Application of rare earths in consumer electronics and challenges for recycling

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- Rare earth elements
- Global production and reserves
- Environmental aspects of rare earth during mining and processing
- Rare earths used in consumer electronics
- Developing a recycling scheme
- Conclusions
Rare Earth Elements (REEs)

LREE: lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), and scandium (Sc)

HREE: yttrium (Y), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), lutetium (Lu)
Global production and reserves

- Global production in 2010: 133 600 t
- Reserves according to USGS: 110 000 000 t (factor 823)

(reserve which can be economically extracted)

World Mine production in 2010 (USGS 2011). REO: rare earth oxide

<table>
<thead>
<tr>
<th>Country</th>
<th>t REO</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>130 000</td>
<td>97.3%</td>
</tr>
<tr>
<td>Brazil</td>
<td>550</td>
<td>0.4%</td>
</tr>
<tr>
<td>India</td>
<td>2 700</td>
<td>2.0%</td>
</tr>
<tr>
<td>Malaysia</td>
<td>350</td>
<td>0.3%</td>
</tr>
<tr>
<td>World Total*</td>
<td>133 600</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

* without 20 000 t REO illegal mining

Rare earth reserves by countries (USGS 2011)
Global demand and development of the demand

2008

- Phosphors, Luminescence: 9,000 t (~7%)
- Metal alloys / batteries: 17,000 – 23,000 t (~18%)
- Catalysts: 20,000 – 25,000 t (~20%)
- Magnets: 21,000 – 27,000 t (~20%)
- Glass, Polishing, Ceramics: 33,000 – 42,000 t (~30%)
- Others: 3,000 t (~5%)

Unit: t REO per year

Source: Compiled by Oeko-Institut from the sources Jefferies 2010, Oakdene Hollins 2010, Kingsnorth 2010, GWMG 2010, BGR 2009 and Lynas 2010
### Rare earths used in consumer electronics

<table>
<thead>
<tr>
<th>Products</th>
<th>Rare earth/Components</th>
<th>Amount</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable-frequency air conditioning</td>
<td>NdFeB</td>
<td>100-200</td>
<td>g/unit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>250</td>
<td>g/unit</td>
</tr>
<tr>
<td>DVD Player/DVD ROM/Driver</td>
<td>NdFeB</td>
<td>5</td>
<td>g/unit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>500</td>
<td>g/unit</td>
</tr>
<tr>
<td>E-Bike</td>
<td>NdFeB</td>
<td>15</td>
<td>g/unit</td>
</tr>
<tr>
<td>Hard disc drives (HDD)</td>
<td>NdFeB</td>
<td>22</td>
<td>g/unit</td>
</tr>
<tr>
<td>Loudspeaker</td>
<td>Magnet</td>
<td>153</td>
<td>g/unit</td>
</tr>
<tr>
<td>Mobil phone</td>
<td>NdFeB</td>
<td>50</td>
<td>g/unit</td>
</tr>
<tr>
<td>Mobil phone</td>
<td>Permanent magnet</td>
<td>5</td>
<td>g/unit</td>
</tr>
<tr>
<td>Laptop</td>
<td>light phosphors</td>
<td>0.006</td>
<td>g/unit</td>
</tr>
<tr>
<td>LCD TV</td>
<td>light phosphors</td>
<td>0.05-0.6</td>
<td>g/unit</td>
</tr>
<tr>
<td>Plasma TV</td>
<td>light phosphors</td>
<td>4.5-6</td>
<td>g/unit</td>
</tr>
<tr>
<td>LCD Display</td>
<td>light phosphors</td>
<td>1.5-2.5</td>
<td>g/unit</td>
</tr>
<tr>
<td>fluorescent lamp (market average)</td>
<td>Lanthanum</td>
<td>0.35</td>
<td>g/unit</td>
</tr>
<tr>
<td></td>
<td>Cerium</td>
<td>0.46</td>
<td>g/unit</td>
</tr>
<tr>
<td></td>
<td>Europium</td>
<td>0.20</td>
<td>g/unit</td>
</tr>
<tr>
<td></td>
<td>Terbium</td>
<td>0.19</td>
<td>g/unit</td>
</tr>
<tr>
<td></td>
<td>Yttrium</td>
<td>2.87</td>
<td>g/unit</td>
</tr>
</tbody>
</table>

