Low Carbon Ferro-Manganese Production from Bauxite with Aluminum

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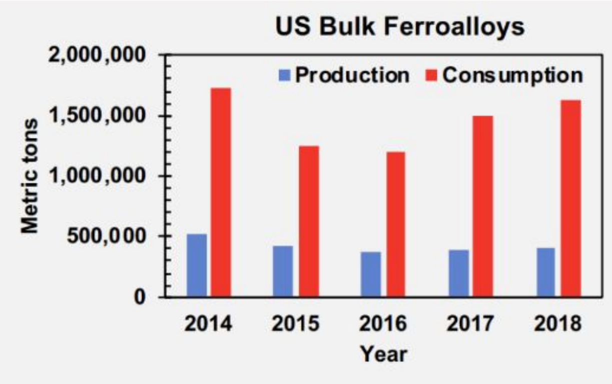
OpenAvenues

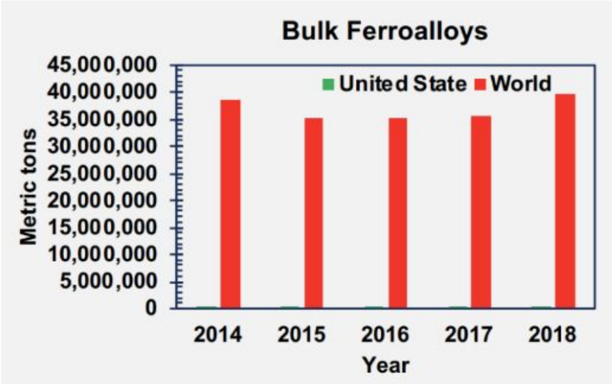
PHOENIX TAILINGS

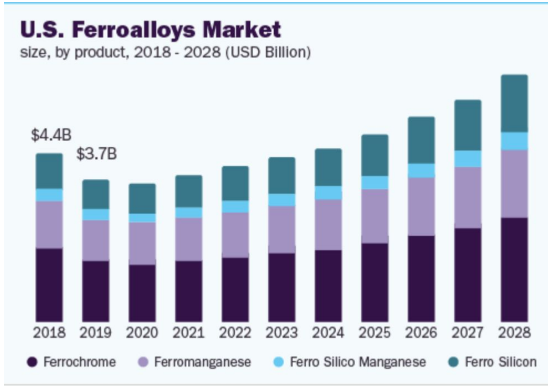
MECHANICAL ENGINEERING
COLORADO STATE UNIVERSITY

Current Ferro-Alloy production status and usage in US

Very **underdeveloped domestic production of Ferro-alloys** as global steel production and demand for advanced steel infrastructure grows.

