Rare Earth Materials

China’s Role and Emerging Sources

Date: February 24, 2011

Presented By: TBD

To: Rare Earth Roundtable
China supplies nearly all rare earth materials to the world and is aggressively pursuing strategies to maintain and expand control as a cornerstone of their economic development.

A major increase in the demand for rare earth materials is anticipated as China and India industrialize rapidly, even beyond what China can supply.

Rare earth materials are vital for many more consumer, industrial, and military applications than is generally recognized.

China is restricting exports of certain rare earths for their own use, raising concerns about supply stability to the U.S., EU, and Japan.

China is pursuing a forcing strategy -- moving from supply of raw materials to producing the higher value/critical end products.
Historical Production

Global Production of Rare Earth Oxides, 1950 – 2000

USGS Fact Sheet 087-02
2002

Production, kt


Monazite-placer era
Mountain Pass era
Chinese era

Total
China
USA
Other

Ref [22. p. 2]
Supply and Demand

Rare Earth Metals
Supply and Demand

2004
92 GLOBAL DEMAND
35 CHINESE DEMAND

2008
124 GLOBAL DEMAND
74 CHINESE DEMAND

2014 (PROJECTED)
180 GLOBAL DEMAND
117.5 CHINESE DEMAND

Sources: NGS, U.S. Geological Survey

Ref [16, p. 80]
### Table 2. Rare Earth Elements: World Production and Reserves—2009

<table>
<thead>
<tr>
<th>Country</th>
<th>Mine Production (metric tons)</th>
<th>% of total</th>
<th>Reserves (million metric tons)</th>
<th>% of total</th>
<th>Reserve Base (million metric tons)</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>none</td>
<td></td>
<td>13.0</td>
<td>13</td>
<td>14.0</td>
<td>9.3</td>
</tr>
<tr>
<td>China</td>
<td>120,000</td>
<td>97</td>
<td>36.0</td>
<td>36</td>
<td>89.0</td>
<td>59.3</td>
</tr>
<tr>
<td>Russia</td>
<td></td>
<td></td>
<td>19.0</td>
<td>19</td>
<td>21.0</td>
<td>14</td>
</tr>
<tr>
<td>(and other former Soviet Union countries)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td></td>
<td></td>
<td>5.4</td>
<td>5</td>
<td>5.8</td>
<td>3.9</td>
</tr>
<tr>
<td>India</td>
<td>2,700</td>
<td>2</td>
<td>3.1</td>
<td>3</td>
<td>1.3</td>
<td>1</td>
</tr>
<tr>
<td>Brazil</td>
<td>650</td>
<td>small</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malaysia</td>
<td>380</td>
<td>small</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>270</td>
<td></td>
<td>22.0</td>
<td>22</td>
<td>23</td>
<td>12.5</td>
</tr>
<tr>
<td>Total</td>
<td>124,000</td>
<td>99.0</td>
<td>154</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Ref [8, p. 9]
Summary of Situation

- Competition for rare earth resources will present many challenges to companies/governments in industrialized nations and additional pressure to move manufacturing to emerging industrial nations.

- Molycorp is restarting rare earth mining operations at Mountain Pass, CA, but production will not prevent potential shortfalls in supply, at least in the near to mid term. Mountain Pass ore may not provide critical heavy rare earths such as dysprosium and terbium.

- Other mines/sources planned in Canada and Australia may take 7-10 years to develop, even without China price control measures.
1992 - Chinese leader Deng Xiaoping made his famous proclamation, “There is oil in the Middle East; there is rare earth in China,”

1992 - Chinese State Council approved the establishment of the Baotou Rare Earth Hi-Tech Industrial Development Zone. Seven years later, President Jiang Zemin wrote, “Improve the development and application of rare earth, and change the resource advantage into economic superiority.”

Xu Guangxian, “Father of China Rare Earth Chemistry”

“China should squeeze the world...its rare earth supply.”

[Ref 13]
State-run ("State-Key") labs in China:

1. **Rare Earth Materials Chemistry and Applications**, which has focused on rare earth separation techniques and is affiliated with [Peking University](#).

2. **Rare Earth Resource Utilization**, which is associated with the [Changchun Institute of Applied Chemistry](#).

3. Additional labs concentrating on rare earth elements include the [Baotou Research Institute of Rare Earths](#), the largest rare earth research institution in the world, established in 1963, and the General Research Institute for Nonferrous Metals established in 1952.
The Baiyunebo (Bayan Obo) area is the world’s largest concentration of Rare Earth Elements (REE) – essential ingredients in products ranging from automobile catalytic converters to computer screens and electric motors.
A laborer works at the site of a rare earth metals mine at Nancheng county, Jiangxi province.
China Rare Earth Mining
The rare earth metal lanthanum is poured into molds at the Jinyuan smelting workshop near the town of Damao in China.

