The Rare Earth Elements in the European context

“ASTER – REE Systemic analysis – Flows and stocks”

A project co-funded by ANR, the French National Research Agency

Project closing Conference

Dr. Patrice Christmann
p.christmann@brgm.fr
Presentation outline

1. Reminder on Rare Earth Elements
2. The Rare Earth industry in 2015
3. A European perspective
4. Europe’s response to the REE challenges
5. Conclusions: the end of the Chinese monopoly?
1 – REMINDER ON RARE EARTH ELEMENTS
A group of 17, 16, or 15 elements?

<table>
<thead>
<tr>
<th>IA</th>
<th>IIA</th>
<th>IIIB</th>
<th>IVB</th>
<th>VIB</th>
<th>VIIB</th>
<th>VIIIB</th>
<th>IB</th>
<th>IIB</th>
<th>IIIA</th>
<th>IVA</th>
<th>VA</th>
<th>VIA</th>
<th>VIIA</th>
<th>VIA</th>
<th>VIIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>He</td>
<td>Li</td>
<td>Be</td>
<td>B</td>
<td>C</td>
<td>N</td>
<td>O</td>
<td>F</td>
<td>Ne</td>
<td>Na</td>
<td>Mg</td>
<td>Al</td>
<td>Si</td>
<td>P</td>
<td>S</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>C</td>
<td>Hg</td>
<td>H</td>
<td>Solid</td>
<td>Hg</td>
<td>Liquid</td>
<td>Hg</td>
<td>Gas</td>
<td>Hg</td>
<td>Unknown</td>
<td>Hg</td>
<td>Unknown</td>
<td>Hg</td>
<td>Unknown</td>
<td>Hg</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

**4f block - Ln**

**5f block - An**

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.


Here we consider: 14 lanthanides + Y (15 elements!)
A group of 15 elements splitted into light and heavy REE!

