Sustainably Transforming Bauxite Residue into Critical Minerals

Christopher Cannon Young
Chief Strategy Officer
Elementus Minerals, LLC
Corresponding author: Chris.Young@Element.us.com

Abstract

ElementUS plans to construct operations that will utilize bauxite residue to produce pig iron, alumina, critical minerals (CM) including scandium, and additional saleable products. The ElementUS process combines established chemical separation technologies with thermal separation technology in a novel and proprietary method that will require significantly less energy input than traditional smelting techniques. As a result of energy savings and the ready availability of raw material at surface level with no mining requirements, ElementUS will be the low-cost producer of pig iron in the United States and a near low-cost producer of other products. In addition, the energy savings provided by the ElementUS process will result in direct greenhouse gas emissions reductions. Additional benefits are the production of alumina and CMs which are critical in the transition to renewable energy and zero carbon goals. ElementUS will also remove a pollutant from the environment by reducing bauxite residue currently stagnant in retaining ponds while producing zero waste. The waste from this process will be used and sold as construction material while CO_2 emissions will be captured and used as feedstock. An independent third-party laboratory has completed successful testing of the process and preparations are underway to conduct pilot testing.

Keywords: Bauxite residue, Red mud, Critical materials, Scandium, Uses.

1. Introduction

The potential for bauxite residues as a resource of critical mineral commodities has been recognized worldwide and has been the subject of work in the U.S., including by the U.S. Geological Survey (USGS, Van Gosen and Choate, 2021), and internationally (Borra et Al., 2016). In addition to elevated grades of aluminum and iron, these residues can also contain significant concentrations of critical mineral elements including rare earths, titanium, gallium, and niobium.

Our management team, and our current list of interested investors, are developing this facility as a for profit business with an anticipated return on capital expenditures of under 4 years. This rapid return is made possible by the production of additional saleable products beyond metallic iron, including:

- Critical Minerals (Scandium)
- Alumina
- Construction Aggregate

Figure 1. provides a high-level overview of the ElementUS process and product mix. For clarification, “EcoIron” is our name for the metallic iron that will be produced, suitable for use in the electric arc furnace operations of steel mills, comparable in quality to pig iron and direct reduced iron, but made from waste.

2. Technology

Process technologies that can unlock the full value of bauxite residues in the U.S. has remained elusive. While multiple commodities could contribute to revenues for a commercial recovery operation, the lack of environmentally friendly process technologies capable of simultaneous recovery of these commodities, in saleable forms, has inhibited the development of production facilities for this purpose. In addition to recovery of critical minerals and other commodities that are needed for the U.S. economy, the reclamation of old bauxite residue dumps in the U.S. for this purpose can lead to the restoration of environmentally degraded lands that can be returned to productive use.

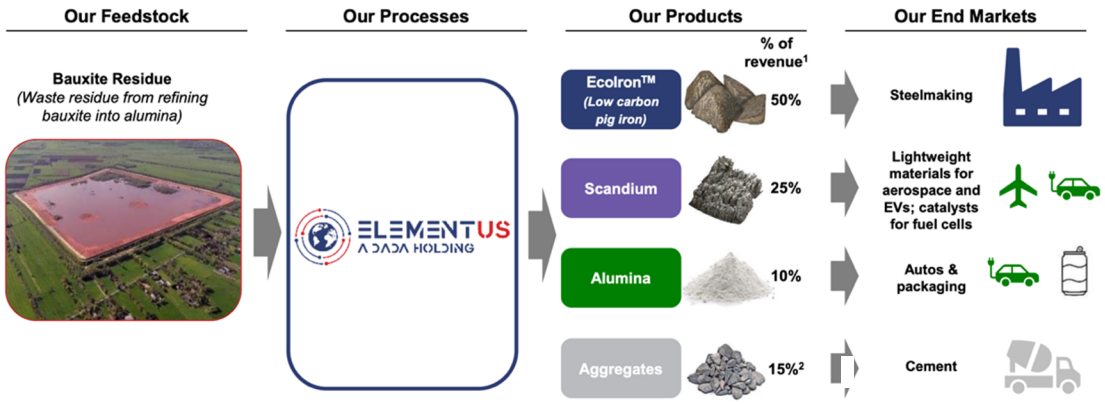

Figure 1. ElementUS High-Level Process and Anticipated Product Mix.