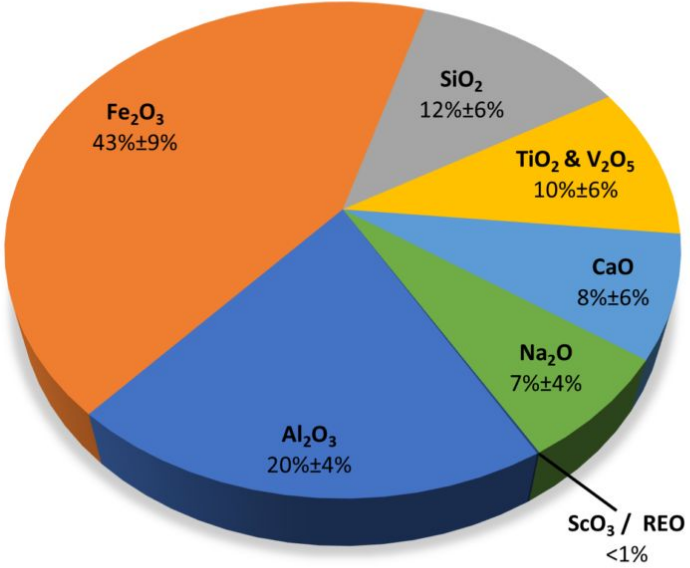


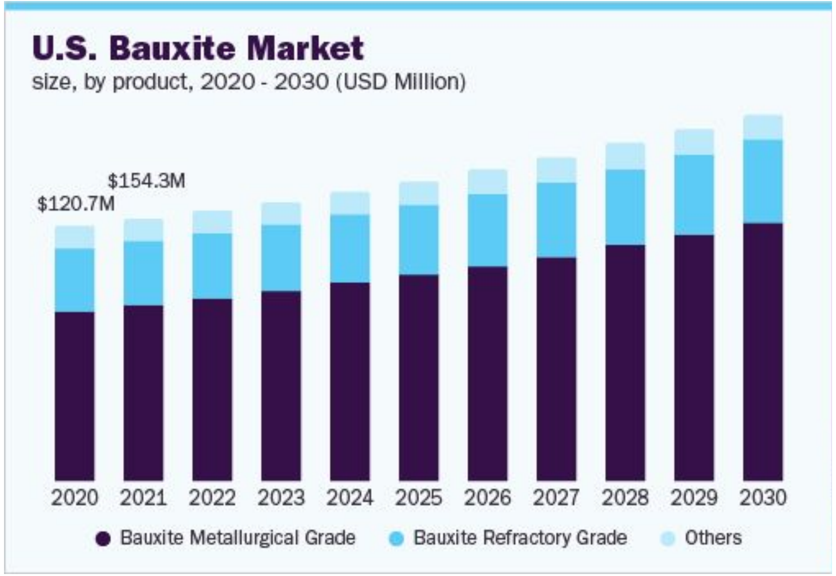




(Left Center) (https://pubs.usgs.gov/myb/vol1/2018/myb1-2018-ferroalloys.pdf)
(Right) (https://www.grandviewresearch.com/industry-analysis/ferroalloys-market)

How Pheonix Tailings Can extract value from Bauxite





(**Left**) (https://geomega.ca/bauxite-residues-processing/)
(**Right**) (https://www.grandviewresearch.com/industry-analysis/bauxite-market)

Metallothermic Reduction of Iron(III) Oxide and Manganese Dioxide With Aluminum Metal

$$Fe_2O_3 + MnO_2 + CaO + Al \rightarrow FeMn + CaAl_2O_4$$

Fe 20% Mn 80% Molar ratio Alloy*
With Low Carbon Content unlike traditional methods