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Y(39)</td>
<td>21</td>
<td>+3</td>
<td>no color</td>
<td>4d^5s^1</td>
<td>180</td>
<td>103</td>
<td>88.9</td>
<td>0.003</td>
<td>3611</td>
<td>1795</td>
<td>4469</td>
</tr>
<tr>
<td>La(57)</td>
<td>57</td>
<td>+3</td>
<td>no color</td>
<td>5d^6s^2</td>
<td>187</td>
<td>103</td>
<td>138.9</td>
<td>0.002</td>
<td>3730</td>
<td>1194</td>
<td>6145</td>
</tr>
<tr>
<td>Ce(58)</td>
<td>58</td>
<td>+3</td>
<td>nearly no color</td>
<td>4f^6s^2</td>
<td>182</td>
<td>101</td>
<td>140.1</td>
<td>0.004</td>
<td>3699</td>
<td>1072</td>
<td>8240 [298K]</td>
</tr>
<tr>
<td>Pr(59)</td>
<td>59</td>
<td>+3</td>
<td>yellow green</td>
<td>4f^5s^6</td>
<td>182</td>
<td>99</td>
<td>140.9</td>
<td>5*10^-4</td>
<td>3785</td>
<td>1204</td>
<td>6773</td>
</tr>
<tr>
<td>Nd(60)</td>
<td>60</td>
<td>+2</td>
<td>yellow green</td>
<td>4f^5s^5</td>
<td>181</td>
<td>98</td>
<td>144.2</td>
<td>0.002</td>
<td>3341</td>
<td>1294</td>
<td>7007</td>
</tr>
<tr>
<td>Sm(62)</td>
<td>62</td>
<td>+3</td>
<td>yellow</td>
<td>4f^6s</td>
<td>179</td>
<td>94</td>
<td>150.4</td>
<td>6*10^-4</td>
<td>2064</td>
<td>1350</td>
<td>7520</td>
</tr>
<tr>
<td>Eu(63)</td>
<td>63</td>
<td>+3</td>
<td>yellow</td>
<td>4f^6s</td>
<td>179</td>
<td>91</td>
<td>152.0</td>
<td>9*10^-3</td>
<td>2064</td>
<td>1350</td>
<td>7520</td>
</tr>
<tr>
<td>Gd(64)</td>
<td>64</td>
<td>+3</td>
<td>yellow</td>
<td>4f^6s</td>
<td>177</td>
<td>90</td>
<td>157.3</td>
<td>4.2*10^-3</td>
<td>3396</td>
<td>1595</td>
<td>8229</td>
</tr>
<tr>
<td>Tb(65)</td>
<td>65</td>
<td>+4</td>
<td>yellow green</td>
<td>4f^7</td>
<td>176</td>
<td>89</td>
<td>164.9</td>
<td>2*10^-3</td>
<td>2835</td>
<td>1629</td>
<td>8550</td>
</tr>
<tr>
<td>Dy(66)</td>
<td>66</td>
<td>+4</td>
<td>yellow green</td>
<td>4f^7</td>
<td>175</td>
<td>88</td>
<td>167.3</td>
<td>2*10^-3</td>
<td>2968</td>
<td>1685</td>
<td>8795</td>
</tr>
<tr>
<td>Ho(67)</td>
<td>67</td>
<td>+4</td>
<td>yellow</td>
<td>4f^7</td>
<td>174</td>
<td>87</td>
<td>168.9</td>
<td>3*10^-3</td>
<td>3136</td>
<td>1747</td>
<td>9066</td>
</tr>
<tr>
<td>Er(68)</td>
<td>68</td>
<td>+4</td>
<td>pink</td>
<td>4f^7</td>
<td>174</td>
<td>86</td>
<td>173.0</td>
<td>7*10^-3</td>
<td>2220</td>
<td>1802</td>
<td>9321</td>
</tr>
<tr>
<td>Tm(69)</td>
<td>69</td>
<td>+4</td>
<td>green</td>
<td>4f^7</td>
<td>174</td>
<td>86</td>
<td>175.0</td>
<td></td>
<td>3668</td>
<td>1936</td>
<td>9840 [298K]</td>
</tr>
<tr>
<td>Yb(70)</td>
<td>70</td>
<td>+4</td>
<td>no color</td>
<td>4f^7</td>
<td>174</td>
<td>86</td>
<td>175.0</td>
<td></td>
<td></td>
<td>1936</td>
<td>9840 [298K]</td>
</tr>
<tr>
<td>Lu(71)</td>
<td>71</td>
<td>+4</td>
<td>no color</td>
<td>4f^7</td>
<td>174</td>
<td>86</td>
<td>175.0</td>
<td></td>
<td></td>
<td>1936</td>
<td>9840 [298K]</td>
</tr>
</tbody>
</table>

**Grouping into LREE, MREE and HREE**

- **HREE (Heavy Rare Earth Elements)**: Elements with fully filled 4f^14 (Lu) orbitals.
- **LREE (Light Rare Earth Elements)**: Elements with half-filled 4f^7 (Gd) orbitals.
- **MREE (Middle Rare Earth Elements)**: Elements with partially filled 4f orbitals.

This is the view of geochemists.
A group of 15 elements splitted into light and heavy REE!