No single component that is included in our separation processes is proprietary or a new invention. However, the order in which these components are combined in this series, is new and unique. Moreso, the application of these separation technologies, and our methodology that incorporates them to create saleable products from bauxite residue, is completely new and proprietary. Our process is a substantial improvement over other tailing treatment processes. In 2022 ElementUS operated a pilot scale facility and this was expanded to a demonstration facility in Louisiana in H1 2023.

Separation processes intending to produce marketable products benefit from higher concentrations of the desired product in the raw material. The efficiency of the separation process is improved with higher concentrations versus lower concentrations of specific components, for example, an iron oxide content above 45% is advantageous. Our raw material, bauxite residue, or "red mud," a waste product from an alumina refinery contains high concentrations of iron. In addition, the feedstock in Gramercy, Louisana is a karstic bauxite, and has been tested to be higher in concentration of critical minerals than other deleterious materials such as coal mine tailings. We intend to establish a beachhead in the separation and refining of metallic iron, and the aforementioned list of products from this more highly concentrated raw material. Once optimized, our process can then be extended to other bauxite residue materials.

This above ground resource is readily available in holding ponds ready to be dredged. We plan to have dredging and a vertically integrated separation, and beneficiation process. Our process will produce no waste and has the potential to transform all bauxite residues across the globe. This process achieves zero-waste due to the conversion of our waste to marketable products, including aggregates that will be used in road construction and emissions that will be reused as feed stocks.

Not only is our selected location advantageous as a source of raw material (only dredging will be needed), but we also have access to the Mississippi River and the transportation corridors already in place for the refineries. These include truck, rail, barge, and ocean freight corridors.

10. References

1. Agnihotri, A. et al. Studies on Beneficiation and Leaching Characteristics of Rare Earth Elements in Indian Red Mud. *Russian Journal of Non-Ferrous Metals*. Vol. 60 335–340 (2019 https://doi.org/10.3103/S1067821219040151.
2. Anawati, J. *Elements US Rare Metals Red Mud Concept Study*. (2022). Hatch Engineering.
3. Bera, R. HRC index spikes as metallic iron soars in US. (2022). *Fast Markets.* https://www.fastmarkets.com/insights/hrc-index-spikes-as-pig-iron-soars-in-us, (Accessed Aug 2023)
4. Borra, C. Recovery of Rare Earths and Other Valuable Metals from Bauxite Residue (Red Mud): A Review. *Journal of Sustainable Metallurgy.* Vol 2. 365–386 (2016). https://doi.org/10.1007/s40831-016-0068-2
5. Fan, Z. (2021). Low-Carbon Production of Iron & Steel: Technology Options, *Economic Assessment, and Policy*. Columbia Center on Global Energy Policy. https://www.energypolicy.columbia.edu/research/article/low-carbon-production-iron-steel-technology-options-economic-assessment-and-policy#_ftn1 (Accessed Aug 2023)
6. Farjana, S. Impacts of aluminum production: A cradle to gate investigation using life-cycle assessment (2019). *Science of the Total Environment*. Vol. 663. pp 958-970 https://doi.org/10.1016/j.scitotenv.2019.01.400
7. Ferreira, H. A Life Cycle Assessment study of iron ore mining. (2015). *Journal of Cleaner Production*. Vol 108, Part A. pp. 1081-1091, https://doi.org/10.1016/j.jclepro.2015.05.140
8. Fick, G. Using Biomass for Metallic iron Production: A Technical, Environmental and Economical Assessment. *Waste and Biomass Valorization*. Vol 5, 43–55 (2014) https://doi.org/10.1007/s12649-013-9223-1
9. Gentzmann, M. Investigation of scandium in bauxite residues of different origin. (2021). App*lied Geochemistry*. Vol 126, 2021, 104898, https://doi.org/10.1016/j.apgeochem.2021.104898.
10. IEA. (2020). *Iron and Steel Technology Roadmap*. IEA. https://www.iea.org/reports/iron-and-steel-technology-roadmap (accessed Aug 2023)
11. Klauber, C. Review of Bauxite Residue "Re-use" Options. (2009). *Australian National Research Flagships*. CIRSO Document DMR-3609 https://www.xn--krinfo-wxa.hu/sites/default/files/Review%20of%20Bauxite%20Residue%20Re-use%20Options_Aug09_sec.pdf (accessed Aug 2023)
12. Korol, D. Life cycle assessment of steel production in Poland: a case study. (2013). *Journal of Cleaner Production*. Vol 54, 2013, Pages 235-243, https://doi.org/10.1016/j.jclepro.2013.04.031
13. Li, P et al., Recover Iron from Bauxite Residue (Red Mud). (2019). *IOP Conf. Ser.: Earth Environ. Sci.* 252 042037, doi: 10.1088/1755-1315/252/4/042037
14. Liu, Y. Hidden values in bauxite residue (red mud): Recovery of metals. (2014). *Waste Management*. Vol 34, Issue 12, December 2014, Pages 2662-2673, https://doi.org/10.1016/j.wasman.2014.09.003
15. Mombelli, D. Iron Recovery from Bauxite Tailings Red Mud by Thermal Reduction with Blast Furnace Sludge. Appl. Sci. 2019, 9(22), 4902; https://doi.org/10.3390/app9224902
16. Norgate, T. Energy and greenhouse gas impacts of mining and mineral processing operations. (2010). *Journal of Cleaner Production*. Vol 18. pp. 266-274, https://doi.org/10.1016/j.jclepro.2009.09.020
17. Quang, D. The Utilization of CO2, Alkaline Solid Waste, and Desalination Reject Brine in Soda Ash Production. (2018). *Energy, Environment, and Sustainability*. https://link.springer.com/chapter/10.1007/978-981-13-3296-8_9