Inside the Baotou Xijun Rare Earth refinery in Baotou, where neodymium, essential in new wind turbine magnets, is processed.
One Ton Rare Earths

9,600-12,000 cubic meters waste gas
- Fluorine - 8.5 kg
- Hydrofluoric acid
- Sulfur dioxide
- Sulfuric acid

75 cubic meters acidic wastewater
1 ton radioactive waste residue containing water
2,000 tons mine tailings, often containing thorium

6-mile-wide lake of toxic waste at Baotou, China, which as been dumped by the rare earth processing plants in the background

Total of 10 million tons wastewater discharged per year, mostly untreated
Maritime Incident – 7 Sept 2010

Disputed islands

Islands claimed by China and Taiwan, under Japanese control
Named Senkaku in Japanese, Diaoyu in Chinese

Sources: Global Security/EIA

EWI
Joining Innovation
Molycorp resuming rare earth mining in 2011; newly announced Phase 2 expansion plans expect to produce up to 40,000 metric tons by the end of 2013.
Figure 6. Proportions of individual REE in two representative ores: bastnäsite, dominated by La, Ce, and Nd, with Eu through Lu plus Y totaling only 0.4%; and lateritic ion-adsorption ore, Y-dominated. Dark blue and light blue sectors represent lanthanides of even and odd atomic number, respectively (see figs. 2, 3). Yttrium is indicated by green.
Great Western Minerals Group (GWMG) of Canada and Avalon Rare Metals have deposits with an estimated high content (1%-2%) of heavy rare earth elements (dysprosium and terbium). GWMG owns a magnet alloy producer in the U.K.
Arafura Resources Ltd. is in talks to sell rare earths to Japan from its 1 billion Australian dollar (US$996 million) Nolans project. East China Exploration & Development Bureau holds a 16.7% stake in Arafura.

The Lynas Corp., based in Australia, has immediate potential for light rare earths development. Japan’s Sojitz Corp. says it will partner with Lynas Corp. to supply rare earth metals to Japan.

There is potential to reopen the rare earth mine Steenkampskraal in South Africa. An agreement between GWMG and Rare Earth Extraction Co. Ltd. of Stellenbosch to develop the mine is in progress.
## Estimated Production

### Rare Earth Supply by Element: Production Sources and Volume (tonnes/yr)

<table>
<thead>
<tr>
<th>Element</th>
<th>Estimated 2010 Production</th>
<th>Assumed Additional Production by 2015</th>
<th>Total Additional Production by 2015</th>
<th>Estimated 2015 Production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mountain Pass (USA)</td>
<td>Mt. Weld (Australia)</td>
<td>Nolans Bore (Australia)</td>
<td>Hoidas Lake (Canada)</td>
</tr>
<tr>
<td>Lanthanum</td>
<td>33,887</td>
<td>6,640</td>
<td>3,840</td>
<td>2,000</td>
</tr>
<tr>
<td>Cerium</td>
<td>49,935</td>
<td>9,820</td>
<td>6,855</td>
<td>4,820</td>
</tr>
<tr>
<td>Praseodymium</td>
<td>6,292</td>
<td>860</td>
<td>810</td>
<td>590</td>
</tr>
<tr>
<td>Neodymium</td>
<td>21,307</td>
<td>2,400</td>
<td>2,790</td>
<td>2,150</td>
</tr>
<tr>
<td>Samarium</td>
<td>2,666</td>
<td>160</td>
<td>360</td>
<td>240</td>
</tr>
<tr>
<td>Europium</td>
<td>592</td>
<td>20</td>
<td>90</td>
<td>40</td>
</tr>
<tr>
<td>Gadolinium</td>
<td>2,257</td>
<td>40</td>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td>Terbium</td>
<td>252</td>
<td>15</td>
<td>10</td>
<td>90</td>
</tr>
<tr>
<td>Dysprosium</td>
<td>1,377</td>
<td>30</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>Yttrium</td>
<td>8,750</td>
<td>20</td>
<td>60</td>
<td>370</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>127,315</strong></td>
<td><strong>19,960</strong></td>
<td><strong>15,000</strong></td>
<td><strong>9,980</strong></td>
</tr>
</tbody>
</table>

Ref [6, p.73]
Global RE Projects

Selected rare earth projects outside China


Ref [6, p.74]
Since the early 1980s, EWI has helped manufacturers in the energy, defense, transportation, construction, and consumer goods industries improve their productivity, time to market, and profitability through innovative materials joining and allied technologies. Today, we also operate a variety of centers and consortia to advance U.S. manufacturing through public/private cooperation.

- **Introduction – The Importance of Rare Earth Materials and Uses by Element**
- **Key Industrial Uses**
- **Key Military Uses**
- **China’s Role and Emerging Sources**
- **Opportunities and Needs**