<table>
<thead>
<tr>
<th>Atomic number</th>
<th>21</th>
<th>39</th>
<th>57</th>
<th>58</th>
<th>59</th>
<th>60</th>
<th>61</th>
<th>62</th>
<th>63</th>
<th>64</th>
<th>65</th>
<th>66</th>
<th>67</th>
<th>68</th>
<th>69</th>
<th>70</th>
<th>71</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element</td>
<td>Y(39)</td>
<td>La(57)</td>
<td>Ce(58)</td>
<td>Pr(59)</td>
<td>Nd(60)</td>
<td>Sm(62)</td>
<td>Eu(63)</td>
<td>Gd(64)</td>
<td>Tb(65)</td>
<td>Dy(66)</td>
<td>Ho(67)</td>
<td>Er(68)</td>
<td>Tm(69)</td>
<td>Yb(70)</td>
<td>Lu(71)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orbitals</td>
<td>4d^5s^2</td>
<td>5d^6s^2</td>
<td>4f^6s^2</td>
<td>4f^6s^2</td>
<td>4f^6s^2</td>
<td>4f^6s^2</td>
<td>4f^6s^2</td>
<td>4f^6s^2</td>
<td>4f^6s^2</td>
<td>4f^6s^2</td>
<td>4f^6s^2</td>
<td>4f^6s^2</td>
<td>4f^6s^2</td>
<td>4f^6s^2</td>
<td>4f^6s^2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxidation states</td>
<td>+3</td>
<td>+3</td>
<td>+3</td>
<td>+3</td>
<td>+3</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td>no color</td>
<td>no color</td>
<td>yellow</td>
<td>green</td>
<td>violet</td>
<td>yellow</td>
<td>green</td>
<td>yellow</td>
<td>pink</td>
<td>green</td>
<td>no color</td>
<td>no color</td>
<td>no color</td>
<td>no color</td>
<td>no color</td>
<td>no color</td>
<td></td>
</tr>
<tr>
<td>Atomic radius (pm)</td>
<td>180</td>
<td>187</td>
<td>182</td>
<td>182</td>
<td>181</td>
<td>178</td>
<td>177</td>
<td>177</td>
<td>177</td>
<td>175</td>
<td>174</td>
<td>193</td>
<td>174</td>
<td>193</td>
<td>174</td>
<td>174</td>
<td></td>
</tr>
<tr>
<td>Ionic radius (pm)</td>
<td>96</td>
<td>95</td>
<td>94</td>
<td>94</td>
<td>94</td>
<td>94</td>
<td>94</td>
<td>94</td>
<td>94</td>
<td>94</td>
<td>94</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>Atomic mass [u]</td>
<td>88.9</td>
<td>138.9</td>
<td>140.1</td>
<td>140.1</td>
<td>144.2</td>
<td>150.4</td>
<td>152.0</td>
<td>157.3</td>
<td>158.9</td>
<td>162.5</td>
<td>164.9</td>
<td>167.3</td>
<td>168.9</td>
<td>173.0</td>
<td>175.0</td>
<td>175.0</td>
<td></td>
</tr>
<tr>
<td>Mass in geosphere [%]</td>
<td>0.003</td>
<td>0.002</td>
<td>0.004</td>
<td>5 x 10^-4</td>
<td>0.002</td>
<td>18.04</td>
<td>18.04</td>
<td>18.04</td>
<td>18.04</td>
<td>18.04</td>
<td>18.04</td>
<td>18.04</td>
<td>18.04</td>
<td>18.04</td>
<td>18.04</td>
<td>18.04</td>
<td></td>
</tr>
<tr>
<td>Boiling point [K]</td>
<td>3611</td>
<td>3730</td>
<td>3699</td>
<td>3785</td>
<td>3341</td>
<td>3396</td>
<td>3283</td>
<td>2968</td>
<td>3136</td>
<td>3124</td>
<td>2228</td>
<td>1466</td>
<td>3668</td>
<td>1936</td>
<td>1936</td>
<td>1936</td>
<td></td>
</tr>
<tr>
<td>Melting point [K]</td>
<td>1795</td>
<td>1194</td>
<td>1072</td>
<td>1204</td>
<td>1294</td>
<td>1350</td>
<td>1095</td>
<td>1586</td>
<td>1629</td>
<td>1685</td>
<td>1747</td>
<td>1802</td>
<td>1818</td>
<td>1097</td>
<td>1936</td>
<td>1936</td>
<td></td>
</tr>
<tr>
<td>Density [kg/m^3 at 293K]</td>
<td>4469</td>
<td>6145</td>
<td>8240</td>
<td>6773</td>
<td>7007</td>
<td>8229</td>
<td>8550</td>
<td>8795</td>
<td>9066</td>
<td>9321</td>
<td>6965</td>
<td>9840</td>
<td>9840</td>
<td>9840</td>
<td>9840</td>
<td>9840</td>
<td></td>
</tr>
</tbody>
</table>

Classification of metals: Light metals | Heavy metals (Density > 5000 kg/m^3)

HREE
LREE

This is the view of metallurgists

Half-filled 4f^7 (Gd)
Fully filled 4f^{14} (Lu)
2 – THE RARE EARTH INDUSTRY IN 2015
La production mondiale de terres rares 2013 représentait environ 4 milliards $US, éclatés en divers marchés très spécialisés, dominés par le marché des aimants permanents Nd-Fe-B (Dy) (50% de la valeur totale) et celui des poudres luminophores (18% du marché).
Essentially a producer of light rare earth. 10 years Nd supply contract signed with Siemens on mid-April.