Example: NdFeB: 15g/unit
HDD shipment in 2010: 651 million

$9765t \text{NdFeB} \approx 3039t \text{REO}$

$\Rightarrow 13\%$ of global demand of rare earth for magnets
Global magnet production

- **RE Mining & Concentration**: 97% in China
- **Separation of Ores into Oxides**: 97% in China
- **Refining of Oxides to Metals**: almost 100% in China
- **Forming Metals into Magnet Alloy Powders**: 75 - 80% in China, 20 - 25% in Japan
- **NdFeB Magnet Manufacturing**: 75 - 80% in China, 17 - 25% in Japan, 3 - 5% in Europe
Energy efficient lighting

- Most new energy efficient lighting systems contain rare earths (compact fluorescent lamps, LED, plasma displays, LCD displays)

- High growth rates due to the ban on classic incandescent bulbs, dissemination of LEDs and shift to plasma and LCD displays

- Substitutions are rare. R & D required for alternative phosphors with high efficiency and high light quality
Development of prices

Light rare earth elements

Heavy rare earth elements

- Neodymium Oxide
- Cerium Oxide
- Lanthanum Oxide

- Europium Oxide
- Terbium Oxide
- Dysprosium Oxide
Risks of REE mining without Environmental Protection Systems

- **Waste rock storage**
- **Mining** (< 1-10% REO)
  - **Milling**
  - **Floatation** (~60% REO)
  - **Tailings:** (impoundment areas or stockpiles)
  - **Further processing**

Ores with low concentration

Concentrate
Advantages of recycling

- Secondary REE potential in Europe.
- Lower dependency on foreign material supply.
- Build-up of know-how on rare earth processing.
- No radioactive waste in processing.
- Environmental benefits regarding air emissions, groundwater protection, acidification, eutrophication and climate protection.
# Developing a recycling scheme

<table>
<thead>
<tr>
<th>Basic research</th>
<th>Identification of stakeholders</th>
<th>European Material Flow Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>European Competence Network on Rare Earth</td>
<td>Identification of initial products to be recycled</td>
</tr>
<tr>
<td></td>
<td>Installation of Pilot Plants for Recycling / R&amp;D</td>
<td>Development of Pre-treatment &amp; Collection Schemes</td>
</tr>
<tr>
<td></td>
<td>Financial support</td>
<td>Improvement of legal framework in EU</td>
</tr>
<tr>
<td></td>
<td>Implementation of large scale collection and recycling for initial products</td>
<td>Promotion of re-use</td>
</tr>
</tbody>
</table>
Promotion of sustainable mining

Green technologies call for “green metals”

- There are manifold initiatives for sustainable mining.
- Among them are certification schemes addressing different problems:
  - Environmental, small-scale mining, safety issues, human rights.
- Increasing interest in politics and industry on certified minerals
- Today’s mining companies could be interested in certification schemes or similar co-operations in order to highlight their environmental efforts.
- The Analytical Fingerprint is a control instrument if other control mechanism fail.
Conclusions

- Identification of REE with high relevance: Dysprosium; Terbium; Yttrium; Lanthanum; Neodymium; Europium; Praseodymium
  - potential shortages in the short-term
  - important role in Green Technologies
- Rare Earth Mining and Processing shows high environmental risks → sustainable mining initiatives like certification schemes should be integrated into an environmentally sound strategy.
- R & D needed for all applications concerning
  - avoidance / substitution
  - higher material efficiency
  - recycling
Thank you for your attention!

The work which led to the results presented here was financed by: the Greens/European Free Alliance in the European Parliament.

More detailed information can be found on the following websites:
www.oeko.de
www.resourcefever.org