Rare earth market overview

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Agenda

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- Supply Overview
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<td>• Typically ‘Market Strategy’ projects</td>
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<td>• We help clients evaluate potential investments and support market entry decisions</td>
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<td>• Our work is built off the foundation of Argus data and knowledge</td>
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Introduction

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Introduction
Reserves

• China dominates reserves of rare earths – close to 40pc of the global total

• Brazil and Vietnam both represent around 18pc

• Russia also has significant RE reserves – 15pc

• India, Australia and US account for 1-6pc of global reserves

• Relative abundance of rare earths in the earths crust, but mineable concentrations less common

Global Rare Earth Reserves, 2017

— USGS
Reserves

- Relative abundance of LREEs:
  - Cerium = +30mn t
  - Lanthanum = +20mn t
  - Neodymium = +15mn t

- HREEs less abundant but still not that rare:
  - Dysprosium ≈ 3mn t

- Mineable resources more the issue
• Bastnasite, Monazite and Loparite are the main cerium and light lanthanide-containing minerals

• Xenotime is the main Yttrium-containing rare earth mineral & also high in dysprosium

• Two main types of rare earth laterites (ion adsorption clays) in southern China:
  ◦ Type A (Xunwu) – V. low Ce & higher La, Nd & Pr
  ◦ Type B (Longnan) – V. high yttrium and dysprosium

Rare earth content of selected source materials

--- USGS
Rare earth refining process

- **Mine Ore**: Ores contain low concentrations of REE, with composition varying between deposit.
- **Produce Concentrate**: Milled ores produce higher concentrations of mixed REE. Difficult to transport due to volume of material, so generally processed local to the mine.
- **Produce RE Compounds**: Further processing to upgrade the material, eliminate impurities and typically produce a mixed REE concentrate. If there is a high concentration of REE within the compound then transportation is viable.
- **Produce RE Oxides**: Separation of REO through further processing. Highly resource intensive process, particularly for HREOs. Done by atomic weight, starting with cerium.
  - Oxides are most stable form of element and most widely traded.
  - Fluorides are used when oxygen would cause contamination.
- **Produce RE Metals**: Process of benefication to produce oxides, metals or magnetic powders, typically to the specifications of the customer.
- **End Use**: Material is used in production of a wide range of products.

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The eight industry sectors require different types of rare earth and options to substitute can be limited.

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<th>RE used</th>
<th>LRE/HRE</th>
<th>Substitution potential</th>
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</thead>
<tbody>
<tr>
<td>Glass</td>
<td>Cerium, Lanthanum, Praseodymium, Neodymium, Yttrium</td>
<td>LRE</td>
<td>High</td>
</tr>
<tr>
<td>Neodymium magnets</td>
<td>Neodymium, Praseodymium, Dysprosium, Gadolinium, Terbium</td>
<td>HRE/LRE</td>
<td>Low-Medium</td>
</tr>
<tr>
<td>Refinery catalysts</td>
<td>Lanthanum, Cerium</td>
<td>LRE</td>
<td>Low</td>
</tr>
<tr>
<td>Battery alloys</td>
<td>Lanthanum, Cerium, Neodymium, Praseodymium, Samarium</td>
<td>LRE</td>
<td>Between battery types</td>
</tr>
<tr>
<td>Metallurgy (excl. batteries)</td>
<td>Cerium, Lanthanum, Neodymium, Praseodymium</td>
<td>LRE</td>
<td>Medium</td>
</tr>
<tr>
<td>Phosphors</td>
<td>Yttrium, Lanthanum, Cerium, Gadolinium, Europium, Terbium</td>
<td>LRE/HRE</td>
<td>Low</td>
</tr>
<tr>
<td>Ceramics</td>
<td>Yttrium, Lanthanum, Cerium, Neodymium, Praseodymium</td>
<td>LRE</td>
<td>High</td>
</tr>
<tr>
<td>Catalytic converters</td>
<td>Cerium, Lanthanum, Neodymium, Praseodymium</td>
<td>LRE</td>
<td>Low</td>
</tr>
<tr>
<td>Other</td>
<td>Cerium, Lanthanum, Yttrium, Neodymium, Praseodymium, Samarium, Gadolinium, Other REOs</td>
<td>LRE/HRE</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Supply Overview
Gradual decline in production from 2008 to 2011/12 - Chinese controls on output and exports

Jump in production 2013/14 – reaction to higher prices

Further jump in 2015/16 – ‘illegal’ production in China (despite Molycorp closure)

Increase in 2018 – Mountain Pass?
Chinese RE mining quota by company, 2018

- Northern Rare Earth: 58%
- Southern Rare Earth: 23%
- China Minmetals: 7%
- Chinalco: 6%
- Guangdong Rare Earth: 3%
- Xiamen Tungsten: 2%