Recycling Materials From E-Waste

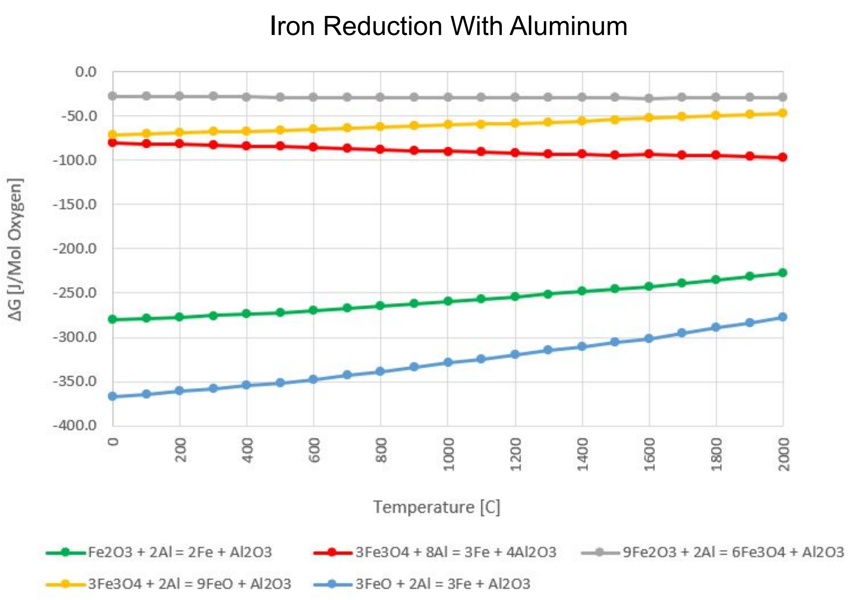
Manganese Dioxide

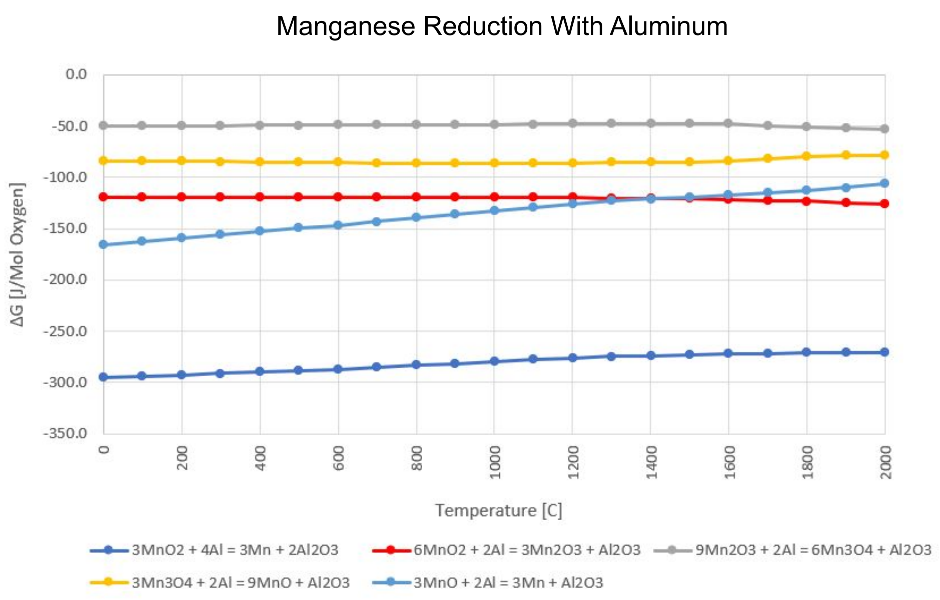
Can be extracted as a waste material from Alkaline zinc-carbon batteries

- This process is very labor intensive and not financially feasible
- Significant carbon content which is undesired and troublesome to remove.

(https://www.huffpost.com/entry/how-to-recycle-batteries_l_5d274fdbe4b07e698c46e7b0)

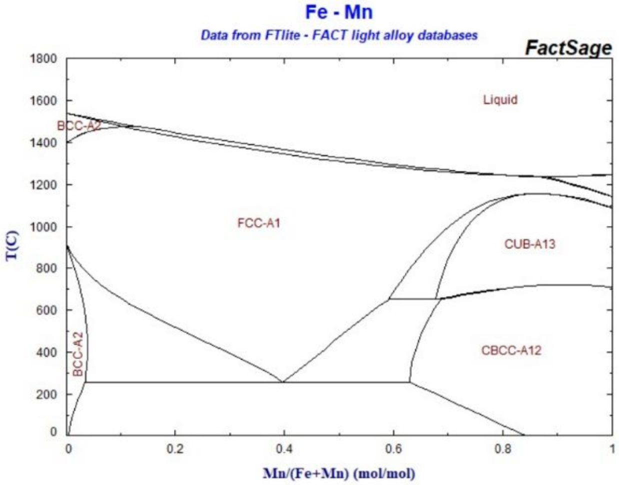
Ellingham Diagrams

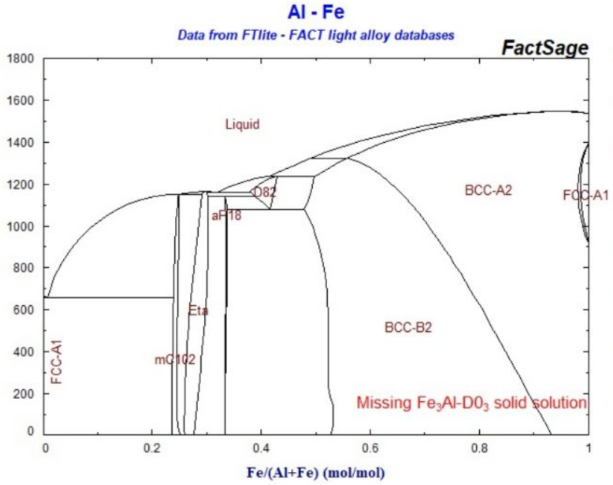


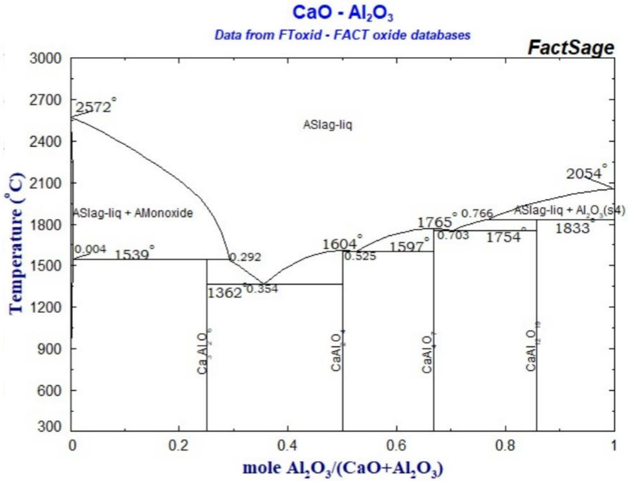


(plotted with data provided upon request by Peace)

