



WPI

Analysis of Novel, Sustainable Magnesium Production Process

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Why Magnesium?

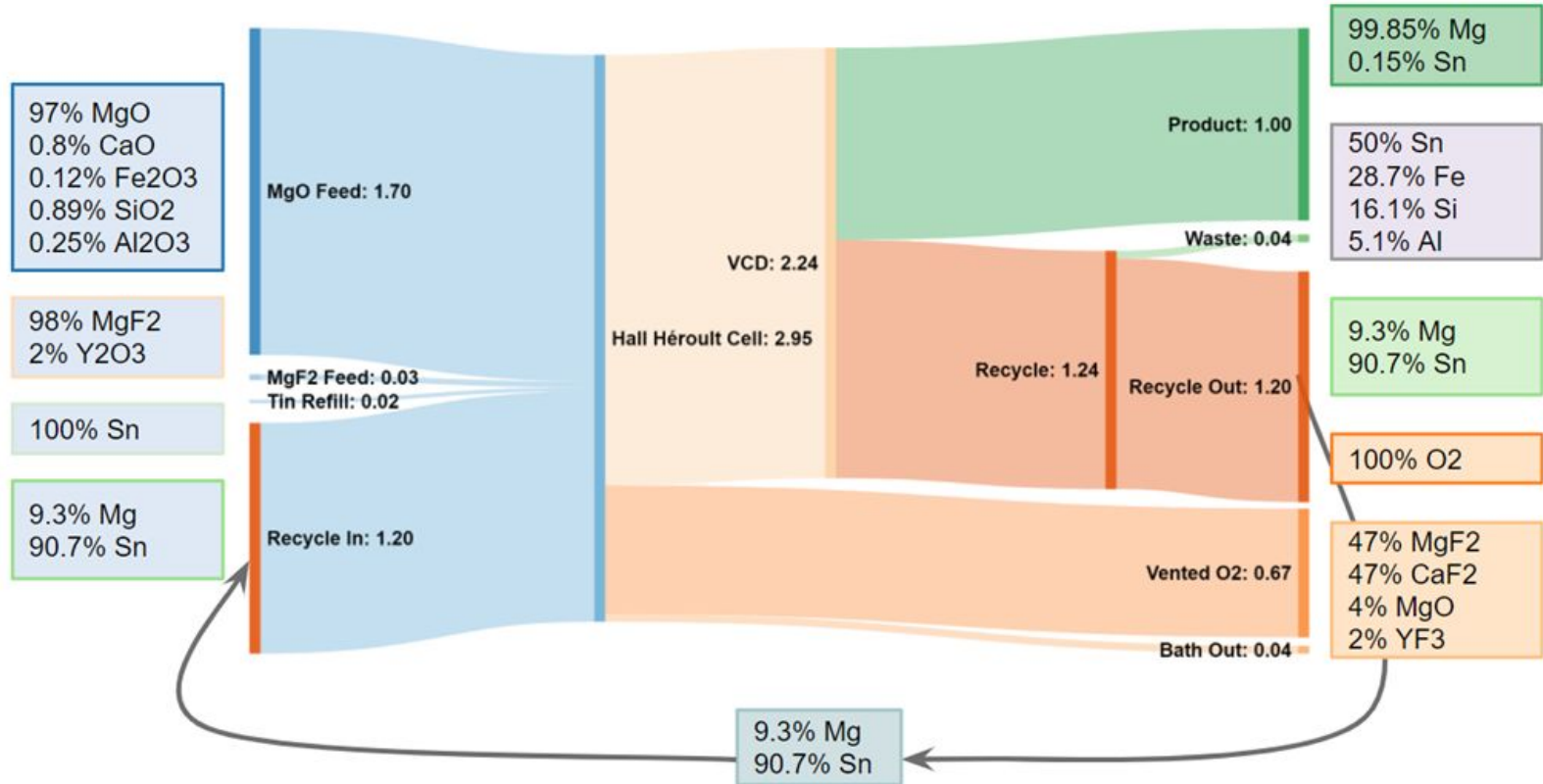
- Lightest structural metal with unique properties
- Current production processes face several challenges
 - Pidgeon process in China
 - Carbothermic process in US
- Recycling magnesium currently costly and difficult
- Novel, sustainable process

