

NRRI Mineral Innovation Project Overview

February 21, 2024



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NRRI Mineral Innovation Project Overview

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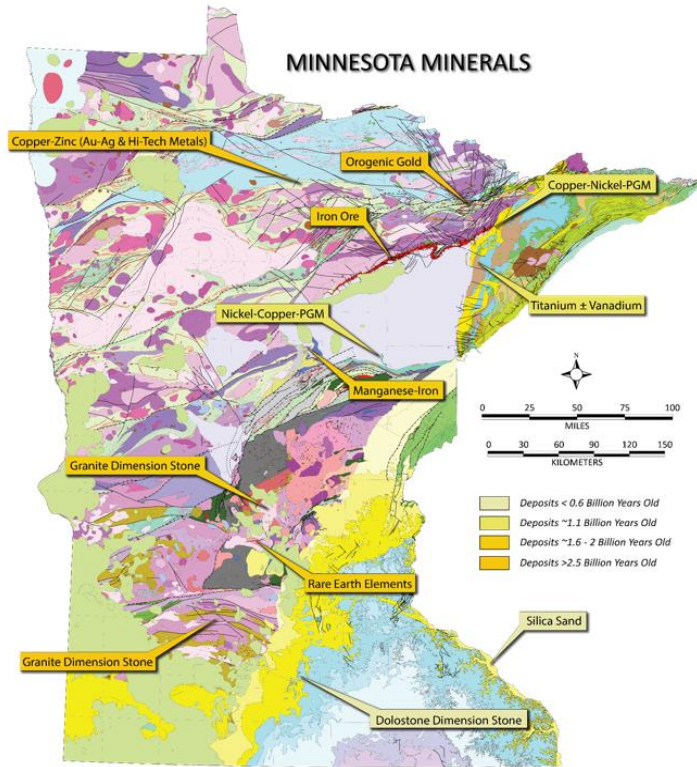
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Overview/Agenda

- Minnesota Minerals Challenges
- New Capabilities
- Research Project Portfolio
 - Iron & Steel
 - Other
- Conclusions



Mineral Challenges and NRRI Goal



- Minnesota and Global:
 - Recovery of materials from waste or by-products
 - Waste and effluent management (Hg, S); water quality and scarcity
 - Tailings and waste as resources
 - Social license
- Increased demand for base metals and critical minerals for green economy
- Iron Ore - changing ore grades, market dynamics, decarbonization, industry “greening”

Produce high-value mineral, metal and material products safely and economically while reducing environmental and social impact.

Minnesota Iron – Today's Challenges

Today's challenges include:

1. Decarbonization of the industry
2. Energy and water conservation
3. Changing nature of MN iron ore
4. Broader product portfolio



**Ore
Characterization**



**Iron Ore
Processing**



Ironmaking



Steelmaking

**NRRI is working on all aspects
of Iron and Steel Production**



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New Processing Capabilities at NRRI

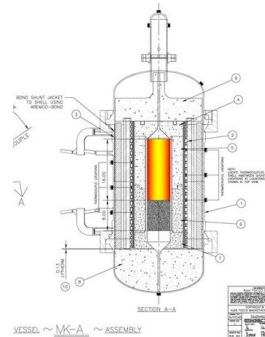
- Fine Grinding
 - Swiss Tower Mill (STM)
 - VRM5 and VRM25
- Flotation
 - Eriez HydroFloat
 - Jameson Pneumatic
- Pellet Quality
 - RB Automazione LR 8000 and MM 6000
- Electric Smelting
- NRRI DRI Simulator



Swiss Tower Mill



NRRI Pellet Quality Lab



NRRI DRI Simulator Design



Eriez HydroFloat



Jameson Pneumatic Flotation

Enhanced Iron Ore Pellet Chemistry

Project Sponsor: US Dept. of Energy Industrial Efficiency & Decarbonization Office (IEDO)

- **Duration:** 2021-2025
- **Federal Funding:** \$2.1M
- **State/NRRI Funding:** \$1.6M

Concept

- Improve the high temperature properties of iron ore pellets to:
 - Allow for lower quality iron ore pellets to be used in reduction
 - Enhance removal of gangue
 - Promote smelting to produce granulated pig iron

Impact to the Iron and Steel Industry

- Expanded iron product portfolio with reductions in energy and carbon for steelmaking
- Investigating impact of hydrogen on pellet quality