Total Debt to Total Capital: 66%
Debt/total equity: 197%

Total Debt to Total Capital: 60% (important role of Japanese lenders)
Debt/total equity: 147%

Rich in Dy, Tb, Eu
Rare Earth based value adding

(Examples, average 2014 prices)

Data sources: IMCOA - Duddley Kingsnorth, Conférence ERECON 10/2014

- Hybrid car, per unit
- Hybrid car engine, per unit
- Nd2Fe14B alloy for magnets
- LaNi5 alloy for NiMh batteries, $ per kg
- Nd metal, $ per kg
- Separated pure Nd oxyde, $ per kg
- Monazite concentrate, 50% TREO, $ per kg
- Monazite ore, 8% TREO, $ per kg

Barriers to entry: Hitachi/Sumitomo patents on permanent magnets. Main patent elapsed in 2014, but…

300 to 600 M$ CAPEX is needed to build a new separating plan, new processes may lower costs

300 to 1 000 M$ CAPEX is needed to start a new mine
The 2013 global REE production was worth about 4 bn US $, split across very diversified markets, dominated by the REE permanent magnets (50% of the total market value) and the phosphors markets (18%). Only 8 out of the 15 REE have a significant market value: Nd, Pr, Dy, Eu, Ce, La, Tb. Nd + Pr are worth almost 50% of the total REE market. The per kg. value is highest for Tb, Eu and Dy.
<table>
<thead>
<tr>
<th>Matière</th>
<th>Année</th>
<th>CAGR 2010–2020</th>
<th>Valeur du marché 2012</th>
<th>Différence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalyseurs</td>
<td>2011</td>
<td>5%</td>
<td>+/- 24 M USD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verre</td>
<td>2011</td>
<td>3%</td>
<td>+/- 107 M USD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Médias de polissage</td>
<td>2011</td>
<td>5%</td>
<td>+/- 160 M USD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alliages métalliques</td>
<td>2011</td>
<td>6.5%</td>
<td>+/- 400 M USD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2017</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Catalysts - 2011**
- CAGR 2010–2020: 5%
- Valeur du marché 2012: +/- 24 M USD

**Glass - 2011**
- CAGR 2010–2020: 3%
- Valeur du marché 2012: +/- 107 M USD

**Polishing media - 2011**
- CAGR 2010–2020: 5%
- Valeur du marché 2012: +/- 160 M USD

**Metal alloys - 2011**
- CAGR 2010–2020: 6.5%
- Valeur du marché 2012: +/- 400 M USD

**Direction de l’Évaluation et de la Stratégie**

>> vendredi 24 avril 2015

---

**Graphiques**

- **Catalysts - 2011**
- **Catalysts - 2017**
- **Glass - 2011**
- **Glass - 2017**
- **Polishing media - 2011**
- **Polishing media - 2017**
- **Metal alloys - 2011**
- **Metal alloys - 2017**
CAGR 2010 – 2020: **10%**
Market value 2012: +/- **2 020 M USD**

CAGR 2010 – 2020: **4%** (possibly much less)
Market value 2012: +/- **214 M USD**

CAGR 2010 – 2020: **5%**
Market value 2012: +/- **100 M USD**

Data sources: Dudley Kingsnorth, IMCOA;
3 – A EUROPEAN PERSPECTIVE
Europe’s situation

> Rare Earth derived products (not Rare Earth!) are essential inputs to numerous downstream industries in sectors as diverse as aeronautics, automobile, defence, renewable energy, health, ICT, space

