raw feedstocks and electrical power provided by solar panels and batteries. If successful, the approach would reduce the greenhouse gas emissions of the ironmaking industry and clean up mine tailing storage facilities across the country.

Electra – Boulder, CO

Low-Temperature Green Ironmaking from Unconventional Feedstocks - $2,874,596

Electra is developing a process for producing iron at the temperature of a cup of coffee using unconventional feedstocks. The process involves two electrochemical cell stacks: First, an ultra-low-cost acid-base generator that uses electricity to produce sulfuric acid and sodium hydroxide, and then uses these chemicals for the processing and separation of the feedstock into its constituent materials, including ferrous hydroxide. The second electrochemical cell stack is an electrowinning cell that converts ferrous hydroxide into iron metal at an unprecedented high efficiency. If successful, the project will produce iron for use in green steel with 80% less greenhouse gas emissions at half the cost of existing fossil fuel-based processes.

Form Energy – Somerville, MA

Intensification of Continuous Alkaline Electrochemical Ironmaking with Net-Negative CO2 Emissions at Cost Parity with Pig Iron - $1,000,000

Form Energy is leveraging its patent-pending breakthrough to directly produce iron powders from alkaline iron ore slurries in a first-of-a-kind powder-to-powder process. The technology features an electrolyzer designed to allow continuous electrolytic production of high-purity iron with high efficiency from slurries with low solids content. Using domestically available iron ore feedstocks, the process has the potential to produce greenhouse gas emission-free iron at cost parity with today's carbon-intensive ironmaking methods.

Georgia Institute of Technology – Atlanta, GA

Direct Hydrogen Reduction of Iron Ore Concentrate and Net-Shaped Fabrication of Linear Cellular Alloy Steels - $2,843,274

Georgia Institute of Technology is developing a method to produce net-shaped engineered lattice structures and cellular structures of alloy steels by solid-state direct reduction of extruded structures. Domestically mined taconite ore would be refined to remove impurities and obtain finely ground sinter-grade iron oxide powders. The fine iron oxide powder combined with other oxide powders and polymer binders would then be extruded into desired structures. The structures will be reduced in a flowing atmosphere containing hydrogen to obtain the final net-shaped alloy steel products via solid-state sintering.

Limelight Steel – Oakland, CA

Laser Furnace for Reduction of Iron Ore to Iron Metal - $2,910,346

Limelight Steel is developing a laser furnace to convert iron ore into iron metal without emitting carbon dioxide at lower cost than a blast furnace. The process leverages semiconductor laser diodes, which enable new temperature and pressure ranges to reduce high- and low-grade iron ore fines into molten iron metal. The approach eliminates the need to sinter or pelletize iron ore for traditional ironmaking furnaces. Limelight estimates that their technology would reduce energy consumption of steelmaking by 46% and emissions by 81%.

Pennsylvania State University – State College, PA

Multi-Cation Electrolytes for Electrolytic Reduction of Complex Iron Oxides at Low Temperatures - $760,000

The Pennsylvania State University is developing an efficient, productive, and reliable electrochemical process for the economical reduction of iron ore at temperatures below 600°C without direct greenhouse gas emissions. Iron oxide ore would be electrochemically reduced to metallic iron at the cathode, and oxygen gas would be generated as the only byproduct at the anode using stable oxygen-evolving anode materials. The approach of a metallic anode protected by a solid metal oxide would overcome many of the challenges of anodic degradation that have hindered historical progress in this area. A host of electrolytes will be investigated while processing mixed Fe(II) and Fe(III) ores and simultaneously addressing ore impurities.

Phoenix Tailings – Woburn, MA

Novel Electrolytic, Zero Carbon Emission Direct Reduced Iron Production - $1,000,000

Phoenix Tailings is developing an ore-to-iron production process using the arc generated from an electrode to electrolyze the molten oxide electrolyte powered by clean electricity. Molten oxide electrolysis is a promising alternative to conventional approaches, but until now has required anode materials that are either consumable or prohibitively expensive. Instead, Phoenix Tailings' technology places the anode above the melt, keeping it safe from corrosion.

Tufts University – Medford, MA

Solving Ore Concentrate Reduction with New Chemistry - $2,924,514

Tufts University is developing a method to directly reduce iron ore concentrates with ammonia, eliminating all direct process emissions from the ironmaking step, as well as emissions that result from baking iron ore with clay to make hard pellets. The proposed approach would use ammonia to enable reduction of high-gangue ores as well as decrease melting costs of the reduced iron product. By bypassing the pellet-hardening step, using low-grade ores, and lowering melting costs, this new approach to ammonia-based reduction would reduce the cost of domestic steel while decreasing total steel emissions by greater than 60%.

University of Minnesota – Minneapolis, MN

Ultrafast Hydrogen Microwave Plasma Reduction of Iron Ore - $2,820,071

The University of Minnesota is developing a fully electrified microwave hydrogen plasma process to replace blast furnace technology. The proposed approach uses microwaves to generate an ionized hydrogen gas that supplies significant gas heating at ambient pressures. The technology will use blast furnace and direct reduction grade iron ore concentrates, eliminating the emissions associated with the palletization, sintering, and coke-making steps in the conventional blast furnace process.

University of Nevada, Las Vegas – Las Vegas, NV

Fast Electrowinning via Rotors for Responsible Iron Creation (FERRIC) - $2,102,353

The University of Nevada, Las Vegas is developing technology to use electrowinning to convert pulverized iron ore into pure iron that is deposited on a cathode. The approach leverages a rotating impeller to speed up chemical reactions ten-fold and facilitate the transport of iron to the electrode. The goal is to create a laboratory-scale prototype of an impeller-accelerated reactor that maintains the production of one kilogram per hour of over 98% pure iron for 100 hours.

University of Utah – Salt Lake City, UT

Producing Clean Steel Directly from Iron Ore Concentrate - $3,479,082

The University of Utah is developing a hydrogen-reduction melt-less steelmaking technology. The cornerstone of the technology is the direct reduction and alloying from concentrated ore to make steel products, thereby circumventing traditional iron and steelmaking methods. The proposed process has the potential to drastically reduce energy consumption by eliminating several high-energy steps in traditional iron and steelmaking. The process is conducted at substantially lower temperatures than conventional methods.

Worcester Polytechnic Institute – Worcester, MA

Low-Carbon Iron Production and High Silicon Steel Manufacturing (LCIPHSSM) - $1,241,919

Worcester Polytechnic Institute is developing manufacturing technologies for low carbon electrolyzed iron powder to be used in iron-silicon electrical steel. In the proposed electrolysis technology, the simultaneous percolation of electrons and ions effectively allows for 3D reaction areas and enables the process to function at higher currents and rates. The approach overcomes the challenges of solid diffusion and collection in conventional electrolysis, and the work could revolutionize iron production by replacing the traditional carbothermic process while significantly reducing energy usage, greenhouse gas emissions, and cost.