Research Goals



- Determine feasibility of process
 - Techno-Economic Analysis
- Simulate electric flux & magnetic fields
 - Industrial-scale models
- Predict environmental impact
 - Life Cycle Assessment
- Preliminary proof-of-concept experiments

Process Flow Diagram



Results & Moving Forward

- Cost to produce 1kg Mg:
\$2.20-\$3.75
 - Needs to be within 1.8 ratio of the cost of Al
 - Al currently \$2.35/kg
- Electrolysis experiment was successful
- Continue refining electrolysis cell design and current efficiencies
- Continue to develop LCA and study impact of SOM anodes
- A company has shown interest in using process in conjunction with desalination plant

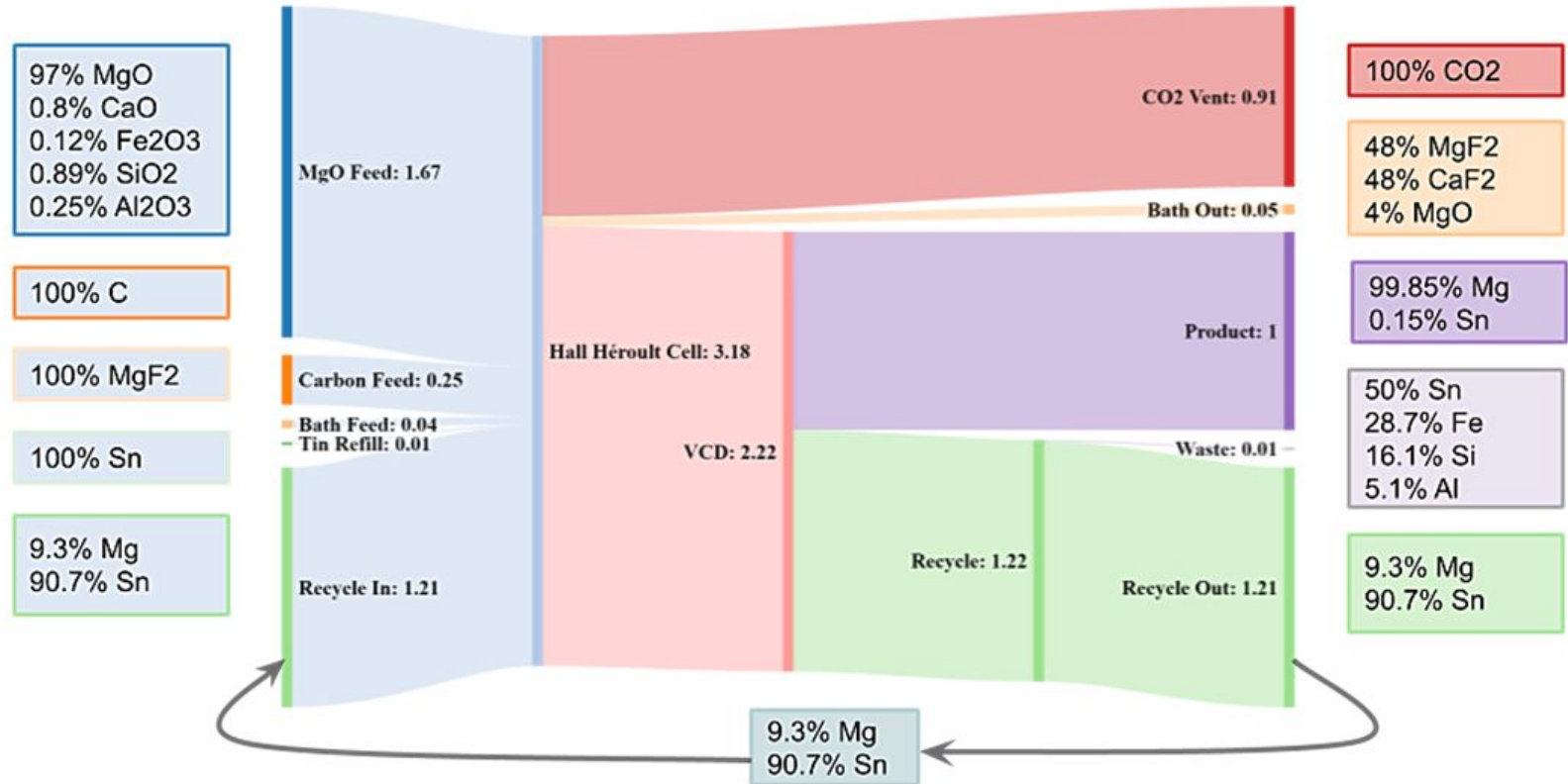
Appendix



Operating Cost Assumptions

- Operating labor: based on 600 total labor for 200 kT/yr aluminum smelter incl. cast shop → 60-90 total labor for 20 kT/yr magnesium
- Utilities: all electricity, 12-13 kWh/kg Mg
 - 9¢/kWh → \$1.08-\$1.17/kg Mg
 - 3.5¢/kWh + shipping MgO to smelter (\$35/ton MgO) → 48-52¢/kg Mg
- Other materials:
