Criticality screening for raw materials in energy technologies

Vangelis Tzimas

Energy Systems Evaluation Unit
Institute for Energy and Transport (Petten, NL)
Joint Research Centre
European Commission
JRC-IET provides validated information and scientific assessments about the link between materials and energy technology deployment, in support of implementation of the European Strategic Energy Technology Plan (SET-Plan).

- **Scientific assessment for the SET-Plan Materials Roadmap (2011)**
  - Materials synthesis and processing and component manufacturing priorities for 11 energy technologies.
  - Key materials research and innovation activities to advance energy technologies for the next 10 years.

- **Materials Information System (MIS)**
  - Technology and materials-related public information (supply chain data, material requirements, projections, etc.) along with the available references and public literature sources (links)

- **Assessment of raw material supply-chain bottlenecks to the large-scale deployment of energy technologies**
Europe is 100% import dependent for many materials used in energy technologies.

There is a growing demand, limited global supplies and geopolitical competition over the control of resources.

Increasing production is difficult, environmentally challenging and takes a long time.

The availability of rare metals in particular may dictate the rate of deployment of low-carbon energy technologies.
The JRC undertook a study on metals as bottlenecks to energy technology deployment. Its aims:

• Identify metal requirements for the high-priority low-carbon technologies: wind, solar, bio-energy, CCS, nuclear and electricity grids.

• Identify the critical metals, for which a disrupted supply can affect technology deployment (based on technology penetration scenarios).

• Explore possible strategies to prevent or mitigate the negative impacts of rare metal supply and its restrictions on the SET-Plan goals.

Report available from the SETIS website
A wide portfolio of metallic elements were considered:

- 60 metallic elements identified
- Only structural metals (iron, aluminium) were excluded from further study
Shortlist of metals for in-depth analysis

- Assessment of average annual demand over the decades 2010-2020 and 2020-2030, based on Commission estimates and industry targets for technology penetration
- Comparison of demand against current (2010) world supply: i.e. comparison of the most optimistic demand scenario to the most pessimistic supply scenario
- A metal was considered significant when demand > 1% of supply
• 14 metals were identified as significant

• Selenium was also included on the list of significant metals, as additional sensitivity analysis on the solar technology mix highlighted that selenium could have significant usage for the SET-Plan, in case CIGS have a larger than expected share of the technology mix.

1. Tellurium
2. Indium
3. Tin
4. Hafnium
5. Silver
6. Dysprosium
7. Gallium
8. Neodymium
9. Cadmium
10. Nickel
11. Molybdenum
12. Vanadium
13. Niobium
14. Selenium

Te: 50.4%
In: 19.4%
Criticality screening

Evaluation of future supply-chain bottlenecks, based on geo-graphical, geo-political, demand growth, supplier reliance, production capabilities (qualitative)

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Rationale</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Concentration of supply</strong></td>
<td>If supply is fairly concentrated within a very few countries, the risk of possible supply disruptions increases together with the ability of individual players to restrict access for political or economic advantage.</td>
<td>• Production estimates</td>
</tr>
<tr>
<td><strong>Political risk of producing countries</strong></td>
<td>Greater political risk in the main supplying countries increases the likelihood of supply disruptions and the likelihood that individual suppliers will seek to restrict access.</td>
<td>• Failed States Index</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Worldwide Governance Index</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Expert assessment</td>
</tr>
<tr>
<td><strong>Inability to expand production capacity rapidly</strong></td>
<td>Risk are higher if suppliers are unable to expand output relatively easily in the short to medium term in response to demand and price increases (e.g. due to a lack of known reserves, a lack of idle production capacity or because the metal is a by-product of other mining activities).</td>
<td>• Reserve Estimates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Supply chain analysis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• By-product dependencies</td>
</tr>
<tr>
<td><strong>Likelihood of rapid demand growth from competing applications</strong></td>
<td>Greater risks persist if demand from significant applications other than low carbon energy generation technologies is expected to grow rapidly over the coming years.</td>
<td>• Applications</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Supply/demand forecasts</td>
</tr>
</tbody>
</table>
## Results of criticality screening

<table>
<thead>
<tr>
<th>Metal</th>
<th>Market Factors</th>
<th>Political Factors</th>
<th>Overall risk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Likelihood of rapid demand growth</td>
<td>Limitations to expanding production capacity</td>
<td>Concentration of supply</td>
</tr>
<tr>
<td>Dysprosium</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Neodymium</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Tellurium</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Gallium</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Indium</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Niobium</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Vanadium</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Tin</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Selenium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Silver</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Medium</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Hafnium</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Nickel</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>
Results of the study

• Rare Earths: Dysprosium & Neodymium
  • Essential for wind energy
  • Fast growing demand
  • Limited potential for supply expansion over the coming years
  • High political risks through near-monopoly on supply by China

• Indium, Gallium, & Tellurium
  • Essential for solar energy (PV)
  • High demand growth
  • By-products with limited supply elasticity
  • Medium political risk
Critical materials for energy technologies

Identified Metals

Significance Screening

Based on supply & demand figures

60 Metals

All metals except Fe, Al & radioactive elements

Criticality Screening

Based on market & geopolitical factors

14 Metals

Used in significant amounts in set-plan technologies

5 Metals

With serious supply-chain bottlenecks

Te, In, Sn, Hf, Ag, Dy, Ga, Nd, Cd, Ni, Mo, Va, Nb, Se

Te, In, Ga, Nd, Dy

Policy Implications, Mitigation

Joint Research Centre
The second study has an expanded portfolio:

