Sustainable Sourcing of Rare Earth Elements

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What Is Sustainable Sourcing?

Selection of raw materials that:

1) Provide good economic value at competitive cost
2) Meet high environmental standard
3) Conform to purchasers’ social values and standards

Tate et al (2014)
Why Is The USGS Involved?

- Approached by researchers from a European company for LCA data on REE mines
- Invited by European Commission to contribute LCA data for mining
- Ongoing efforts to integrate environmental factors into mineral resource assessments
- Mineral supply issues – environmental and regulatory risks
How Is Sustainability Assessed?

- European cooperators use LCA methods
- Initial effort for REE began with commercial LCA software
- There is no standard industrial process for REE production – an LCA required for each REE mining project
- Are there efficiencies to scale with respect to sustainability?
Reconnaissance Study REEs

- System boundary: mine face to final mineral product (LOM)
- Excludes exploration and mine construction
- Final mineral product varies from project to project – mixed REE flotation concentrate, various mixed REE leach products, separated REEs or mixtures as oxides, oxalates, carbonates, etc.
- No work yet on LCA for custom cracking and separation facilities
Reconnaissance Study REEs

- Select Sustainability Indicators
- Started with a standard list (Azapagic, 2004)
- Selected a subset based on data availability: geometallurgical, economic, process inputs, process outputs (including wastes)
- Social measures largely outside USGS capability
Reconnaissance Study REEs

- Tried to learn as much as possible about sustainability of Chinese REE production
- Studies 2 new REE mines and about 35 proposed REE mines outside of China
- Data from NI 43-101 reports (feasibility studies), CPRs, EIAs and other permitting documents
- Lots of data gaps and inconsistencies – will have to develop estimation capability
Lessons Learned

Three major determinants of REE sustainability:

- Mineral deposit type (carbonatite, alkaline-igneous rock related, etc)
- Geometallurgical variations within deposit type (grain size, optimal grind, acid consumption)
- Location (climate, distance from existing infrastructure, depth/orientation of orebody)
Carbonatite

Mountain Pass Discovery Outcrop Sample

Araxá Laterite
Alkaline Igneous Rock-Related

Bokan Mountain REE Deposit, Alaska

Dotson Vein
‘Weathered Crust’

Stewartsville, Virginia, USA

Ganzhou, South China
Heavy Mineral Sands

OSCOM Plant, India

Mineral Sands Dredge, Sierra Leone
Other Deposit Types

Paleoplacer U-REE (Elliot Lake, Ontario)

IOCG/IOA

Monazite pegmatite/dike (Steenkampskraal, South Africa)

Aluminous clay (Grand Vallée, Québec)

Metalliferous black shale (Buckton, Alberta)

Bauxite residues ("red mud")

Sedimentary phosphate
Results - Geometallurgy

- Significant variation in ore mineral grain size within and across deposit types
- Carbonatite generally finer grained than alkaline igneous rock-related deposits
- Carbonatite generally higher in grade
- Acid consumption lower for alkaline igneous rock-related deposits, highest for weathered carbonatite
Results - Economics

- Carbonatites (except Lofdal, Namibia) LREE rich – Ce in excess supply
- Some alkaline igneous rock-related deposits enriched in REEs in short supply (Y Nb Tb Dy Eu Er)
- Capital intensity highest for alkaline igneous rock-related deposits
- Significant variations in metallurgical recovery within deposit types
Results – Process Inputs

- Footprint of REE projects range from 3 to 115 m² per t TREO recovered – UG mines have a much smaller footprint than OP mines.
- Water requirements range from 10 to 3,275 m³ per t TREO recovered – lowest for projects that recycle process water.
- Diesel fuel requirements depend on mining method, strip ratio, and whether power is generated on site.
Results – Process Outputs

- Projects examined would produce between 980 to 55,000 tpy TREO
- Projects would produce up to 6,700 t waste rock and 13,300 t tailings per t TREO recovered
- Alkaline igneous rock-related deposits generally more radioactive than carbonatites
- Highest radioactivity per t TREO recovered is in heavy mineral placers
Final Thoughts

- Need a unifying metric that combines various Sustainability Indicators
- Not clear how to develop and objective metric – much subjectivity in choices of indicators and weighting of indicators
- Given common environmental standards, would cost of production be a good proxy for sustainability?