 - Most of other materials cost is tin, can likely recover some from sludge, or make it internally from tin oxide
 - Some is MgF₂ to react with CaO, might recover some from bath out
 - Carbon anodes cost \$150/T Mg, inert anodes would remove this cost - but add 2.2 kWh/kg and some cost for inert anode replacement

Material Flow - Carbon Anode

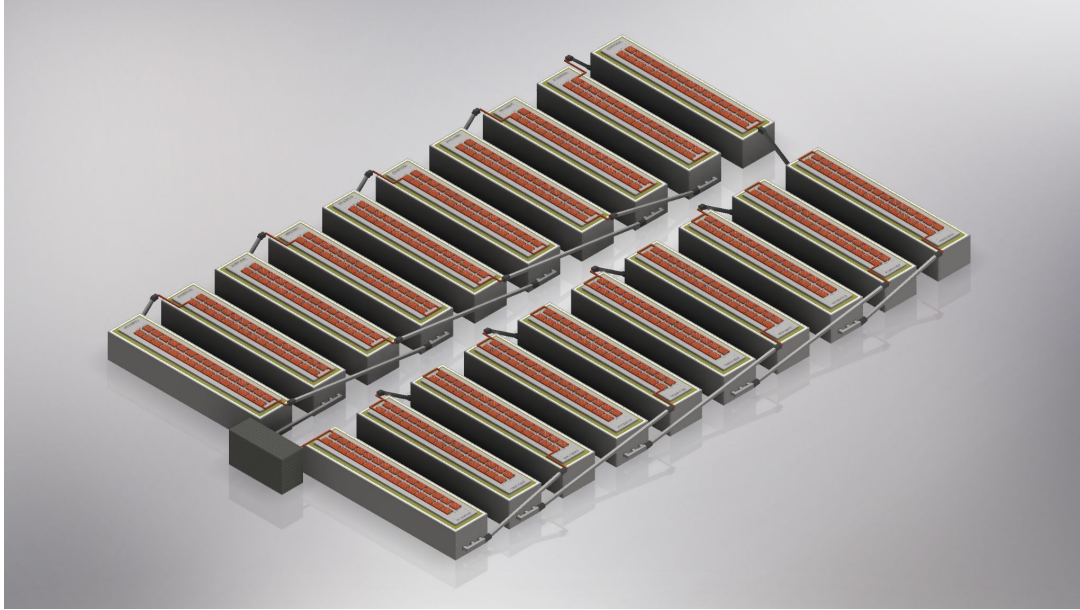


Experiment Mg/Sn Compositions

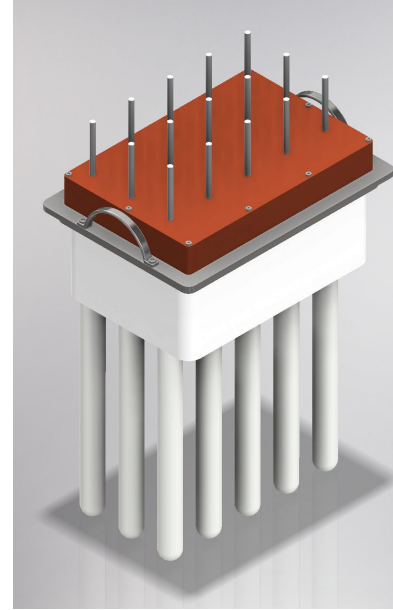
Experiment	Avg. Mg:Sn
Control (no electrolysis)	0.0001260:1
First experiment with electrolysis	0.0005554:1
Second experiment with electrolysis (more tin input, better seal, longer electrolysis)	0.0025402:1

Our experiments so far with the carbon anode have shown a substantial increase in the amount of magnesium present in the tin metal. Comparing either experiment with the control shows that the electrolysis that we have performed has increased the percentage of Mg. Comparing the first and second electrolysis experiments show that our alterations have drastically improved the quantity of magnesium present in the tin.