- Fuel cells and hydrogen
- Electricity storage
- Road transport incl. e-mobility
- Energy efficiency in buildings (inc. lighting) and in industry
- Other energy technologies (hydropower, geothermal energy, marine energy, co-generation (CHP), advanced fossil fuel power)
- Desalination
- Update of the results of the first study

A modified methodological approach:

- Projected demand based on the Commission’s Energy Roadmap 2050 and when not possible, from the most up-to-date scenarios from validated sources
- Significance screening based on projected supply data using the long term projections for 2020 and 2030 (USGS) – a more dynamic approach than the previous comparisons to 2010 supply data

Results will be published in early 2013
<table>
<thead>
<tr>
<th>Criterion</th>
<th>Rationale</th>
<th>Basis of assessment</th>
<th>Scoring criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Likelihood of rapid global demand growth</td>
<td>Greater risks persist if demand is expected to grow rapidly over the coming years.</td>
<td>Analysis of demand structure and demand forecasts</td>
<td>High: Industry forecasts expect rapid demand growth from several applications (e.g. close to double-digit growth)  Medium: Industry forecasts expect moderate and steady demand growth  Low: Industry forecasts expect slow or stable demand from mature applications</td>
</tr>
<tr>
<td>Limitations to expanding supply capacity</td>
<td>Risk are higher if suppliers are unable to expand output relatively easily in the short to medium term in response to demand and price increases</td>
<td>Reserve estimates, supply forecasts and evaluation by-product dependencies</td>
<td>High: There is a strong by-product dependency with little opportunity to increase extraction rates or low reserves.  Medium: There is a by-product dependency or severe underinvestment.  Low: Sufficient reserves and mining as primary product.</td>
</tr>
<tr>
<td>Concentration of supply</td>
<td>If supply is fairly concentrated within a few countries, the risk of possible supply disruptions increases, together with the ability of individual players to restrict access for political or economic advantage</td>
<td>Production statistics</td>
<td>High: Most of supply is concentrated in one country  Medium: Most of supply is concentrated in two or three countries  Low: Supply is dispersed among a number of countries</td>
</tr>
<tr>
<td>Political risk of major supplying countries</td>
<td>Greater political risk in the main supplying countries increases the likelihood of supply disruptions and the likelihood that individual suppliers will seek to restrict access.</td>
<td>Political risk indicators (‘Failed States Index’ and ‘Worldwide Governance Index’)</td>
<td>High: The major producing countries have a high score for political risk (&gt;60)  Medium: The main producing countries have mixed scores for political risks  Low: The main producing countries have low political risk scores (&lt;40)</td>
</tr>
</tbody>
</table>
Methodological strengths and weaknesses

• Supply and demand figures compared with like-years
• Better criticality criteria:
  ✓ More dynamic approach
  ✓ Reliance on forecasts
  ✓ A more elaborated qualitative approach allows for a greater degree of judgement
  ✓ A simple risk scale (non-quantitative) avoids misleading impression of preciseness
Recent studies have identified and used various “criteria / factors”

All of them are worth considering when deciding on a criticality screening methodology

Whether it is possible to assess or weigh or discard any criterion today is open for discussion

<table>
<thead>
<tr>
<th>Study</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minerals, Critical Minerals, and the US Economy (USA, 2007)</td>
<td>US consumption (value) Substitutability Emerging uses US import dependence Ratio of world reserves to production Ratio of world reserve base to production World by-product production compared to total primary production US secondary production from old scrap compared to consumption</td>
</tr>
<tr>
<td>Material Security (UK, 2008)</td>
<td>Global consumption levels Lack of substitutability Global warming potential Total material/ environmental requirement Physical scarcity Monopoly supply Political instability Climate change vulnerability</td>
</tr>
<tr>
<td>Critical Materials Strategy (USA, 2010)</td>
<td>Basic availability Competing technology demand Political, regulatory and social factors Co-dependence on other markets Producer diversity Demand for clean energy Substitutability</td>
</tr>
<tr>
<td>Critical Raw Materials for the EU (EU, 2010)</td>
<td>Concentration of supply Governance rating of producing countries (alternatively environmental performance) Substitutability Recycling rate Value added of end use sectors</td>
</tr>
<tr>
<td>Critical metals in strategic energy technologies (EU, 2011)</td>
<td>Limitations to expanding world supply Concentration of supply (country level) Political risk related to major suppliers Likelihood of rapid demand growth</td>
</tr>
<tr>
<td>Methodology of metal criticality determination at the national level (global, national—USA as example, companies, 2012)</td>
<td>Depletion times (reserves) Companion metal fraction Policy potential index Human development index Worldwide governance indicators: Political stability Global supply concentration National economic importance Percentage of population utilizing Substitute performance Substitute availability Environmental impact ratio Net import reliance Net import reliance Global innovation index LCA cradle-to-gate: ‘human health’ LCA cradle-to-gate: ‘ecosystems’</td>
</tr>
</tbody>
</table>
Thank you!

Evangelos.Tzimas@ec.europa.eu

Please visit the SETIS website:

http://setis.ec.europa.eu