Phase Diagrams







(provided by Peace sourced from FactSage)

Flux and Crucible Material

Using the phase diagram data we can determine the right Flux and Crucible

$$CaO + Al_2O_3 \rightarrow CaAl_2O_4$$

Thermite Reaction Temperature: 2200°C (4000°F)

Flux Effect on Slag Melting Temperatures:

- Aluminum oxide (Al_2O_3): The melting point is around 2072°C (3762°F).
- Calcium aluminate ($CaAl_2O_4$): The melting point is around 1650°C (2912-3002°F).

Potential Undesired Reactions

$CaO + Fe_2O_3 \rightarrow CaFe_2O_4$

$CaO + MnO \rightarrow CaMnO_3$

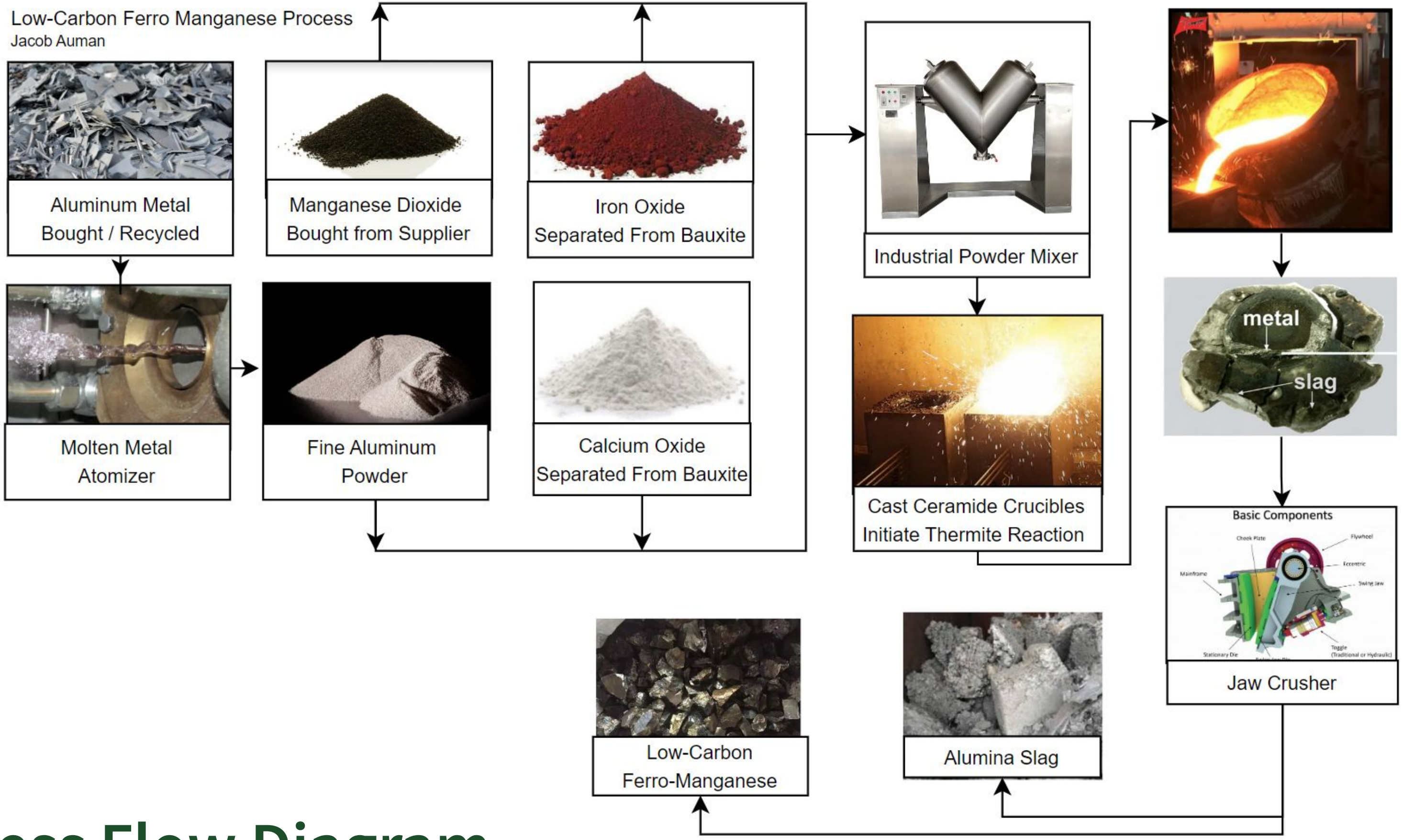
Non-graphite crucible results in low-carbon alloy