Industrial Scale Modeling

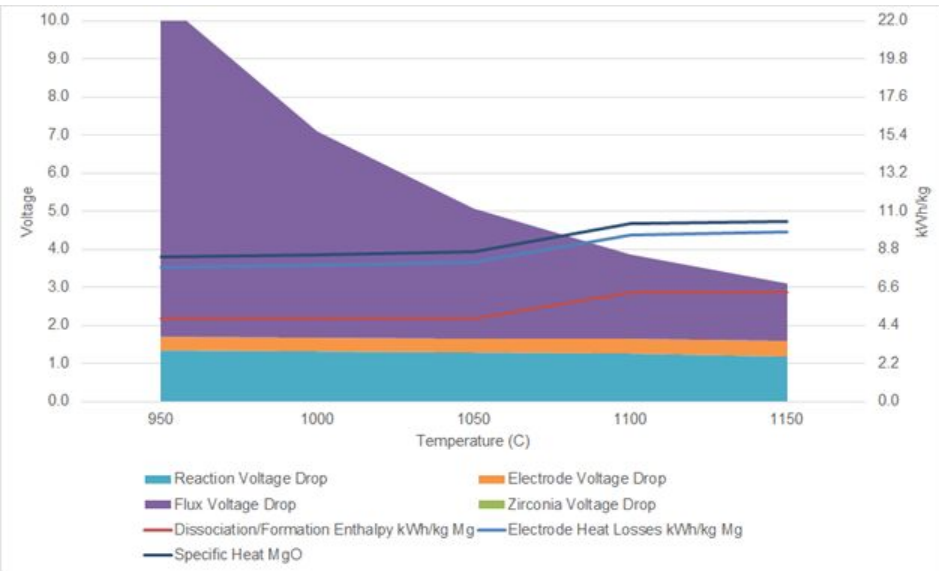


Industrial scale electrolysis plant featuring alternating junctions between individual cells to minimize magnetic fields and promote stirring.

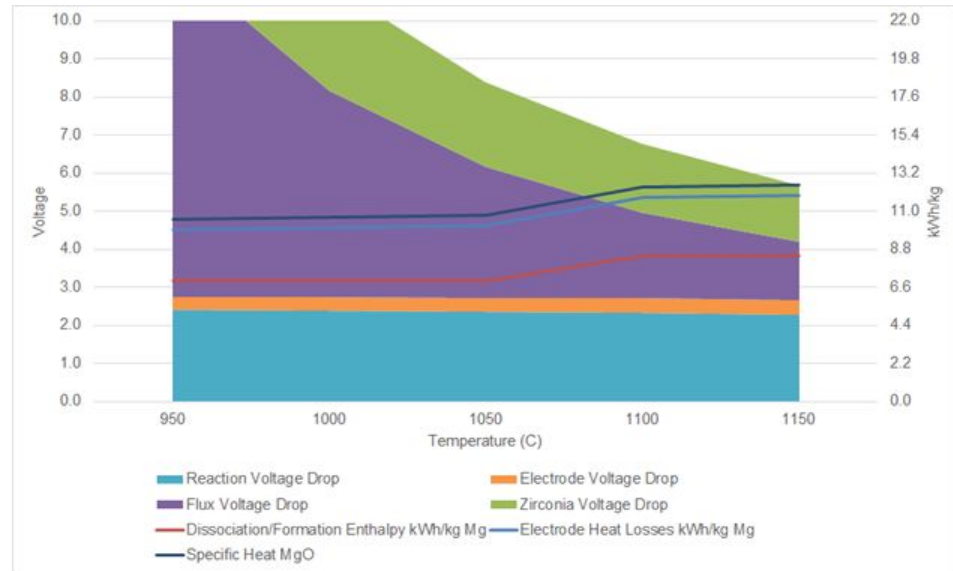


Single zirconium anode cluster, each cell contains 30 clusters of 15 anodes each.

