Systems Perspective

Expanding Focus to Critical Minerals

Morgan Summers & Clint Noack
Overview

• REE Overview
  • Changing markets

• Life Cycle Analysis (LCA)

• Focus on Critical Materials
  • Growth potential

• Future Work
### Domestic Demand

<table>
<thead>
<tr>
<th>Imported Product</th>
<th>Parts with REES</th>
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</thead>
<tbody>
<tr>
<td>1. Light Emitting Diodes (Modules/Lamps)</td>
<td>Modules/Lamps</td>
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<tr>
<td>2. Ceramic Capacitors</td>
<td>Capacitors</td>
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<td>3. Headphones</td>
<td>Permanent Magnets</td>
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<tr>
<td>4. Linear Fluorescent Lamps</td>
<td>Modules/Lamps</td>
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<tr>
<td>5. Mobile Phones</td>
<td>Vibration Motor, Speakers, Screen (Permanent Magnets/Phosphors)</td>
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<td>6. Laptops</td>
<td>HDD, Speakers, LED display (Permanent Magnets/Phosphors)</td>
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<tr>
<td>7. Speakers</td>
<td>Permanent Magnets</td>
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<td>8. PVC Stabilizers</td>
<td>PVC stabilizer</td>
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<tr>
<td>9. Desktop Monitors (Non Cathode Ray)</td>
<td>LED Backlight (Large Screen)</td>
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<tr>
<td>10. AC and Refrigerator Compressors</td>
<td>Magnetic Pumps</td>
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<tr>
<td>11. Finished Refrigerators</td>
<td>Magnetic Pumps</td>
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</tbody>
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Source: Adamas Intelligence

**US Imports of REEs**

COVID caused imports of REE raw materials to decrease while imports of finished goods containing REEs remained strong.

**Source:** USGS
In 2018, 93% of all passenger EVs sold used permanent magnet traction motors.

– Adamas Intelligence

Source: IEA Global EV Outlook 2020
Life Cycle Analysis

• Key tool to demonstrate the potential benefits of developing a domestic REE/CM supply chain

• Literature review on publicly available REE unit processes focusing on emissions related to the current REE industry including mining technics used, extraction processes, waste streams, along with downstream processes where available.
What’s critical when everything is “critical”? Only 23 naturally occurring elements not deemed critical by at least one country.

Synthesis of various outlooks paints a picture of diverse outcomes where we look for common ground.

Which is uncertain: Economically important sectors of the energy industry that rely on critical minerals.

Defined here as:

Find where growth is happening

How will the energy sector respond to market forces with tech?

Tech trends + Energy futures = Big, growing domestic markets that will matter in the future.
Global, unifying trends driving technology

1. Decarbonization
2. Sustainable Energy
3. Circular Economy
4. Prosumerism
5. Environmental Justice
Evaluate multi-sector impacts

Review of incumbent and emerging technology concepts in the power generation, transportation, and industrials subsectors shows the climate-driven energy transition will continue to drive demand for CM.

SCOPE OF ANALYSIS – TECHNOLOGY CONSUMERS

<table>
<thead>
<tr>
<th>Energy Sector</th>
<th>High market growth</th>
<th>High material usage</th>
<th>&quot;Pulls&quot; additional CM tech</th>
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<tbody>
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<td>Power Generation</td>
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<td>Iron/Steel</td>
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ASSESSMENT METHODOLOGY

Technology platforms that will shape 2035 CM demand.
Future Work

Market Analysis
• Continue developing an understanding of CM markets and the drivers that predict future growth
• Development of domestic resource recovery potential from conventional and unconventional sources

LCA
• Identifying the process gaps for specific feedstocks
• Assess the LCA impacts of utilizing waste coal-based feedstocks (refuse, fly ash, and AMD)
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