> There is No EU REE production so far, but there are advanced REE mining projects:

  • Norra Kärr in Sweden, estimated CAPEX: 423 M$, no refinery and separation plant (presentation later on during this conference)
  • Kvanefjeld in Greenland, estimated CAPEX 1.53 bn M$, including a refinery in Greenland. Separation would take place at a Chinese plant.
Europe’s situation

> Kvanefjeld, the world largest advanced REE project outside China, may end up as a China-controlled operation. China Non-Ferrous Metal Mining Group (CNMC) has signed an MOU with Greenland Minerals & Energy in April 2014 to cooperate on the preparation of the feasibility study. CNMC is building a 7000 tpa separation plant in China that would be well suited to the processing of RE concentrate from Kvanefjeld (# 3 Dy + Eu + Nd + Pr + Tb stock outside China, # 28 by grade, out of 45 deposits)

> This appears as one of several moves by China to take control of key Nd-Pr-Dy-Eu-Tb rich deposits outside China. Other Chinese participations are developing:

- Nolans Bore, Australia (Shenghe Resources) - # 10, #12
- Tantalus, Madagascar – ionic clay (Ganzhou Qiandong RE Group) - # 16, #42
- Steenkampskraal, South Africa (Ganzhou Qiandong RE Group) - #25, #1
- Browns Range, Australia (Jilin Jien Ni industry Co. Ltd.) - # 39, #40
- Milo/ Mount Isa, Australia (Jiangxi Centre Mining Co. Ltd.) ?, ?
Europe’s situation

> Europe has excellent know-how in REE separation and the production of several REE-derived materials for catalysis, lighting (phosphors), high-precision polishing, medical and nuclear applications, pigments (Solvay) and has two separation plants: one at La Rochelle, France (Solvay, about 10 000 tpa separated purified oxydes capacities) and the other in Silmet, Estonia (Molycorp, 3 000 tpa capacity, tailored to the processing of Russian iloparite ore)

> Europe has several REE permanent magnet production facilities, operating under Hitachi licence:
  - Vacuumschmelze, Germany;
  - Magnetfabrik Schramberg, Germany (older Hitachi Patents Only);
  - Neorem Oy, Finland (a subsidiary of Vacuumschmelze)

> Some companies operate under their own patents:
  - Magnetfabrik Bonn, Germany
  - Magneti Ljubljana, Slovenia
  - Less Commo Metals, UK (produces only NdFeB alloy)

> All together thy represent only a tiny share of the global NdFeB production
4 – EUROPE’S RESPONSE TO THE REE CHALLENGES
Europe’s responses

> The EU raw materials initiative [COM(2008)699], launched in November 2008, is the broad policy framework designed to address the EU dependence on raw materials imports and the sustainability issues related to its raw materials use by:
  • Fostering access to raw materials on world markets at undistorted conditions;
  • Foster sustainable supply of raw materials from European sources
  • Reduce the EU's consumption of primary raw materials

> In the REE domain this materialized in:
  • Setting-up the European Rare Earths Competency Network (ERECON), a joint European Parliament and European Commission (2013-2015)
  • Support to REE-related research and innovation, via the 7th EU Research & Innovation Framework Programme (2007-2013) and, now, Horizon 2020 (2014-2020)
Europe’s responses: ERECON

> The Final ERECON report publication is pending.
> The conclusions of its draft version include:

- Detailed mapping and CONTINUOUS monitoring of complex and changing REE supply chains – from mines to separation plants to end-users and end-of-life disposal.
- Generous support to RE related research and technical education in exploration, mining, separation, recycling and substitution.
- Support and accelerate the scaling up and commercialization of key technologies through co-financing industry-led pilot plants for rare earth production and processing.
- Provide financial support for the extensive R&D that is necessary to produce pre-feasibility and bankable feasibility studies.
- Develop an EU circular REE economy through eco-design, collection of specific EOL products, development of an EU product-centric recycling policy, streamlining of the existing EU recycling policy and waste regulation.
- Set-up a voluntary “EU critical raw materials fund” that de-risks project” and an “EU resource alliance” to take stakes in EU and foreign projects.
Europe’s responses: research and innovation