18. Rai, S. (2019). Recovery of iron from bauxite residue using advanced separation techniques. *Minerals Engineering* Vol 134, 2019, Pages 222-231, https://doi.org/10.1016/j.mineng.2019.02.018
19. Rao, M. Carbothermic Reduction of Nickeliferous Laterite Ores for Nickel Metallic iron Production in China: A Review. *JOM* Vol. 65, No. 11, 2013. DOI: 10.1007/s11837-013-0760-7.
20. Silveira, N. Red Mud from the Aluminum Industry: Production, Characteristics, and Alternative Applications in Construction Materials—A Review. (2021). *Sustainability* 2021, 13(22), 12741; https://doi.org/10.3390/su132212741
21. Sutar, H. Progress of Red Mud Utilization: An Overview. (2014). *American Chemical Science Journal*, 4(3): 255-279, 2014.
22. Subin, S. The new U.S. plan to rival China and end cornering of market in rare earth metals. (2021). *CNBC EVOLVE*. https://www.cnbc.com/2021/04/17/the-new-us-plan-to-rival-chinas-dominance-in-rare-earth-metals.html
23. U.S. Geologic Survey. Mineral Commodity Study – Iron Ore. (2022). *USGS*. https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-iron-ore.pdf
24. U.S. Geologic Survey. Mineral Commodity Study – Rare Earths. (2022). *USGS*. https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-rare-earths.pdf
25. Wang, L. Environmental impacts of scandium oxide production from rare earths tailings of Bayan Obo Mine. (2020). *Journal of Cleaner Production*. Vol 270. https://www.sciencedirect.com/science/article/pii/S0959652620325117
26. Xiao, G. Evaluation of Ship Pollutant Emissions in the Ports of Los Angeles, and Long Beach. J. *Mar. Sci. Eng.* 2022, 10, 1206. https://doi.org/10.3390/jmse10091206.
27. Yusuf, A. CO2 utilization from power plant: A comparative techno-economic assessment of soda ash production and scrubbing by monoethanolamide. (2019). *Journal of Cleaner Production*. Vol. 237. https://www.sciencedirect.com/science/article/pii/S0959652619326204?casa_token=Jwz9h-6zNq4AAAAA:dh-CRrKUa4SDHtwytqe08J1E4Nz063mXZsjPO4BoAV4EucD5kgqiHePby9L1BvTCnoE0h5tY3w