CRITICAL MATERIALS - THE RARE EARTHS: THE DEMISE OF AN INDUSTRY AND ITS REBOUND (!)

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Critical Materials Shortages: Opportunity for Competitive Innovation
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In 1980 China had 70% of the known Rare Earth Reserves (18 M metric tons of 26 M metric tons)

They made a deliberate effort to control the World Rare Earth Market (1970 → 2000) – successful in early 2000s

1970s: Sold Rare Earth Mineral Concentrates
1980s: Sold Mixed Rare Earth Chemical Concentrates
1990s (early): Sold Separated Rare Earth Oxides and Metals
1990s (late): Sold Magnets, Phosphors, Polishing Compounds
2000s: Sold Finished Products – Electric Motors, Computers, Batteries, LCDs, Cell Phones, etc.
MOVING UP THE VALUE CHAIN

Step 1: Sold Metals, Compounds on the World Market

Step 2: Told the non-Chinese manufacturers they would no longer sell them raw products (metals, compounds) unless they moved their factories to China

Step 3: US and World-wide producers closed up their manufacturing facilities, laid-off their employees and many moved to China

Step 4: Undercut the rest of the world’s remaining rare earth producers with low prices, even at a loss, to gain markets

Result: China controlled over 95% of the rare earths produced in the mid- to late 2000s
DEVELOPMENTS IN THE REST OF THE WORLD IN THE MID- TO LATE-2000s

**Molycorp** – only U.S. Mine, located at Mountain Pass, CA
- Developed a leak in a holding pond in 2002 and the mine was shut down
- Repaired the leak and passed all state and federal regulations to renew mining
- Out of operation for about 9 years
- Restarted mine on January 2, 2011

**Rare Earth Industry**, lead by Mark Smith of Molycorp
- Pointed out our military and energy security was in serious jeopardy

**Military Security**
- All US weapon systems depend on rare earths – especially \( \text{Nd}_2\text{Fe}_{14}\text{B} \) permanent magnets in electric motors, computers, guidance systems; phosphors for optical displays

**Energy Security**
- Electric motors and batteries, wind turbines, petroleum refining, optical displays, fluorescent lighting, oxygen and electrical sensors (automotive engines)
THE THREE PARTS OF THE RARE EARTH CRISIS

1. Mining and extraction of the rare earths from the ores to make rare earth concentrates and separated rare earths

2a. Producing rare earth intermediate products: metals, magnets, oxides, chemical compounds, phosphors, catalysts

2b. Manufacturing of rare earth containing devices and other objects: hard drives, electric motors, cell phones, CFLs and long tubes, wind turbines, sensors

3. Replacing the loss of intellectual capital
Part 1: The mining portion is basically solved, just needs time: Molycorp has been mining for nearly one year (since January 2, 2011).
Will mine ~6,000 tons in 2011; 20,000 tons in 2012 and 40,000 tons in 2013.

Lynas started mining on May 14, 2011
Mound Weld, Australia

TODAY America’s Crisis is basically parts 2 and 3
Rebuilding of rare earth industry, especially beyond mining

Smaller mining companies – may need assistance

Loan guarantees to help businesses, manufacturers (parts 2a and 2b) get started

Tax incentives (federal, state, local)

Education and training

Need to rebuild and then continuously resupply intellectual capital
<table>
<thead>
<tr>
<th>Field or Area</th>
<th>Annual College Trained Personnel Requirements</th>
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<tbody>
<tr>
<td>Exploration and evaluation of ores</td>
<td>1-2</td>
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<tr>
<td>Mining and beneficication</td>
<td>2-4</td>
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<tr>
<td>concentrates</td>
<td></td>
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<td>Separation and processing</td>
<td>4-6</td>
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<tr>
<td>mixed and individual REs; recycling</td>
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<tr>
<td>Production of primary materials</td>
<td>10-15</td>
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<tr>
<td>metals, starting chemicals, polishing compounds</td>
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<tr>
<td>Manufacturing of semi-finished products</td>
<td>15-25</td>
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<tr>
<td>magnets, materials for batteries and catalysts, alloy additives,</td>
<td></td>
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<td>phosphors</td>
<td></td>
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<tr>
<td>Original equipment manufacturers (OEM)</td>
<td>25-50</td>
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<tr>
<td>electric motors, wind turbines, MRI magnets, hard drives</td>
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<tr>
<td>cell phones, i-Pods</td>
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<tr>
<td>color TV, monitors, laser devices, CFL, long tubes</td>
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<tr>
<td>3-way catalytic converters, fuel cells</td>
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<tr>
<td>Totals</td>
<td>59-102</td>
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</tbody>
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FIELDS OF TRAINED SCIENTISTS & ENGINEERS (B.S., M.S., Ph.D., Post-Docs)

Chemistry – physical, inorganic, organic, analytical
Chemical and metallurgical engineers
Material scientists
Physical metallurgists
Ceramists
Condensed matter physicists
Electrical, mechanical, industrial engineers

Necessary Requirements:
Some knowledge of rare earth science, engineering, technology
Rare earth courses at a few major universities
(e.g. Iowa State University, Colorado School of Mines)
Distance learning
Short courses
SCIENTIFIC & ENGINEERING INFRASTRUCTURE

Training students – RESEARCH

Scholarships

Research projects funding
NSF, DOE, DoD, NIST
  single investigators or small group teams
  national laboratories and national research centers

National Research Center for Rare Earths and Energy
  • Educational institution with a strong tradition on REs
  • Link with industry and national laboratories
  • Subsidiary branches at other universities