Several REE related EU co-funded research and innovation projects aim at addressing different issues all along the REE supply chains:

- EURARE: EU REE resources knowledge, mibing, beneficiation, separation (to be presented later during this conference);
- REMSIL also looks at RE separation by means of ionic liquids;
- Numerous projects look are related to materials science, aiming either at a more efficient use of REE or at novel applications: RECRYSTENG, CIPRIS, NANOSWITC, NANOSPEC, REALISE, HI-WI, DRREAM, CEREPEP, TARTASEAL are examples of such projects;
- NANOPYME, MRHELIMAG are more specifically addressing magnetic materials;
- VENUS, ROMEO and REFREEPERMAG look at substitution of REE in permanent magnets.
5 – CONCLUSIONS: THE END OF THE CHINESE REE MONOPOLY?
Conclusions

> The mastery of the REE dependent industrial supply chain appears to be a key component of China’s industrial policy, whose objectives are to be a world leader in the aeronautics, automotive, solar and wind energy, electronics industries.

> Its 863 (launched in 1986, 22 years before the launch of the EU Raw Materials Initiative) and its siblings the 973 and 985 research programmes were very effective at bolstering the Chinese REE related innovation capacities.

> Europe’s permanent magnet industry suffers from China’s competition:

  - A 18/02/2015 Vacuumschmelze press release states that due to growing competitive pressure from China, it will reduce staff at its Hanau facilities by nearly 25% (-340 jobs). Part of its magnets production will be transferred to China.

  - All EU producers will be confronted with the nefarious consequences of China’s persisting REE export restrictions and growing control of some of the best non-Chinese REE deposits. On 07/04/2015 Metal Pages listed the price Dy metal at an average of $ 525/ kg FOB China, while on the Chinese market the same metal was listed for $ 433, that is 17.5% less.
Europe’s situation

> Kvanefjeld, the world largest advanced REE project outside China, may end up as a China-controlled operation. China Non-Ferrous Metal Mining Group (CNMC) has signed an MOU with Greenland Minerals & Energy in April 2014 to cooperate on the preparation of the feasibility study. CNMC is building a 7000 tpa separation plant in China that would be well suited to the processing of RE concentrate from Kvanefjeld (# 3 Dy + Eu + Nd + Pr + Tb stock outside China, # 28 by grade, out of 45 deposits)

> This appears as one of several moves by China to take control of key Nd-Pr-Dy-Eu-Tb rich deposits outside China. Other Chinese participations are developing:
  • Nolans Bore, Australia (Shenghe Resources) - # 10, #12
  • Tantalus, Madagascar – ionic clay (Ganzhou Qiandong RE Group) - # 16, #42
  • Steenkampskraal, South Africa (Ganzhou Qiandong RE Group) - #25, #1
  • Browns Range, Australia (Jilin Jien Ni industry Co. Ltd.) - # 39, #40
  • Milo/ Mount Isa, Australia (Jiangxi Centre Mining Co. Ltd.) ?, ?
Conclusions

> China faces a number of domestic issues that are likely to further stimulate its interest in REE mining projects beyond its borders:

• Widely spread thorium contamination in the Bayan Obo and Baotou REE mining and REE processing/separation facilities call for costly management of low-activity waste from light REE mining, processing and separation facilities;

• The high environmental impacts (forest clear-cutting, contamination of aquifers, land degradation and erosion of bare soil) of heavy REE production in South China and the existence of unregulated illegal mines are challenging the capacity of China to maintain vital heavy REE production at current levels.

• Reorganisation of the Chinese REE industry has started

> De-siloing EU research and innovation across disciplines and national borders is key to meet the challenges posed by REE as essential vitamins. FP7, EIT Raw Materials and, hopefully, the Juncker Plan are keys to address the de-industrialisation challenge threatening the EU and its Member States.
THANK YOU FOR YOUR ATTENTION