Energy Balance



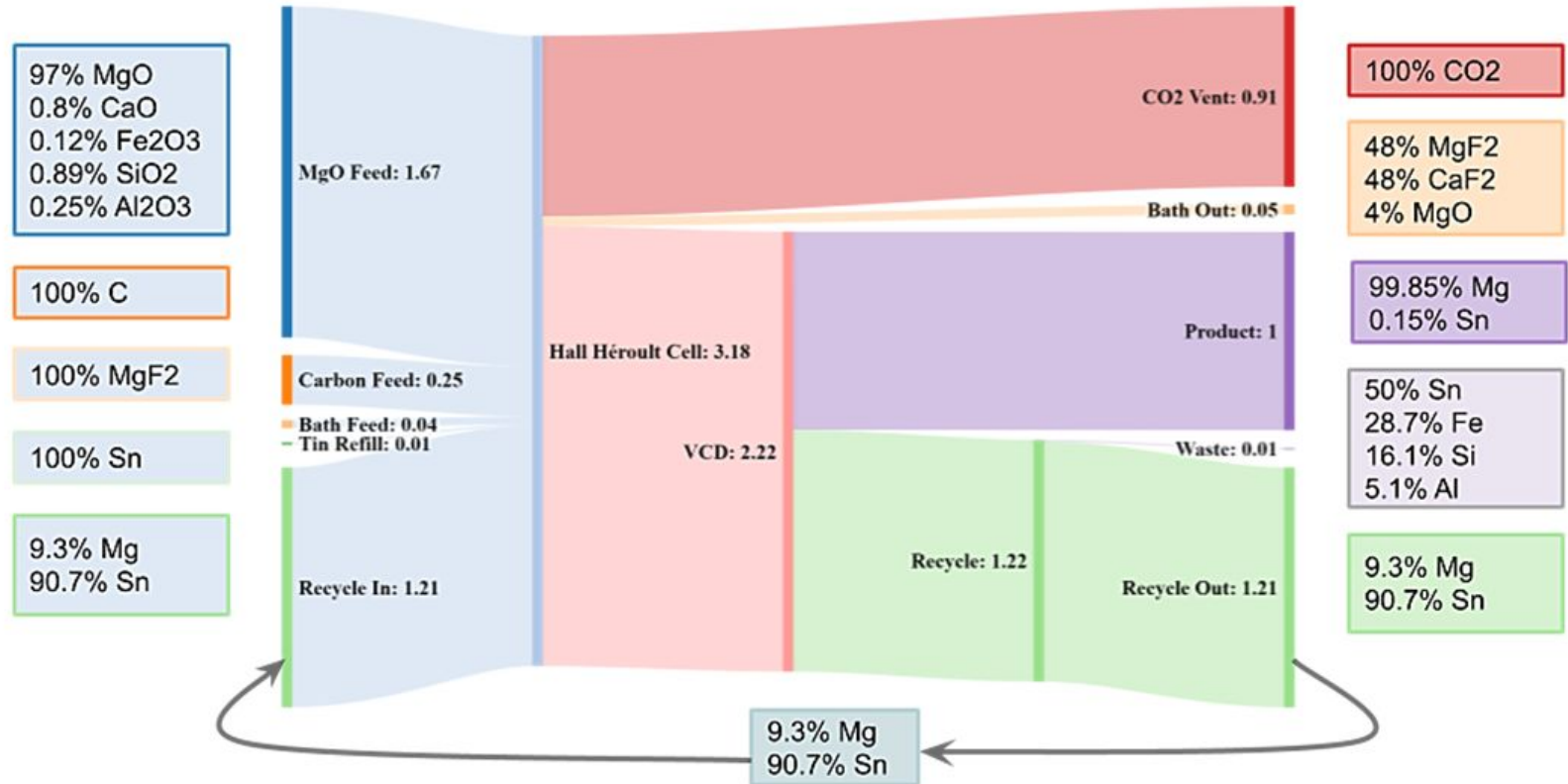
Carbon Anode



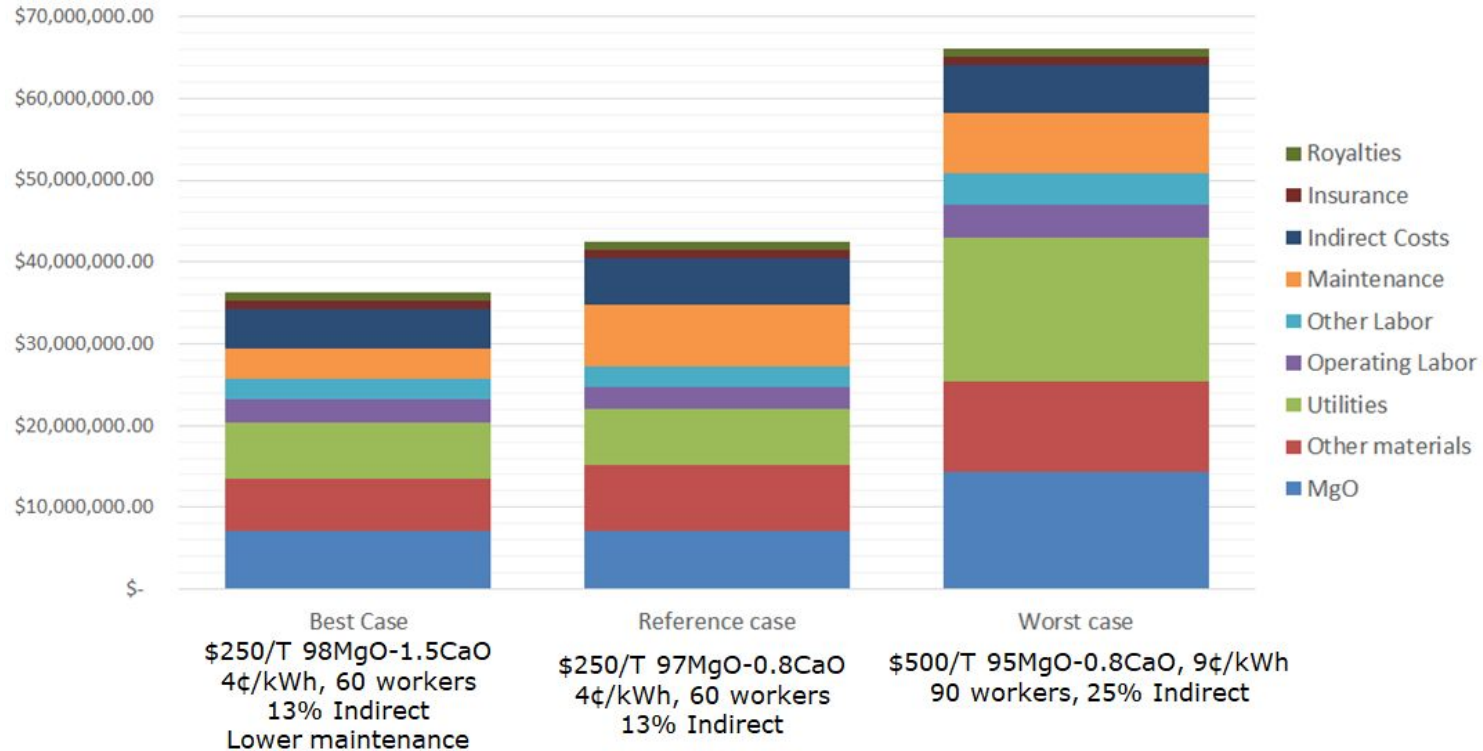
SOM Anode

- Electrolysis process takes less kWh/kg than Hall-Heroult cell with Aluminum
- SOM Anode increases energy requirement significantly

Material Flow - Carbon Anode



Operating Costs for 20kT/yr Plant



Life Cycle Assessment



- Program: OpenLCA
- Cradle to Gate Analysis
- Comparing
 - Traditional Anode vs Zirconium Anode Production
 - MgO Production Methods
- Expected Results
 - The zirconium anodes, coupled with environmentally friendly methods of MgO production, will have lowered environmental impacts