--- MIIT

Chinese RE separation quota by company, 2018

- Northern Rare Earth: 53%
- Southern Rare Earth: 14%
- Chinalco: 12%
- China Minmetals: 10%
- Guangdong Rare Earth: 4%

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Demand Overview
Rare Earth Demand

- Steady growth in RE demand in volume terms:
  - ≈132,000t REO in 2010 to ≈165,000t REO in 2018 (CAGR = 3 pc/yr)

- Volume growth is steady supported by:
  - Traditional industries for LREEs (e.g. glass, catalysts 7 ceramics)
  - Rapidly expanding industries such as the wind energy, battery-electric vehicle and consumer electronics industries

- REO demand has declined in the battery alloy and lighting phosphor industries due to increasing competition from non-RE-based technologies
Rare Earth Demand

Rare earth consumption by application, 2018 (volume & value)

**Volume**
- Magnets: 20%
- Batteries: 7%
- Catalysts: 7%
- Glass industry: 6%
- Phosphors: 4%
- Ceramics: 4%
- Metal alloys: 26%
- Others: 19%

**Value**
- Catalyts: 65%
- Ceramics: 5%
- Glass: 4%
- Metal alloys: 4%
- Magnets: 7%
- Batteries: 4%
- Phosphors: 4%
- Others: 5%

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Rare Earth Demand

Rare earth consumption by element, 2018 (volume & value)

Volume

Cerium: 35%
Lanthanum: 18%
Neodymium: 6%
Praseodymium: 1%
Dysprosium: 1%
Gadolinium: 0%
Europium: 0%
Terbium: 7%
Samarium: 2%
Yttrium: 0%

Value

Cerium: 49%
Lanthanum: 13%
Neodymium: 20%
Praseodymium: 4%
Dysprosium: 4%
Gadolinium: 0%
Europium: 4%
Terbium: 2%
Samarium: 1%
Yttrium: 6%

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Chinese rare earths exports, 2009-18

- Chinese exports dropped dramatically 2009-2011 (export restrictions, mainly to Japan):
  - Oxides ≈ 25.4mn kg to 8.0mn kg
  - Metal ≈ 3.3mn kg to 1.3mn kg

- Strong growth in exports since 2012 (relaxing of export restrictions & removal of export quota/taxes in 2015):
  - Oxides ≈ 8.0mn kg to 38.4mn kg
  - Metal ≈ 1.3mn kg to 5.5mn kg

- Forecast for 2018:
  - Oxides ≈ drop to 33.7mn kg
  - Metal ≈ slight rise to 5.7mn kg

Notes: * - right-hand axis
— Official customs data
Chinese REO exports by destination, 2018

- Official customs statistics

Chinese RE metal exports by destination, 2018

- Official customs statistics
Historic Rare Earths Pricing

Annual average Chinese fob rare earth oxide prices, 2009-18

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Historic Rare Earths Pricing

Monthly average Chinese fob rare earth oxide prices, 2017-19

Notes: * - right-hand axis

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Future Dynamics/Conclusions
New projects that could affect supply