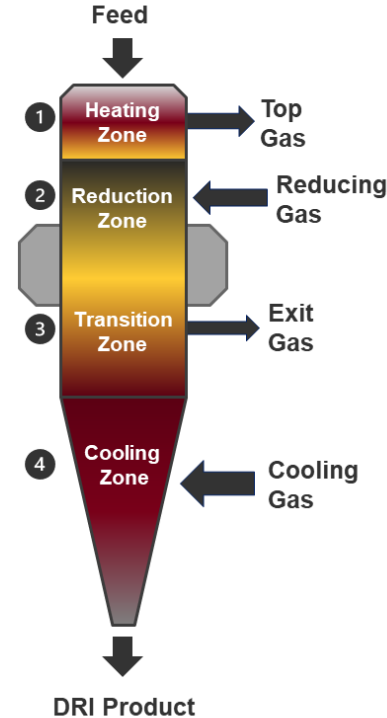
Enhanced Iron Ore Pellet Chemistry DRI Simulator

Concept

- Unique simulation of the entire shaft furnace direct reduction process in one reaction vessel

Impact to Iron & Steel Industry

- Reduce risk associated with evaluating feedstocks and process changes for the shaft furnace reduction process



DRI PROCESS TRANSITIONS

1) Pre-Heating

- Moisture Evaporation
- Under N_2

2) Reduction

- Hematite to Magnetite
 - $3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$
 - $3Fe_2O_3 + H_2 \rightarrow 2Fe_3O_4 + H_2O$
- Magnetite to Wustite
 - $Fe_3O_4 + CO \rightarrow 3FeO + CO_2$
 - $Fe_3O_4 + H_2 \rightarrow 3FeO + H_2O$

3) Metallization

- Wustite to Iron
 - $FeO + CO \rightarrow Fe^o + CO_2$
 - $FeO + H_2 \rightarrow Fe^o + H_2O$

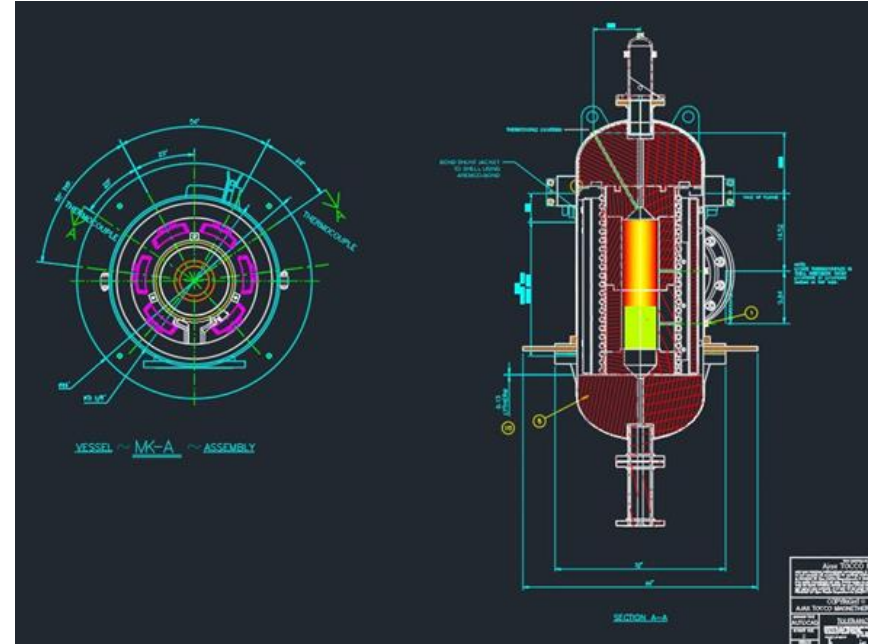
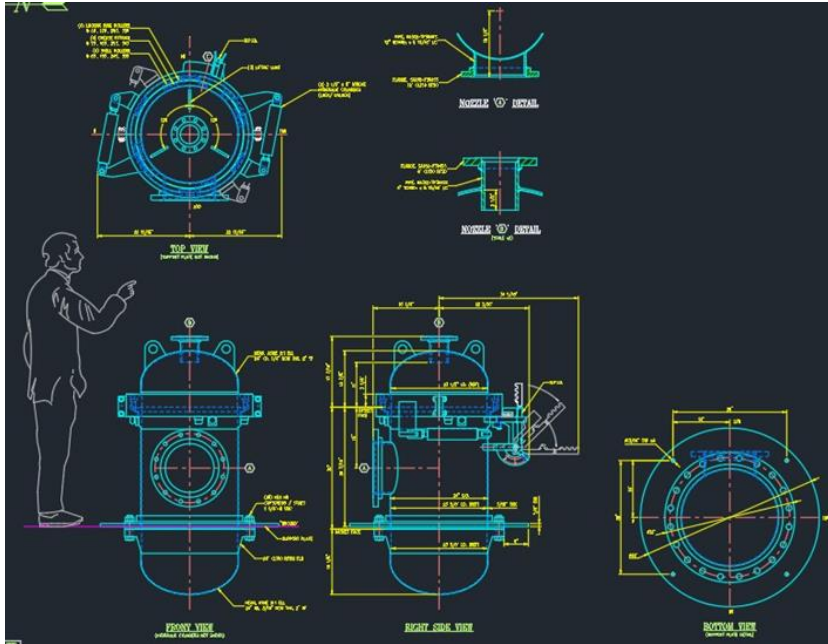
4) Carburization and Cooling