2.5 Ton Pyrotek Ceramite Cast Crucible

(Right)(https://www.pyrotek.com/blog/ceramite-dual-cast-crucibles-offer-maximum-life/)

Mass Balance Calculation

Input	Mol	MM [g/mol]	Mass [g]	Note
Fe2O3	1	159.69	159.69	fine powder
MnO2	8	86.94	695.52	fine powder
Al	6.3	26.98	169.974	fine powder
CaO	3.2	56.07	177.555	fine powder
			1056.938	
Output	**Mol**	**MM [g/mol]**	**Mass [g]**	**Note**
CaAl2O4	3.2	158.04	505.728	slag
FeMn	10	55.121	551.21	alloy (80%20)
			1056.938	



Process Flow Diagram

CAPex OPex

Production Target:	100kg	Daily
Alloy Price:	1191.00 $/t	2020 HC-FeMN MetalHub Report (Foreign)
	1.31 $/kg	
Shipping Distribution Cost:	$0	

Capital Expenditure Costs	Quantity	Cost	Note
Warehouse and Facilities Rent	1000 Sq ft	6800/mo	Difficult without creating factory footprint
Process equipment: Atomizer	1	Link	Aluminum powder can also be purchased
Process equipment: Jaw Crusher	1	$10,000	
Personal Protective Equipment	5	$744	A set for each employee on the floor
Plant Design and Engineering	-	-	Can be done in house or by contractor
Safety Control Systems	-	-	Fire Control and Automation
Quality control and testing equipment	-	-	Testing alloy for impurities
Shipping and Recieving Infrastructure	-	-	Pallet Jacks and possibly forklift
Legal and consulting fees	-	-	Enviromental considerations and Osha
Initial workforce training	-	-	Dependant on employee turnover
Contingencies	-	-	Either liquidity or alloy held in reserve

Ongoing Operating Costs	Quantity	Cost	Note
Utilities (water, electricity, internet)	-	-	Dependent of location and Plant design
Raw materials: Aluminum	340 g/kg	0.006 $/g	either scrap or powdered
Raw materials: Mangnanese Dioxide	1400 g/kg	0.003$/g	common from pottery suppliers
Raw materials: Calcium Oxide	355 g/kg	-	sourced from bauxite
Raw materials: Iron Oxide	320 g/kg	-	sourced from bauxite
Labor: Engineers	2	35/hr	monitoring crucibles and reaction temps
Labor: Shipping and Recieving	2	25/hr	preparing supplies and packaging alloy
Labor: Supervisor	1	40/hr	saftey and logistics
Replacing damaged crucibles	-	-	dependent on size and durability
Maintenance and repairs	-	-	
Environmental monitoring and compliance	-	-	
Quality control testing and inspection	-	-	
Transportation and logistics	-	-	
Insurance and taxes	-	-	
Plant management and administration	-	-	
Depreciation	-	-	
Financing costs (ongoing interest payments)	-	-	

Conclusion

- Importance of Ferro-Alloys In general due to global economic factors.
- Use of Aluminum as reductant for low carbon ferro-alloy production process increases value.
- Metallothermic reactions do not require extensive infrastructure, low emissions footprint.

Great experience of learning from Peace during this project (history, metallurgy, systems engineering)

I want to contribute value to the Phoenix Tailings team by innovating new processes downstream of the rare earth extraction from Bauxite currently being conducted. Which will generate value for the company and consumer while reducing waste.

Thank you

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