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<tr>
<th>Company</th>
<th>Mine</th>
<th>Country</th>
<th>Stage of Development</th>
<th>TREO (mn t)</th>
<th>Production (tREO/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainbow Rare Earths</td>
<td>Gakara</td>
<td>Burundi</td>
<td>575t REO concentrate exported by June 2018 (Sep 18)</td>
<td>10.00</td>
<td>0.14</td>
</tr>
<tr>
<td>Northern Minerals</td>
<td>Browns Range</td>
<td>Australia</td>
<td>Pilot plant commissioned; 2,578kg shipment to China (Dec 18)</td>
<td>9.00</td>
<td>0.06</td>
</tr>
<tr>
<td>Hastings Technology Metals</td>
<td>Yangibana</td>
<td>Australia</td>
<td>50pc increase in ore reserves; 5th offtake agreement (Nov 18)</td>
<td>17.02</td>
<td>0.22</td>
</tr>
<tr>
<td>Arafura Resources</td>
<td>Nolans Bore</td>
<td>Australia</td>
<td>DFS due end 2018; pilot plant produced Nd-Pr oxide (Dec 18)</td>
<td>56.00</td>
<td>1.46</td>
</tr>
<tr>
<td>Greenland Minerals and Energy</td>
<td>Kvanefjeld</td>
<td>Greenland</td>
<td>DFS completed; deal signed with Shenghe Resource (Aug 18)</td>
<td>956.00</td>
<td>10.30</td>
</tr>
<tr>
<td>Mkango Resources</td>
<td>Songwe</td>
<td>Malawi</td>
<td>Feasibility study due in 2019; resource update 1Q 19 (Dec 18)</td>
<td>31.80</td>
<td>0.47</td>
</tr>
<tr>
<td>Peak Resources</td>
<td>Nguala</td>
<td>Tanzania</td>
<td>PFS completed in 2014; awaiting mining licence (Aug 2018)</td>
<td>214.40</td>
<td>4.60</td>
</tr>
<tr>
<td>Steenkampskaal Holdings</td>
<td>Steenkampskaal</td>
<td>South Africa</td>
<td>Raising finance for bankable feasibility study (Dec 18)</td>
<td>0.61</td>
<td>0.09</td>
</tr>
<tr>
<td>Alkane Resources</td>
<td>Dubbo Zirconia</td>
<td>Australia</td>
<td>Detailed engineering assessment ongoing</td>
<td>73.20</td>
<td>0.70</td>
</tr>
<tr>
<td>Avalon Advanced Materials</td>
<td>Nechalacho</td>
<td>Canada</td>
<td>Definitive feasibility study completed (October 2013)</td>
<td>269.40</td>
<td>3.90</td>
</tr>
<tr>
<td>Commerce Resources</td>
<td>Ashram</td>
<td>Canada</td>
<td>Pre-feasibility study ongoing</td>
<td>249.60</td>
<td>4.70</td>
</tr>
<tr>
<td>Galileo Resources</td>
<td>Glenover (JV)</td>
<td>South Africa</td>
<td>No longer focused on REE at the site (July 2017)</td>
<td>28.90</td>
<td>0.40</td>
</tr>
<tr>
<td>Geomega Resources</td>
<td>Montviei</td>
<td>Canada</td>
<td>NI 43-101 resource estimate completed (June 2015)</td>
<td>250.60</td>
<td>3.50</td>
</tr>
<tr>
<td>Matamec Exploration</td>
<td>Kipawa</td>
<td>Canada</td>
<td>Definitive feasibility study completed (October 2013)</td>
<td>19.70</td>
<td>0.08</td>
</tr>
<tr>
<td>Namibian Critical Metals</td>
<td>Loftdal</td>
<td>Namibia</td>
<td>Partnership agreement with Gecko Namibia (Nov 2017)</td>
<td>6.20</td>
<td>0.02</td>
</tr>
<tr>
<td>Pele Mountain Resources</td>
<td>Eco Ridge</td>
<td>Canada</td>
<td>Site sold. Now focusing on lithium reserves (July 2017)</td>
<td>59.30</td>
<td>0.09</td>
</tr>
<tr>
<td>Quest Rare Minerals</td>
<td>Strange Lake</td>
<td>Canada</td>
<td>No active work at/on site (April 2014)</td>
<td>492.50</td>
<td>4.43</td>
</tr>
<tr>
<td>Rare Element Resources</td>
<td>Bear Lodge</td>
<td>US</td>
<td>Pre-feasibility study completed (August 2015)</td>
<td>18.00</td>
<td>0.50</td>
</tr>
<tr>
<td>Rwenzori Rare Metals</td>
<td>Makuutu</td>
<td>Uganda</td>
<td>Exploration and PFS ongoing (Feb 2018)</td>
<td>&gt;300</td>
<td>0.21</td>
</tr>
<tr>
<td>Search Minerals</td>
<td>Foxtrot</td>
<td>Canada</td>
<td>Feasibility study ongoing (Oct 17)</td>
<td>9.35</td>
<td>0.01</td>
</tr>
<tr>
<td>Hudson Resources</td>
<td>Sarfartoq</td>
<td>Greenland</td>
<td>Preliminary economic assessment completed (November 2011)</td>
<td>343.00</td>
<td>0.21</td>
</tr>
<tr>
<td>Ucore Rare Metals</td>
<td>Bokan Mountain</td>
<td>US</td>
<td>No longer developing Bokan Mountain</td>
<td>5.20</td>
<td>0.03</td>
</tr>
</tbody>
</table>
World Rare Earth Production Outlook

- Declining to 2021 (Chinese government targeting 140,000t REO in 2021) – mitigated by some production from new projects
- Moderate growth to 2025 - new projects and growth in China
- Slow growth after 2025
Rare Earth Demand

Rare earth consumption by application, 2028 (volume & value)

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Price Forecasts

Nd price forecast

Y price forecast

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Future risks

- Supply risks
  - Chinese market dominance (changes in policy, protectionism, adding value downstream)
  - Stockpiles

- Downstream risks
  - Technological change (competing technologies e.g. batteries for EVs etc.)
  - Substitution risk (depends on application and product)

- Price risk (potential price volatility, price spikes)
  - Likelihood of supply squeeze leading to price rises?
  - Growing demand in certain sectors could push up prices for certain REEs (e.g. magnet materials?)
Conclusions

• China still keen to control production, reduce ‘illegal’ mining and add value to rare earth resources (ambitious target to reduce production to 140,000t by 2020/21)

• Success of new projects dependent on Chinese cut in output and sustained price rise (mix of elements also important)

• Magnet sector key to growth in rare earths demand (EVs and clean energy)
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