Oakdene Hollins

ICSG: Study of By-Products of Copper, Lead, Zinc and Nickel

- Peter Willis
- 26th April 2012

Agenda

- Presentation of Draft Report
- Policy Context
- Scope
- Methodology
- Overview of Findings:
  - Molybdenum, Cobalt
  - Rhenium, Selenium, Tellurium, Bismuth
  - Rare Earth Elements
- General Conclusions
- Questions & Answers
Presentation of Draft Report

- Joint project between: ICSG, INSG, ILZSG
- Aim: produce in depth information on production, use and trade
- Comments and additional information are welcome
- Final report due for publication in June 2012
- Directory of producers

Policy Context

- Sources: KITECH, US Dept. of Energy, EU RMI, EC JRC IET
Project Scope

- Selection criteria of the by-product metals:
  - Linked to the production of study group metals
  - No or limited own-production infrastructure
  - Typically have high value
  - Increasing use in new technologies e.g. electronics, renewable energy

- Scope of the study:
  - Lead and Zinc: indium, germanium, bismuth, tellurium
  - Nickel: scandium, platinum group metals, cobalt
  - Copper: cobalt, rhenium, tellurium, selenium, rare earths, molybdenum

Methodology

- Methodology:
  - Review of the literature
  - Web-based survey of producers, consumers, traders
  - Expert industry interviews
  - Research conducted January-April 2012
Overview of Findings

- Latest Production Statistics:

<table>
<thead>
<tr>
<th>Principal Metal</th>
<th>Mine Production (tonnes)</th>
<th>By-product Metal</th>
<th>Production (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>16,100,000</td>
<td>Molybdenum</td>
<td>250,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cobalt</td>
<td>98,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rhenium</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Selenium</td>
<td>2,600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tellurium</td>
<td>450</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bismuth</td>
<td>8,500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rare Earth Elements</td>
<td>130,000</td>
</tr>
</tbody>
</table>

Sources: USGS & Industry Estimates

Molybdenum: Production

- Supply split between: Mo-only and Cu-Mo
- China and United States as major producers
- Some dislocation in mine and roasting capacity

Mine Capacity by Type

Sources: USGS & Roskill
Molybdenum: Use

- Diverse end-markets: importance of steel alloys
- Growth of 3.6% p.a. to 2020
- LME traded; low volumes
- Export levies: China, Russia

Cobalt: Production

- Cu, Ni & primary supply
- Trade of ores for refining
- Large number of pipeline projects – oversupply
- High recycling rate (68%)
Cobalt: Use

- Diverse end-markets; recent growth in batteries
- Possible substitution in Li-ion batteries
- REACH Concerns (5 SVHCs)
- LME traded; low volumes

End use of Primary Cobalt

- Batteries: 27%
- Super-alloys: 19%
- Carbides & Tooling: 13%
- Catalysts: 9%
- Other: 9%
- Magnets: 7%
- Hard-facing & Other Alloys: 6%
- Pigments: 10%

Co Metal Price, min. 99.3% (US$/kg)

Sources: CDI, Metal Pages

Rhenium: Production

- By-product from Copper Porphyry (Mo)
- Importance of Chile, emergence of Poland
- Limited pipeline of projects
- Efforts to improve recycling efficiency

World Rhenium Production (t)

Source: USGS
Rhenium: Use

- Importance of (aerospace) superalloys
- Growth in aerospace engines to result in rationing – substitution/reduction of rhenium content
- No major stockpiles or restrictions
- High and volatile prices

![Rhenium Price Chart](chart)

Use of Rhenium

- Aerosp. Super-alloys, 65%
- Other Super-alloys, 21%
- Catalysts, 9%
- Other, 7%

Selenium: Production

- By-product of copper, recoverable from slimes
- Incomplete official data – industry estimates
- Concentration varies – highest for refineries in Japan, Korea, CIS
- Often not recovered
- Technology shift to SE-EW may hurt recovery

![Selenium Refinery Production Chart](chart)

Source: Industry Estimates
Selenium: Use

- China as main consumer: Electrolytic Mn production
- Uncertain short term outlook
- Some risk of substitution
- Modest use in solar

Tellurium: Production

- By-product of copper, recoverable from slimes
- Lack of official data
- Diverse supply, but fewer high purity refiners
- Often not recovered, or efficiency not high
- Technology shift to SE-EW may hurt recovery
- Gold as possible source
Tellurium: Use

- CdTe solar as major market:
  - Long term strong growth, short term weakness
- Some applications price sensitive or could be substituted
- Recent price falls

Sources: STDA, Metal Pages

Bismuth

- Lead, tungsten as sources
- Limited production from Cu
- China, Peru and Mexico as largest suppliers
- Metal alloys, additives and chemicals as major markets
- Mature, slow growing

Sources: USGS, Metal Pages
Rare Earth Elements: Production

- Dominance of China, large fall in quotas in 2010
- Tightening of China production
- Numerous pipeline projects
- Limited prospects from copper
- Development of recycling

Rare Earth Supply by Element

<table>
<thead>
<tr>
<th>Element</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>La</td>
<td>24.8%</td>
</tr>
<tr>
<td>Ce</td>
<td>31.2%</td>
</tr>
<tr>
<td>Nd</td>
<td>19.8%</td>
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<tr>
<td>Pr</td>
<td>5.7%</td>
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<tr>
<td>Dy</td>
<td>1.9%</td>
</tr>
<tr>
<td>Y</td>
<td>11.0%</td>
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<tr>
<td>Others</td>
<td>5.6%</td>
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China Export Quotas (t REO)

<table>
<thead>
<tr>
<th>Year</th>
<th>Quota (t)</th>
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<tr>
<td>2004</td>
<td>80,000</td>
</tr>
<tr>
<td>2006</td>
<td>60,000</td>
</tr>
<tr>
<td>2008</td>
<td>40,000</td>
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<tr>
<td>2010</td>
<td>20,000</td>
</tr>
<tr>
<td>2012</td>
<td>(Estimate)</td>
</tr>
</tbody>
</table>

Sources: US Dept. Energy, TMR, Lynas

Rare Earth Elements: Use

- Strong market growth
- Deficits likely for HREEs
- Price ramp up in in 2010/11, now partially unwound

REO prices, 99% purity ($US/kg)

<table>
<thead>
<tr>
<th>Year</th>
<th>Nd</th>
<th>Pr</th>
<th>La</th>
<th>Ce</th>
</tr>
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<tbody>
<tr>
<td>2005</td>
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<tr>
<td>2013</td>
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</tbody>
</table>

Outlook for Rare Earths (t)

Sources: IMCOA, Metal Pages
General Conclusions

- Spectrum of availability of data:
  - Government, industry could collaborate to improve it
  - Better trade statistics could be recorded
- Economics of by-production:
  - Mo, Co, REEs with primary production
  - Bi, Re, Se, Te solely as by-products
- Market outlook strongest for Te, REEs, Re
- Considerable opportunities to increase recovery of certain by-products or its efficiency
- Wastes could be sold on for by-product recovery

Barriers to By-Product Recovery

<table>
<thead>
<tr>
<th></th>
<th>Not present in ore/concentrate</th>
<th>Outside core business</th>
<th>Technology not available</th>
<th>Extraction not economic</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Lead/Zinc</td>
<td>0%</td>
<td>50%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Nickel</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
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</tr>
<tr>
<td>Copper</td>
<td>100%</td>
<td>0%</td>
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<td>0%</td>
</tr>
</tbody>
</table>

Sources: Oakdene Hollins Industry Survey
Questions & Answers

Thank-you for listening!

Peter Willis

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ICSG Environmental and Economic Committee April 2012