- $3Fe^o + CH_4 \rightarrow Fe_3C + 2H_2$
- $3Fe^o + 2CO \rightarrow Fe_3C + CO_2$
- $3Fe^o + CO + H_2 \rightarrow Fe_3C + H_2O$

Final Cooling

- N_2

Enhanced Iron Ore Pellet Chemistry DRI Simulator



Engineered Biocarbon

Project Sponsor: US Dept. of Energy Industrial Efficiency & Decarbonization Office (IEDO)

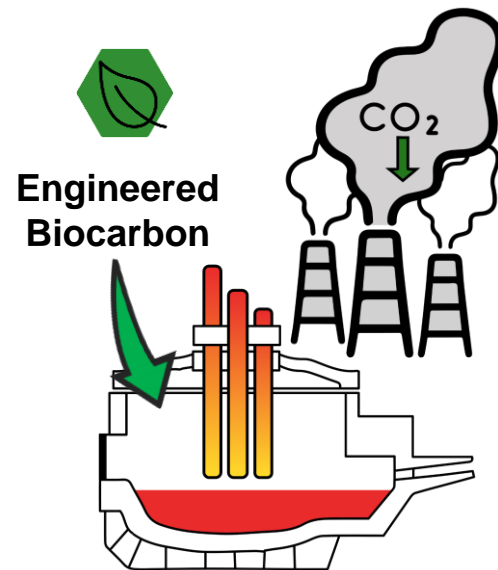
- **Duration:** Dec. 2023 to Nov. 2026
- **Federal Funding:** \$2.9M
- **NRRI Funding:** \$1.6M

Concept

- To demonstrate the use of carbon-neutral engineered biocarbon products as fossil fuel substitutes for EAF steel production
 - Improve the density of biocarbon agglomerates
 - Byproduct addition to improve EAF performance

Impact to the Iron and Steel Industry

- A viable carbon-neutral alternative to fossil carbon sources with no reduction in performance or steel quality



Business & Industry

US Steel Keetac receiving a **\$150 million investment** for Direct Reduce (DR) grade pellets.

- Blast furnace to direct reduction pellet conversion
- State-of-the-art fine grinding technologies

MagIron intends to invest more than **\$100 million and create over 130 jobs** in NE Minnesota.

- Production of low-silica iron concentrate from legacy mine waste piles and tailings ponds



NRRI Research is Not Just Iron & Steel – Innovation Portfolio

Sponsor	State of Minnesota			US Dept. of Defense	US Dept. of Energy
Abbreviated Title	W. Mesabi Iron Resources of the Future (2019, 2020)	Reduction of Iron with Hydrogen Plasma	Iron Battery Materials from Minnesota Iron Resources	Fossil Carbon Replacement in Lead Battery Recycling	ASPEN LEAF
Primary Goal	Characterize underutilized Minnesota iron ore resources; investigate alternative iron products	Proof of concept for hydrogen plasma reduction of iron concentrate fines	Investigate production of battery-grade iron from Minnesota resources	Replace fossil carbons with carbon-neutral biochars to decarbonize lead battery recycling	Produce carbon neutral combustion fuels via carbon looping technology, biomass sourced injection material, and replacement of needle coke and incorporation of biomass-sourced pitch in electrode production
Lead (Partners)	NRRI	UM Twin Cities (NRRI)	Form Energy (NRRI)	Worcester Polytechnic Institute (NRRI, Gopher Resources)	National Renewable Energy Lab (NREL) (NRRI, Nucor, ASU, Biochar Now, Ensyn, Graftech)
Budget Duration	\$0.8k 5 years	\$0.8M 3 years	\$0.5M 2 years	\$0.9M (NRRI share) 4 years	\$3.8M (total) 3 years
Start Date	Jan 2020	Jul 2023	TBD 2024	Jun 2022	TBD 2024



Summary and Conclusion

- Significant challenges facing minerals industry:
 - Resources
 - Technical
 - Social license
- A portfolio of new technologies and innovations required to achieve “green” iron products
- Collaboration between industry, Federal & State agencies, and research necessary to drive change
- We’re here to help the industry decarbonize, reduce energy and water consumption, find alternative use for byproducts/waste, and anticipate new challenges

Focused on the Future



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Thank You

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